Effects of additional carbohydrate supplementation on soccer skill performance.

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Effects of Additional Carbohydrate Supplementation on Soccer Skill Performance

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Abstract

Purpose: The performance of soccer skills has been demonstrated to decrease during match-play. Previous literature has mainly focused on concentrations of 6 – 8 % carbohydrate, and therefore no optimal dose of carbohydrate has been determined. This previous research has found conflicting results when soccer skill performance was assessed with additional carbohydrate supplementation. The aim of this study was to investigate the effects of ingesting different amounts of carbohydrate, in the form of carbohydrate-electrolyte beverages and carbohydrate gels, prior to and during the 90 min Soccer Match Simulation protocol (SMS) on performance of shooting, passing and dribbling. **Methods:** Fourteen male, recreational soccer players ingested a 6 % carbohydrate-electrolyte solution and carbohydrate gel (CHO6), a 10 % carbohydrate-electrolyte/caffeine solution and carbohydrate gel (CHO10) or placebo solution with a placebo gel (PLA). Players consumed 5.25 $ml.kg^{-1}$ body mass before each half and 2.63 $ml.kg^{-1}$ body mass every 15 min of exercise, in a double-blind cross-over design. After a 12 h overnight fast, players performed soccer skill tests at regular intervals during each 45 min half of the SMS, separated by 15 min half time. All trials were separated by 7 d. **Results:** Blood glucose concentrations increased from baseline until 45 min in CHO6 and CHO10 ($P < 0.05$). Sharp reductions in blood glucose were seen at 60 min in all trials (PLA: -16.1 ± 3.2 %; CHO6: -38.3 ± 2.0%; CHO10: -40.0 ± 3.1%; $P < 0.05$). Passing speed was slower at 45 min (-11.4 ± 3.9%) 60 min (-6.8 ± 3.0%) and 90 min (-7.0 ± 3.2%) when compared with 15 min ($P < 0.05$) in PLA; however, passing speed was maintained in CHO6 and CHO10. Also, passing performance (SP Index) was lower at 45 min (-11.6 ± 4.0%) 60 min (-6.9 ± 3.1%) and 90 min (-7.0 ± 3.3%) compared with 15 min ($P < 0.05$) in PLA. Dribbling and shooting performances were maintained throughout exercise and were not affected by supplementation. **Conclusions:** Skill performance, specifically passing speed and SP Index, were compromised during simulated soccer in the last 15 min of each half and at the beginning of the 2nd half when recreational players received a very low carbohydrate. Ingestion of carbohydrate during the exercise protocol attenuated this drop in skill performance; however, it was not possible to distinguish between skill performance in moderate (CHO6) and high (CHO10) carbohydrate trials. Recreational players should be encouraged to consume carbohydrate during soccer match-play; however, individual responses might be important when considering the optimal strategy for carbohydrate ingestion during soccer training and match-play.

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List of Abbreviations

AMP	Adenosine Monophosphate
ATP	Adesonsine Triphosphate
ATP-PCr System	Adesonsine Triphosphate - Phosphocreatine System
BM	Body Mass
CHO	Carbohydrate
CHO6	6% Carbohydrate-Electrolyte Beverage + Active Gel
CHO10	10% Carbohydrate-Electrolyte/Caffeine Beverage + Active Gel
CNS	Central Nervous System
CRT	Choice Reaction Time
DOMS	Delayed Onset Muscle Soreness
FFA	Free Fatty Acids
FT	Fast Twitch Muscle Fibres
GLUT5	Glucose Transporter Type 5
H_2O_2	Hydrogen Peroxide
IMP	Inosine Monophosphate
LIST	Loughborough Intermittent Shuttle Test
LSPT	Loughborough Soccer Passing Test
LSST	Loughborough Soccer Shooting Test
mosmol·kg H_20^{-1}	Osmolality
MSFT	Multi Stage Fitness Test
η_p^2	Partial Eta Squared

NH_3	Ammonia
PLA	Placebo Beverage with Placebo Gel
SEM	Standard Error of the Mean
SGLT1	Sodium Dependant Glucose Transporter 1
SMS	Soccer Match Simulation Exercise Protocol
SP Index	Speed Precision Index
SPS Index	Speed/Precision/Success Index
ST	Slow Twitch Muscle Fibres
$\dot{V}O_{2max}$	Maximal Oxygen Consumption

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CHAPTER ONE

1.0Introduction

1.0 Introduction

FIFA (2006) estimates that there are 265 million people that participate in soccer throughout the world. Therefore, it is not surprising that soccer is one of the most broadly researched sports.

Within sports science, most early research was based on the physiology of soccer (Bangsbo, 1994) and although this type of research is very relevant to soccer performance and helps to quantify the demands of different players in different positions, it lacks the capacity to evaluate soccer skills, which are essential in producing successful outcomes, and ultimately winning games (Reilly, 1996). Therefore, Ali (2011) suggested that there are very few, if any soccer fitness tests that comprehensively assess the skill performance of soccer players.

It is surprising that until recently very little research had been conducted to evaluate skill performance as previous research has reported that, during soccer match-play, the number of goals conceded increases as the game approaches its end (Reilly, 1996). Consequently, the increase in goals scored could be attributed to physiological fatigue and the decline in optimal decision making; hence, the ability to compare different interventions throughout a reliable soccer match simulation including soccer skills is crucial to advancing the research literature currently available because successful execution of skill is the most important characteristic of soccer play (Ali, 2011).

A definition of skill is "the learned ability to bring about pre-determined results with maximum outlay of time, energy or both" (Knapp, 1977). The dynamic nature of soccer categorizes it as an "open skill" game, which identifies the difference between technique (a player having good patterns of movement) and skill (performing the right action at the right time) (Knapp, 1977).

Having specific tests that measure skill, which are ecologically valid, allow researchers and coaches to identify talent and employ interventions to maintain skill performance during match-play (Ali 2011). Therefore, identifying methods of testing and analysing skill performance, which incorporate skill into a setting which replicates the physiological demands of a real match has been a recent area of interest for researchers, and is key to being able to identify possible advantages of different interventions, such as the effects of additional carbohydrate on soccer skill performance.

Different tests have been developed to test certain skills that are completed during a soccer match. These can be single skill tests such as dribbling, passing and shooting or multi-faceted in nature, which encompasses different features of match-play into one test. Many of these tests have been devised so that they are easy to set up, carry out, and analyse; however, the methodological differences in these tests have led to conflicting literature when intervention studies have been conducted. Many tests use criterion-based outcomes to measure skilled performance and, by doing so allow the research teams to analyse data quickly and efficiently. However, simply giving points for accuracy of a pass or shot and time for a dribble does not allow a true representation of soccer performance to be analysed. Additionally, using these kinds of tests and including penalty points for error may not allow discrete differences to be observed (Russell & Kingsley, 2011c).

Soccer skill protocols devised by Russell et al. (2010) were developed to provide outcome measures with greater ecological validity. These tests provide the precision, speed and success of passing, shooting and dribbling by digitalization of video footage of the tests. This approach allows deviations from the centre of the target, the mean ball speed and the success of a player to be scrutinized with greater test-retest reliability than comparable criterion-based skill tests. In addition, these tests have been shown to be reliable and have been validated using elite and recreational players, whereas many of the soccer skill tests produced in the past have not (Zelenka et al., 1967; Northcott et al., 1999; Hoare & Warr, 2000; Rosch et al., 2000).

Moreover, these skill tests can be undertaken in conjunction with an exercise protocol (Soccer match simulation; SMS) which, unlike other protocols (Currell et al., 2009; Rampinini et al., 2008; Foskett et al., 2009; Ali et al., 2007; Lyons et al., 2006; McGregor et al., 1999; Ostojic & Mazic, 2002), has been demonstrated to replicate the physiological demands of actual soccer match-play whilst incorporating soccer specific skills into the protocol (Russell et al., 2011b).

Although considerable previous research has been undertaken to evaluate the effects of carbohydrate supplementation on endurance and intermittent exercise, there has been a relative lack of literature produced on soccer, specifically soccer skill performance. Some previous research has investigated the influence of carbohydrate supplementation on soccer skill performance (Muckle, 1973; Zeederberg et al., 1996, Abt et al., 1998; Northcott et al., 1999; Ostojic & Mazic, 2002; Ali et al., 2007b; Ali & Williams, 2009; Currell et al., 2009) with conflicting results. However, these authors have used different skill tests and employed criterion-based measures to assess soccer skill performance. Additionally, some of these papers only measured soccer skill through actual match-play (Muckle, 1973; Zeederberg et al., 1996), which, as there are too many other factors in actual match-play that influence skill performance, these findings have limited practical application (Zeederberg etal., 1996). Also, previous research has only looked at skill pre and post exercise (Abt et al., 1998; Ali et al., 2007b) and just post exercise (Ostojic & Mazic, 2002). Measuring skill in this way does not give an idea of when skill performance changed throughout exercise and therefore carry very little information for players and coaches. Measuring overall skill performance through one skill (Ali & Williams, 2009) does not give a true representation of actual skill performance in soccer and, therefore, these findings are limited. Using criterion-based measures to measure skill performance does not give 'real' data of the skill as a whole. Therefore, using tests that encompass precision of a skill, speed of a skill and the success of a skill allows research to be used by coaches and players alike to help them to determine whether or not one concentration of carbohydrate drink is better than another during a match for example.

Recently, Bandelow et al. (2010) demonstrated that higher blood glucose concentrations during soccer match-play were associated with improved cognitive function, even though players remained euglycaemic. Therefore, the provision of greater carbohydrate might help attenuate the decline in decision making and physiological fatigue (Russell et al., 2011c). Previous research in this area has used carbohydrate solutions with concentrations between 6 % and 8 %; consequently, it is unclear if this supplementation regime is optimal, or not. By using the combination of drinks and gels it is suggested that this may provide the optimal carbohydrate supplementation strategy (Pfeiffer et al., 2010). It has also been seen that carbohydrate absorption is increased with the addition of caffeine due to caffeine-induced enhancement of sodium-glucose-linked transporter protein activity, thus leading to an increased jejunal glucose uptake (Van Nieuwenhoven et al., 2000). Therefore increased concentrations of carbohydrate, above that of commercially available sports drinks (> 8 %), with the addition of caffeine will probably help maintain blood glucose throughout soccer exercise, potentially reducing fatigue and improving cognitive functioning and skill performance. By measuring skill performance at regular intervals during a simulation of soccer match-play such as the SMS exercise protocol does, enables the researchers to determine when, during a match, skill performance is affected by fatigue and therefore at which point the benefits of high blood glucose concentrations could help to maintain or better performance. By using skill tests that allow continuous measurements of skill such as Russell et al. (2010) protocols use measurements of skill such as speed, precision and success which allows researchers, coaches and players to determine the benefits of additional carbohydrate or another interventions.

The current study investigated whether ingestion of two combinations of different concentrations of carbohydrate beverages and gels (6 % carbohydrate beverage and an active gel, CHO6; 10 % carbohydrate beverage and an active gel, CHO10) would influence blood glucose concentrations and improve the quality of the performance of soccer skills when assessed at regular intervals during an exercise protocol that simulates the movement patterns of soccer as opposed to a placebo beverage and gel.

1.1 Null Hypotheses

HO_1: Blood glucose concentrations will not be influenced by the ingestion of additional carbohydrate beverages and gels.

HO_2: Performance of soccer specific skills (shooting, dribbling and passing) will not be influenced by additional carbohydrate supplementation compared to a placebo.

HO_3: Carbohydrate supplementation will not attenuate the decline in skill performance associated with fatigue at the end of a soccer match.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 Energy Metabolism in Soccer

Bangsbo (1994a) stated that the mean relative work rate in soccer is approximately 70 % $\dot{V}O_{2max}$, which corresponds to an energy production of 5690 kJ for a player weighing 75 kg with a $\dot{V}O_{2max}$ of 60 ml·kg·min^{-1}. However, the diverse activities involved in soccer means that a variety of factors contribute to the metabolic and physiological demands of soccer match-play. The metabolic demands can be broadly classified into aerobic and anaerobic sources of energy production.

2.1.1 Aerobic Metabolism

Many researchers have stated that the aerobic energy system is highly stressed during a soccer match, with mean and peak heart rates reported to be around 85 % and 98 % of maximal values, respectively (Reilly & Thomas, 1976; Ali & Farrally, 1991; Bangsbo, 1994a; Ekblom, 1986). Heart rate values can be transformed into oxygen uptake using the individualised relationship between heart rate and oxygen uptake from treadmill running (Bangsbo, 1994a; Esposito et al., 2004; Krustrup & Bangsbo, 2001). Bangsbo et al. (2006) suggested that the method of conversion appears to be valid and Esposito et al. (2004) acknowledged that heart rate measured during soccer effectively reflects the metabolic expenditure. However, additional factors such as dehydration, hyperthermia and mental stress can cause heart rate to increase and overestimate oxygen uptake as no changes would be seen to oxygen uptake. Therefore, Bangsbo et al. (2006) concluded that heart rate measurements during a game suggest that the average oxygen uptake is around 70 % $\dot{V}O_{2max}$ when all of these factors are taken into account.

This statement is supported by results gained from studies measuring core temperature, which is an indirect measurement of aerobic production during exercise (Ekblom, 1986; Mohr et al., 2004b; Smodlaka, 1978) where core temperatures of 39 –

40 °C which have been reported during a game, predict the average oxygen uptake to be around 70 % $\dot{V}O_{2max}$ during a match.

2.1.2 Anaerobic Metabolism

Within the literature there appears to be some debate as to which section of anaerobic metabolism is the most important during a soccer match. Some suggest the ATP-PCr system is dominant because of the length of time that the high-intensity periods of a match last (Tumilty, 1992). Mohr et al. (2003) suggested that elite soccer players perform 150 – 250 brief intense actions during a match.

Also, anaerobic glycolysis forms lactate and this can be used to indicate the amount of glycolysis that has occurred (Bangsbo et al., 1991). Using this method, Bangsbo et al. (1991) reported blood lactate values of 4.8 and 3.7 $mmol.l^{-1}$ at the end of the first and second halves, respectively; therefore, indicating that more glycolysis occurred in the first half when compared to the second half.

Research demonstrates that mean blood lactate concentrations of 2 - 10 $mmol.l^{-1}$ have been recorded during soccer games (Agnevik, 1970; Bangsbo, 1994b; Ekblom, 1986; Krustrup et al., 2006). Bangsbo et al. (2006) suggested that these findings indicate that the rate of muscle lactate production is high during match-play, but muscle lactate has been measured in only a single study (Krustrup et al., 2006). Values of muscle lactate in Krustrup et al. (2006) study were less than one third of the concentrations seen during short-term intermittent exhaustive exercise (Krustrup et al., 2003). Krustrup et al. (2003) also reported that muscle lactate concentration was not correlated with blood lactate concentration. Therefore, it is not surprising that authors have questioned the role of blood lactate as an indicator of glycolysis because the concentration of blood lactate is dependent on the release of lactate from the muscle and the removal of lactate from the blood (Bangsbo, 1994b).

Due to the intermittent nature of soccer, differences are seen between blood lactate concentrations when compared to continuous exercise. During continuous exercise, blood lactate concentrations are lower than in intermittent exercise; but, because of the nature of continuous exercise, the values represent muscle lactate levels well (Bangsbo et al., 2006). The differences between intermittent and continuous exercise are more than likely due to the difference in muscle lactate and blood lactate turnover rates during the two types of exercise, with the rate of lactate clearance being significantly higher in muscle than in blood (Bangsbo et al., 1993). Therefore, blood lactate concentration can be high even though the muscle lactate concentration is relatively low during intermittent exercise, such as soccer (Bangsbo et al., 2006).

Bangsbo et al. (1991) and Krustrup & Bangsbo (2001) also investigated lactate levels during soccer matches. Krustrup & Bangsbo (2001) tested player's blood lactate levels at the end of the 1st and 2nd halves and suggested that although some of the players had low blood lactate levels, this does not mean that they didn't produce high amounts of lactate during the match. It can also be suggested that blood lactate concentrations seen during a match may not be a true reflection of the activities immediately prior to sampling, but, instead a response to a number of high intensity periods of the match, where high muscle lactate concentrations have been cleared into the blood (Bangsbo et al., 2006).

2.1.3 Substrate Utilisation

Understanding the energy demands and which substrates are utilised during a soccer match allows coaches and nutritionists to provide nutritional strategies for soccer players.

Carbohydrates and fats are important fuel sources during soccer performance. Bangsbo et al. (1994b) reported a mean respiratory exchange ratio of 0.88 during soccer match-play, which implies that 60 % of the energy was obtained from carbohydrate metabolism (glucose and glycogen) and 40 % of the energy was

obtained from fats. One of the first studies to measure muscle glycogen stores during a soccer match was Saltin (1973) who found that muscle glycogen stores were nearly depleted at half-time when the pre-match levels were low. It was also seen that muscle glycogen concentrations decreased by 91 % throughout a match.

Krustrup et al. (2006) analysed single muscle fibres after a soccer match and results showed that a significant number of muscle fibres are completely depleted or partly depleted at the end of a match (Krustrup et al., 2006). Nordheim & Vollestad (1990) hypothesised that glycogen degradation could actually be greater than the amount that has been suggested in other research due to glycogen resynthesis during the low intensity and rest periods of the game.

Krustrup et al. (2006) also found that blood glucose concentrations were kept elevated throughout a match, whereas there was a progressive increase in free fatty acids (FFA) concentration. Findings such as these suggest that the rate of glucose release from the liver is high enough to compensate for the use of blood glucose throughout a game (Bangsbo et al., 2006). However, the increase in FFA concentrations, especially in the second half of the match, can be explained by the frequent rest and low-intensity periods of the game, which allow increased blood flow to adipose tissue, promoting release of fatty acids (Krustrup et al., 2006). Although protein metabolism does play a role during exercise it only provides approximately 10 % of energy for muscular contraction (Wagenmakers et al., 1989) and, therefore, is not considered to play a major part in energy provision of a soccer match.

2.2 Fatigue in Soccer

Russell et al., (2011a) demonstrated that fatigue caused a decline in soccer skill performance during the soccer match simulation protocol (SMS). Shooting precision was 25.5 % less accurate at the end of the 90 min protocol compared to shots taken before exercise and passing speed decreased by 7.8 % in the last 15 min of exercise compared to the first 15 min. No difference was seen in dribbling skill tests and

authors concluded that interventions to maintain skill performance in the second half of a soccer match are warranted.

The findings of Russell et al. (2011a) are in agreement with previous research, where modifications in speed and/or precision of sports skills have been reported under fatiguing conditions (Ali et al., 2007b). The authors also suggest that the results exemplify the importance of measuring precision and speed of skills.

The mechanisms of match-related fatigue involved in soccer are likely to be multifaceted, but the main causes suggested by Krustrup et al. (2006) are muscle damage, influencing proprioception and glucose transportation into active muscle as well as differences in fibre-specific muscle glycogen levels, hypohydration (Ostojic & Manzic, 2002; Bangsbo et al., 2006) and reductions in blood glucose concentrations.

2.2.1 Muscle Glycogen Depletion

Reilly & Thomas (1976) showed that the amount of sprinting, high-intensity running and the distance covered are all lower in the second half of a soccer match compared to the first half. Therefore suggesting that performance is inhibited in the second half and fatigue occurs towards the end of a game (Mohr et al., 2005).

In laboratory investigations, Bangsbo (1994a) attempted to identify the intramuscular factors causing fatigue. The author concluded that it was not possible to identify any single factor (e.g., hydrogen ions, lactic acid, potassium imbalance, ammonia or energy depletion) or combination of factors that would explain fatigue definitively; however, several studies have investigated this area after Bangsbo (1994a).

Bangsbo (1994b) and Krustrup et al. (2006) showed that blood lactate concentrations declined in the later stages of a soccer match, whereas plasma FFA concentrations are

increased. It is probable that low muscle glycogen concentrations together with elevated catecholamine concentrations are associated causes of increased lipid turnover as match-play progresses (Bangsbo, 1994b).

Shepard (1992) suggested that there is a limited store of carbohydrate in the body, which is small enough to be threatened during a soccer match, whereas fat stores are more than sufficient for the duration of a soccer match. For example, a player with 28 kg of skeletal muscle will have a total intramuscular store of ~ 6700 kJ of carbohydrate, with an additional 90 - 100 g of glycogen (1500 - 1675 kJ of energy) stored in the liver (Shephard, 1992). In comparison, the amount of energy stored as fat can amount to 209340 - 418680 kJ in lean men and women (Shephard, 1992).

Saltin (1973) found that muscle glycogen stores were almost depleted at half time when levels of muscle glycogen were low before match-play (~ 200 $mmol \cdot kg^{-1}$ dry weight). Conversely, when players started the game with normal muscle glycogen levels (~ 400 $mmol \cdot kg^{-1}$ dry weight), the concentrations of muscle glycogen were still relatively high when the half time biopsy was taken, but below 50 $mmol \cdot kg^{-1}$ dry weight at the end of the match.

Similarly, other researchers have seen that muscle glycogen concentrations are ~ 50 $mmol \cdot kg^{-1}$ wet weight at the end of a match (Samaros, 1980; Jacobs et al., 1982; Leatt and Jacobs, 1989; Krustrup et al., 2006) when muscle biopsy techniques were used. Therefore, research suggests that muscle glycogen depletion to concentrations below 200 $mmol \cdot kg^{-1}$ dry weight slows the glycolytic rate to below maximum capabilities; consequently, fatigue might occur (Bangsbo et al., 1992).

2.2.2 Evidence that Muscle Glycogen Depletion Causes Fatigue

Studies that have manipulated dietary intake demonstrate that low muscle glycogen contributes to the development of fatigue during long-term intermittent exercise (Bangsbo et al., 1992; Balsom et al., 1999). Balsom et al. (1999), although not specific to soccer, showed that increasing glycogen concentrations allowed the participants to complete more work during a 10 min and 30 min cycling protocol. Therefore, elevating glycogen concentrations has the potential to improve physical performance.

Saltin (1973) showed that low muscle glycogen concentrations were associated with a reduced work rate in a soccer match. When players started matches with reduced muscle glycogen concentrations they covered 25 % less distance than those who started with normal concentrations of muscle glycogen. In addition, players with lower concentrations of glycogen completed less high-intensity running than players with normal concentrations of glycogen. However, skill performance was not evaluated in this study.

Krustrup et al. (2006) took muscle biopsies from 31 players before and after three friendly matches. It was seen that muscle glycogen decreased from 449 $mmol \cdot kg^{-1}$ dry weight before exercise to 255 $mmol \cdot kg^{-1}$ dry weight after match-play, with 35 % of the muscle fibres being almost depleted of glycogen and 12 % being completely devoid of glycogen at the end of the match. Interestingly, sprint time was increased by 2.8 % at the end of a match when compared to the beginning and this was related to low glycogen levels in individual muscle fibres.

Carling & Dupont (2010) found that when studying elite players during three soccer matches, over 7 days, skill performance was able to be maintained throughout a match. However, the ability to sprint was decreased at the end of a match. The authors acknowledged that glycogen depletion could cause a reduction in the amount of sprinting at the end of a match; nevertheless, they did not show any decrease in the

total number of passes, percentage of completed or uncompleted passes, number of ball possessions and possessions gained or lost, number of touches per possession, number of duels, percentage of duels won or lost, total number of shots and the percentages of shots on target. Skills were measured by a semi-automatic player tracker and a trained match analyst. Carling & Dupont (2010) suggested that the gross nature of the measures employed were not sensitive enough to detect changes in skill, as it was in the field, whereas most other recent research into fatigue and skill performance had been performed in a laboratory/controlled setting.

2.2.3 Mechanisms for Low Glycogen Concentration Causing Fatigue

Broberg & Sahlin (1989) concluded that submaximal exercise to fatigue, causing low intra-cellular levels of muscle glycogen, results in a breakdown of the total adenine nucleotide pool in the working muscle through deamination of adenosine monophosphate (AMP) to inosine monophosphate (IMP) and ammonia (NH_3). The authors suggested that the higher average rate of AMP deamination during exercise is due to a relative impairment of ATP resynthesis caused by the low muscle glycogen level. Therefore, fatigue may be a consequence of the ATP resynthesis failure, due to a relative pyruvate deficiency, which results in reduced substrate availability for anapleorotic reactions that supply the tricarboxylic acid cycle (Costill & Hargreaves, 1992).

Krustrup et al. (2006) studied blood metabolites during a soccer match and found that muscle ATP was only moderately reduced (15 %) during a match. Krustrup et al. (2006) also stated that during intense short term exhaustive exercise, muscle ATP is not lowered more than 30 %, and the resynthesis rate is rather low in recovery. Therefore, the observed ATP levels may reflect actual lowering of muscle ATP and a corresponding accumulation of muscle IMP, which has been observed during a match (Krustrup et al., 2006).

2.2.4 Dehydration

Exercise can induce significant elevations in body (core and skin) temperature (ACSM, 2007), which increases sweat rate and fluid loss. The combination of these factors can seriously compromise performance through dehydration (Casa et al., 2005). Saltin & Costill (1988) suggest that fluid losses totalling greater than 2 % of body mass can reduce performance in continuous aerobic activity by as much as 20 %. As well as the physical deterioration in performance, cognitive function can also be impaired when body mass loss exceeds 2 % (Gopinathan, 1988).

It has been observed that professional soccer players become hypohydrated in soccer matches. Edwards et al. (2007) examined the effects of hypohydration on soccer performance and found that ingesting no fluid over 90 min of exercise significantly impaired the physiological performance of a sport-specific fitness test (Yo-Yo intermittent recovery test) after exercise, compared with a trial that included fluid provision. This finding was in agreement with Walsh et al. (1994) who suggested that high-intensity cycling performance was decreased when participants were slightly hypohydrated. Additionally, Edwards et al. (2007) reported significantly greater ratings of perceived exertion and elevated sensations of thirst when no fluid was allowed throughout the 90 min exercise protocol. The authors suggested that consciously perceived (negative) factors such as thirst could be responsible for the observed limitations in performance.

Specifically related to soccer skill, McGregor et al. (1999) simulated soccer exercise using the LIST protocol and reported that performance of dribbling was compromised in a moderately hypohydrated condition. However, McGregor and co-authors noted that performance in a mental concentration test was unaffected by fluid losses of 2.4 % of body mass.

Davies et al. (1995) investigated the fluid loss of an English Premier League team for 4 weeks, under English winter conditions (mean temperature of 6.9 °C, relative

humidity of 81 %), and found that the mean mass lost was 2.9 %; this finding suggests that soccer players do not routinely consume enough fluids even in temperate regions.

2.3 Soccer Skill Tests

2.3.1 Multi-faceted Tests

Multi-faceted tests include more than one skill type which allows a closer look at skill performance throughout a protocol that represents the demands of a soccer match (Ali, 2011). Table 2.1 provides an overview of tests that have adopted a multi-faceted approach to soccer skill performance.

Many skill tests have undertaken this multi-faceted approach. For example, an early protocol by Zelenka et al. (1967) has since been modified by Abt et al. (1998) and Vanderford et al. (2004). The later versions of this protocol removed some of the different movement patterns that were included in the Zelenka test, such as crawling under netting, because this movement is not a feature of actual soccer match-play.

Ali et al. (2007a) developed two tests that can be used in combination within the same exercise protocol (LIST). Forty-eight university players (24 elite and 24 non-elite) volunteered to complete The Loughborough Soccer Passing Test (LSPT) to assess the validity and reliability of the test. The players complete sixteen passes against four different coloured target areas as quickly as possible. The Loughborough Soccer Shooting Test (LSST) was the second test proposed by Ali et al. (2007a). This test used the same 48 players as the LSPT and the protocol required players to complete 10 shots with one min rest periods between each shot sequence.

The tests devised by Ali et al. (2007a) are dynamic because players have to decide on how best to control the soccer ball and how to subsequently position themselves for

the next pass or shot. A more skilful player should be able to complete both protocols quicker than a recreational player and the results that Ali et al. (2007a) presented showed this in terms of improved movement time, reduced penalty time and better overall performance. The LSST measures the speed of the ball by speed gun, allowing additional performance data to be recorded. However, this method measured ball speed at a certain point in flight and although this gives an idea of speed, if the ball is not measured at the same point each time a shot is taken, the speed values might not provide a consistent measure of average ball speed. Also, shot speed was rejected if it was below a certain speed (64 $km \cdot h^{-1}$) as the researchers conceded that if all shot speeds were included in subsequent analysis, there would be no statistical difference between groups. Whereas, the skill tests used by Russell et al. (2010) (described in sections 2.4.3 and 2.4.4) use video analysis to determine the average ball speed throughout flight. In addition, Russell et al. (2010) tests provide distinct outcome measurements for ball speed, precision and success in shooting, passing and dribbling tests. These methods allow researchers to provide actual measures of skill in ecologically valid units, unlike criterion-based methods.

The LSST and LSPT can distinguish between elite and non-elite players; however, as with many shooting and passing protocols the precision of the shots and passes are not measured. It is hard to suggest that the pass or shot would have been successful by simply recording that the soccer ball hit the correct target. Also, the results from these tests can be difficult to interpret because they lack ecological validity.

Table 2.1: Summary of studies that use a multi-faceted approach

Study (year)	No. of Participants	Measurement	Assessment of Method	Outcome Measures	Reliability
Zelenka et al. (1967)	12 male players aged 17-18 yrs old.	Sprinting, jumping, slalom dribbling and passing a soccer ball over a circuit (123 m).	Timing and Criterion-based measure	Time and Points.	No systematic check for reliability. No validity data reported.
Northcott et al. (1999)	10 male university players.	2 x 45 min circuits. Soccer skill assessed using 2 x10 m, 1 x 20 m, 1 x 30 m passes and a 15 m shooting test assessed every 15 min.	Criterion-based measure	Points	No systematic check for reliability. No validity data reported.
Ali et al. (2007a)	48 male university players.	Loughborough Soccer Passing Test: 16 passes against 4 different coloured targets as quick as possible.	LSPT- Timing: penalty time added for inaccurate passing, poor control and taking too long to complete circuit.	LSPT- Time.	LSPT: Coefficient of variation of 14.4 %. Construct validity: elite 20 % better than non-elite ($P <$ 0.01).
		Loughborough Soccer Shooting Test: Sprint to cone and back to start, passes a ball against a bench and shoots at full size goal 16.5 m away. Player sprints past the 4.5 m line to finish.	LSST- 10 shots performed per trial. Timing: mean time recorded for each sequence. Speed: speed of shot measured by radar gun. Criterion-based measure: points accrued for accuracy of shot.	LSST- Total time to complete sequence, shot speed and points scored.	LSST: Coefficient of variation of 4.4 %, 9.5 % and 57.8 % for time taken, shot speed and points scored. No difference between elite and non-elite in points scored. Elite had faster shot speed and performed each sequence quicker.

2.3.2 Soccer Ball Dribbling Tests

Different studies have analysed dribbling performance (Reilly & Holmes, 1983; McGregor et al., 1999; Hoare & Warr, 2000; Rosch et al., 2000; Haaland & Hoff, 2003); however, many of these test have used time of dribble as the single measure to measure ball dribbling skill. Table 2.2 provides an overview of protocols that have analysed dribbling skill.

Most of the dribbling tests that have been devised, adopt the style of dribbling around cones placed at set distances away from each other (Reilly & Holmes, 1983; McGregor et al., 1999; Hoare & Warr, 2000; Rosch et al., 2000; Haaland & Hoff, 2003, Mirkov et al., 2008; Currell et al., 2009; Figueiredo et al., 2010; Russell et al., 2010). Many authors have evaluated the test-retest repeatability of soccer dribbling tests (e.g., Reilly & Holmes, 1983; McGregor et al., 1999; Haaland & Hoff, 2003, Mirkov et al., 2008; Currell et al., 2009; Figueiredo et al., 2010; Russell et al., 2010). However within this previous research, with the exception of Russell et al. (2010) the most commonly used criteria for dribbling skill is dribbling time. Relying on dribbling time as the outcome measure of performance does not provide information on dribbling accuracy or success.

Some tests (e.g., Figueiredo et al., 2010) include penalty points in their dribbling tests. However, adding 'penalty time' to real data reduces the ecological validity of a test as results are not representative of actual dribbling performance as the values added are constant values and not actually representative of the mistake made. It also doesn't provide a representation of the skill of the player. Nevertheless, using dribbling tests that only measure time might increase the reliance on sprinting ability rather than the features that make up complete skilled performance (Ali et al., 2011).

Russell et al. (2010) assessed test-retest reliability and construct reliability for dribbling skill performance using twenty outfield soccer players. The test required players to dribble through 7 cones over a 20 m distance as quickly and accurately as

possible. Measurements taken were speed, success and precision (precision was defined as the distance of the centre of ball to the centre of the cone, captured using video cameras and digitalised). Coefficient of variation for ball speed for dribbling was calculated to be 2.4 %, 4.6 % for precision and 2.2 % for success. The methods used by Russell et al. (2010) also included the construct validity of the tests and they demonstrated that dribbles performed by the professional players were 14 % faster, 17 % more precise and 20 % more successful than those made by recreational players.

Therefore, the dribbling tests developed by Russell et al. (2010) that incorporate precision, success, and speed from video digitalization allow more information about the proficiency of the technical action of dribbling to be assessed. Additionally, for an intervention study this method of assessment allows more subtle changes to be detected than previous tests (Russell et al., 2010).

Table 2.2: Summary of studies that use ball dribbling tests

Study (year)	No. of Players	Measurement	Assessment of Method	Outcome Measures	Reliability
Reilly and Holmes (1983)	40, 12 and 13 yr old players	Ball Control; 5 cones spaced 4.5 m away from each other.	Timing	Time; aggregate time of four trials used as performance score.	Validity coefficients of -0.24 to 0.6.
McGregor et al. (1999)	37 players	Ball Control; 6 cones spaced 3 m apart.	Timing; 10 trials completed with 1 min rest between each	Time; sum of 10 trials used as performance score.	Validity coefficients of $r = 0.78$ ($P < 0.01$) and 95 % confidence intervals of 0.08 ± 6.43 s.
Hoare and Warr (2000)	Used for Talent ID	Ball Control; slalom course of four markers placed in reverse 'T' position.	Coaches providing subjective rating of performance.	Subjective rating of performance.	No validity or reliability data published.
Rosch et al. (2000)	588 players aged between 14 -41 yrs old.	Ball Control; dribble around a 20 m course, around obstacles.	Timing	Time	Top-level players significantly faster than novice players ($P < 0.05$)
Haaland and Hoff (2003)	47 male competitive players	Ball Control; using one foot, dribbling around 5 cones, 1 m apart.	Timing	Time	Coefficient of Variation of 4.3 %
Mirkov et al. (2008)	20 elite level soccer players	Ball Control; zig-zag dribble.	Timing	Time	Coefficient of Variation of 3.3 %.
Currell et al. (2009)	11 recreational players	Ball Control; dribbling around cones on a circuit of 9.14 m.	Timing; 2 attempts per player (6 in total).	Time; combined time for all 6 attempts.	Coefficient of Variation of 2.2 %.
Figueiredo et al. (2010)	39 youth players	Ball Control; 9 x 9 m square, cone on each corner, and 1 in middle. Dribble around each cone.	Timing	Time; mean time of four recorded trials.	Coefficient of Reliability of 0.74.
Russell et al. (2010)	20 outfield soccer players (19 ± 4 yrs)	Speed, accuracy, ball control; Dribble through 7 cones over a 20 m distance as quickly and accurately as possible.	Video Digitalization	Ball speed, precision, success rate measured for each dribble.	Coefficient of Variation of 2.4 %, 4.6 % and 2.2 % (ball speed, precision, success respectively).

2.3.3 Shooting Tests

Arguably, the most highly valued and important skill within the game is the ability to score goals (Jinshen et al., 1991). Consequently, many studies have evaluated shooting performance of soccer. For example, Reilly & Holmes (1983) conducted research with players using both feet to shoot towards a target measuring 3.6 x 2.4 m from a distance of 8.1 m. Forty players aged between 14 and 41 years old were used for the research and values of 0.65 and 0.81 were reported for reliability coefficients and -0.24 to 0.65 for validity coefficients. Table 2.3 provides an overview of studies that have devised shooting tests.

Rosch et al. (2000) asked 588 players aged 14 to 41 to conduct two shooting protocols, one from a 'dead' start and one from a pass. Players shot at targets within a full size goal from a 'dead' ball situation at 16 m and points were awarded for accuracy. The shooting from a pass protocol was conducted by passing a ball, 20 m along the ground towards the penalty spot. The player takes a short run up and shoots towards the goal (divided into six segments) and points are awarded for accuracy. For both protocols, no systematic check for reliability and validity were reported. As the ball was passed to the player by the examiner it is hard to see how the speed of the pass could be kept consistent as well as the ball being passed to the penalty spot accurately each time.

Forty-seven competitive soccer players participated in a study by Haaland & Hoff (2003). The players received the ball at chest height in front of the goal at 10 m. The player then controls the ball and volleys it towards the goal, which was divided into different scoring zones. A Test-retest repeatability of 11.5 % was reported by the research team suggesting that the testing procedure could not be repeated in the same manner from test to test.

Williams et al. (2010) reported TEM % of 19.6 % for shooting accuracy when data was collected from 15 players. Players were fed 6 soccer balls, individually onto their dominant foot and had to shoot at a soccer goal. Points were scored by shooting at either side of a centre object that mimicked a real goal keeper. One point was scored if the ball hit either side of object. If the ball managed to hit the object, no points were given to the player. This type

of criterion measurement gives no data of deviation away from the centre of the goal. Therefore it cannot be said, whether the goal keeper would have saved the ball if it were a real match.

Figueiredo et al. (2010) measured shooting accuracy in five attempts at kicking the ball at a 2 x 3 m goal located at the end line of a 9 x 9 m square. The test was recorded and scored subsequently. A coefficient of reliability of 0.71 was recorded for this test by the authors.

Russell et al. (2010) shooting protocol measured three different outcomes of the skill; speed, precision and success. The protocol consisted of footballs being released from mechanisms which allowed the ball to be consistently passed to the player at a speed of 2.3 $m.s^{-1}$ and accurately into a 1.5 x 1.5 m square where the player would jog to the centre and strike the ball towards a target light in the goal, which involved the player actively searching for the target before shooting. Precision, speed and success were determined by digitalising the image when the ball struck the net. The distance from the centre of the target to the centre of the ball was then determined. Coefficients of variations of 6.9 %, 23.5 % and 14.4 % were calculated for ball speed, precision and success respectively.

In the majority of the protocols described previously, with the exception of Russell et al. (2010), points were awarded for hitting various parts of targets, where more points were awarded for hitting the corners and less for the middle of the goal as this is more difficult for the goalkeeper to defend. In some of the tests, players were required to shoot from distances close (< 10 m) to the goal; therefore, resembling a pass rather than a shot. In addition, some shots were taken from static positions, and it can be argued that this type of protocol would better assess technique rather than skill.

Many of the shooting skill tests measure shooting precision and success in points. The tests described by Russell et al. (2010) developed outcome measures based on absolute measures of technical proficiency (i.e., precision and success of skills). These types of tests enable players and coaches to directly compare performances among players of different standards and to literature, when players have been subjected to different conditions. Also, Russell et al.

(2010) suggested that the value of an intervention can be evaluated more effectively if the outcome measure is expressed in ecologically valid units. For example, if an intervention is accompanied by an improvement in the precision of passing by, say 20 cm, a coach can interpret this outcome as meaningful or not.

With the exception of Russell et al. (2010) and Ali et al. (2007a; described in section 2.4.4) the other studies did not provide information on the ball speed during the shot which could mean that players were trying to be more accurate at hitting the target as there was no goalkeeper present. Therefore the speeds might not represent match-play, and actually might not be good enough to score in an actual match.

Table 2.3: Summary of studies that use shooting tests.

Study (year)	No. of Players	Measurement	Assessment of Method	Outcome Measures	Reliability
Reilly and Holmes (1983)	40, 12 and 13 yr old players	Accuracy; using both feet, shooting towards a target of 3.6 x 2.4 m from 8.1 m away.	Criterion-based measure.	Points	Reliability coefficients of 0.65 and 0.81. Validity coefficients of -0.24 to 0.65.
Rosch et al. (2000)	588 players aged between 14 - 41 yrs old.	Accuracy; shot at full sized goal from dead ball situation, 16 m away (a). From a pass 20 m away (b).	Criterion-based measure; goal divided into 6 segments.	Points	No systematic check for reliability and validity reported.
Haaland and Hoff (2003)	47 male competitive players	Accuracy; received ball at chest height in front of goal (10 m away), controls and shoots at goal.	Criterion-based measure; goal divided into different scoring zone.	Points	Test-retest repeatability of 11.5 %.
Williams et al. (2010)	15 male amateur players	Accuracy; ball rolled to dominant foot, shooting at goal (4.5 x 3.0 m).	Criterion-based measure; points awarded for shooting either side of a centre object.	Points	TEM% for shooting accuracy 19.6 %.
Figueredo et al. (2010)	39 youth players	Accuracy; 5 attempts shooting at a goal (2 x 3 m) located at end of 9 x 9 m square.	Criterion-based measure; points awarded for different sections of goal.	Points	Coefficient of Reliability of 0.71
Russell et al. (2010)	20 outfield soccer players (19 ± 4 yrs)	Speed, accuracy, ball control; shoot at target light in a goal (7.33 x 2.44 m)	Video Digitalization	Ball speed, precision, success rate measured for each shot.	Coefficient of Variation of 6.9 %, 23.5 % and 14.4 % (speed, precision, success respectively).

2.3.4 Passing Tests

Hughes & Franks (2005) concluded that more shots were taken in teams that were able to pass the ball for longer periods of time, ultimately allowing more chances to score. Many researchers have proposed protocols to examine the passing aspect of match-play (Hoare & Warr, 2000; Rosch, et al., 2000, Haaland & Hoff, 2003, Rostgaard et al., 2008; Curell et al., 2009; Figueiredo et al., 2010; Russell et al., 2010). Many different approaches have been taken to assess passing performance during non-match settings as accurately passing the ball during a match is an essential skill needed by soccer players (Ali et al., 2011). Table 2.4 provides an overview of previous studies that have devised passing tests.

Hoare & Warr (2000) developed a passing test that involved the players being placed in pairs, with two lines formed 5 m apart. Players passed the ball back and forth to each other for 15 min. After this time the distance was increased to 10 m and the task was repeated. A 'selection panel' of coaches moved among the line of players to assess the direction and flight of the soccer ball when kicked and control of the ball when received. A subjective rating of excellent, good, average or poor was determined for each player. However, a limitation of this method is that no objective measures of accuracy, success and speed of the soccer ball were calculated and measurements relied on subjective measures from coaches. By relying on coaches to assess the performance of the player has inherit errors, including the subjective opinion of coaches and the availability of the coaches on repeated testing sessions. Therefore, Franks et al. (1986) stated that this method of assessment by experts is potentially unreliable and should not be used whenever possible.

The skill of passing is more complex than just passing to a stationary player over a set distance. This method of assessing 'skill' might actually only measure technique, as there are no cognitive and perceptual aspects involved. During a match situation, players need to be able to distinguish who to pass to, under pressure of opposition and time. There is also a need for the player to accurately pass the ball to their team mate as well as knowing how quickly the pass needs to be performed. The only test that incorporates any of these considerations is Russell et al. (2010) protocol as it includes visual searching for the correct target to pass to.

Furthermore, the type of pass performed changes during a match, (i.e., in the air, along the ground) and different tests have been devised to measure the different passes in the air (Rosch et al., 2000; Rostgaard et al., 2008; Currell et al., 2009) and along the ground (Hoare & Warr, 2000; Haaland & Hoff, 2003; Figueiredo et al., 2010; Russell et al., 2010).

Although many passing tests have demonstrated that they are reliable measures of soccer passing performance (Haaland & Hoff, 2003; Rostgaard et al., 2008; Currell et al., 2009; Figueiredo et al., 2010; Russell et al., 2010), most of these tests, with the exception of Russell et al. (2010), use criterion-based measures to measure performance. Also, many of these tests instruct players to pass a soccer ball from a stationary position (Rosch et al., 2000; Haaland & Hoff, 2003; Rostgaard et al., 2008; Currell et al., 2009), something that limits the ecological validity of the test, and therefore assessing technique of the player, rather than the skill of the performer.

Unlike previous tests, which classify performance of a pass in time and attempt to combine all aspects of skill performance into one outcome measure, Russell et al. (2010) use a passing test that quantifies the quality of passing in terms of precision, speed and success. In addition, using continuous data (i.e., outcomes can take any value) as opposed to discrete data (i.e. outcomes can only take certain values) is preferable because this method does not require subjective values to be attributed to errors and target regions (Russell et al., 2011c).

Table 2.4: Summary of studies that use passing tests.

Study (year)	No. of Players	Measurement	Assessment of Method	Outcome Measures	Reliability
Hoare and Warr (2000)	Used for Talent ID	Accuracy; Players in pairs, 5 m apart and 10 m apart.	Coaches providing subjective rating of performance.	Subjective rating of excellent, good, average or poor.	No reliability/validity data calculated
Rosch et al. (2000)	588 players aged between 14 -41 yrs old.	Accuracy; long passing over 36 m from a dead position into target area (10 x 10 m)	Criterion-based measure; points awarded for accuracy.	Points	No systematic check of reliability, however elite were better than novice.
Haaland and Hoff (2003)	47 male competitive players	Accuracy; soccer ball passed towards a mini goal (1 x 0.40 m) from 10 m away.	Criterion-based measure; points awarded for each successful pass.	Points; one point awarded for each successful attempt.	Coefficient of Variation of 11.3 %.
Rostgaard et al. (2008)	21 players (14 youth elite, 7 sub elite)	Accuracy; passing over 30 m in the air.	Criterion-based measure; points awarded for accuracy.	Points; 3,2,1 point awarded for precision of pass into target area, closer to the centre the more points are awarded.	Coefficient of Variation of 11.7 % (with exercise), 16.0 % (standalone test).
Currell et al. (2009)	11 recreational players	Accuracy; kicking ball at a target divided into 9 sections. Ball passed from stationary position.	Criterion-based measure; more points awarded for hitting centre of target compared to corners.	Points; centre of target worth 5 points, corners worth 1 point.	Coefficient of Variation of 2.8 %.
Figueiredo et al. (2010)	39 youth players	Accuracy and ball control; passing at target (1.22 x 2.44 m). Player made as many passes as possible in 20 s.	Criterion-based measure; three trials recorded. Best trial retained for analysis.	Points; 1 point awarded for each successful pass, if ball was handled or the player left the action area, 1 point was deducted from the total.	Coefficient of Reliability of 0.83.
Russell et al. (2010)	20 outfield soccer players (19 ± 4 yrs)	Speed, accuracy, ball control; passing a moving ball at 1 of 4 targets (2 x 1 m), passed at distances of 4.2 m and 7.9 m.	Video digitalization.	Ball speed, precision, success rate measured for each pass.	Coefficient of Variations of 6.5 %, 10 % and 11.7 % respectively.

Through cerebral blood flow studies, it has been demonstrated that exercise increases the brains metabolic requirements in critical regions, consequently, increasing central energy requirements (Ide & Secher, 2000). Glucose is the brain's principal energy substrate under normal physiological and environmental conditions (Evans & Amiel, 1998).

Early studies offered contradictory findings to how cognitive function/performance was influenced by exercise (Thomas et al., 1994; Brisswalter & Legros, 1996; Etnier et al., 1997). However more recently, choice reaction time (CRT) has been evaluated during prolonged exercise (10 - 60 min); results have shown that cognitive function improves with exercise duration at moderate intensity (Paas & Adam, 1991; Arcelin et al., 1997). This finding has been explained by activation of the central nervous system (CNS), assuming that exercise-induced arousal leads to a narrowing of the attentional focus (Martens et al., 1990; Gould & Krane, 1992). However, when exercise duration increases to above 1 hour, cognitive function has been seen to decrease (Grego et al., 2004).

It has been demonstrated, through the stepped hyperinsulinaemic glucose clamp technique that a threshold exists at which reduced blood glucose concentrations impair cognitive function. The results of previous research (Holmes et al., 1984; Stevens et al., 1989; Widom et al., 1990; Fanelli et al., 1993; Fanelli et al., 1994a; Fanelli et al., 1994b; Veneman et al., 1994; Maran et al., 1995; Evans et al., 2000) show that almost instantaneous reductions in cognitive function occur when blood glucose concentrations fall below 3.4 $mmol \cdot L^{-1}$. Additionally, restoring cognitive function to pre-hypoglycaemic levels after a hypoglycaemic episode can take up to 90 min, even when euglycaemia is restored.

Recently, many authors have demonstrated that the provision of sugar can influence cognitive functioning (e.g., Donohoe & Benton, 1999; Benton, 2002; Benton et al., 2003; Benton & Nabb, 2003); however, findings relate to non-sports settings. Lieberman et al. (2002) have published data suggesting that ingesting carbohydrate solutions of varying concentrations (6 % and 12 %) improved vigilance and self-reported mood during sustained aerobic activity.

Using a slightly lower concentration of carbohydrate (5.5%), Collardeau et al. (2001) demonstrated that cognitive performance was improved during a choice reaction task that was completed after prolonged steady-state running, even though exercise did not lead to a hypoglycaemic response. Therefore, endogenous carbohydrates can enhance cognitive and motor skill performance at rest and following continuous activity, even when the players remain euglycaemic.

Bandelow et al. (2010) tested cognitive function of soccer players in the heat, providing the players with either little water or a sports drink where they were encouraged to drink. Results showed that drinking a sports drink with carbohydrate helped to preserve fast reaction times, but only at the expense of decreased accuracy for cognitively complex tasks.

2.5 Carbohydrate Ingestion on Soccer Skill Performance

Match analysis demonstrated that soccer players work at around 70 – 80 % of $\dot{V}O_{2max}$ during an elite level match (Bangsbo, 1994), covering between 10 and 13 km (Osgnach et al., 2010). It has been shown that exercising at these intensities for prolonged periods of time places a heavy burden on glycogen stores and glucose as the main substrate for energy metabolism (Saltin, 1973; Romijin et al., 1993). Therefore, additional carbohydrate ingestion, with the potential to attenuate fatigue, has been a key point of investigation by research teams in recent times. Table 2.5 provides a summary of studies that have investigated additional carbohydrate supplementation and soccer skill performance.

It is not surprising that many studies have focused on the use of additional carbohydrate in an attempt to improve soccer performance, as well as other intermittent sports. Some of the earliest literature (Foster et al., 1986; Kirkendall et al., 1988; Nicholas et al., 1995) focused on the amount of work done by players (i.e., endurance running, distance covered, time at high-intensity running) and findings of these studies were in general agreement that supplementing players with carbohydrates, results in improvements in physical performance. For example, when players ingested up to 400 ml of a glucose polymer, it was seen that the distance covered at speed was 40 % greater in the carbohydrate group compared to the

placebo group and distance covered in the 2nd half of a match was 25 % greater in the carbohydrate group compared to the placebo group (Kirkendall et al., 1988). Similarly, Foster et al. (1986) supplemented players in an indoor match with either a placebo or glucose polymer solution and saw that players that ingested carbohydrates ran further and faster than those who ingested the placebo.

Additionally, Nicholas et al. (1995) found that by ingesting a 6.9 % carbohydrate solution endurance running was improved by 33 % compared to just a placebo when nine trained male players performed an intermittent exercise protocol (completing 75 min of intermittent running, in 15 min blocks and then an intermittent run to fatigue).

Few studies have examined the effects of carbohydrate ingestion on soccer skill performance. Those that have researched this area have incorporated different methodologies, exercise protocols and skill tests. The first study to primitively investigate this area was Muckle (1973) who reported that performance was improved with carbohydrates provision. Zeederberg et al. (1996) suggested that carbohydrate could increase performance due to the fact that without sufficient blood glucose concentrations, skill performance (requiring sensory-visual information) may be inhibited; however, the findings of Zeederberg's study did not show any improvements with carbohydrate. Zeederberg et al. (1996) found no improvements of tackling, heading, dribbling or shooting. In fact, success of tackling was lower when the glucose polymer was ingested compared to a placebo. The authors suggested that there were no measureable benefits of glucose polymer ingestion to improve motor skill performance. One of the limitations Zeederberg et al. (1996) suggested was that, results provided from field settings are limited because of the amount of extraneous factors that can influence skill performance in soccer matches.

Consequently, many of the more recent studies (Abt et al., 1998; Northcott et al., 1999; Ali et al., 2007b; Ali & Williams, 2009; Currell et al., 2009) have used simulations of soccer match-play as opposed to actual match-play because they are able to control the experimental conditions much more stringently than when using actual match-play for intervention studies.

Nevertheless, methodological differences in the exercise protocols used and the skill tests undertaken have provided conflicting results in the literature.

Some studies have found that no differences were seen between placebo and carbohydrate trials (e.g., Abt et al., 1998; Ali and Williams, 2009). Abt et al. (1998) suggested that no differences were seen because the glycogen depleting treadmill protocol used did not actually deplete the players' glycogen stores. However, the protocol used was an adapted Zelenka performance test (Zelenka, 1967) which, when it was published did not provide any data on the reliability of the protocol. Whereas, Ali & Williams (2009) only measured one soccer skill (passing) throughout the protocol. It was seen that there was a significant difference in soccer skill performance from the 1st half to the end of the 2nd half. However, no differences existed between the placebo and carbohydrate groups; therefore, any decline in soccer skill performance was not attenuated by carbohydrate. The protocols employed by both of these studies employ criterion-based measures, which might lack the sensitivity required to show a decrease in soccer skill.

Although Ali et al. (2007b) used the same passing test (LSPT) as used in Ali & Williams (2009), soccer skill testing was completed before and after exercise. Therefore, as conceded by Ali & Williams (2009), simply measuring soccer skill before and after exercise on an intervention study was inappropriate. Ali et al. (2007b) did find an improvement in shooting performance after exercise in the carbohydrate group when compared to the placebo group; however, no differences were observed in passing. By measuring skilled performance like this, there is no way to pinpoint where the change in performance occurred. Although this test has been validated and has been demonstrated to be reliable as a measure of skill performance it does not represent a soccer match completely because skills are performed throughout a match and not merely at the beginning and end.

Additionally, because of the limitations already highlighted, and due to the fact that players underwent a glycogen depleting exercise protocol prior to each test, the ecological validity of these results are questionable as it would not be common practice for players to start a match with depleted glycogen stores. Making players undergo a glycogen depleting exercise

protocol allowed the research team to more easily distinguish between differences in the placebo trial and the carbohydrate trial as plasma glycogen was only increased during the carbohydrate trial because of the additional supplementation with carbohydrate. Abt et al. (1998) employed a similar exercise depleting protocol and reported no differences in skilled performance between placebo and carbohydrate groups.

Other tests that propose to measure the influence of additional carbohydrate on soccer skill include Ostojic & Mazic (2002) and Currell et al. (2009). Neither of these studies included pre-trial protocols to deplete glycogen stores. Both studies found that when players ingested additional carbohydrate, they completed the dribbling protocols faster than the players in a placebo trial. Currell et al. (2009) also reported that carbohydrate improved shooting performance. However, Ostojic & Mazic (2002) did not include a baseline measurement of skill performance and no crossover trial was completed by players. Therefore, it cannot be assumed that the players in the two different trial groups were as skilful as each other.

In summary, early research suggests that carbohydrate supplementation may attenuate the decline in soccer skill performance; however, inconsistent methods have led to contradictory findings. Therefore, studies that use validated procedures in a protocol to replicate soccer performance are warranted in order to evaluate the influence of exogenous carbohydrate on soccer skill performance. Using methods that can detect small changes and allow continuous data to be collected could potentially highlight these small differences and give vital, meaningful feedback to coaches, players and researchers alike.

Table 2.5: The influence of carbohydrate supplementation on soccer skilled performances

Study (Year)	Experimental Design	Amount and Timing of Carbohydrate	Results
Muckle (1973)	Over 40 matches (20 supplemented, 20 no supplement) the frequency of ball contacts, goals scored or conceded and ball involvements per player were measured.	High carbohydrate diet for 24 h before a match and 46 % concentrated glucose syrup 30 min prior.	With extra carbohydrate team scored more goals and conceded fewer in the 2nd half of a match compared to the no supplement trials. More shots and touches of the ball were also seen in the extra carbohydrate matches.
Zeederberg et al. (1996)	22 male players, under 19 yrs old played two matches separated by 7 days. Players either ingested a placebo or glucose polymer and the reverse was ingested in the 2nd trial.	5 $ml.kg^{-1}$ of either an artificially sweetened placebo or 6.9 % glucose polymer-electrolyte beverage, 15 min before each half.	No effects of carbohydrate supplementation was seen on subjective evaluations of controlling, passing, dribbling, heading, tackling and shooting.
Abt et al. (1998)	6 midfield players completed a simulated soccer match protocol (modified from Zelenka et al., 1967) measuring shooting and dribbling by criterion-based measures pre and post intermittent exercise.	A high carbohydrate diet or a mixed diet 48 h prior to protocol were ingested by each player.	No differences were seen between the high carbohydrate diet or mixed diet on shooting or dribbling performance.
Northcott et al. (1999)	10 male players undertook a 90 min simulated match consisting of moving at different paces and criterion-based measures of passing and shooting skill were used to assess skill throughout exercise.	8 % glucose-polymer or a water placebo at 8 $ml.kg\ BM^{-1}$ prior to both halves.	Carbohydrate increased skill proficiency in last 15 min of the simulation compared to the placebo group.

Table 2.5: continued..

Study (Year)	Experimental Design	Amount and Timing of Carbohydrate	Results
Ostojic and Mazic (2002)	22 male players were split into two groups (PLA or CHO) and assessed for dribbling performance after a 90 min match.	7 % carbohydrate-electrolyte solution or a water placebo.	Carbohydrate supplementation improved dribbling performance compared with the placebo group.
Ali et al. (2007b)	16 male players, crossover design using a 90 min soccer match simulation and were assessed for shooting and passing pre and post exercise using criterion based measures.	6.4 % carbohydrate-electrolyte solution or a non-electrolyte placebo immediately prior (5 ml.kg BM^{-1}) and every 15 min during exercise (2 ml.kg BM^{-1}).	It was seen that carbohydrate improved shooting performance compared with placebo post exercise. No effects of exercise of carbohydrate supplementation were seen on passing.
Ali and Williams (2009)	17 male players, crossover design using a 90 min soccer match simulation and were assessed for passing throughout exercise using criterion-based measures.	6.4 % carbohydrate-electrolyte solution or a non-electrolyte placebo immediately prior (8 ml.kg BM^{-1}) and every 15 min during exercise (3 ml.kg BM^{-1}).	No effects of supplementation with carbohydrates were seen when compared to a placebo.
Currell et al. (2009)	11 male players, crossover design using a 90 min soccer match simulation. Skills were assessed using criterion-based measures and a timed dribbling test throughout exercise.	7.5 % maltodextrin beverage or a placebo 30 min prior (6 ml.kg BM^{-1}), at half time (4 ml.kg BM^{-1}) and every 12 min during exercise (1 ml.kg BM^{-1}).	Results showed that carbohydrate improved dribbling and shooting performances.

2.6 Caffeine Ingestion on Cognitive Function and Skill Performance

Although physical attributes are important for successful match-play, the major difference between elite and recreational players is their cognitive functioning and skilful performance (Williams, 2000). Gillingham et al. (2004) and other studies, (e.g., Tikuisis, et al., 2004; McLellan, et al., 2005a; McLellan, et al., 2005b; Lohi et al., 2007) have reported increased arousal and vigilance in non-sports settings after caffeine ingestion.

There is also evidence to suggest that the ingestion of caffeine can improve visual information processing and reaction time during computer and hand written tasks (Brice & Smith, 2001; Haskell et al., 2005; van Duinen et al., 2005). Furthermore, Marsden & Leach (2000) reported improved performance after ingestion of caffeine (as 250 mg of black coffee) in maritime navigational skill (visual search) but not in others (chart search or problem solving).

Caffeine on its own has been shown to increase physical performance, which is probably due to caffeine influencing the central nervous system, without any detectable alterations in substrate utilization occurring during exercise (Doherty & Smith, 2005). Previous research has shown that caffeine can be equally as effective at lower doses (2 - 6 $mg \cdot kg^{-1}$ BM) in increasing endurance capacity of athletes (Graham & Spriet, 1995; Kovacs et al., 1998).

Specifically related to skill performance, Stuart et al. (2005) were the first authors to report enhanced skill performance after caffeine ingestion (6 $mg \cdot kg^{-1}$ BM), in rugby passing accuracy. During a protocol that simulated the demands of rugby match-play, players completed seven circuits in each 40 min halves with a 10 min half-time. Each circuit included stations for measurement of sprint time (two straight-line and three agility sprints), power generation in two consecutive drives, and accuracy for passing balls rapidly. However, the performance measured was a closed skill (one performed in a stable or largely predictable environment and self-paced), rather than the open skills (motor skills performed in an unpredictable, changing environment, which dictates how and when the skill is performed, externally paced) typical of team-sport match-play (Knapp, 1977).

Foskett et al. (2009) found that soccer skill was enhanced with the ingestion of 6 $mg \cdot kg^{-1}$ BM of caffeine with water ingested 1 h before exercise when compared with a placebo. During this study, the authors suggest that skill performance (LSPT) was increased in the caffeine trial as total time and penalty time were both better compared to the placebo trial.

2.7 Practical Issues Concerning Carbohydrate Ingestion

2.7.1 Type of Carbohydrate

According to the ACSM position stand on exercise and fluid replacement, carbohydrate consumption can be beneficial to sustain exercise intensity during high-intensity exercise events of ~ 1 h or longer, as well as less intense exercise events sustained for longer periods (ACSM, 2007).When carbohydrate is consumed at a rate of ~ 30-60 $g \cdot h^{-1}$ studies have demonstrated that blood glucose levels are maintained and subjects can sustain exercise capacity (Coyle & Montain, 1994; Coyle, 2004).

Hawley et al. (1992) suggested sucrose, glucose and maltodextrins have similar oxidation rates when ingested individually, as long as they provide sufficient amounts of carbohydrates to the working muscles. Therefore, to increase carbohydrate oxidation rates and ultimately increase performance, Shi et al. (1995, 1997) hypothesized that a mixture of carbohydrates may reduce competition for transport and increase total carbohydrate absorption. Shi et al. (1995, 1997) suggested that adding a second transportable substrate to a solution (e.g., fructose) stimulates additional transport mechanisms. Glucose is transported across the luminal membrane by SGLT1, whereas fructose is transported by GLUT5 (Ferraris, 2001).

Adopo et al. (1994) combined 50 g glucose and 50 g fructose in the same solution and results showed that combined ingestion of carbohydrates increased oxidation rates by 21 % compared to ingesting the same total amount of one carbohydrate (100 g glucose). Many recent studies (Jentjens et al., 2004; Wallis et al., 2005; Jeukendrup et al., 2006) have demonstrated that ingesting solutions of glucose and fructose improves carbohydrate

oxidation by 25 – 50 %, when compared to a glucose solution; however, many of these studies use concentrations of carbohydrates that are much higher (> 10 % CHO) than commercially available sports drinks (4 – 8 % CHO) and large volumes of fluid, which could compromise performance (Jeukendrup et al., 2010). It should also be mentioned that increasing fructose intake should be undertaken with caution because of the potential to cause gastro-intestinal discomfort (Convertino et al., 1996; Casa, 2000).

Although intestinal carbohydrate absorption rates were not determined in previous studies (Jentjens et al., 2004; Wallis et al., 2005 and Jeukendrup et al., 2006), the fact that free glucose or glucose derived from the hydrolysis of maltodextrins and fructose are absorbed by different intestinal transporters could explain the high rates of exogenous CHO oxidation observed when mixtures of these CHO are consumed. Therefore, the ACSM position stand (2007) advised that to achieve the highest rates of carbohydrate delivery it is necessary to use a mixture of sugars (e.g., glucose, fructose, sucrose, maltodextrine).

2.7.2 Amount and Timing of Carbohydrate Ingestion

According to Casa et al. (2000), an ingestion rate of about 1 $g \cdot min^{-1}$ maintains optimal carbohydrate metabolism. Higher ingestion rates do not appear to influence performance when compared to a placebo solution (Mitchell et al., 1989). This is probably because the rate of gastric emptying is reduced and carbohydrate ingestion above 60 $g \cdot h^{-1}$ means that glucose oxidation rates do not significantly increase (Wagenmakers et al., 1993).

Researchers now understand that the slight slowing of gastric emptying caused by solutions containing up to 8 % carbohydrate is a relatively minor factor in fluid replacement rate compared with the large influence of increased fluid volume for increasing gastric emptying and fluid replacement rate (Maughan, 1991; Maughan & Noakes, 1991; Coyle & Montain, 1992).

According to ACSM (2009), the recommendation is that athletes do not lose more than 2 % of their body weight during exercise as this can cause performance to decrease. Therefore, Casa et al. (2000) recommends that athletes consume between around 200 ml of fluid every 10 - 20 min. Therefore, for an 80 kg athlete, 2.5 ml·kg BM^{-1} of fluid and carbohydrates every 15 min on average.

2.7.3 Drinks vs. Gels

Campbell et al. (2008) investigated the difference in performance between carbohydrate in different forms (gel and drink) and a placebo (water). They found that there was no difference in performance of a 10 km time trial when ingesting either carbohydrate in the form of a drink or gel (both equivalent to 5.9 % carbohydrate); however, both significantly improved performance more than just a placebo ($P < 0.05$). This result supports previous research that shows that carbohydrate ingestion improves performance, but this could have been exaggerated in this study as supplements were not disguised; consequently, players knew which supplement they were consuming.

Pfeiffer et al. (2010) investigated the difference in carbohydrate oxidation rates between carbohydrate gels and drinks (glucose and fructose; in a ratio of 2:1, at a rate of 1.8 g·min^{-1}). The results of a 180 min cycle at 59 ± 4 % of $\dot{V}O_{2max}$ found that the gel and drink showed similar carbohydrate oxidation rates throughout the trials. Therefore, it was concluded that the findings suggested that the intake of carbohydrate gels and drinks are an effective way to deliver intake rates of carbohydrate with limited gastro-intestinal tolerance problems (Pfeiffer et al., 2010).

Gastro-intestinal discomfort can be associated with carbohydrate gels (and high amounts of carbohydrate; Pfeiffer et al., 2010), which can reduce performance capabilities (Burke et al., 2005). Ingesting high amounts of carbohydrate in a semi-solid form could also slow gastric emptying because of the gel forming properties (guar-gum) (Meyer et al., 1988). However, Leiper et al. (2000) showed that gastric emptying rates were faster from a gel-forming carbohydrate compared with an isocaloric low-viscosity carbohydrate solution. The gel used

was a long chain glucose polymer which has the tendency to form a gel and was not actually ingested in gel form.

Pfeiffer et al. (2009) investigated the gastro-intestinal tolerance to different types and rates of ingestion of carbohydrate gels. They found no difference in gastro-intestinal discomfort in any of the treatment conditions, indicating a predominantly good tolerance during a 16 km run. In addition, it might be easier for athletes in the field to consume carbohydrate gels rather than a sports drink as it allows the athlete to take on a lot of carbohydrate without the extra fluid, thus dissociating fluid and carbohydrate intakes (Pfeiffer et al., 2010).

2.7.4 Gastric Emptying

Rates of gastric emptying and intestinal absorption should also be considered when exercise is undertaken (Casa et al., 2000). Studies have shown that the volume and formulation of a beverage that is consumed can influence the rate of gastric emptying. However, it has been assumed that exercise intensity plays a relatively minor role in determining the absorption of ingested drinks in most sports (Murray, 1987; Maughan & Leiper, 1994; Shi & Gisolfi, 1998). Maughan & Leiper (1994) used isotopic water tracers, and demonstrated that cycling at 40 % $\dot{V}O_{2max}$ and above can reduce the availability of ingested fluids, and that the effect is proportional to the exercise intensity. Leiper et al. (2001) suggests that if gastric emptying is significantly slowed by the intensity of physical exercise during a game, the players may derive insufficient benefit from ingested fluids to make it worthwhile to drink immediately before playing. Specific to soccer, Leiper et al. (2001) found that the high-intensity, intermittent nature of a soccer match was enough to slow gastric emptying when players ingested a carbohydrate-electrolyte drink when playing a 5 a-side soccer match.

Leiper et al. (2005) also investigated the effects of ingesting a 6.4 % carbohydrate solution against a placebo on gastric emptying during high-intensity intermittent exercise using the LIST protocol. The results showed that the intensity of the LIST was high enough to slow gastric emptying in both trials, therefore concluding that dilute carbohydrate-electrolyte

beverages empty at the same rate as placebo, carbohydrate-free beverages during variable intensity exercise.

2.7.5 Caffeine and Carbohydrate Co-ingestion

Van Nieuwenhoven et al. (2000) reported that when caffeine and carbohydrates are co-ingested, glucose absorption was increased when compared to carbohydrate ingestion alone. Therefore, a potential benefit of caffeine co-ingestion is to allow more carbohydrates to be absorbed into the working muscles and reduce the effects of fatigue associated with prolonged exercise.

As well as increasing the absorption of carbohydrate, caffeine has potential to enhance performance. Integrating caffeine with existing fluid and fuel replacement strategies might provide an effective and practical supplementation regimen during training and competition (Gant et al., 2010). Several studies have evaluated the effects of co-ingestion of caffeine and carbohydrate in the form of sports drinks on exercise performance (Kovacs et al., 1998; Cox et al., 2002; Cureton et al., 2007; Millard-Stafford et al., 2007; Del Coso et al., 2008; Hulston & Jeukendrup, 2008); however, the majority of these were not soccer-specific. To date, one study has measured soccer skills after players ingested a caffeinated, carbohydrate solution (Gant et al., 2010). The players ingested a 6 % carbohydrate electrolyte solution with 160 $mg \cdot l^{-1}$ of caffeine. In the cross-over trial, players only ingested the 6 % carbohydrate electrolyte solution. Drinks were administered 60 min before the exercise protocol at 8 $ml \cdot kg\ BM^{-1}$ and during the protocol at 3 $ml \cdot kg\ BM^{-1}$. These authors found that sprint times were improved during the LIST protocol; however, no improvements were seen in the LSPT skill performance test when compared to just a carbohydrate electrolyte solution alone in any of the outcomes (movement time, penalty time, total time).

CHAPTER THREE

3.0 METHODS

3.0 Methods

3.1 Participants

Fourteen male recreational soccer players that play at least twice weekly (age: 24.1 ± 4.4 years; stature 1.81 ± 0.07 m; mass 79.2 ± 8.5 kg) volunteered to participate in the study, which had been granted University ethical approval (see appendix A). Prior to starting the study, all the players were fully informed about the testing procedures and risks associated with the study (see appendix B) and signed an informed consent form (see appendix C). All players were health screened and risk assessed prior to undertaking testing (see appendix D). Players were recruited on the basis that they were apparently healthy, had no injuries, were non-diabetic and did not smoke.

3.2 Experimental Design

All players completed two preliminary sessions to habitualise themselves with experimental protocols and to take a baseline measurement of their individual fitness levels.

During the initial preliminary session, players completed 10 repeats of the passing, shooting and dribbling tests in order to habitualise themselves with the skill tests, which are part of the Soccer Match Simulation (SMS) protocol, and a multistage fitness test (MSFT; Ramsbottom et al., 1988), which was used to estimate maximum oxygen uptake and, through linear regression, the movement speeds for the main trials.

The second preliminary session was conducted to allow players to habitualise themselves with the SMS protocol (Russell et al., 2011a) and to reduce the anticipated learning effects. This consisted of 45min (or 1 half) of the main trial protocols with skills.

Players completed three main trials, with each trial separated, on average by 10.0 ± 1.2 days, in a randomised, double-blind and cross-over fashion. Supplementation differed between trials: Electrolyte solution with a placebo gel (PLA); 10 % CHO-electrolyte and caffeine solution with CHO gel (CHO10); and 6 % CHO-electrolyte solution with CHO gel (CHO6). Supplements were specifically manufactured for the present study (High Five Ltd, UK).

Players were informed to refrain from strenuous physical activity and caffeine consumption for two days before all testing sessions. Players were also required to record all food consumption for the previous two days before each trial (see appendices G and I). The records were then analysed using CompEat Pro Dietary Analysis computer software (Nutrition Systems, Banbury, UK). At the end of the study, players gave their verbal confirmation that they had complied with all instructions.

3.3 Preliminary Testing

Two preliminary testing sessions were completed by the players. On arrival at the laboratory players were required to empty their bowels and void their bladder.

During the first preliminary session, anthropometric measurements were determined before a standardised warm-up (Appendix E), which consisted of 5 min of light aerobic activity and 10 min of dynamic stretching and sprinting (that progressed to near maximal speeds). Skill performance protocols were introduced to the participant and each participant completed 10 passes (5 from the left ramp and 5 from the right ramp), as well as 10 shots (5 from the left ramp and 5 from the right ramp). Maximal oxygen uptake was then estimated using the MSFT protocol (Ramsbottom et al., 1988) in order to determine the running speeds for the exercise protocol.

The second preliminary session was used to habitualise players with the procedures of the main trials, including 45 min (one half) of the SMS protocol, including all skill dimensions

(passing, shooting and dribbling). Therefore, players were habitualised with the exercise regime and skilled components of the SMS.

3.4 Main trial procedures

During the three main trials, the players arrived at the laboratory at 08:00 am (i.e. 2.5 h before commencing exercise) after an overnight fast of 12 h. After providing a mid-flow urine sample, baseline body mass, stature and a blood sample were taken. Players consumed a standardised 1470 kJ meal (Energy content: 62 % carbohydrates, 25 % fats, 13 % proteins) and 500 ml of the supplement beverage at 08:30 am, which was followed by a rest period of 120 min.

After the rest period heart rate, a pre-exercise blood sample and body mass was recorded before players commenced a standardised warm-up (consisting of running, dynamic stretching and ball skills; Appendix E). Air temperature was kept at an average of 18.8 ± 1.0 °C, humidity of 61.2 ± 7.8 % and barometric pressure of 1018 ± 6.1 mbar (mean ± SD).

Supplement beverages were consumed throughout all trials to supply 21 $ml \cdot kg^{-1}$ BM (see chapter 3.4.3 for further supplementation details) at specific time points, which were 10 min before 1st half, 15, 30 min, 10 min before 2nd half, 60 and 75 min. Capillary blood samples were also taken throughout the protocol, on arrival at the test site, pre-exercise, 15, 30 and 45 min into exercise, 10 min into half time, 60, 75 and 90 min into exercise. Abdominal Discomfort was recorded at the end of each cycle during each half. Body mass was recorded immediately after the completion of the first half and immediately after the second half. At the end of the trial a controlled warm down was carried out by each participant to reduce effects of DOMS. A schematic of the procedure undertaken during all trials is presented in Figure 1.

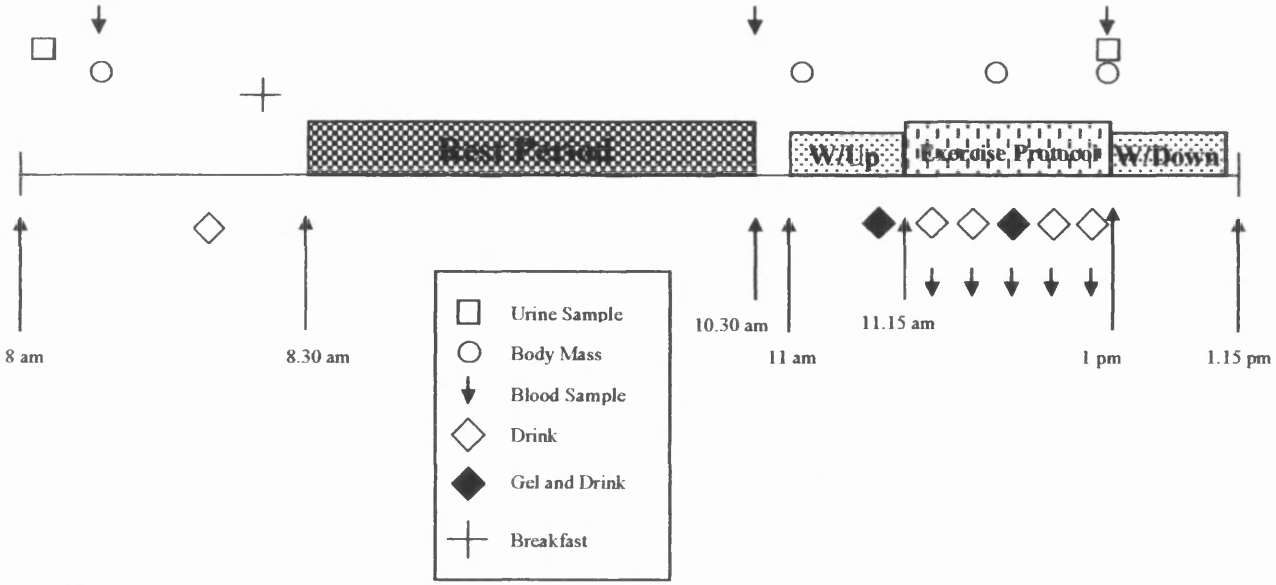

Figure 3.1 Schematic of Main Trial Day

3.4.1 The Soccer Match Simulation Exercise Protocol

During the SMS, players moved at different speeds and intensities, dictated by audio signals from a CD over a 20 m distance. The players also perform soccer skills at regular intervals throughout two 45 min halves of soccer-specific activity.

Exercise was made up of 4.5 min blocks that consisted of 3 repeated cycles of three 20 m walks, one walk to the side, an alternating 15 m timed sprint (Brewer Timing Gates, Utah, USA) or an 20 m dribble, a 4 s passive recovery period, five 20 m jogs at a speed corresponding to 40 % $\dot{V}O_{2max}$, one 20 m backwards jog at 40 % $\dot{V}O_{2max}$ and two 20 m strides at 85 % $\dot{V}O_{2max}$. Half time was incorporated into the SMS and this consisted of 15 min of passive recovery. The exercise protocol is similar to Nicholas et al. (2000) protocol but has been validated against actual match-play to replicate the demands, movement patterns and physiological responses of soccer match-play (Russell et al., 2011a). A 3 min period between the exercise blocks incorporating the skill of passing (1 min) and a recovery block (2 min) followed. Six blocks of intermittent activity and skills were completed during each half of exercise. Shooting tests preceded and followed each the 1st half of exercise and at the end of the second half. The players covered a total distance of approximately 10.0 km and completed 48 passes, 12 shots 18 dribbles and 18 sprints during the protocol. Figure 3.2 presents a schematic of the SMS protocol.

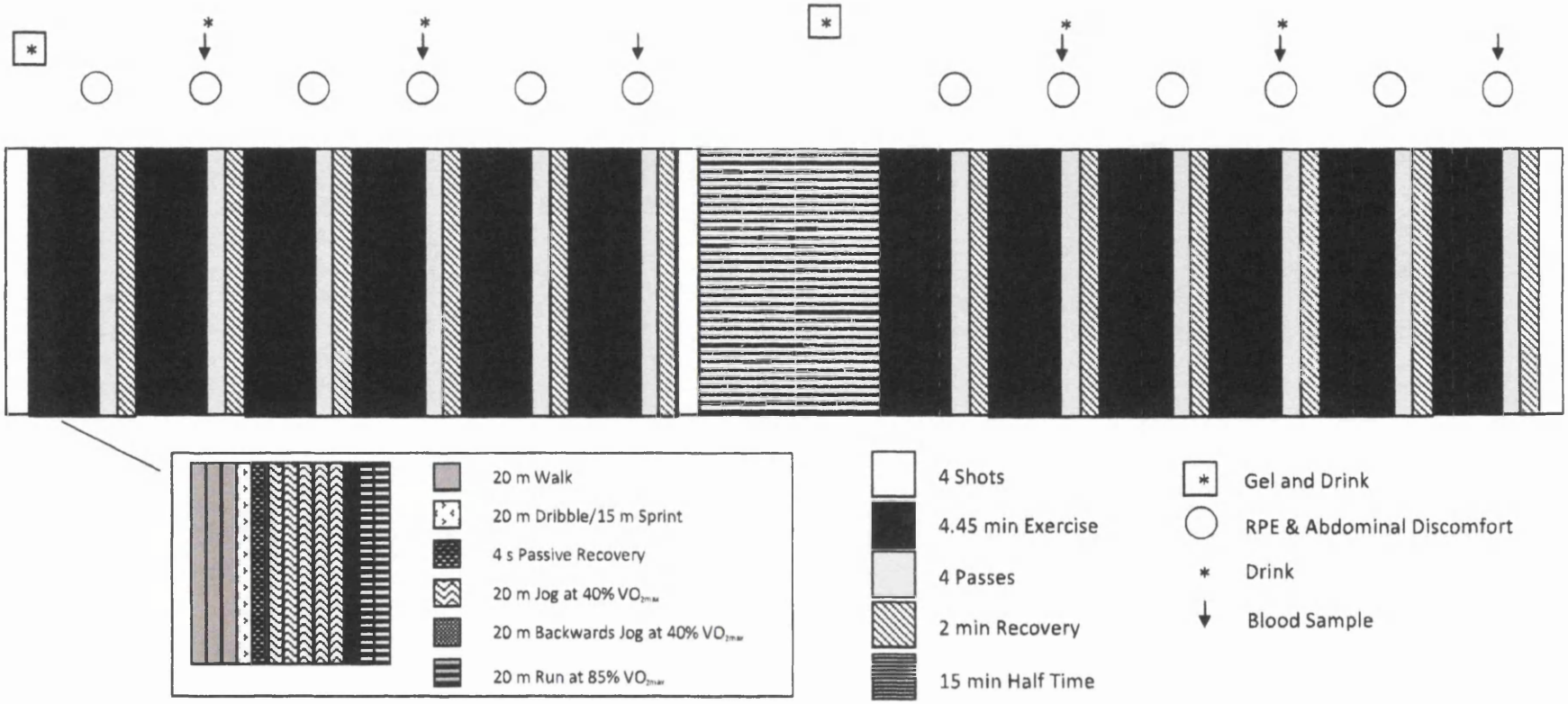

Figure 3.2 Schematic of the Soccer Match Simulation (SMS) Exercise Protocol

3.4.2 Skill Tests

The testing sessions were carried out on a synthetic running track in an indoor training facility. Skills tests were the same as those used in Russell et al. (2010), however passing protocols were changed to left and right passes only, instead of the long left, short left, long right and short right targets. Players used were recreational players. When Russell et al. (2010) looked at the variability between recreational and elite soccer players and results showed that when using the SMS protocol and associated skill tests, although the absolute reliability (absolute reliability is the degree to which repeated measurements vary for individuals (Baumgarter, 1989)) was higher in recreational players, the relative reliability (relative reliability is the degree to which individuals maintain their position in a sample with repeated measurements (Baumgarter, 1989)) using the same protocols was similar to elite players.

3.4.2.1 Passing and Shooting Skill Tests and Analysis

Ramps were positioned to each side of an action zone (1.5 m^2) and balls (Total 90 Aero: size 5; Nike Inc., USA) were released at a constant speed of 2.3 $m{\cdot}s^{-1}$ towards the action zone, where players were instructed to pass the ball towards one of two randomly determined targets (identified by a lighting system). A delay of 0.64 s separated target identification and the ball reaching the centre of the action zone. Pilot work completed by Russell et al. (2010) identified this to be the most appropriate time delay. No prior touches were allowed to control the ball as this was felt that it would enhance ecological validity (Dooan et al., 2001) and players chose to kick the ball with the foot that they felt was most comfortable with to gain success.

Videos of the skills tests were recorded at a frame rate of 30 Hz (Casio Exilim Ex-F1, Casio Computers Ltd., Japan) and cameras were placed 0.5 m above the ground for passing, 1.25 m above the ground for shooting and one additional camera 2.5 m above the ground as an overview camera for passing and shooting. All cameras were set to record independently and synchronized to ensure that analysis was able to be carried out accurately and cameras could

be alternated between easily. Target-to-camera distances were set to maximum to minimize parallax errors which could affect results because of the displacement in the apparent position of an object viewed along two different lines of sight. All of the main outcome variables (precision, speed and success) have been shown to be reliable and have demonstrated construct validity (Russell et al., 2010).

3.4.2.2 Passing Skill Test and Analysis

The protocol for the passing test was identical to the long pass performed in Russell et al. (2010). Players stood at a starting position (2.65 m away from the centre of the action zone) before jogging into the action zone when the ball was released to pass at the designated targets. Passing targets were placed at distances of 7.9 m away from the centre of the action zone. Each passing banner measured 2.0 m by 1.0 m and included a 0.50 x 0.25 m red target box centred at ground level. The remainder of the target was made up of a blue background to make the red target box easily distinguishable. To allow calibration when digitalising images for analysis the banner was marked with horizontal graduation lines at 0.25 m intervals. The players were instructed to aim passes at the centre of the target banner which was lighted in a random order by via a lighting system and sensor underneath each ball delivery mechanism.

3.4.2.2.1 Precision

The position of the ball was determined using commercial computer aided drawing software Microsoft Visio 2010, (Microsoft Corp. USA). Precision was defined as the distance from the centre of the ball to the centre of the target. Deformations in video images according to the angle at which the camera had been positioned (kept constant throughout each trial) were corrected by modified direct linear transformation, where the known positions of calibration markers were used to calculate calibration constants. The co-efficient of variance for the measurement of ball position across the target range was < 1 %. Figure 3.3 represents a schematic of the passing skill test.

3.4.2.2.2 Speed

Video footage, from the camera capturing the whole passing skill protocol (Figure 3.3), was analysed to determine the time taken for the ball to travel between the player's foot and the target banner. Subsequently, the average pass speed was calculated. The co-efficient of variation for the measurement of passing speed was < 1 %.

3.4.2.2.3 Success

Success was defined as the centre of the ball landing within the outside calibration lines on the passing targets. Therefore the width of the target banner (2 m). Any pass which deviated outside of this area were deemed unsuccessful and were removed from analysis.

3.4.2.2.4 Speed Precision Index

As the quality of a pass is dependent upon both the speed and precision of that pass, Speed Precision Index (SP Index) was calculated using Equation 1. Equation 1 was derived from Fitts' law and represents an interaction between speed, accuracy, target size and distance to the target.

$$\text{Eq 1: SP Passing Index} = \frac{\text{Speed}}{(\text{Log}_2((\text{Deviation}/\text{Target size}) + 1))) + 15} \times 100$$

Where speed is expressed in $m \cdot s^{-1}$, precision is represented by deviation from the target (cm) and target size is fixed at 200 cm between passes. A higher index indicates greater speed and precision of pass.

3.4.2.2.5 Speed/Precision/Success Index

As an overall index of passing performance, Speed/Precision/Success Index (SPS Index) was calculated by multiplying the mean SP Index by the proportion of successful passes in each 15 min of exercise. Higher values represent greater speed, precision and success of passes.

3.4.2.3 Shooting Skill Test and Analysis

The target for the shooting skill test was a standard 11-aside adult soccer goal measuring 7.32 x 2.44 m with netting stretched across the frame. Four target lights were positioned behind the netting, 1.0 m horizontally inside each post and 0.5 m vertically inside the upper and lower edges of the goal. These light targets were placed in the corners of the goal because these positions have been identified to be the optimal positions to place the ball to beat a goalkeeper when shooting (Ali et al., 2007). During the shooting skill test, players were instructed to strike the ball as accurately as possible at the illuminated target within the goal, figure 3.5 shows the overall layout of the shooting skill test.

3.4.2.3.1 Precision

Precision analysis for shooting was measured by digitalising the image where the ball impacted the goal (Microsoft Visio, Microsoft Corp. USA). Distances were then measured horizontally and vertically from the target light and Pythagoras Theorem was used to calculate the distance away from the target. The coefficient of variance for ball positions across the area of the goal did not exceed 2 % and 3 % for the x and y co-ordinates, respectively. Figure 3.4 shows the position of target lights on the goal face.

3.4.2.3.2 Speed

Video footage was analysed to determine the time taken for the ball to travel between the player's foot and the goal area. Subsequently, the average shot speed was calculated.

3.4.2.3.3 Success

Shooting success was determined as the percentage of shots that fell within the confines of the goal. Shots, where the centre of the ball fell outside of the central line of the goal frame or missed the goal area completely, were classified as unsuccessful shots.

3.4.2.3.4 Speed Precision Index

Similar to passing, shooting quality is dependent upon both the speed and precision of the shot. SP Index was calculated for shooting, using Equation 2.

$$\text{Eq 2: SP Shooting Index} = \frac{\text{Speed}}{(\text{Log}_2((\text{Deviation}/\text{Target size}) + 1))) + 15} \times 100$$

Where speed is expressed in $m \cdot s^{-1}$, precision is represented by deviation from the target (cm) and target size is fixed at 732 cm. A higher index indicates greater speed and precision of shot.

3.4.2.3.5 Speed/Precision/Success Index

As an overall index of shooting performance, a Speed/Precision/Success Index was calculated by multiplying the mean SP Index for shooting by the proportion of successful shots for each of the three time points (pre and post 1st half and end of 2nd half). Higher index values represent greater speed, precision and success of shots.

3.4.2.3 Ball Dribbling Skill Test and Analysis

The dribbling course was based over a 20 m distance. Cones one and seven were placed 1 m away from each end of the course and cones 2 - 7 were placed 3 m away from the preceding cone. This layout was identical to that of Russell et al. (2010). Players dribbled the ball as quickly and accurately as possible between all cones. Players dribbled towards a video camera that was placed directly in line with the cones.

3.4.2.4.1 Precision

To analyse ball dribbling, images taken from the camera were digitalised using Microsoft Visio (2010, Microsoft Corp. USA) and analysed at the frame where the ball was in a perpendicular position to the cone in question. The lane markings of the indoor track were used as calibration lines (1.95 m to the centre of the cones). The actual distance that the ball deviated from the centre of the corresponding cone was calculated as the calibration lines were set distances apart. This known distance could then be used to calculate the distance the ball was from the centre of the target using percentage change.

Precision was defined as the average distance away from the cones on each dribble. Due to the inter-individual differences in the techniques used when finishing the dribble, cones 1, 2, 3, 4, 5 and 6 were subject to precision analysis. The overall co-efficient of variance of dribbling precision at all positions was < 1 %.

3.4.2.4.2 Speed

The time taken to dribble between cones 1 - 6 was used to calculate mean dribbling speed.

3.4.2.4.3 Success

If a ball touched a cone, went outside the calibration lines or the dribble was not completed in the required direction, it was considered that the cone had not been negotiated successfully. Figure 3.6 represents the ball dribbling skill test.

3.4.2.4.4 Speed Precision Index

Similar to passing and shooting, dribbling quality is dependent upon both the speed and precision of the dribble. SP Index for dribbling was calculated using Equation 3.

$$\text{Eq 3: SP Dribbling Index} = \frac{\text{Speed}}{(\text{Log}_2((\text{Deviation}/195) + 1))) + 15} \times 100$$

Where speed is expressed in $m \cdot s^{-1}$, precision is represented by deviation from the target (cm) and the value 195 represents the maximum distance either side of the cones. A higher index indicates greater speed and precision of dribble.

3.4.2.4.5 Speed/Precision/Success Index

As an overall index of dribbling performance a Speed/Precision/Success Index for dribbling was calculated by multiplying the mean SP Index by the proportion of successful cones completed during each 15 min time window. Higher values represent a greater speed, precision and success of dribbles.

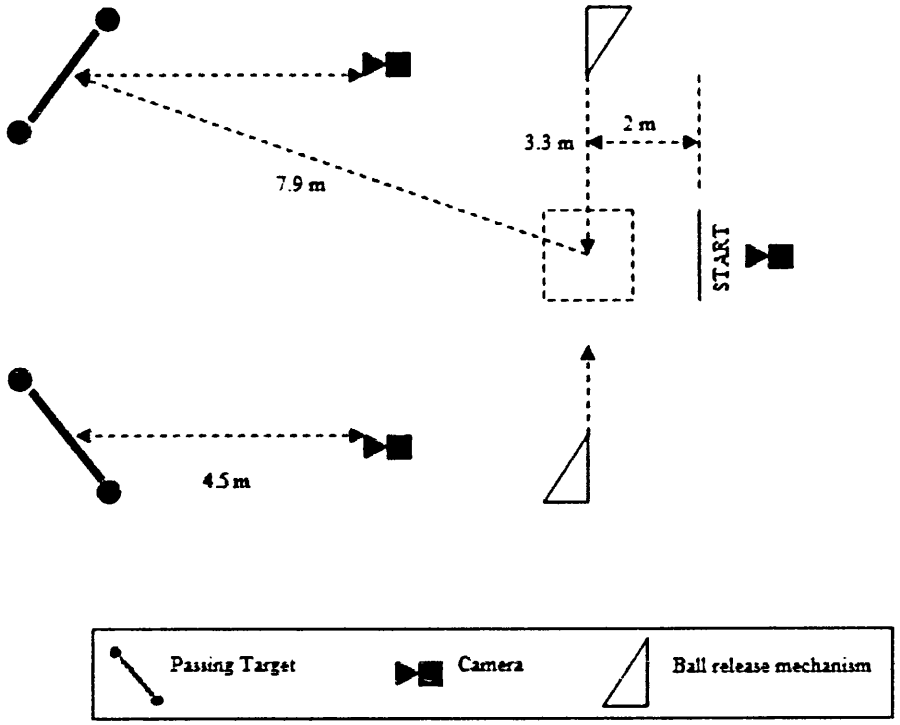

Figure 3.3 Schematic of Passing Skill Test Layout

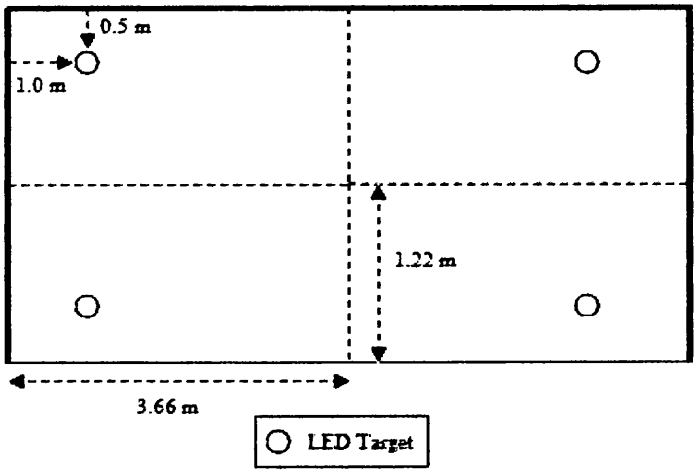

Figure 3.4 Dimensions of goal and positioning of target lights

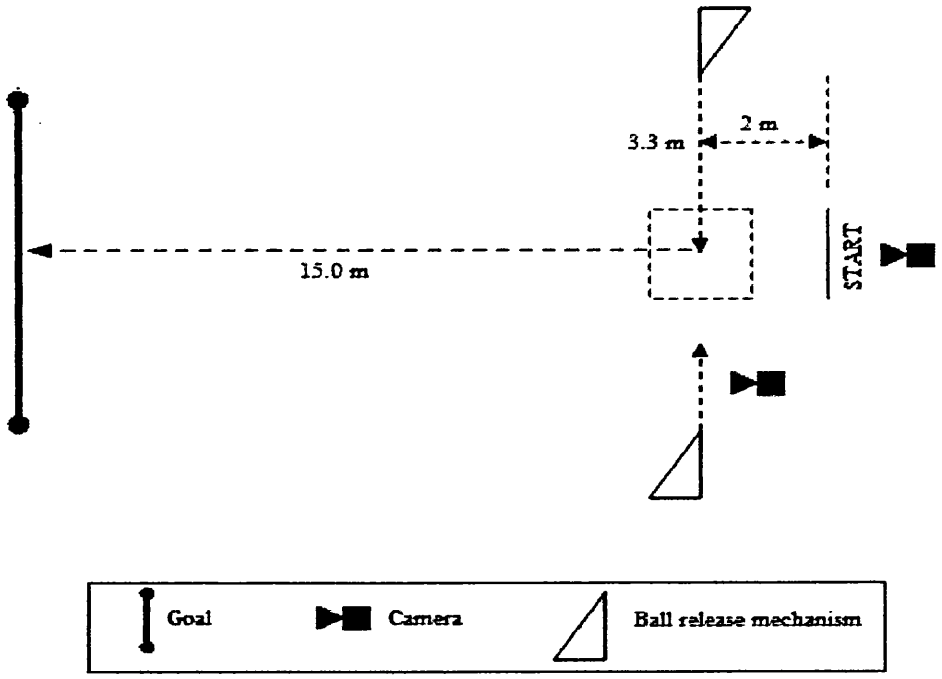

Figure 3.5 Schematic of Shooting Skill Test Layout

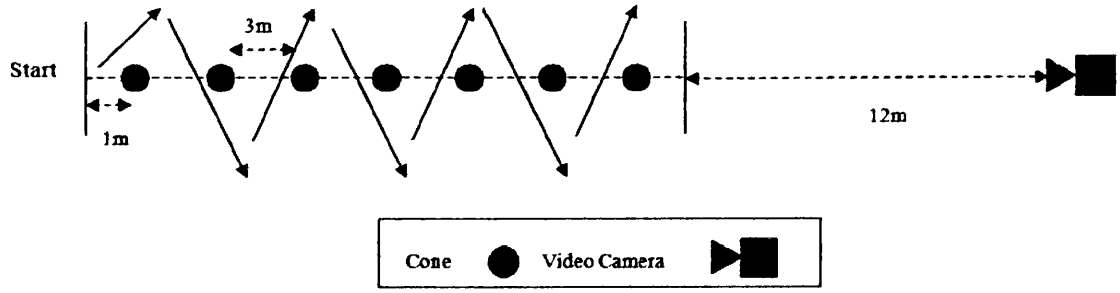

Figure 3.6 Schematic of Ball Dribbling Skill Test Layout

3.4.3 Supplementation

After reporting to the laboratory during the main experimental trials, participants consumed a standardised pre-exercise meal, which consisted of 2 slices of white bread toast, with butter and marmalade (energy content was 1470 kJ) and 500 ml of the randomised treatment beverage. Treatment beverages were manufactured specifically for the present study (High Five Ltd, UK) and were consumed throughout all trials to supply 21 $ml \cdot kg^{-1}$ BM. This volume was delivered so that 5.25 $ml \cdot kg^{-1}$ BM was consumed 10 min prior to commencing each half of the SMS and 2.63 $ml \cdot kg^{-1}$ BM after 15, 30, 60 and 75 min of exercise. In addition, 2 x 60 ml gel sachets were consumed 10 min prior to commencing each half of the SMS. The beverage and gel types differed between the three trials, as follows: electrolyte solution with a placebo gel (PLA); 10 % CHO-electrolyte and caffeine solution with CHO gel sachets (CHO10); and 6 % CHO-electrolyte solution with CHO gel sachets (CHO6). All treatment beverages and gels were manufactured to be similar in taste to stop players knowing what treatment they were having on each trial.

The different treatment beverages were analysed by an independent laboratory (Eclipse Scientific Group, Cambridgeshire, UK) to determined supplement compositions. Table 3.1 provides the composition of the treatment beverages and gels). During the three main trials (115 min, comprised of beverage intake 10 min prior to 1st half, 1st half, 15 min half time, 2nd half), players were consuming, throughout the trial, in the combined form of beverages and gels, 2.28 ± 0.04 $g.min^{-1}$ of carbohydrate (CHO10); 1.63 ± 0.02 $g.min^{-1}$ of carbohydrate (CHO6); and 0.08 ± 0 $g.min^{-1}$ (PLA).

Table 3.1 Composition of the three treatment beverages and the active and placebo gels ingested during the main trials (mean ± *SEM*).

	Beverages			Gels	
	CHO10 (per 100 ml)	**CHO6 (per 100 ml)**	**PLA (per 100 ml)**	**Active (per 100 ml)**	**Placebo (per 100 ml)**
Solution Osmolality (mosm/kg)	292 ± 3	112 ± 16	78 ± 1	1250 ± 31	82 ± 9
Caffeine (mg)	32.6	0	0	0	0
Fat (g)	0	0	0	0.3	0.3
Protein (g)	0	0	0	0.2	0.2
Carbohydrate (g)	10.4	5.9	0.5	37.3	0.4
Carbohydrate (g/min)	1.502 ± 0.044	0.85 ± 0.024	0.072 ± 0.007	0.778	0.008
Energy (kJ/kcal)	177 / 42	99 / 24	8 / 2	647 / 152	20 / 5
Potassium (mg)	23.2	20.5	0.16	21.5	19.2
Magnesium (mg)	0.1	0.1	0	1.0	1.3
Sodium (mg)	88.3	82.9	0.35	47.3	50.1

3.4.4 Anthropometry

Stature was measured (to the nearest cm) using a portable stadiometer (Harpenden stadiometer; Holtain, UK) while players stood erect with their feet flat and heels touching the backboard. The head of the players were held in the Frankfurt plane while measurements were taken. Body mass determined upon arrival at the test site, after the participant had initially voided their bowels. Body mass was again taken at half time and at the end of exercise. It was also measured if the participant emptied their bowels during the protocol (pre and post). Body mass was measured using digital scales (model 770; Seca Ltd, Birmingham, UK) to the nearest 0.1 kg. Subjects wore minimal clothing and were instructed to remain still whilst measurements were taken. Anthropometric measurements were taken in accordance to the ISAK guidelines (2001).

3.4.5 Abdominal Discomfort

Abdominal Discomfort was also recorded throughout each main trial (Appendix F). The players rated any stomach pain during the exercise protocol, 0 being the lowest (no pain) and 10 the highest degree of pain (very severe pain).

3.4.6 Blood Sampling and Analysis

3.4.6.1 Capillary Blood Sampling

A capillary blood sample was taken from the tip of a finger at the following time points: at rest, pre-exercise, following the start of exercise; 15, 30, 45, half-time, 60, 75 and 90 min. The finger was cleaned using a 70 % alcohol swab, left to dry and punctured using an Accu-chek Safe-T-Pro Plus lancet (Roche products Ltd, UK). The initial drop of blood was removed using a clean tissue and approximately 170 µL of blood was collected in a lithium-heparin capillary tube (Sangius Counting GmbH, Germany) for analysis by an automated blood gas analyser (GEM Premier 3000 blood gas analyser; Instrumentation Laboratory, UK)

which gave glucose and lactate concentrations. An additional 80 µL of blood was collected in a heparinised capillary tube (Hawksley and Sons Ltd, UK) for determination of Haematocrit (Microhaematocrit reader, Hawksley and Sons Ltd, UK) and one further drop of blood was collected for Haemoglobin concentration (Hemocue limited, UK).

3.4.6.2 Blood Glucose Concentrations

An automated electrochemical analyser (GEM Premier 3000; Instrumentation Laboratory Ltd., UK) was used to determine concentrations of glucose using the manufacturer directions. The manufacturer described the method of measurement used to analyse glucose concentrations as being determined by enzymatic reaction with oxygen in the presence of glucose oxidase to produce hydrogen peroxide (H_2O_2).

3.4.6.3 Estimated Changes in Plasma Volume

Haemoglobin was determined from whole blood using an automated 2-wavelength photometer (570 nm and 880 nm) (B-Haemoglobin analyser; HemoCue, UK) following instructions as manufacturers specified. The photometer was calibrated daily using a microcuvette of known absorbance. Blood haematocrit was calculated manually at baseline and post exercise. Haematocrit was determined using heparinised 80 µL capillary tubes filled with whole blood. Each tube was centrifuged for 5 min at 12000 rpm (Micro Haematocrit MK IV; Hawksley Ltd., UK). A micro-haematocrit reader (Hawksley and Sons, UK) was then used to quantify the packed cell volume (Haematocrit %).

Measurements of blood haemoglobin and haematocrit concentration have been widely used to calculate changes in plasma volume therefore as a marker of hydration status (Dill and Costil, 1974; Harrison, 1985; Linnane et al., 2004; Bishop and Maxwell, 2009). Changes in plasma volume were calculated using the blood haemoglobin and haematocrit values using the Dill and Costill (1974) method. Postural changes from lying to standing can result in a

decrease in plasma volume of up to 10 % (Rowel, 1974, Harrison, 1985). Therefore, all blood samples during the main trials were taken from a standardised standing position.

3.5 Statistical analysis

Statistical analysis was carried out using IBM SPSS software (Version 19.0; IBM Inc., USA). Data was tested for normality using Shapiro-Wilks test of normality before statistical analysis was run. All results were reported as the mean ± standard error of the mean (SEM) and statistical significance was set at $P \leq 0.05$. In addition, $P > 0.05$ to $P \leq 0.10$ was interpreted as a trend and if a trend was seen in the main effects of the ANOVA it was investigated further using Simple Main Effects. Two-way repeated measure ANOVA's were used to analyse data when repeated time points were included in the analysis (within-subject effects: treatment and time). Mauchly's test was consulted and Greenhouse–Geisser correction was applied if the assumption of sphericity was violated. Treatment was deemed to have influenced the pattern of response if there was a significant interaction effect (treatment*time). If this was the case, Simple Main Effects were carried out to determine whether there was a difference between the three treatments at specific time points. If the Simple Main Effects showed a significant value, a Tukey post-hoc was used to identify where the difference lay. If a significant main effect of treatment was identified, CHO supplementation was deemed to influence the variable, and Simple Main effects were run to identify at which time point differences in treatment could be seen. A Tukey post hoc was then used to identify in which treatment differences were seen at the specific time point. Significant main effects of time (time of sample) were further investigated using Simple Main Effects, to identify in which treatment, time had influenced the variable. A Tukey post-hoc was then carried out to identify which time points were different.

CHAPTER FOUR

4.0 RESULTS

4.0 Results

4.1 Environmental Conditions

Environmental conditions were similar during the three main trials (Mean ± S.D), where mean ambient temperatures were 18.8 ± 1.0 °C (trial effect: $F_{(2,26)} = 0.497$, $P = 0.614$, $\eta_p^2 = 0.037$), humidity values were 61.2 ± 7.8 % (trial effect: $F_{(2,26)} = 0.710$, $P = 0.501$, $\eta_p^2 = 0.052$) and atmospheric pressures were 1018 ± 6 mbar (trial effect: $F_{(2,26)} = 0.848$, $P = 0.440$, $\eta_p^2 = 0.061$) (Table 4.1).

4.2 Participant Characteristics at Baseline

No differences existed in body mass (trial effect: $F_{(2,26)} = 0.574$, $P = 0.570$, $\eta_p^2 = 0.042$) or stature (trial effect: $F_{(2,26)} = 0.275$, $P = 0.762$, $\eta_p^2 = 0.021$) during the baseline measurement (Table 4.2).

Additionally, players reported to the laboratory in a similarly hydrated status; mean baseline urine osmolality values were 799 ± 48 mosmol·kg H_20^{-1} (PLA), 722 ± 66 mosmol·kg H_20^{-1} (CHO6), and 842 ± 53 mosmol·kg H_20^{-1} (CHO10; trial effect: $F_{(2,26)} = 1.573$, $P = 0.226$, $\eta_p^2 = 0.108$).

No significant differences were evident between blood glucose when players first arrived at the testing site (pre- breakfast) (trial effect: $F_{(2,26)} = 2.237$, $P = 0.127$, $\eta_p^2 = 0.147$).

4.3 Nutritional Intake

No significant differences were found in dietary intake between the three trials (trial effect: $F_{(2,26)} = 0.212$, $P = 0.810$, $\eta_p^2 = 0.016$). No differences were seen in alcohol or other dietary intakes prior to test days (Table 4.3).

Table 4.1 Environmental conditions during the main trials. (Mean ± *SEM*, n = 14)

Trial	Temperature (°C)	Humidity (%)	Atmospheric Pressure (mbar)
PLA	19.0 ± 0.2	62.8 ± 2.2	1020 ± 2
CHO6	18.6 ± 0.2	61.6 ± 2.0	1017 ± 2
CHO10	18.7 ± 0.4	59.0 ± 2.2	1017 ± 2

No significant differences ($P > 0.05$) exist between treatment conditions.

Table 4.2 Body mass and height data recorded across all treatment conditions. (Mean ± *SEM*, n = 14)

Measurement	PLA	CHO6	CHO10
Morning BM (kg)	79.24 ± 2.29	78.90 ± 2.26	79.14 ± 2.34
Height (cm)	181 ± 2	181 ± 2	181 ± 2
Baseline Blood Glucose ($mmol.l^{-1}$)	5.32 ± 0.22	4.95 ± 0.24	5.48 ± 0.11

No significant differences ($P > 0.05$) exist between treatment conditions.

Table 4.3 Dietary intake (Mean ± *SEM*, $n = 14$) prior to each of the three trials (PLA, CHO6, CHO10)

	PLA	CHO6	CHO10	*P* Value
Energy (kJ)	6904 ± 452	7277 ± 423	7029 ± 473	0.810
Protein (g)	66.7 ± 4.9	79.5 ± 5.0	71.3 ± 6.3	0.137
Fat, total (g)	69.6 ± 5.1	69.8 ± 5.4	64.5 ± 3.9	0.679
Carbohydrate (g)	201.8 ± 18.1	206.6 ± 14.5	216.1 ± 21.2	0.836
Sugars, total (g)	67.6 ± 16.6	74.2 ± 13.0	75.2 ± 11.3	0.822
Starch (g)	133 ± 12	129 ± 7	139 ± 14	0.833
Fibre (Englyst) (g)	9.6 ± 0.9	10.0 ± 0.9	7.9 ± 0.6	0.199
Calcium (mg)	658 ± 67	669 ± 103	712 ± 88	0.902
Sodium (mg)	2619 ± 208	2297 ± 250	2297 ± 192	0.577
Thiamin (B1) (mg)	1.1 ± 0.1	1.1 ± 0.1	1.2 ± 0.1	0.806
Riboflavin (B2) (mg)	1.0 ± 0.1	1.2 ± 0.1	1.3 ± 0.2	0.576
Vitamin B6 (mg)	1.3 ± 0.2	1.8 ± 0.1	1.7 ± 0.3	0.264
Vitamin B12 (µg)	3.0 ± 0.6	3.9 ± 0.4	4.5 ± 1.0	0.171
Folate (µg)	177 ± 30	164 ± 21	173 ± 16	0.906
Vitamin C (mg)	62.4 ± 21.2	65.0 ± 21.1	56.1 ± 17.9	0.945
Vitamin A (µg)	405 ± 88	350 ± 71	304 ± 62	0.671
Vitamin D (µg)	1.4 ± 0.4	1.7 ± 0.3	3.0 ± 1.8	0.383
Vitamin E equivalents (mg)	6.0 ± 0.6	4.9 ± 0.7	5.2 ± 1.1	0.682
Cholesterol (mg)	231 ± 49	225 ± 21	204 ± 39	0.878
Alcohol (g)	0.9 ± 0.9	1.6 ± 1.6	0.5 ± 0.5	0.608
Water (g)	1501 ± 253	1751 ± 251	1870 ± 278	0.340

P Value presents trial effect

4.4 Physiological Responses

4.4.3 Plasma volume changes

Calculated changes in plasma volume did not change over the duration of the protocol ($F_{(1,13)} = 2.370$, $P = 0.148$, $\eta_p^2 = 0.154$). Importantly, supplementation did not affect plasma volume (trial effect: $F_{(2,26)} = 1.444$, $P = 0.254$, $\eta_p^2 = 0.100$) or the pattern of response (interaction effect: $F_{(2,26)} = 2.208$, $P = 0.130$, $\eta_p^2 = 0.145$).

4.4.4 Blood Glucose Concentrations

Supplementation influenced the pattern of blood glucose concentration throughout the trial (interaction effect: $F_{(12,156)} = 7.800$, $P < 0.001$, $\eta_p^2 = 0.375$; Figure 4.1). After 15 min of the exercise protocol, blood glucose concentrations were 22.5 ± 6.2 % higher in the CHO10 when compared with the PLA trial ($P < 0.05$); however CHO10 and CHO6 were similar at 15 min. Similarly, after 30 min CHO10 was 25.2 ± 6.7 % higher than PLA ($P < 0.05$) and after 45 min, both CHO6 and CHO10 were higher than PLA (26.4 ± 6.1 %; 44.6 ± 6.7 %, CHO6 and CHO10, respectively; $P < 0.05$). Furthermore, at the end of the first half (45 min), CHO10 was 13.4 ± 11.6 % higher than CHO6 ($P < 0.05$).

Blood glucose concentrations significantly decreased at 60 min in all trials compared to 45 min (PLA: -16.1 ± 3.2 %; CHO6: -38.3 ± 2.0 %; CHO10: -40.0 ± 3.1 %; $P < 0.05$) and values were similar for all trials at 60 min ($P > 0.05$). Blood glucose concentrations in the CHO10 trial were raised above PLA (15.6 ± 4.2 %, $P < 0.05$) and CHO6 (16.1 ± 5.2 %, $P < 0.05$) at 75 min of exercise. At 90 min, blood glucose concentrations were significantly higher in both CHO trials when compared with the PLA trial (CHO10, 38.1 ± 6.8 %; CHO6, 23.0 ± 6.5 %, $P < 0.05$) (Figure 4.1).

During the second half of exercise, mean blood glucose concentrations were lower in all three trials compared to the 1st half (PLA: -14.8 ± 2.5 %; CHO6: -23.2 % ± 2.1; CHO10: -21.7 ± 2.6 %; $P < 0.05$).

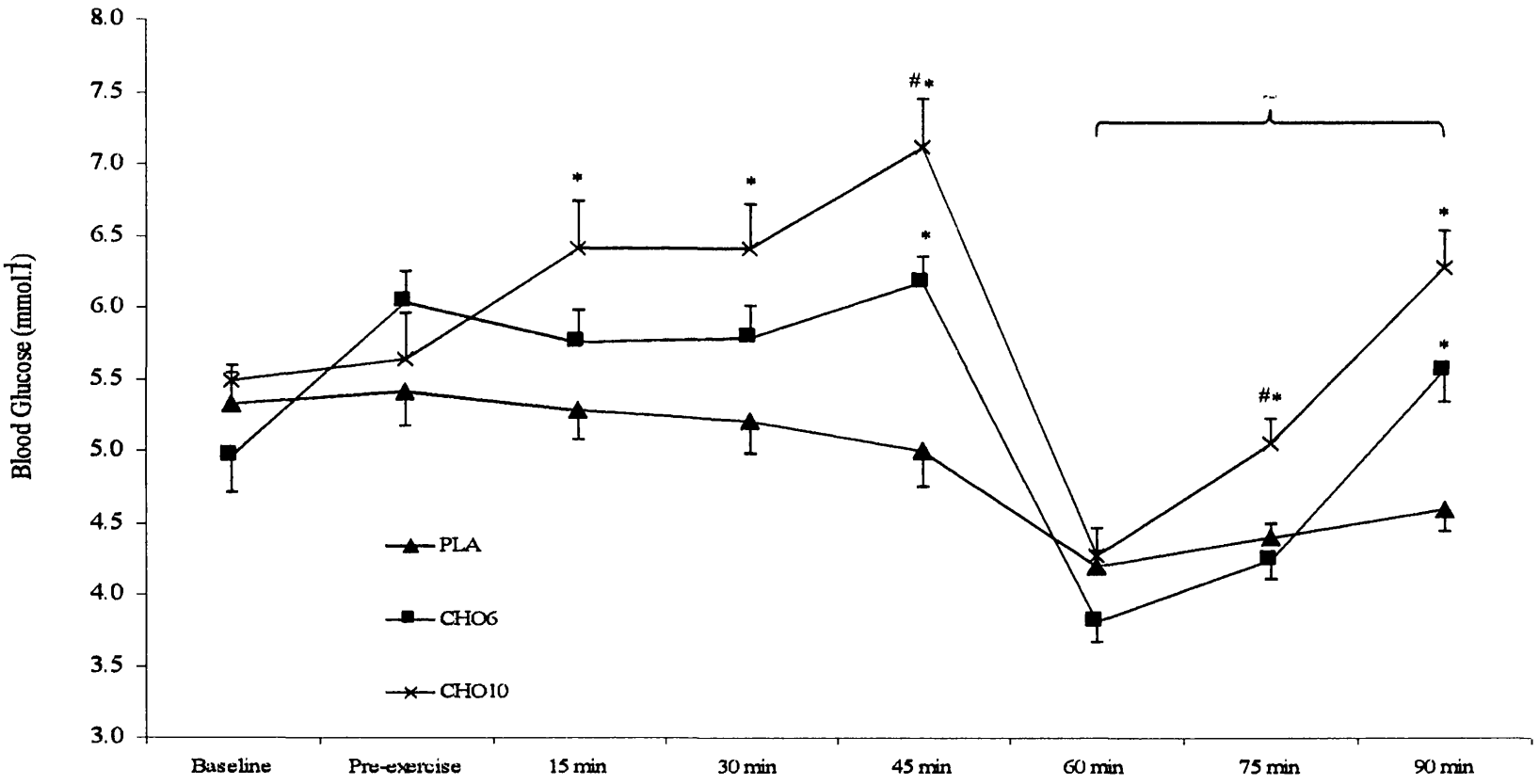

Figure 4.1 Mean (± *SEM*, $n = 14$) blood glucose concentrations at each time point, during each main trial. * Represents a significantly higher concentration than PLA ($P < 0.05$) at specific time point. # Represents CHO10 had a significantly higher concentration than CHO6 ($P < 0.05$) at specific time point. ~ Represents significantly lower mean blood glucose concentration in 2nd half compared to 1st half in all trials ($P < 0.05$)

4.5 Skill Performance

4.5.1 Passing

The pattern of response in passing precision over the duration of the exercise protocol was similar for all trials (interaction effect: $F_{(10,130)} = 0.490$, $P = 0.894$, $\eta_p^2 = 0.036$). Passing precision was maintained throughout the protocol (time effect: $F_{(5,65)} = 1.028$, $P = 0.409$, $\eta_p^2 = 0.073$) and supplementation did not influence the outcome (trial effect: $F_{(2,26)} = 0.585$, $P = 0.564$, $\eta_p^2 = 0.043$), with mean passes being 41.4 ± 1.2 cm, 41.4 ± 1.0 cm, and 42.9 ± 1.1 cm from centre of target during PLA, CHO6 and CHO10, respectively (Table 4.4).

The pattern of response for passing speed over the duration of the exercise protocol tended to be influenced by supplementation (interaction effect: $F_{(10,130)} = 1.795$, $P = 0.068$, $\eta_p^2 = 0.121$). Post hoc analysis revealed that passing speed was maintained throughout exercise following supplementation with CHO6 and CHO10. However, passing speed was slower at every time point (except 30 and 75min) compared to the first 15 min of the exercise protocol in the PLA trial ($P < 0.05$) (Table 4.4; Figure 4.3). It was also seen that passing speed was significantly slower at 45 min compared to 30 and 75 min ($P < 0.05$).

Supplementation did not influence the pattern of response in passing success at all time points (interaction effect: $F_{(10,130)} = 1.030$, $P = 0.422$, $\eta_p^2 = 0.073$) (Table 4.4). However, when passing success was analysed across halves (i.e., 1st to 2nd half mean values) a trend was seen, (interaction effect: $F_{(2,26)} = 3.166$, $P = 0.080$, $\eta_p^2 = 0.196$) and post hoc analysis revealed that CHO10 trial passes were more (+ 7.44 ± 1.70 %) successful in the 2nd half compared to the 1st half ($P < 0.05$). Whereas no differences were observed in CHO6 or PLA between halves (Figure 4.2).

The pattern of response in the passing SP Index tended to be different between trials (interaction effect: $F_{(10,130)} = 1.803$, $P = 0.066$, $\eta_p^2 = 0.122$). Post hoc analysis showed that passing SP Index was significantly lower in PLA at time points 45, 60 and 90 min, when

compared to 15 min, also, passing SP Index was also significantly lower at 45 min compared to 30 min and 75 min in PLA. However, this was not the case in the two carbohydrate trials where the passing SP Index was maintained in both (Table 4.4; Figure 4.4).

Passing SPS Index demonstrated a similar pattern of response over the duration of the exercise protocol with supplementation (interaction effect: $F_{(10,90)} = 1.732$, $P = 0.086$, $\eta_p^2 = 0.161$; Figure 4.4). Nevertheless, the pattern of response from 1st to 2nd half between treatments tended to be different (interaction effect: $F_{(2,26)} = 2.852$, $P = 0.076$, $\eta_p^2 = 0.180$), with the mean score in CHO10 significantly increased from 1st to 2nd half (9.1 ± 4.3 %, $P < 0.05$), whereas the other two trials remained constant.

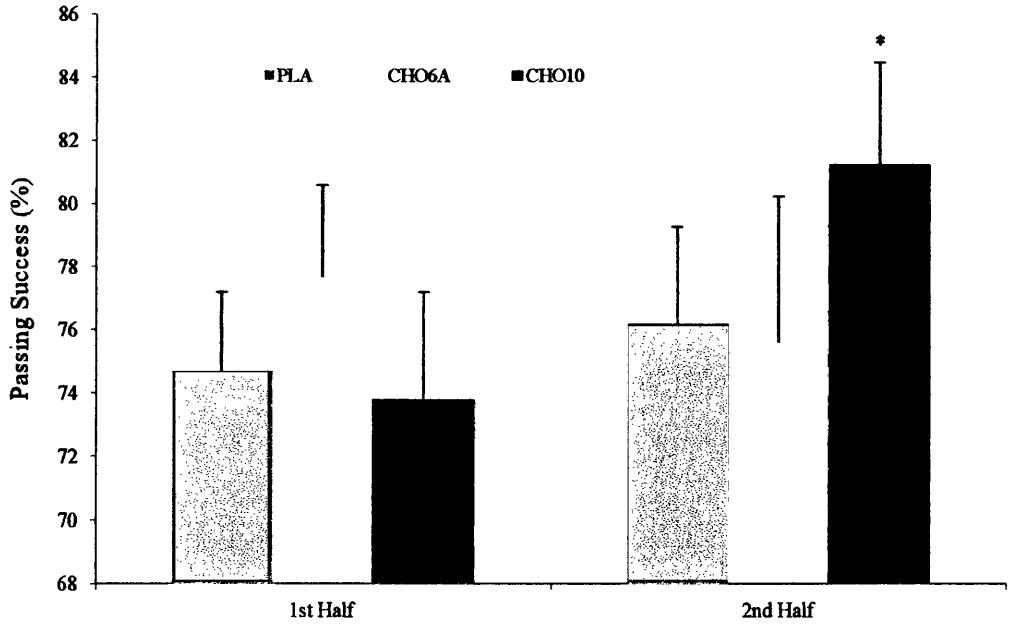

Figure 4.2 Passing Success (%) for the three experimental treatments. Mean ± *SEM*, $n = 14$. * Indicates significantly higher passing success in second half in CHO10 trial ($P < 0.05$).

Table 4.4 Indices of passing performance over 90 min for CHO6, CHO10 and PLA treatments (Mean ± *SEM*, $n = 14$)

Outcome	Trial	15min	30min	45min	60min	75min	90min	1st Half	2nd Half
Passing Speed ($m.s^{-1}$)	PLA	13.7 ± 0.6	12.9 ± 0.7#	11.9 ± 0.4*	12.6 ± 0.4*	13.0 ± 0.4#	12.6 ± 0.4*	12.8 ± 0.4	12.7 ± 0.4
	CHO6	13.2 ± 0.5	12.7 ± 0.5	13.0 ± 0.5	13.1 ± 0.5	12.7 ± 0.4	13.0 ± 0.4	13.0 ± 0.4	12.9 ± 0.4
	CHO10	13.0 ± 0.7	12.7 ± 0.6	12.9 ± 0.6	13.1 ± 0.6	12.5 ± 0.6	12.8 ± 0.5	12.9 ± 0.6	12.8 ± 0.6
Passing Precision (cm)	PLA	39.9 ± 2.6	36.9 ± 2.7	44.8 ± 3.4	43.3 ± 3.6	42.1 ± 3.4	41.4 ± 3.9	40.6 ± 1.8	42.3 ± 2.1
	CHO6	43.9 ± 2.8	39.1 ± 2.3	39.8 ± 2.7	41.4 ± 2.9	41.7 ± 3.1	42.9 ± 2.3	40.9 ± 1.4	42.0 ± 1.3
	CHO10	45.8 ± 2.9	41.6 ± 3.3	44.6 ± 2.0	44.4 ± 3.1	39.5 ± 2.0	41.8 ± 3.0	44.0 ± 1.6	41.9 ± 1.4
Passing Success (%)	PLA	68.8 ± 5.0	78.6 ± 3.6	76.8 ± 4.5	76.8 ± 5.1	75.0 ± 4.7	76.8 ± 4.7	74.7 ± 2.5	76.2 ± 3.1
	CHO6	74.1 ± 3.8	79.5 ± 4.1	79.5 ± 3.8	72.3 ± 5.9	72.3 ± 5.1	82.1 ± 5.0	77.7 ± 2.9	75.6 ± 4.6
	CHO10	73.2 ± 4.1	71.4 ± 5.0	76.8 ± 3.7	78.6 ± 4.8	82.1 ± 6.1	83.0 ± 4.3	73.8 ± 3.4	81.3 ± 3.2~
Passing Speed-Precision Index	PLA	90 ± 4	85 ± 3#	78 ± 3*	82 ± 3*	85 ± 3#	82 ± 3*	84 ± 2	83 ± 2
	CHO6	86 ± 3	83 ± 3	85 ± 3	86 ± 3	83 ± 3	85 ± 3	85 ± 2	84 ± 2
	CHO10	85 ± 5	83 ± 4	84 ± 4	86 ± 4	82 ± 4	84 ± 4	84 ± 2	84 ± 2

* Indicates that values at time point was significantly lower than 15 min ($P < 0.05$). # Indicates that value at time point was significantly higher than 45 min ($P < 0.05$). ~ Indicates that time point was significantly higher than previous time point ($P < 0.05$).

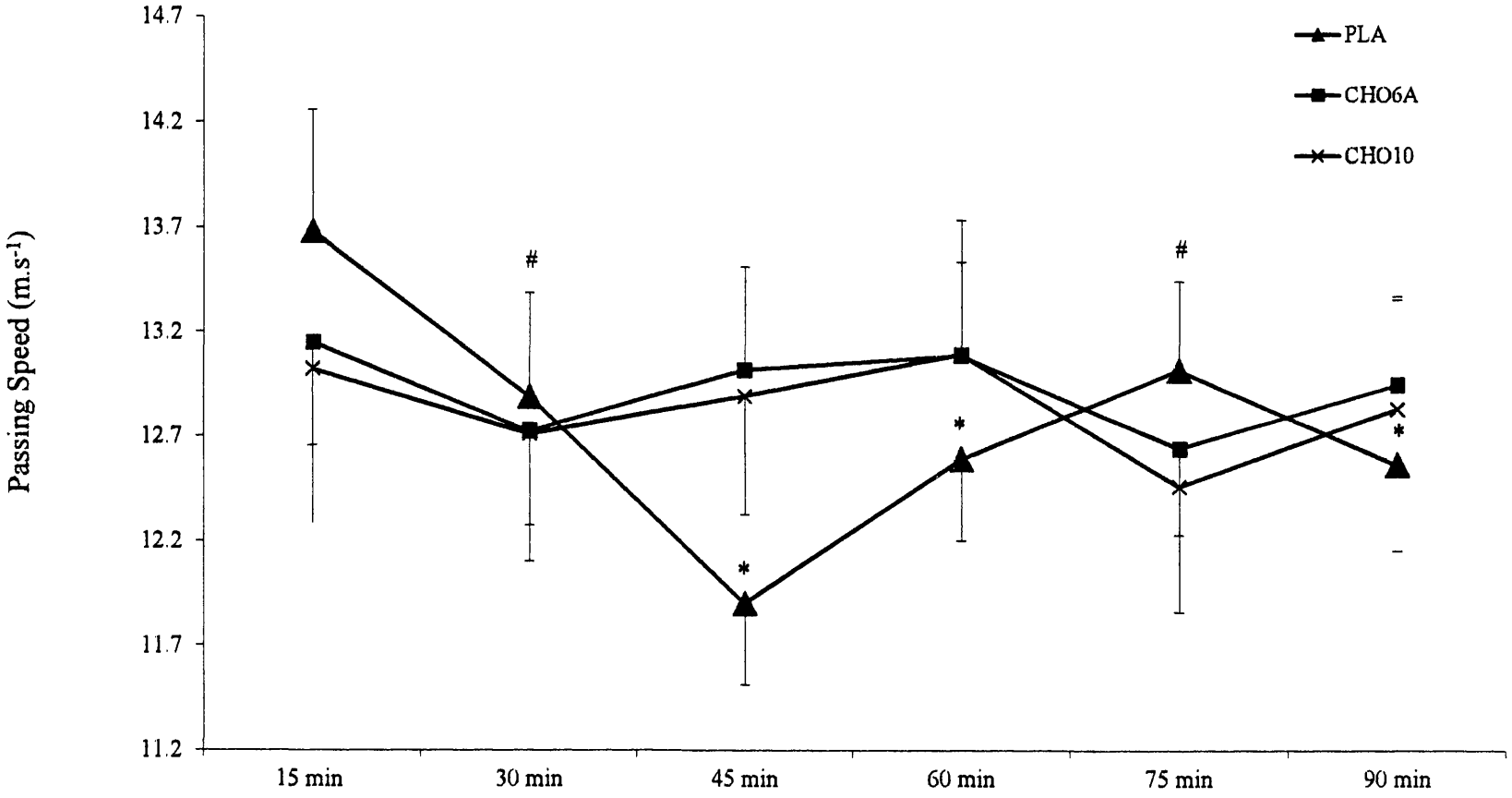

Figure 4.3 Passing Speed ($m.s^{-1}$) for the three experimental treatments. Mean ± *SEM*, $n = 14$. * Indicates significantly lower passing speed than 15 min in PLA ($P < 0.05$). # Indicates significantly faster passing speed compared to 45 min at respective time point ($P < 0.05$).

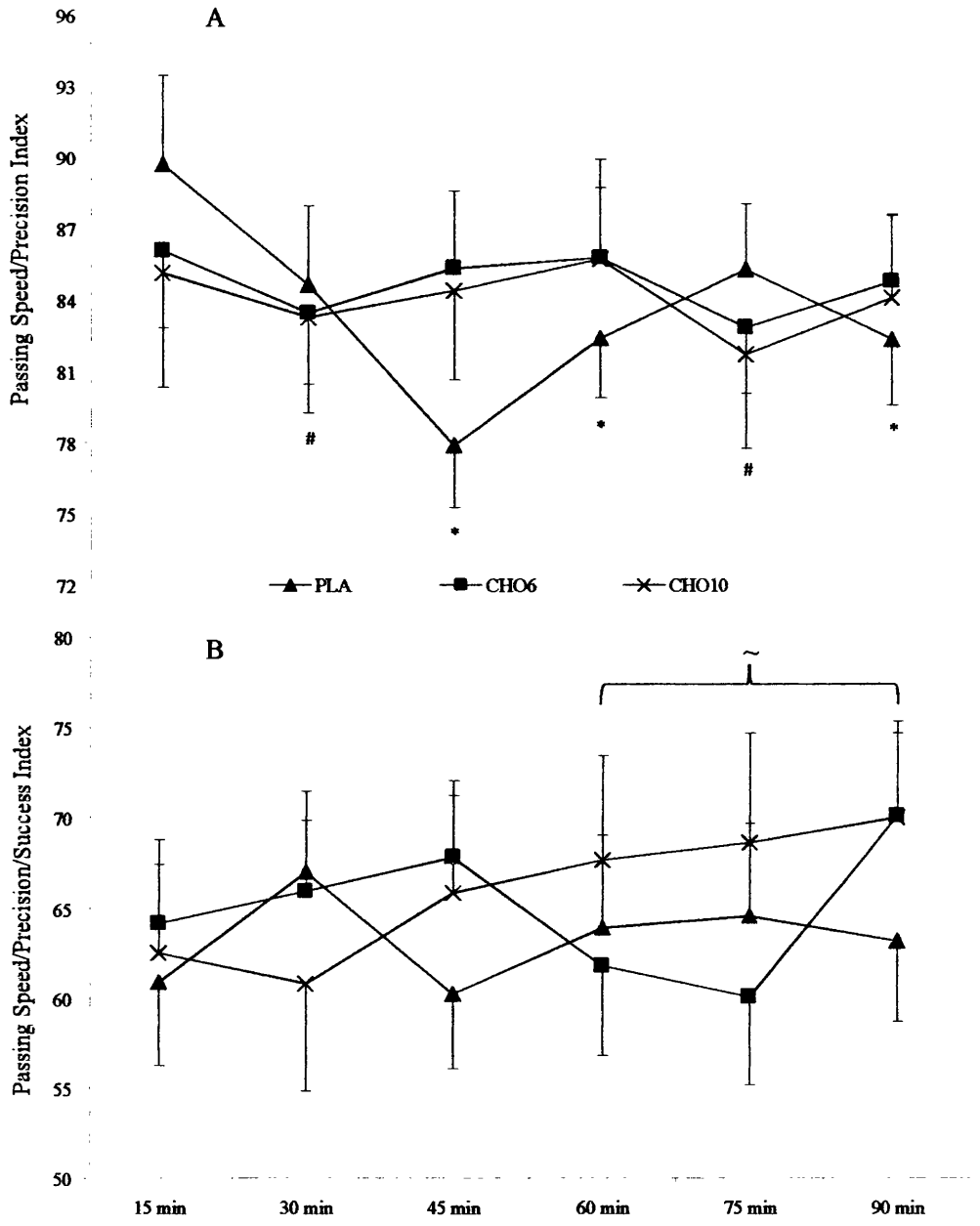

Figure 4.4 Mean (± *SEM*, $n = 14$) values of (A) Speed/Precision Index and (B) Speed/Precision/Success Index for PLA, CHO6 and CHO10 trials. * Indicates significantly lower SP Index compared to 15 min (PLA) ($P < 0.05$). # Indicates significantly higher SP Index compared to 45 min (PLA) ($P < 0.05$). ~ Indicates significantly higher mean in 2nd half compared to 1st in CHO10 ($P < 0.05$).

4.5.2 Ball Dribbling

Mean dribbling precision during PLA, CHO6 and CHO10 were 85.2 ± 1.9 cm; 85.9 ± 2.0 cm; 83.1 ± 1.9 cm, respectively (Table 4.5). The pattern of response in dribbling precision was not influenced by supplementation (interaction effect: $F_{(10,130)} = 1.097$, $P = 0.370$, $\eta_p^2 = 0.078$). Similarly, dribbling precision was not affected by supplementation (trial effect: $F_{(2,26)} = 0.352$, $P = 0.707$, $\eta_p^2 = 0.026$) or exercise (time effect: $F_{(5,65)} = 0.718$, $P = 0.555$, $\eta_p^2 = 0.052$).

The pattern of response in dribbling speed over the duration of the protocol was similar with supplementation (interaction effect: $F_{(10,130)} = 1.494$, $P = 0.220$, $\eta_p^2 = 0.103$) with mean values being 2.55 ± 0.03 $m.s^{-1}$ (PLA), 2.58 ± 0.04 $m.s^{-1}$ (CHO6) and 2.57 ± 0.09 $m.s^{-1}$ (CHO10) (Figure 4.5). Similarly, no differences were seen between the 1st and 2nd half across any treatment (interaction effect: $F_{(2,26)} = 1.279$, $P = 0.197$, $\eta_p^2 = 0.117$).

When dribbling success was analysed, the pattern of response was similar between the three trials (interaction effect: $F_{(10,130)} = 0.690$, $P = 0.732$, $\eta_p^2 = 0.05$). Similarly, no differences were seen between trials (trial effect: $F_{(2,26)} = 1.594$, $P = 0.222$, $\eta_p^2 = 0.109$) or over time (time effect: $F_{(5,65)} = 1.011$, $P = 0.393$, $\eta_p^2 = 0.072$) (Table 4.5).

The pattern of response in the SP Index for dribbling was similar between the three trials (interaction effect: $F_{(10,130)} = 1.655$, $P = 0.176$, $\eta_p^2 = 0.113$), with mean values across each trial of 16.46 ± 0.17 (PLA), 16.22 ± 0.21 (CHO6) and 16.61 ± 0.25 (CHO10). Similarly, no difference was seen between halves (interaction effect: $F_{(2,26)} = 0.506$, $P = 0.609$, $\eta_p^2 = 0.037$).

The pattern of response was similar between the three trials (interaction effect: $F_{(10,130)} = 1.295$, $P = 0.240$, $\eta_p^2 = 0.091$) for dribbling SPS Index; similarly, no difference was seen between trials (trial effect: $F_{(2,26)} = 0.884$, $P = 0.394$, $\eta_p^2 = 0.064$) or over time (time effect: $F_{(5,65)} = 1.111$, $P = 0.364$, $\eta_p^2 = 0.079$). 1st to 2nd half revealed no differences (interaction effect: $F_{(2,26)} = 0.275$, $P = 0.761$, $\eta_p^2 = 0.021$) in dribbling SPS Index.

Table 4.5 Indices of dribbling performance over 90 min for CHO6, CHO10 and PLA treatments (Mean ± *SEM*, $n = 14$)

Outcome	Trial	15min	30min	45min	60min	75min	90min	1st Half	2nd Half
Dribbling Speed ($m.s^{-1}$)	PLA	2.47 ± 0.07	2.58 ± 0.07	2.53 ± 0.08	2.52 ± 0.06	2.60 ± 0.05	2.64 ± 0.06	2.52 ± 0.06	2.59 ± 0.04
	CHO6	2.51 ± 0.07	2.58 ± 0.09	2.52 ± 0.07	2.50 ± 0.09	2.65 ± 0.12	2.69 ± 0.12	2.54 ± 0.07	2.61 ± 0.10
	CHO10	2.61 ± 0.09	2.70 ± 0.09	2.58 ± 0.08	2.50 ± 0.08	2.50 ± 0.09	2.52 ± 0.08	2.63 ± 0.08	2.50 ± 0.07
Dribbling Precision (cm)	PLA	80.5 ± 4.0	87.3 ± 4.0	88.7 ± 3.6	89.5 ± 6.8	84.8 ± 4.4	80.7 ± 4.7	85.5 ± 2.6	85.0 ± 4.3
	CHO6	88.2 ± 5.6	85.8 ± 5.5	87.2 ± 5.1	83.3 ± 4.5	82.1 ± 5.6	90.8 ± 4.6	87.1 ± 3.6	84.7 ± 3.9
	CHO10	80.9 ± 4.8	81.5 ± 3.3	84.5 ± 5.5	83.4 ± 4.9	78.2 ± 3.7	86.3 ± 6.5	82.0 ± 3.5	84.3 ± 4.1
Dribbling Success (%)	PLA	92.2 ± 2.9	88.9 ± 2.8	89.3 ± 2.3	86.1 ± 4.6	91.7 ± 2.8	91.3 ± 3.4	90.1 ± 1.5	89.7 ± 2.5
	CHO6	86.7 ± 4.8	86.5 ± 3.6	86.6 ± 4.0	86.9 ± 3.3	88.9 ± 2.8	84.5 ± 2.6	86.6 ± 2.2	86.8 ± 1.9
	CHO10	90.1 ± 3.2	89.3 ± 2.0	86.9 ± 3.4	80.6 ± 5.5	89.8 ± 2.2	83.1 ± 3.7	88.8 ± 2.3	84.5 ± 2.8
Dribbling SPS Index	PLA	15 ± 1	15 ± 1	15 ± 1	14 ± 1	15 ± 1	16 ± 1	15 ± 1	15 ± 1
	CHO6	14 ± 1	14 ± 1	14 ± 1	15 ± 1	15 ± 1	13 ± 1	14 ± 1	14 ± 1
	CHO10	15 ± 1	15 ± 1	14 ± 1	13 ± 1	15 ± 1	15 ± 1	15 ± 1	14 ± 1

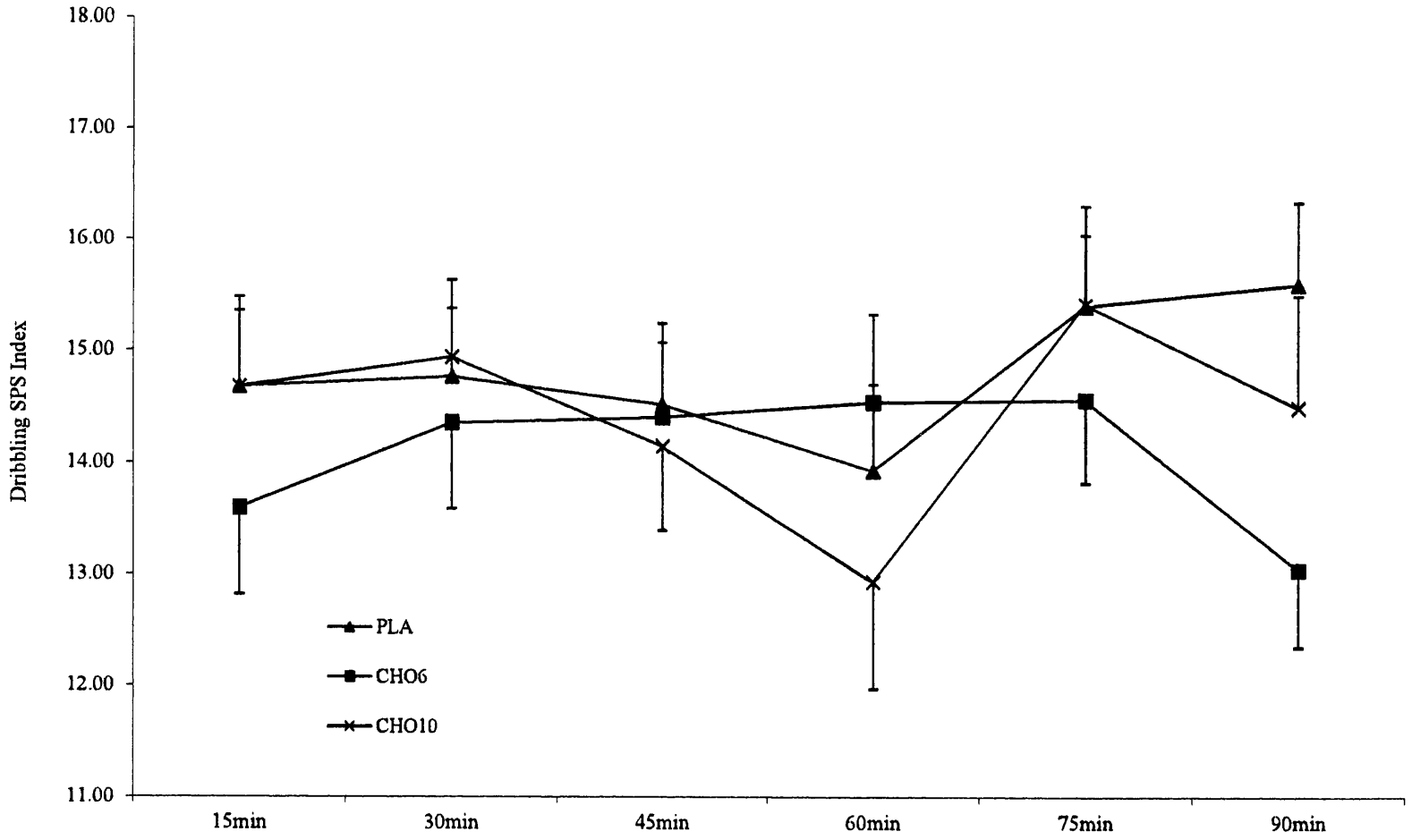

Figure 4.5 Dribbling SPS Index for the three experimental treatments. Mean ± *SEM*, $n = 14$.

4.5.3 Shooting

The pattern of response for shooting precision did not differ between trials, over the duration of the exercise protocol (interaction effect: $F_{(4,52)} = 0.204$, $P = 0.935$, $\eta_p^2 = 0.015$). Mean shot precision was similar between trials, being 142.0 ± 10.4 cm in the CHO10 trial compared with 153.4 ± 12.1 cm (PLA) and 169.6 ± 11.5 cm (CHO6) (trial effect: $F_{(2,26)} = 1.543$, $P = 0.233$, $\eta_p^2 = 0.106$). A difference was seen over time (time effect: $F_{(2,26)} = 3.990$, $P = 0.031$, $\eta_p^2 = 0.235$); however post hoc analysis could not reveal where the difference was.

The pattern of response for shooting speed remained consistent between trials, over the duration of the exercise protocol (mean: 14.97 ± 0.33 $m.s^{-1}$, PLA; 14.69 ± 0.36 $m.s^{-1}$, CHO6; 15.11 ± 0.34 $m.s^{-1}$, CHO10; interaction effect: $F_{(4,52)} = 1.023$, $P = 0.404$, $\eta_p^2 = 0.073$) (Table 4.6).

Again, the pattern of response for shooting success remained consistent between trials, over the duration of the exercise protocol (interaction effect: $F_{(4,52)} = 1.374$, $P = 0.256$, $\eta_p^2 = 0.096$) (Table 4.6).

The three trials were similar in terms of SP Index throughout the exercise protocol, with CHO6 trial having a slightly smaller SP Index (96.1 ± 2.4) compared to the PLA (98.1 ± 2.2) and the CHO10 (99.1 ± 2.2) trials (trial effect: $F_{(2,26)} = 0.754$, $P = 0.481$, $\eta_p^2 = 0.055$). No differences were seen over time (time effect: $F_{(2,26)} = 0.464$, $P = 0.634$, $\eta_p^2 = 0.034$).

The shooting SPS Index was not influenced by time or treatment in the shooting protocol (interaction effect: $F_{(4,52)} = 1.459$, $P = 0.228$, $\eta_p^2 = 0.101$). SPS Index was similar between the trials, being 50 ± 4 (PLA); 59 ± 4 (CHO6) and 64 ± 4 (CHO10) (Table 4.6).

Table 4.6 Indices of shooting performance over 90 min for CHO6, CHO10 and PLA treatments (Mean ± *SEM*, n = 14)

Outcome	Trial	Pre 1st Half	Post 1st Half	Post 2nd Half
Shooting Speed ($m.s^{-1}$)	**PLA**	14.89 ± 0.64	15.41 ± 0.55	14.62 ± 0.54
	CHO6	15.44 ± 0.58	14.29 ± 0.48	14.34 ± 0.76
	CHO10	14.84 ± 0.47	15.54 ± 0.67	14.96 ± 0.63
Shooting Precision (cm)	**PLA**	136.1 ± 21.0	186.8 ± 29.0	137.3 ± 9.6
	CHO6	159.6 ± 21.3	192.7 ± 20.2	156.4 ± 17.8
	CHO10	135.1 ± 11.2	156.7 ± 18.1	134.1 ± 15.6
Shooting Success	**PLA**	51.8 ± 4.9	66.1 ± 6.7	71.4 ± 7.8
	CHO6	60.7 ± 5.1	60.7 ± 9.0	60.7 ± 9.0
	CHO10	67.9 ± 7.1	66.1 ± 6.2	60.7 ± 6.3
Shooting SPS Index	**PLA**	50 ± 5	67 ± 8	70 ± 8
	CHO6	60 ± 4	57 ± 9	59 ± 9
	CHO10	67 ± 7	66 ± 6	60 ± 7

CHAPTER FIVE

5.0 DISCUSSION

5.0 Discussion

The main findings of the present study were: (1) carbohydrate supplementation (CHO6 and CHO10) attenuated the exercise-induced decline in passing speed and SP Index at 45 min, 60 min and 90 min, (2) dribbling performance was not influenced by exercise or supplementation, (3) shooting performance was not influenced by exercise or supplementation, and (4) carbohydrate supplementation was effective in increasing mean blood glucose concentrations during exercise (CHO10 > CHO6 > PLA); however, the carbohydrate supplementation strategies did not prevent large exercise-induced declines in blood glucose concentrations at 60 min.

Blood glucose concentrations were successfully manipulated by using different supplementation regimes, where mean blood glucose concentrations throughout the exercise protocol were 4.78 ± 0.08 mmol·l^{-1} (PLA), 5.22 ± 0.12 mmol·l^{-1} (CHO6) and 5.92 ± 0.15 mmol·l^{-1} (CHO10). Blood glucose concentrations declined from baseline to 90 min in PLA, while blood glucose concentrations increased from baseline until 45 min during both carbohydrate trials. However, at 60 min of exercise (after half-time) blood glucose concentrations had decreased by approximately 38 ± 2 % to values of 3.81 ± 0.14 mmol·l^{-1} in CHO6, and by approximately 40 ± 3 % to values of 4.27 ± 0.19 mmol·l^{-1} in CHO10 and although blood glucose recovered in the 2nd half, mean values for the 2nd half were significantly lower than 1st half values.

Bangsbo et al. (2007) reported decreases in blood glucose after half time during soccer match-play; similarly, Russell et al. (2011b) also showed that blood glucose concentrations decreased after half time during soccer match play (17 ± 4 %) and the SMS protocol (19 ± 5 %) when ingesting a carbohydrate-free fluid-electrolyte beverage. Bangsbo et al. (2007) attributed the decrease in blood glucose concentrations to a significant uptake of glucose by the muscles during half-time, and a reduction in the stimulation of liver gylcogenolysis caused by reduced catecholamine levels. It is also possible that cognitive function and soccer performance could be reduced with decreased concentrations of blood glucose as previous research has shown (Benton, 2002; Benton & Nabb, 2003; Ali et al., 2007). Reductions in blood glucose, the primary source of energy for maintenance of cerebral functioning (Duelli & Kuschinsky, 2001) have the potential to influence skilled performances in soccer. To

emphasise this point, Bandelow et al. (2010) have demonstrated that higher blood glucose concentrations were associated with faster visual discrimination, faster fine-motor speed and faster psycho-motor speed after soccer match-play in the heat after players completed four different types of cognitive test.

This is the first study to show that the influence of higher concentrations of carbohydrate with the addition of caffeine (CHO10) causes a significant ($P < 0.05$) decrease in blood glucose levels at half time. However, although decreases in blood glucose were seen, skill performance of passing and dribbling were not compromised.

Passing performance, specifically passing speed was slower at 45, 60 and 90 min when compared to 15 min in the placebo trial ($P < 0.05$), whereas passing speed was maintained throughout exercise in CHO6 and CHO10. Also, passing SP Index was significantly compromised in PLA compared to 15 min at 45, 60 and 90 min. Furthermore, mean passing speed over the whole SMS protocol was faster in both carbohydrate trials when compared with PLA. These finding are consistent with Ali et al. (2009) who suggested that soccer skill declined in the placebo trial by more than a carbohydrate-electrolyte trial; however, the protocol used by Ali and colleagues (2007b; 2009) are not representative of normal pre-match preparation because the completion of a glycogen depleting protocol that included high-intensity sprint cycling on the night before the main trials contradicts usual and recommended preparation for a game. The current results show that passing speed is better maintained when carbohydrates are ingested compared to a placebo, when the skill is measured throughout the exercise protocol and players begin the exercise protocol with normal concentrations of blood glucose. It could be seen that passing speed in both carbohydrate trials followed the same pattern throughout the SMS (Figure 4.3).

Passing precision was similar and remained consistent throughout all trials. These results suggest that the players in the placebo trial compromised their passing speed to maintain precision, which provides direct evidence of a speed-accuracy trade-off (Fitts & Posner, 1967). The trade-off between speed and precision for passing (SP Index) was influenced by exercise in PLA. At 45, 60 and 90 min into the exercise protocol the SP Index was

compromised when compared to 15 min ($P < 0.05$), whereas the SP Index was maintained throughout the trial in the carbohydrate trials.

Previous research and observations have reported that work rate is decreased throughout a soccer match at the end of a match (Mohr et al., 2003; Di Salvo et al., 2007; Rampinini et al., 2009) and simulated matches (Rahnama et al., 2003), suggesting that skill performance is compromised during the last 15 min of a match. Reports of modifications in speed and/or precision of soccer skills have been reported under fatiguing conditions (Kellis et al., 2006; Ali et al., 2007; Russell et al., 2011a) and findings from this study are in general agreement.

An interesting finding of the present study is that passing SP Index was lower at 45 min compared to 90 min in PLA (although SP Index was also lower at 90 min compared to every other time point with the exception of 45 min), which suggests that fatigue can influence passing proficiency at the end of the 1st half of a soccer match in recreational players, consuming no additional carbohydrate, as well as the latter stages of a match.

Russell et al. (2011a) reported that skill performance decreased from 1st to 2nd half of a simulated soccer match in professional players. Specifically passing and shooting speed decreased from 1st to 2nd half, and also, shooting precision was greater at the end of each half compared to the corresponding pre-half values. In the present study, although a trend could be seen in some outcomes decreasing in the 2nd half compared to the 1st, not all reached statistical significance. Interestingly, passing success was improved in the 2nd half of the exercise protocol in CHO10 compared to the 1st half, suggesting that the higher concentration of carbohydrate and additional caffeine not only maintained passing success but improved it.

During the current study, dribbling performance was maintained in each trial and was not affected by supplementation. This finding is in agreement with previous literature (Abt et al., 1998; McGregor et al., 1999; Russell et al., 2011a) that suggests dribbling is more resilient to the effects of fatigue compared to skills that require greater peak muscular activity (Russell et al., 2011a). Although previous studies have identified a fatigue-induced drop in shooting performance after exercise, presumably because of fatigue causing a decrease in peak gross

muscular recruitment (Kellis et al., 2006; Ali et al., 2007; Russell et al. 2011a), shooting speed was not statistically slower at the end of the second half when compared to the previous time points in PLA. Similarly, shooting precision was not affected by supplementation or time. Previous research (Russell et al., 2011a) found that shooting performance was compromised in professional players, whereas shooting performance was unaffected by supplementation in this study, using similar protocols. Differences in the blood sampling regime employed, which required players to have extra blood samples taken immediately after exercise but before the shooting protocol, might partly explain the variation in these findings.

In a non-exercise setting, manipulations of blood glucose concentrations can alter cognitive functioning. Previous research has shown that carbohydrate ingestion improved cognitive performance (Donohoe & Benton, 1999; Benton, 2002; Benton et al., 2003; Benton & Nabb, 2003) when compared to a placebo, or no drink. Lieberman et al. (2002) published work suggesting that ingesting carbohydrate during sustained aerobic exercise improved vigilance and self-reported mood. Lieberman et al. (2002) attributed this increase in cognitive performance to a number of potential mechanisms, including an increase in plasma glucose availability to the brain and generalized increase in brain metabolic activity. Therefore, in agreement with Lieberman et al. (2002), it is highly plausible that the additional carbohydrates provided in this study acted directly on the brain to prevent a reduction in the synthesis of various metabolites and neurotransmitters and protected the brain from the consequences of an energy deficit, allowing cognitive function to be maintained throughout exercise. Thus, the maintenance of passing proficiency attributed to euglycaemia is plausible; unfortunately though, no measure of cerebral glucose levels were taken; consequently, although attractive, this mechanism cannot be confirmed in this study.

During the placebo trial, blood glucose concentrations were highest at 15 min into the exercise protocol, which was then followed by a downward trend (Figure 4.1). Consequently, it is reasonable to speculate that lowered blood glucose concentrations observed in the placebo trial, might have hindered the ability of players to visually search and identify targets in addition to compromising the speed that they passed the ball in order to maintain precision.

During both carbohydrate trials, blood glucose concentrations increased from resting values and remained elevated for the whole of the first 45 min. Unlike other studies in this field (Nicholas et al., 1999; Ali et al., 2007), blood was sampled frequently (i.e., every 15 min during exercise); this blood sampling procedure enabled the identification of an exercise-induced reduction in blood glucose concentrations during soccer specific activity after the half-time break. The ingestion of carbohydrate caused a sharp decline of blood glucose between the 45 min and 60 min time points in both carbohydrate trials (CHO6: -38.3 ± 2.0 %; CHO10: -40.0 ± 3.1 %). Interestingly, although a larger decline in blood glucose was seen in CHO10, the concentration of blood glucose was not lower than PLA at 60 min.

Blood glucose concentrations in all three trials remained below peak values in the 2nd half of exercise and it was seen that mean blood glucose concentrations were lower in the 2nd half of exercise when compared to the 1st in all trials. Also, throughout the trials 8 cases of hypoglycaemia (blood glucose concentration below 3.5 mmol.l^{-1}; Rabasa-Lhoret et al., 2001) were recorded (CHO10: n=2; CHO6: n=5; PLA: n=1). The presence of rebound hypoglycaemia is likely to occur during competitive matches because a similar pattern of response has been demonstrated to occur during actual soccer match-play (Russell et al., 2011b).

Glucose transporter protein, GLUT3, is the most predominant glucose transporter aiding neural transportation (Simpson et al., 2008). The role of glucose uptake into the central nervous system has been widely researched and GLUT3 is the main glucose transporter protein involved in the uptake of glucose by neurons (Duelli & Kuschinsky, 2001). GLUT3 can be increased by a mechanism not affecting transcription or translation of new GLUT3 protein but by stabilization of the protein, prolonging the half-life of GLUT3 protein during an increased glucose demand (Khayat et al., 1998). Due to an increased half-life of GLUT3 at an unchanged synthesis rate, total GLUT3 is then elevated. GLUT3 has a higher affinity for glucose than other similar GLUTs as well as a greater transport capacity (Simpson et al., 2008). The ambient glucose concentration surrounding a neuron is around 1-2 mmol.l^{-1}(about 5 times lower than in serum; Simpson et al, 2008), highlighting how important these properties of the GLUT3 transporter are. Therefore, it is highly unlikely, as seen in previous studies using rats, that chronic hypoglycaemia has any practical impact on the transport of

glucose through GLUT3 into the CNS (Duelli et al., 1999). Hence, it is likely that there was negligible influence of hypoglycaemia on CNS and brain function during the three different trials performed by the players in the current study.

Although the drop in blood glucose concentration at 60 min in CHO6 and CHO10 trials was not associated with an overall decline in skilled performance, it should be noted that shooting was not tested at this time point and passing and dribbling were. Future research could be directed to investigating whether rebound hypoglycaemia is in fact present in a match situation, and if so, what effects this has upon gross motor skill execution.

Sports drinks that contain carbohydrates are amongst the most commonly used supplements in the world (Vergauwen et al., 1998). As the concentration of one of the carbohydrate beverages in this study was similar to that of most branded sports drinks (~ 6 %), the elevated incidence of rebound hypoglycaemia at 15 min into the second half of exercise, observed in this study indicates that research should determine whether the use of different supplementation strategies can better maintain blood glucose levels over the course of a whole match.

It is also worth noting that some players (n = 7) experienced higher levels of abdominal discomfort in the CHO10 trial, especially at the end of both halves of the exercise protocol. Brouns & Beckers (1993) found that ingestion of a hypertonic beverage increases the possibility of gastrointestinal discomfort due to the osmotic attraction of fluid form the blood into the intestine. Jeukendrup (2008) suggested that ingesting carbohydrate at very high rates (< 60 g.h^{-1}) could possibly cause hyperosmolality of the stomach contents, which could cause gastrointestinal discomfort. Players in the present study were ingesting a 10 % solution above this threshold; consequently, this could be a possible explanation for the occurrences of gastrointestinal distress. Jeukendrup (2008) concluded that the likelihood that an athlete would develop gastrointestinal distress as 'highly individualized'. Therefore, strategies should be developed on an individual basis.

Although the current findings suggest that exogenous carbohydrate can maintain soccer skill performance in recreational players throughout exercise when compared with a placebo, the provision of additional carbohydrate did not further enhance performance. Limited research is available to determine the effects of carbohydrate supplementation on soccer skill performance; therefore, it is difficult to make broad comparisons with previous literature. Furthermore, variations in the methods employed further complicate comparisons. For example, the protocol used by Ali et al. (2007b; 2009) is not representative of normal pre-match preparation because the completion of a glycogen depletion protocol that included high-intensity sprint cycling on the night before the main trials contradicts usual and recommended preparation for a game. Additionally, the use of criterion based outcomes for assessing skilled performance as used by many of the authors of previous literature (Abt et al., 1998; Northcott et al., 1999; Ostojic & Mazic, 2002; Ali et al., 2007,2009; Currell et al., 2009) all produce quantative data from discrete sources (e.g., adding time penalties for missing targets). Nevertheless, the current findings suggest that an individualised carbohydrate supplementation strategy might be necessary to maintain blood glucose concentrations and optimise skill performance throughout soccer match-play.

CHAPTER SIX

6.0 CONCLUSIONS AND FUTURE RECOMMENDATIONS

6.0 Conclusions and Recommendations

6.1 Conclusions

Carbohydrate supplementation attenuated the fatigue-induced decline in soccer passing performance in recreational players. Specifically, passing speed declined in the placebo trial while passing speed was maintained during CHO6 and CHO10. As exercise progressed, and players became fatigued, passing speed was sacrificed to maintain accuracy in PLA, as demonstrated by reductions in the SP Index.

Although CHO10 increased blood glucose concentrations above those in CHO6 and PLA, the provision of high carbohydrate concentrations (CHO10) did not further improve skill performance when compared to moderate carbohydrate concentrations (CHO6).

Dribbling performance was not affected by supplementation suggesting that dribbling performance is more resilient to the effects of fatigue than passing.

Unlike previous research, shooting performance was consistent throughout the SMS protocol. The current findings however could have been influenced by the blood sampling regime employed and therefore may not be entirely representative of shooting performance at the end of the second half.

An exercise-induced reduction in blood glucose concentration was present in both carbohydrate trials, whereas blood glucose concentrations decreased throughout exercise in PLA. This sudden drop in blood glucose at 60 min did not influence skill performance in CHO6 or CHO10 in any skill at 60 min; however it could be seen that passing speed and passing SP index were reduced compared to 15 min in PLA.

Therefore, additional carbohydrate can improve some aspects of soccer skill performance in recreational players that are directly related to success in soccer match-play; however, the optimal concentration of carbohydrate is not clear. It is possible that the optimum concentration of carbohydrate is highly individualized with some players experiencing abdominal discomfort when higher concentrations of carbohydrate are consumed before and during exercise that replicates soccer match-play.

6.2 Limitations and Future Recommendations

The influence of carbohydrate-electrolyte supplementation on soccer skilled performance has become the focus of recent research; however, discrepancies in the methods used to quantify soccer skill performance make it difficult to compare findings directly. The use of skill tests that produce criterion-based outcome measures has overcome some of the problems associated with assessing skills throughout match-play; however, the results are often difficult to interpret due to the lack of ecological validity. Therefore, a limitation of the current study is that no other carbohydrate-electrolyte intervention has used the same methods to measure skilled performance. In the future, researchers are advised to use methods that use continuous and ecologically valid outcome measures (such as speed, precision and success) to assess skill performance because this will allow direct comparisons to be made with similar research and allow coaches and players to interpret the findings.

An additional limitation of this study was that the exercise protocol used to analyse the effects of the different supplements was a "simulation" of soccer match-play. Therefore, although a good insight into what may happen during a match, soccer is unpredictable in nature; consequently, the results reported in this study are representative of a standard soccer game rather than match-play.

Recreational players were used in this study because the findings can be translated to a large population that regularly use carbohydrate-electrolyte products. Although the relative test-retest reliability of the outcome measures has been demonstrated to be similar between

recreational and professional players (Russell et al., 2010), it is possible that the carbohydrate supplementation might have a reduced efficacy in this population.

The carbohydrate beverages and gels used in the present study were similar to commercial available products; however, the supplements were specifically manufactured for this study. Therefore, the findings of this research might lack direct translation to commercial products. Nevertheless, the development of individualised optimal carbohydrate-electrolyte supplementation strategies offers a wealth of future research opportunities.

CHAPTER SEVEN

7.0 REFERENCES

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CHAPTER EIGHT

8.0 APPENDICES

Appendix A

Application for ethics committee approval

Swansea University
SPORTS SCIENCE, SCHOOL OF HUMAN SCIENCE

DEPARTMENTAL ETHICS ADVISORY COMMITTEE

APPLICATION FOR ETHICAL COMMITTEE APPROVAL OF A RESEARCH PROJECT

In accordance with Departmental Safety Policy, all research undertaken in the department must be approved by the Departmental Ethics Advisory Committee **prior to** data collection. **Applications for approval should be typewritten on this form using the template available in the Public Folders.** The researcher(s) should complete the form in consultation with the project supervisor. Where appropriate, the application must include the following appendices:

(A) subject information sheet;
(B) subject consent form;
(C) subject health questionnaire.

After completing sections 1-12 of the form, 1 copy of the form should be handed-in to the Department Administrator who will then submit copies of the application for consideration by the Departmental Ethics Advisory Committee. The applicant(s) will be informed of the decision of the Committee in due course.

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1. **DRAFT TITLE OF PROJECT**

   The effects of ingesting a larger dose of carbohydrate on metabolic responses during a soccer-specific exercise protocol.

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2. **NAMES AND STATUS OF RESEARCH TEAM**

   Dr. Mike Kingsley – Supervisor

   Carlos Penas Ruiz – Postgraduate student

   Chris Terry – Postgraduate student

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3. **RATIONALE**

It has been widely identified that a decrease in muscle glycogen and blood glucose availability during soccer games can lead to fatigue (Saltin, 1973; Mohr *et al.*, 2005; Krustrup *et al.*, 2006). Fatigue, especially towards the end of the game can lead to impairments in exercise (Mohr *et al.*, 2003; Rampinini *et al.*, 2007) and soccer skills performance (McGregor *et al.*, 1999; Rampinini *et al.*, 2008; Ali *et al.*, 2009). Interestingly, most of the goals are scored in the last 15 minutes of the game, which may be related with the earlier mentioned decrease in exercise and skills performance (Reilly, 1996).

The provision of carbohydrate (CHO) appears to induce metabolic and perceptual benefits during actual soccer game or soccer match simulations (Coyle *et al.*, 1986; Nicholas *et al.*, 1995; Ostojic and Mazic, 2002; Ali *et al.*, 2009). Sports drinks are usually ingested to prevent dehydration, preserve muscle glycogen and blood glucose levels, and replace electrolytes losses during exercise. However, the optimal characteristics of sports drinks (type, amount and concentration of CHO) are still being debated.

Exogenous CHO oxidation seems to be limited to rates of 1.0 to 1.1g • min^{-1} (Wagenmakers *et al.*, 1993; Bosch *et al.*, 1994; Jeukendrup *et al.*, 1997). However, it has been shown that large doses (2.4 g • min^{-1}) of a blend of different types of CHO can enhance CHO oxidation rates (~1.7 g • min^{-1}) if compared with the administration of a single source of carbohydrate (Jentjens, Achten and Jeukendrup, 2004; Jentjens and Jeukendrup, 2005).

It has been suggested that an increase in the concentration of CHO in sport drinks may lead to a decrease in fluid availability therefore causing dehydration (Maughan and Leiper, 1999). The increase in beverage osmolality originates a water displacement from tissues to the intestinal lumen causing a loss in the body water pool (Gisolfi *et al.*, 1990). Davids *et al.* (1990) suggested that the ingestion of CHO beverages with concentrations ranging between 3% and 10% were not likely to reduce fluid availability if compared with water ingestion. However, a recent study by Jeukendrup *et al.* (2009) showed that fluid availability was compromised with CHO solutions concentration above 6%.

Typically, caffeine has been ingested by athletes because its reported ergogenic effects (Ganio *et al.*, 2009). The ingestion of carbohydrate with small doses of caffeine has been shown to increase exogenous CHO oxidation (Yeo *et al.*, 2005), maintain optimal blood glucose levels (Cureton *et al.*, 2007), and increase intestinal CHO absorption (Van Nieuwenhoven *et al.*, 2000) during exercise. However, there has been cases where the ingestion of CHO with caffeine (5.3 mg • kg^{-1}) did not influence exogenous CHO oxidation or glucose responses during exercise (Hulston and Jeukendrup, 2008).

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5. AIMS and OBJECTIVES

The aim of the study is to assess the influence of different sport drinks and gels (with an increased dose of CHO + caffeine) on the metabolic responses and soccer skills performance during a soccer-specific exercise protocol.

The objectives of the study are:

- To evaluate the metabolic responses and soccer skills performance with the ingestion of a larger dose (above standard 6% CHO-electrolyte beverage) of carbohydrate during a soccer-specific exercise protocol.
- To evaluate the metabolic responses and soccer skills performance with the ingestion of an additional dose of carbohydrate (CHO gel) supplied during the half time period of a soccer-specific exercise protocol.
- To evaluate the metabolic responses and soccer skills performance with the co-ingestion of a larger dose of CHO + caffeine.

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6. METHODOLOGY

6.1 Study Design

A minimum of 15 participants will complete the described procedures of the study. The initial laboratory session will be used to estimate maximum oxygen uptake via the multistage fitness test (MSFT; Ramsbottom, Brewer & Williams, 1988), and the two remaining sessions will familiarise participants with the exercise regime and skill tests incorporated within the SMS protocol undertaken during the main experimental trials.
Following approval by the University ethics committee and informed consent being attained (parental consent where necessary; <18 years), players aged between 14 and 35 years old, and all with two or more years playing experience, will be recruited (diabetics or smokers will not participate). Four main trials (separated by no more than 14 days) will be completed in a randomised, double-blind and cross-over fashion. Supplementation will differ between trials, as follows: (trial A) 6% CHO-electrolyte solution with a placebo gel; (trial B) 6% CHO-electrolyte solution with CHO gel sachets; (trial C) 10% CHO-electrolyte and caffeine solution with CHO gel sachets, and (trial D) a control treatment ingesting only flavoured water. All players will be advised to refrain

from strenuous physical activity and caffeine consumption during the three days before all testing sessions. Additionally, participants will be required to record all food consumption the previous day before each main trial. Food records will subsequently be analysed using commercially available software (CompEat version 5.8.0; Nutrition Systems, UK). At the completion of the study, all participants will be asked whether they had complied with all instructions.

6.2 Experimental Procedures

Preliminary Testing

Three preliminary testing sessions will be completed, and on each occasion arrival at the testing site will require participants to empty their bowels and void their bladder. In the first preliminary session, anthropometric measurements of body mass (model 770; Seca Ltd, Birmingham, UK) and stature (Portable Stadiometer; Holtain Ltd, Wales, UK) will be determined before commencing a controlled warm up that consists of 5 min of light aerobic activity and 10 min of dynamic stretching and sprints (that progress to near maximal speeds). Maximal oxygen uptake will then be estimated using the protocol outlined by Ramsbottom *et al.* (1988) in order to pair participants according to the intensity of the exercise protocol to be used in the main trials (i.e., within 0.5 levels on multistage fitness test). The two remaining sessions will serve to familiarise participants with the procedures of the main trials; consequently, players will be familiarised with the exercise regime and skilled components of the SMS.

Main Experimental Trials

Participants will be required to attend the laboratory after an overnight fast at approximately 08:00 hours (i.e., 2.5 hours before commencing exercise). Upon arrival players will be prompted to provide a mid-flow urine sample and urine osmolality will subsequently be measured by freezing point depression (Gonotec Cryoscopic Osmometer Osmomat 030; YSI Limited, UK). A resting blood sample will then be taken before players consume a standardised 1470 kJ meal (Energy content: 62% carbohydrates, 25% fats, 13% proteins) and 500 ml of the supplement beverage at 08:30 hours. Body mass (model 770; Seca Ltd, Birmingham, UK) and stature (Portable Stadiometer; Holtain Ltd, Wales, UK) will then be measured. Players will remain in a rested state for approximately 100 min. A pre-exercise blood sample will be taken before players commence their final pre-exercise preparations by performing a standardised warm-up (consisting of running, dynamic stretching and ball skills) that precedes the starting the SMS. Supplement beverages will be consumed throughout all trials to supply 21 ml·kg $^{-1}$ BM (~ 14 ml· kg $^{-1}$ h $^{-1}$ BM); where 5.25 ml· kg $^{-1}$ BM will be consumed 10 min prior to commencing each half of the SMS and 2.63 ml· kg $^{-1}$ BM after 15, 30, 60 and 75 min of exercise. In addition, 2 x 38 g gel sachets will be consumed along with fluid 10 min prior to commencing each half of the SMS. A schematic of the trials is presented in Figure 1.

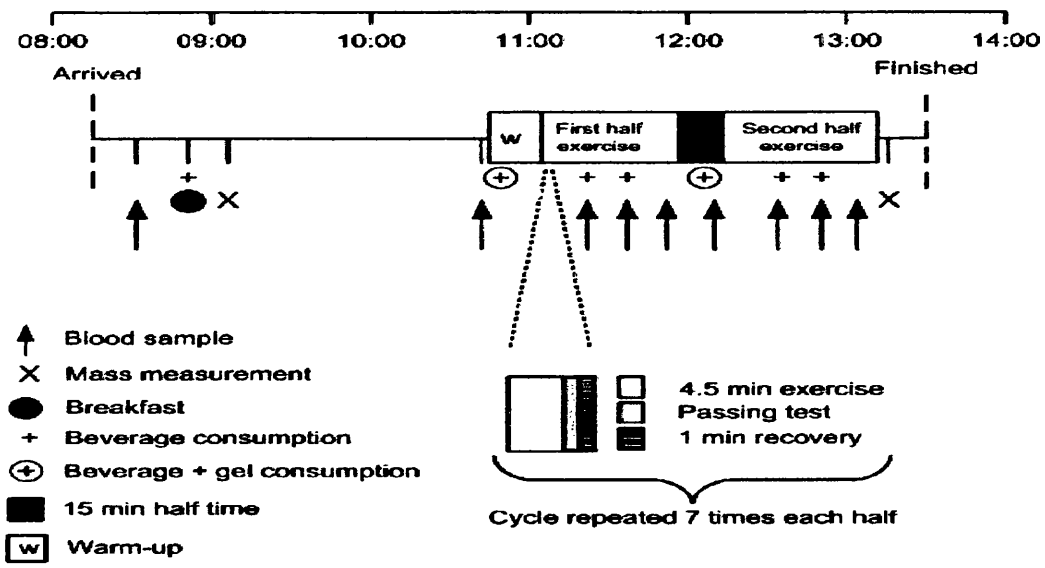

Figure 1: Schematic representation of the trial procedures.

Soccer Match Simulation (SMS)

The SMS requires participants to perform soccer skills throughout two ~47 min halves of soccer-specific activity that are separated by a 15-min passive recovery period (half-time). The exercise protocol is similar to that devised by Nicholas *et al.* (2000) but has subsequently adapted to include additional components that further replicate the movement demands of soccer match-play (Kingsley, Wadsworth, Kilduff, McEneny & Benton, 2005). Movements will be dictated by audio signals from CDs and each participant will alternate between sprinting and dribbling during each cycle.

More specifically, exercise is made up of 4.5-min blocks that consists of 3 repeated cycles of three 20-m walks, an alternating 15-m timed sprint (Brewer timing gates) or an 20-m dribble, a 4-s passive recovery period, five 20-m jogs at a speed corresponding to 40% $\dot{V}O_2$ max, one 20-m backwards jog at 40% $\dot{V}O_2$ max and two 20-m strides at 85% $\dot{V}O_2$ max. A 2 min period incorporating the performance of soccer passing (1 min) and recovery (1 min) will follow all blocks of exercise. Seven blocks of intermittent activity and skills will be completed during each half of exercise. The participants cover a total distance of 10.1 km and will complete 56 passes and 21 dribbles during the protocol.

Figure 2 shows the schematic of the passing skill test. Balls (Total 90 Aerow: size 5; Nike Inc, USA) will be released at a constant velocity of 2.3 $m \cdot s^{-1}$ towards a 1.5 x 1.5-m square (action zone), where participants will be instructed to kick the ball. The participants kick towards one of two randomly determined targets (identified by a custom lighting system); consequently, the players are required to carry out visual searching and decision making during each attempt (similar to a soccer match when looking for space or other players). Motion sensors on the ball release mechanism ensure standardization and repeatability of each attempt; with a delay of 0.64 s between target identification and the ball reaching the centre of the action zone.

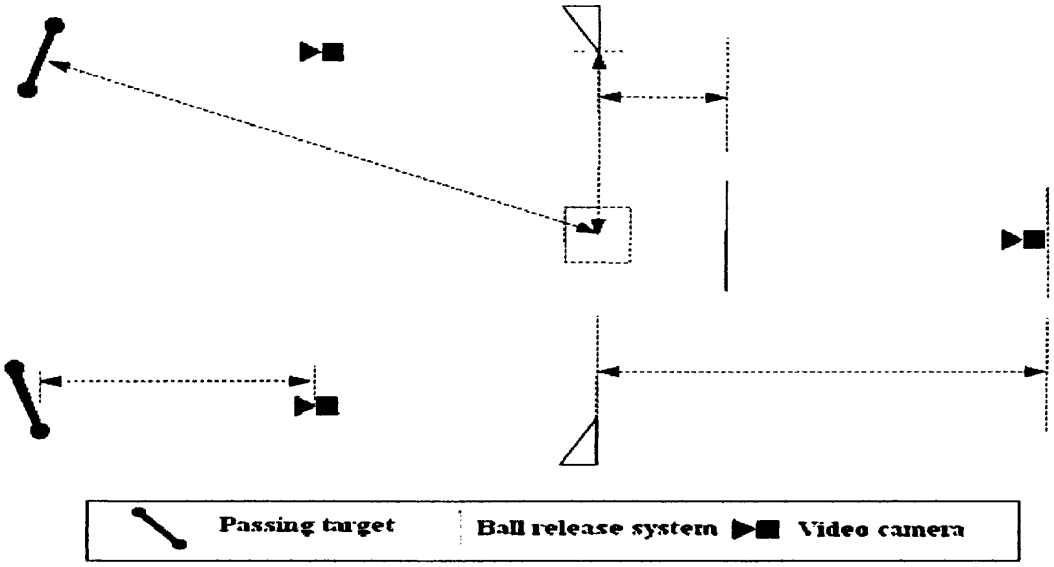

Figure 2: Schematic for the layout of the passing test.

Participants will commence the passing skill tests from a standing start before jogging into the action zone when the ball is released. The 2.0 x 1.0-m passing targets will be placed at distances of 7.9 m away from the centre of the action zone. The participants will be instructed to aim the ball at the centre of the target that is illuminated. The bouts of passing consist of four attempts, where the ball is alternately delivered from the right and left side of the action zone. To enhance ecological validity, no prior touches are allowed to control the ball (Olsen, 1988) and participants choose to kick the ball with the foot that they feel is most suitable to successfully complete the task.

The dribbling task is similar to that employed by McGregor *et al.* (1999) with start and finish lines placed 20-m apart. Cones 2 through 7 are placed 3-m away from the preceding cone, and cones 1 and 7 are 1-m away from each end of the course. Participants will be instructed to dribble the ball as fast and as accurately as possible. Video footage will be captured using 50 Hz video cameras (DCR-HC96E; Sony Ltd, UK) that will be placed 0.5 m above the ground in the positions shown in Figure 1 (passing). All cameras will be synchronised using an audio signal and maximal target to camera distances will be used in order to minimise parallax errors within the field of view. Passing performances will be represented in terms of the success; a variable that has been shown to be reliable and demonstrate construct validity (unpublished observations). Success in passing represents those skills executed within the confines of the action zone and where the ball impacts upon the correct target box.

Physiological testing

Capillary blood samples will be taken at the following time points: rest, pre-exercise and following the start of exercise; 15, 30, 45, half-time, 60, 75 and 90 min. The GEM Premier 3000 analyser (GEM Premier 3000 blood gas analyser, Instrumentation Laboratory, UK) will be used to immediately analyse 170 μL of whole blood at each time point for pH, Na^+, K^+, Ca^{2+} haematocrit, glucose and lactate concentrations.

Exercising HR will be recorded every 5 s using short range telemetry (Polar S610 HR monitor, Polar, Finland). Additional variables of plasma osmolality (Gonotec Cryoscopic Osmometer Osmomat 030; YSI Limited, UK), haemoglobin (HemoCue AB, Sweden), and urine corrected mass changes will be determined and the rate of perceived exertion (Borg, 1973) will be recorded throughout each trial.

Supplementation

During the main experimental trials participants will initially consume (with the standardised pre-exercise meal) 500 ml of beverage. Supplement beverages will be consumed throughout all trials to supply 21 ml·kg^{-1} BM (~ 14 ml· kg^{-1} ·hr^{-1} BM), with 5.25 ml· kg^{-1} BM will be consumed 10 min prior to commencing each half of the SMS and 2.63 ml· kg^{-1} BM after 15, 30, 60 and 75 min of exercise. In addition, 2 x 38 g gel sachets will be consumed along with fluid 10 min prior to commencing each half of the SMS. The beverage and gel will differ

between the three trials, as follows: (trial A) 6% CHO-electrolyte solution with placebo gel; (trial B) 6% CHO-electrolyte solution with CHO gel; and (trial C) 10% CHO-electrolyte and caffeine solution with CHO gel sachets. The total carbohydrate and caffeine ingestion during each of the trials is described in table 1.

Table 1: Total Carbohydrate and caffeine contain of the three experimental conditions during breakfast and exercise.

Trial	Supplement	Breakfast	Exercise	Total (Inc. Breakfast)
A	Fluid (ml • kg^{-1})	~7.8	21	~28.8
	Carbohydrate (g • kg^{-1})	~0.47	1.26	1.73
	Caffeine (mg • kg^{-1})	0	0	0
B	Fluid (ml • kg^{-1})	~7.8	21	~28.8
	Carbohydrate (g • kg^{-1})	~0.47	2.70	3.17
	Caffeine (mg • kg^{-1})	0	0	0
C	Fluid (ml • kg^{-1})	~7.8	21	~28.8
	Carbohydrate (g • kg^{-1})	~0.78	3.54	4.32
	Caffeine (mg • kg^{-1})	~2.34	6.3	8.64
D	Fluid (ml • kg^{-1})	~7.8	21	~28.8
	Carbohydrate (g • kg^{-1})	0	0	0
	Caffeine (mg • kg^{-1})	0	0	0

6.3 Data Analysis Techniques

Version 16 of the SPSS data collection programme will be used to analyse all data. Differences between trials will be assessed using two-way repeated measure ANOVA with intra-class correlation coefficients.

6.4 Storage and Disposal of Data and Samples

All data will be recorded and kept on a Microsoft Excel document in strict accordance with the Data Protection Act. All data will remain anonymous and will only be used for the purpose of the study. The data will be kept on a password locked user area on the Swansea University database, again under strict confidentiality. The data will only be accessible from the researchers (Carlos Penas Ruiz) and the supervisor of the study (Dr. Mike Kingsley).

Furthermore, all data will be deleted at the end of the study.

6.5 Dietary supplementation

(a) Several types of carbohydrate in different forms will be ingested during the main trials. The beverage in trial A, B and C contains a blend of maltodextrin, glucose and fructose. In addition, the beverage in trial C contains caffeine. The active gel ingested during trial B and C contains a blend of maltodextrin and glucose.

(b) All the supplements will be provided by: High Five, Unit 4, Ash Court, Forrest Business Park, Bardon, Leicester, Leicestershire, LE67 1UD.

(c) During the main experimental trials participants will initially consume (with the standardised pre-exercise meal) 500 ml of beverage. Supplement beverages will be consumed throughout all trials to supply 21 ml·kg^{-1} BM (~ 14 ml· kg^{-1} ·hr^{-1} BM), with 5.25 ml· kg^{-1} BM will be consumed 10 min prior to commencing each half of the SMS and 2.63 ml· kg^{-1} BM after 15, 30, 60 and 75 min of exercise. In addition, 2 x 38 g gel sachets will be consumed along with fluid 10 min prior to commencing each half of the SMS.

(d) All beverages and gels will be ingested orally.

(e) The ingestion of a carbohydrate gel during the recovery period (15 min half time) is expected to maintain blood glucose concentration during the second half of the exercise protocol and therefore decrease the use of endogenous carbohydrates. In addition, the typical exercise and soccer skills performance decrease suffered during the second half of the protocol is expected to be attenuated with the ingestion of additional carbohydrates at half time (CHO gel).
It is also expected that a large dose of carbohydrate (10%) ingestion will improve exercise and soccer skills performance without jeopardise hydration levels

(f) The ingestion of carbohydrate has not been associated with important health problems however; a very small number of research studies have shown that ingestion of carbohydrate during endurance running may cause gastrointestinal discomfort (van Nieuwenhoven *et al.*, 2005; Pfeiffer *et al.*, 2009).
The ingestion of large doses of caffeine may produce insomnia, nervousness, irritability, anxiety and wakefulness during resting conditions (Jacobson and Kullin, 1989). However, the caffeine doses administered in exercise research (3 to 9 mg • kg^{-1}) has not been associated with any harmful or negative responses (Wemple *et al.*, 1997; Millar-Stafford *et al.*, 2007; Goldstein *et al.*, 2010).

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7. LOCATION OF THE PREMISES WHERE THE RESEARCH WILL BE CONDUCTED.

- Exercise Physiology Laboratory, Ground floor, Vivian Tower, Swansea University, Singleton Park.
- Trained Swansea University staff (Recreation supervisor and Laboratory technician) will provide supervision during testing.
- Indoor athletic track, Swansea University, Department of sport and physical recreation, Sport Centre, Sketty Lane, SA2 8QB, +44 (0)1792 602 400.

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8. SUBJECT RISKS AND DISCOMFORTS

Participation in any form of physical activity can have some physiological consequences including: abnormal blood pressure, fainting, arrhythmias, post-exercise muscle soreness (24 to 48 hours after), and dehydration. However, all subjects will be health screened and risk stratified prior to undertaking exercise (Appendix A). In addition, subjects will be closely supervised at all times and fluids will be given to avoid dehydration problems.

Capillary blood sampling may cause some discomfort however this will be of short duration and will be reduced to a minimum.

There are no potential psychological problems recognised. Furthermore, participation in the study is voluntary and subjects will be free to withdraw at any time. Swansea University staff and postgraduate students are trained in first-aid and emergency procedures in case any unexpected medical emergency occurs during this study.

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9. INFORMATION SHEET AND INFORMED CONSENT

The submission should be specific about the type of consent that will be sought:

Have you included a Subject Information Sheet for the participants of the study? YES (Appendix B)

Have you included a Subject Consent Form for the participants of the study? YES (Appendix C and D)

If written consent will not be obtained, explain why

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10. COMPUTERS

Are computers to be used to store data? YES

If so, is the data registered under the Data Protection Act? YES

NB: For UWS students, the answer to this question is YES, but the question has been included in order to stress the importance of adherence to the Data Protection Act in research activity

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11. STUDENT DECLARATION

Please read the following declarations carefully and provide details below of any ways in which your project deviates from them. Having done this, each student listed in section 2 is required to sign where indicated.

1. I have ensured that there will be no active deception of participants.

2. I have ensured that no data will be personally identifiable.

3. I have ensured that no participant should suffer any undue physical or psychological discomfort

4. I certify that there will be no administration of potentially harmful drugs, medicines or foodstuffs.

5. I will obtain written permission from an appropriate authority before recruiting members of any outside institution as participants.

6. I certify that the participants will not experience any potentially unpleasant stimulation or deprivation.

7. I certify that any ethical considerations raised by this proposal have been discussed in detail with my supervisor.

8. I certify that the above statements are true with the following exception(s):

9. All collected data will be destroyed immediately after completion of the project.

Student signature: (include a signature for each student in research team)

Date:

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12. SUPERVISOR'S DECLARATION

In the supervisor's opinion, this project (delete those that do not apply):

- Does not raise any significant issues.
- Raises some ethical issues, but I consider that appropriate steps and precautions have been taken and I have approved the proposal.
- Raises ethical issues that need to be considered by the Departmental Ethics Committee.
- Raises ethical issues such that it should not be allowed to proceed in its current form.

Supervisor's signature: Date:

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13. ETHICS COMMITTEE DECISION (COMMITTEE USE ONLY)

ETHICAL APPROVAL: GRANTED REJECTED (delete as appropriate)

The ethical issues raised by this project have been considered by members of the Departmental Ethical Approval Committee who made the following comments:

.....

.....

.....

.....

.....

.....

.....

Please ensure that you take account of these comments and prepare a revised submission that should be shown to your supervisor/ resubmitted to the Department Ethical Approval Committee (delete as appropriate).

Signed: Date:

(Chair, Departmental Ethics Advisory Committee)

Appendix B

Subject information sheet

SUBJECT INFORMATION SHEET

Carlos Penas Ruiz
Research student, Sport and Exercise Science

Swansea University
Mob Phone: 07906199161
E-mail: 445091@swansea.ac.uk

Chris Terry
Research student, Sport and Exercise Science
Swansea University
07852960660
443328@swansea.ac.uk

1. Study title

Metabolic response and soccer skill performance after the ingestion of different doses of carbohydrate during a soccer-specific exercise protocol.

2. Invitation paragraph

The data obtained from your participation in the study will be used to understand the metabolic and performance effects of consuming sport drinks and gels during exercise. In addition, we would like to reward you with £100 worth of High5 products (www.highfive.co.uk), as a token of our appreciation for your time.

3. What is the purpose of this study?

The study will investigate the effects of carbohydrate supplementation during a high-intensity intermittent exercise protocol designed to replicate the activities and exercise intensity of a football match.

4. Why have I been chosen?

You have been asked to volunteer because you are a healthy male football player aged between 18 and 35 years who play football (soccer) regularly.

5. What will happen to me if I take part?

If you take part in the study you will be required to visit the laboratory on six different occasions. The two initial sessions will last approximately one and two hours and the four remaining sessions will last five hours each.

You will be expected to complete the following:

a) Preliminary testing: Following the completion of a health questionnaire, your height and weight will be measured. Subsequently, you will complete the familiarisation with the soccer skill part of the protocol (passing, dribbling and shooting), followed by the Multi-stage fitness test (bleep test) to estimate you maximal oxygen uptake and calculate the exercise intensity in which you will complete the main trials. In the second session, you will be familiarised with the exercise part of the protocol (90 min).

b) Four main trials: You will have to report to the lab at 8 am and after blood and urine samples have been taken, you will be given a standard breakfast. After 100 min of rest, you will perform two halves of 45 min, separated by 15 min recovery period. During the exercise part of the protocol, you will be expected to cover a 20 m distance walking, jogging, cruising, running backwards and sprinting at intensities dictated by an audio CD. You will ingest a flavoured beverage during the exercise and treatment gels at half time. Heart rate, perceived exertion will be monitored throughout. An initial and final venous blood sample will be taken together with capillary (finger prick) blood samples throughout the protocol.

6. What are the possible disadvantages of taking part?

The acute risks associated with exercise are very small however you may suffer post-exercise muscle soreness after exercise (24 to 48 hours). You will be closely supervised at all times and fluids will be provided to maintain normal hydration levels.

7. What are the possible benefits of taking part?

With your help, we will learn more about the metabolic and performance responses after carbohydrate drinks and gels ingestion and we may develop new strategies for carbohydrate use during intermittent exercise.

8. Will my taking part in the study be kept confidential?

All the information collected about you will be kept strictly confidential and will be used only for the purpose of the study.

Appendix C

Subject consent form

SUBJECT CONSENT FORM

Contact Details:

Carlos Penas Ruiz
Research student, Sport and Exercise Science
Swansea University
Mob Phone: 07906199161
E-mail: 445091@swansea.ac.uk

Chris Terry
Research student, Sport and Exercise Science
Swansea University
07852960660
443328@swansea.ac.uk

Project Title:
The effects of ingesting a larger dose of carbohydrate on metabolic responses during a soccer-specific exercise protocol.

Please tick the box

1. I confirm that I have read and understood the information sheet dated ...../...../..... (version number .....) for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that sections of any of data obtained may be looked at by responsible individuals from the University of Wales Swansea or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to these records. ☐
4. I agree to take part in the above study.

Name of Subject	Date	Signature
Name of Person taking consent	Date	Signature
Researcher	Date	Signature

Appendix D ACSM health/fitness facility pre-participation screening questionnaire

AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire.

Name: .....

Address: .....

.....

Tel. Number: .....

Emergency Contact Name: ..... Tel No.: .....

Assess your health needs by marking all *true* statements.

History

You have had:

- ☐ a Heart Attack;
- ☐ Heart Surgery;
- ☐ Cardiac Catheterization;
- ☐ Coronary Angioplasty (PTCA);
- ☐ Pacemaker/implantable cardiac defibrillator/rhythm disturbance;
- ☐ Heart valve disease;
- ☐ Heart failure;
- ☐ Heart transplantation;
- ☐ Congenital heart disease.

*If you marked any of the statements in this section, consult your healthcare provider before engaging in exercise. You may need to use a facility with a **medically qualified staff**.*

Cardiovascular risk factors

- ☐ You are a man older than 45 years.
- ☐ You are a woman older than 55 years or you have had a hysterectomy or you are post-menopausal.
- ☐ You smoke.
- ☐ Your blood pressure is greater than 140/90.
- ☐ You don't know your blood pressure.
- ☐ You take blood pressure medication.
- ☐ Your blood cholesterol level is >240 mg/dL.
- ☐ You don't know your cholesterol level.
- ☐ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
- ☐ You are diabetic or take medicine to control your blood sugar.
- ☐ You are physically inactive (i.e., you get less than 30 minutes of physical activity on at least 3 days per week).
- ☐ You are more than 20 pounds overweight.

***Symptoms* and other health issues:**

- ☐ You experience chest discomfort with exertion.
- ☐ You experience unreasonable breathlessness.
- ☐ You experience dizziness, fainting, blackouts.
- ☐ You take heart medications.
- ☐ You have musculoskeletal problems.
- ☐ You have concerns about the safety of exercise.
- ☐ You are pregnant.
- ☐ You take prescription medication(s).

*If you marked two or more of the statements in this section, you should consult your healthcare provider before engaging in exercise. You might benefit by using a facility with a **professionally qualified exercise staff** to guide your exercise program.*

☐ **None of the above is true.**

You should be able to exercise safely without consulting your healthcare provider in almost any facility that meets your exercise program needs.

AHA/ACSM indicates American Heart Association / American College of Sports Medicine

Appendix E

Standardised warm up protocol

Standardised warm up protocol

Over a 30 m distance

- **4 x 30 m Straight Jog**
- **2 x 30 m Sideways run**
- **2 x 30 m Leg cross-overs**
- **2 x 30 m Hip in/ Hip out**
- **2 x 30 m Lateral jump every 10 m**
- **2 x 30 m Progress speed run**

5 min ball skills- Passing between players, 5 Shots, 5 Dribbles.

5 min self-led stretching

Appendix F

Abdominal Discomfort Scale

Abdominal Discomfort

0 No pain

1

2 Very light pain

3

4 Light pain

5

6 Moderate pain

7

8 Severe pain

9

10 Very severe pain

Appendix G Example of dietary record

Name _____

Day _____ Date _____

- Please record all the food and drink you consume.
- Please record the method of cooking, type of food and quantity of food.

	Time	Description of food/drink		Quantity of food/drink	
		Type of food	Cooking method	Weight of item	Weight remaining
Breakfast					
Snacks					
Lunch					
Snacks					
Dinner					
Snacks					

Appendix H Subject characteristics raw data

PLA	Morning BM	Pre exercise BM	Halftime BM	Post exercise BM	BM change (kg)	% weight change	2% weight loss (kg)	Total fluid ingested (l)	Height (cm)
No.									
1	79.3	79.4	78.9	78.7	-0.7	-0.88	1.586	1.665	188.8
2	70.4	70.1	70.4	70.6	0.5	0.71	1.408	1.478	171.4
3	63.9	64.3	64	64.2	-0.1	-0.16	1.278	1.342	170.4
4	94.9	94	94.1	93.8	-0.2	-0.21	1.898	1.992	179.4
5	75.7	75.4	75.1	75.2	-0.2	-0.26	1.514	1.589	172.7
6	74.1	74.5	74.4	74.3	-0.2	-0.27	1.482	1.556	181.7
7	71.9	72.2	72.1	71.8	-0.4	-0.56	1.438	1.51	184.2
8	78	78.7	78.8	79	0.3	0.38	1.56	1.638	185.7
9	81.2	81.7	81.7	81.4	-0.3	-0.37	1.624	1.705	185.6
10	74.3	74.7	74.5	74.5	-0.2	-0.27	1.486	1.56	185.7
11	85.3	85.5	85.7	85.6	0.1	0.12	1.706	1.791	176
12	92.2	93	93	92.8	-0.2	-0.22	1.844	1.936	181.9
13	81.1	81.4	81	81.1	-0.3	-0.37	1.622	1.703	182.1
14	87.1	87.9	88	88	0.1	0.11	1.742	1.829	192.3
Mean	79.24	79.49	79.41	79.36	-0.13	-0.16	1.58	1.66	181.28
St Dev	8.55	8.53	8.60	8.51	0.30	0.39	0.17	0.18	6.60
SEM	2.29	2.28	2.30	2.27	0.08	0.11	0.05	0.05	1.76

CHO6	Morning BM	Pre exercise BM	Halftime BM	Post exercise BM	BM change	% weight change (kg)	2% weight loss (kg)	Total fluid ingested (l)	Height (cm)
No.									
1	81	80.8	80.8	80.6	-0.2	-0.25	1.62	1.701	188.6
2	70.4	70.3	70.4	70.5	0.2	0.28	1.408	1.489	170.3
3	64	64	64.3	64.4	0.4	0.63	1.28	1.344	169.8
4	94.3	94.3	94.2	94.1	-0.2	-0.21	1.886	1.98	181.28
5	72.5	72.8	72.9	72.9	0.1	0.14	1.45	1.522	172.3
6	73.4	73.9	74	73.9	0	0.00	1.468	1.541	181.1
7	72.1	72.6	72.5	72.2	-0.4	-0.55	1.442	1.514	184.6
8	78.1	78.6	78.8	78.9	0.3	0.38	1.562	1.64	186.1
9	80.3	80.9	80.9	81	0.1	0.12	1.606	1.686	185.2
10	73.8	74.3	74.2	74.1	-0.2	-0.27	1.476	1.549	186.4
11	84.6	84.7	84.8	85	0.3	0.35	1.692	1.777	175.9
12	90.2	90.3	90.4	90.4	0.1	0.11	1.804	1.894	182.4
13	82.5	82.4	82.3	82	-0.4	-0.48	1.65	1.732	181.7
14	87.4	87.3	87.5	87.7	0.4	0.46	1.748	1.835	192.2
Mean	78.90	79.09	79.14	79.12	0.04	0.05	1.58	1.66	181.28
St Dev	8.45	8.37	8.33	8.34	0.28	0.36	0.17	0.18	6.86
SEM	2.26	2.24	2.23	2.23	0.07	0.10	0.05	0.05	1.83

CHO10 No.	Morning BM	Pre exercise BM	Halftime BM	Post exercise BM	BM change (kg)	% weight change	2% weight loss (kg)	Total fluid ingested (l)	Height (cm)
1	79.8	79.7	79.6	79.4	-0.3	-0.38	1.596	1.676	188.8
2	69.9	70.2	70.5	70.5	0.3	0.43	1.398	1.468	171.2
3	62	62.2	62.3	62.4	0.2	0.32	1.24	1.302	170.3
4	94.1	93.4	93.5	93.5	0.1	0.11	1.882	1.976	180.1
5	75.4	75.1	75.3	75.2	0.1	0.13	1.508	1.583	172.4
6	73.7	74.2	73.9	73.9	-0.3	-0.41	1.474	1.548	182.5
7	71.5	71.4	71.5	71.2	-0.2	-0.28	1.43	1.501	184.2
8	79.3	79.7	79.8	79.6	-0.1	-0.13	1.586	1.665	185.7
9	82.4	82.7	82.6	82.9	0.2	0.24	1.648	1.73	184.9
10	74.8	74.8	74.8	74.3	-0.5	-0.67	1.496	1.571	185.2
11	84.4	84.9	84.9	85.3	0.4	0.47	1.688	1.772	176.2
12	92.5	92.4	92.4	92.1	-0.3	-0.32	1.85	1.942	182.8
13	81.9	82.1	82	81.6	-0.5	-0.61	1.638	1.72	182.2
14	86.2	86.8	87	87	0.2	0.23	1.724	1.81	193
Mean	79.14	79.26	79.29	79.21	-0.05	-0.06	1.58	1.66	181.39
St Dev	8.76	8.68	8.66	8.68	0.30	0.39	0.18	0.18	6.70
SEM	2.34	2.32	2.31	2.32	0.08	0.10	0.05	0.05	1.79

Appendix I 2 day Dietary Intake raw data (mean) for each of the three main trials

PLA Subject	Energy kcal	Protein g	Fat, g	Carbohydrate g	Sugars g	Starch g	Fibre g	Calcium mg	Sodium mg	Thiamin (B1) mg	Riboflavin (B2) mg	Vitamin B6 mg
1	2416	85	93	331	241	89	6	974	1444	0.84	2.16	1.40
2	1781	103	88	153	13	140	4	319	4013	1.01	0.65	1.34
3	1218	43	59	139	55	84	12	755	3277	0.83	0.74	1.02
4	1386	59	75	127	50	76	8	948	2840	1.37	0.83	1.01
5	1386	59	75	127	50	76	8	948	2840	1.37	0.83	1.01
6	2103	91	97	229	48	181	12	500	3583	0.84	0.58	1.27
7	1979	83	70	272	77	193	11	361	3450	2.38	2.34	4.07
8	1320	46	55	148	64	84	4	824	1912	0.48	1.23	0.58
9	1551	77	59	190	21	168	15	474	2519	0.80	1.01	1.04
10	1254	49	38	187	26	160	11	581	2144	0.99	0.90	1.25
11	1710	54	77	213	40	171	12	734	2048	0.98	0.72	1.28
12	1237	57	36	182	12	155	11	457	2028	1.19	1.28	0.81
13	1477	71	64	200	95	105	9	361	1683	0.71	0.53	1.26
14	2268	59	89	328	153	172	13	972	2888	1.18	0.85	1.07
Mean	1649	67	70	202	68	133	10	658	2619	1.07	1.05	1.32
St Dev	402	18	19	68	62	44	3	249	776	0.45	0.55	0.82
SEM	108	5	5	18	17	12	1	67	208	0.12	0.15	0.22

PLA Subject	Vitamin B12 µg	Folate µg	Vitamin C mg	Vitamin A µg	Vitamin D µg	Vitamin E mg	Cholesterol mg	Alcohol g	Water g
1	7.94	140	35	804	2.51	6.14	691	0	2265
2	0.40	62	4	9	0.38	5.83	278	0	3123
3	3.20	143	64	680	1.20	3.83	319	0	573
4	3.24	213	45	965	1.97	7.78	123	0	1674
5	3.24	213	45	965	1.97	7.78	123	0	1674
6	3.10	125	28	178	1.16	4.51	268	0	1054
7	1.35	532	205	103	0.42	6.02	231	0	488
8	2.99	96	12	318	0.40	4.57	105	12	1651
9	6.64	192	0	422	5.64	3.72	550	0	611
10	1.55	138	1	182	2.05	4.51	108	0	1522
11	1.62	87	30	149	0.32	6.63	87	0	350
12	0.81	174	6	50	0.00	6.58	98	0	1993
13	2.83	139	158	458	0.29	12.27	82	0	3320
14	2.64	219	241	387	1.11	3.54	165	0	714
Mean	2.97	177	62	405	1.39	5.98	231	1	1501
St Dev	2.08	113	79	330	1.46	2.30	185	3	947
SEM	0.56	30	21	88	0.39	0.62	49	1	253

CHO6 Subject	Energy kcal	Protein g	Fat g	Carbohydrate g	Sugars g	Starch g	Fibre g	Calcium mg	Sodium mg	Thiamin (B1) mg	Riboflavin (B2) mg	Vitamin B6 mg
1	1704	103	64	191	72	119	11	792	1893	1.87	2.49	1.56
2	2093	85	77	281	160	119	12	1036	1750	0.91	2.1	1.96
3	1264	72	56	125	56	68	8	476	2137	1.56	0.79	1.7
4	1589	71	68	184	61	123	6	621	2350	1.53	1.09	1.12
5	1236	74	47	139	36	98	5	129	1289	0.7	0.8	1.65
6	2037	87	76	270	137	130	16	491	1729	1.02	1.13	2.95
7	1589	72	57	210	55	155	11	543	1471	0.9	1.55	2.4
8	2307	109	118	216	83	132	17	1317	3676	1.51	1.26	1.35
9	1347	101	36	151	13	136	9	402	1694	0.59	0.91	1.37
10	1499	46	65	192	37	156	9	313	2547	0.71	0.62	1.11
11	1591	58	75	183	7	176	12	285	2929	0.91	0.54	2.53
12	2351	80	96	311	160	115	8	605	4582	1.58	0.73	1.42
13	2148	98	75	246	82	160	8	1403	2668	1.17	1.41	1.89
14	1572	57	68	196	79	115	9	950	1438	0.93	1.32	1.59
Mean	1738	80	70	207	74	129	10	669	2297	1.14	1.20	1.76
St Dev	379	19	20	54	49	28	3	384	934	0.40	0.56	0.54
SEM	101	5	5	14	13	7	1	103	250	0.11	0.15	0.15

CHO6 Subject	Vitamin B12 µg	Folate µg	Vitamin C mg	Vitamin A µg	Vitamin D µg	Vitamin E equivalents mg	Cholesterol mg	Alcohol g	Water g
1	3.11	237	17	197	0.3	7.23	242	0	1345
2	5.58	171	38	350	0.62	4.92	259	0	3475
3	4.2	64	34	499	2.44	4.53	181	0	667
4	2.43	112	139	205	0.16	5.59	223	0	2132
5	4.16	77	0	40	3.66	6.16	186	0	2408
6	5.95	299	235	894	3.85	9.85	116	0	2181
7	5.28	239	10	222	1.79	6.04	378	0	994
8	2.94	263	217	588	1.86	8.95	261	0	2281
9	5.9	50	2	97	3.65	1.24	281	0	558
10	2.36	127	7	352	0.53	1.85	98	0	855
11	1.6	161	50	56	1.81	3.84	159	0	616
12	3.65	105	15	195	1.83	3.93	355	0	3149
13	4.2	227	40	808	1.09	1.57	231	23	2023
14	3.9	164	107	394	0.69	3.07	186	0	1824
Mean	**3.95**	**164**	**65**	**350**	**1.73**	**4.91**	**225**	**2**	**1751**
St Dev	**1.37**	**79**	**79**	**266**	**1.27**	**2.62**	**80**	**6**	**939**
SEM	**0.37**	**21**	**21**	**71**	**0.34**	**0.70**	**21**	**2**	**251**

CHO10 Subject	Energy kcal	Protein g	Fat g	Carbohydrate g	Sugars g	Starch g	Fibre g	Calcium mg	Sodium mg	Thiamin (B1) mg	Riboflavin (B2) mg	Vitamin B6 mg
1	1803	75	62	251	68	167	4	767	3680	1.94	0.72	0.65
2	1923	80	58	289	133	151	10	737	1876	1.51	2.45	2.6
3	1597	67	60	212	35	176	12	718	3302	0.95	0.85	1.09
4	1160	39	48	152	85	67	9	735	1685	0.9	0.9	1.15
5	1550	62	54	218	56	160	9	468	2590	0.85	1	1.06
6	1600	60	68	198	66	130	7	597	2266	1.09	1.24	1.42
7	2135	101	79	271	56	214	9	1285	2765	1.65	2.28	2.12
8	2818	92	98	405	147	258	9	1046	2891	0.91	2.1	2.56
9	1749	127	53	203	85	119	7	1107	2403	2.21	2.69	4.16
10	1295	56	84	83	9	74	5	979	2113	1.01	0.72	0.89
11	1165	64	58	103	6	96	10	114	1211	1.08	0.43	1.93
12	1534	54	50	231	120	111	5	331	1690	0.91	0.86	1.35
13	1551	44	75	188	91	97	6	315	1307	0.6	0.47	0.86
14	1626	75	55	222	97	121	7	764	2375	0.94	0.85	1.32
Mean	1679	71	64	216	75	139	8	712	2297	1.18	1.25	1.65
St Dev	424	23	15	79	42	54	2	329	719	0.46	0.77	0.95
SEM	113	6	4	21	11	14	1	88	192	0.12	0.21	0.25

CHO10 Subject	Vitamin B12 µg	Folate µg	Vitamin C mg	Vitamin A µg	Vitamin D µg	Vitamin E mg	Cholesterol mg	Alcohol g	Water g
1	2.9	97	0	23	0.3	3.27	134	0	1482
2	1.58	171	43	480	0.13	2.27	144	0	2445
3	5.13	96	20	234	0.03	10.41	101	0	476
4	1.12	220	262	412	0.28	3.01	101	0	2397
5	6.89	165	37	69	0	1.1	281	0	3259
6	5.54	117	6	256	7.36	12.07	123	0	2104
7	6.75	276	19	728	3.21	4.05	604	0	2248
8	12.19	250	61	373	1.09	8.46	412	7	3451
9	10.65	247	70	169	24.85	11.68	239	0	511
10	1.5	121	25	529	1.65	7.57	185	0	957
11	0.4	132	46	108	1.34	3.81	156	0	372
12	2.26	158	8	17	0.73	0.31	145	0	1255
13	3.66	214	112	194	0.38	2.12	48	0	2199
14	3.07	164	76	664	0.35	2.53	185	0	3019
Mean	4.55	173	56	304	2.98	5.19	204	1	1870
St Dev	3.57	59	67	232	6.59	4.02	146	2	1040
SEM	0.95	16	18	62	1.76	1.07	39	1	278

Appendix J Blood Glucose raw data

	Glucose (mmol/l) SUPPLEMENT A							
	Pre exercise samples		1st Half samples			2nd half samples		
PLA	**Pre-breakfast**	**Pre exercise capill**	**15 min**	**30 min**	**45 min**	**60 min**	**75 min**	**post capillary**
No.								
1	5.6	6.2	6.3	6.3	6.2	4.4	5.0	4.6
2	3.7	5.2	5.1	4.5	4.3	4.6	4.6	4.8
3	4.8	4.8	5.0	4.7	4.7	3.9	4.2	4.6
4	5.3	5.5	5.6	5.7	5.0	4.6	4.3	5.0
5	4.5	4.9	5.0	4.4	4.2	3.4	3.5	3.8
6	7.2	3.4	5.2	5.1	4.5	4.3	4.4	4.6
7	5.6	5.9	6.9	7.4	7.5	4.8	4.8	5.2
8	5.1	5.8	3.9	4.4	4.5	4.0	4.3	4.6
9	5.7	5.8	5.6	5.7	5.6	4.6	4.8	5.9
10	5.2	5.3	5.1	4.8	5.0	3.8	4.4	4.9
11	5.5	5.4	4.5	4.7	4.2	4.4	4.3	3.9
12	6.0	7.4	5.5	4.8	4.9	4.0	4.2	4.1
13	4.6	4.7	4.7	4.9	4.5	3.8	4.6	3.9
14	5.7	5.4	5.5	5.4	4.9	4.2	4.2	4.4
Mean	5.32	5.41	5.28	5.20	5.00	4.20	4.40	4.59
St Dev	0.81	0.89	0.74	0.85	0.91	0.39	0.36	0.57
SEM	0.22	0.24	0.20	0.23	0.24	0.11	0.10	0.15

			Glucose (mmol/l) SUPPLEMENT B					
	Pre exercise samples		1st Half samples				2nd half samples	
CHO10	Pre-breakfast	Pre exercise cap	15 min	30 min	45 min	60 min	75 min	post capillary
No.								
1	5.1	5.5	6.4	5.9	5.9	3.3	4.1	4.9
2	6.0	5.6	6.4	6.5	6.3	3.9	5.4	6.2
3	4.9	4.2	6.0	6.0	5.4	4.4	5.7	6.5
4	6.0	5.5	5.8	6.1	7.8	3.9	5.2	5.9
5	4.6	5.7	6.7	6.2	6.5	5.3	4.8	6.7
6	6.0	5.2	7.5	8.7	8.2	3.7	5.1	6.8
7	5.4	5.5	7.7	8.1	9.5	5.0	5.7	6.4
8	5.5	3.7	5.8	5.7	8.1	4.0	4.6	5.8
9	5.6	5.7	7.6	6.8	8.1	4.6	6.4	7.6
10	5.4	6.1	6.3	6.0	6.9	5.1	4.4	6.3
11	5.4	7.2	5.4	5.9	6.7	4.3	5.2	5.0
12	5.8	8.6	8.8	7.9	8.4	5.2	5.2	8.5
13	5.2	4.7	5.5	5.7	6.0	4.1	4.6	5.3
14	5.8	5.8	3.7	4.2	5.9	3.0	4.4	6.0
Mean	5.48	5.63	6.41	6.41	7.12	4.27	5.06	6.28
St Dev	0.43	1.19	1.24	1.15	1.21	0.71	0.63	0.97
SEM	0.11	0.32	0.33	0.31	0.32	0.19	0.17	0.26

	Glucose (mmol/l) SUPPLEMENT D							
	Pre exercise samples		1st Half samples				2nd half samples	
CHO6	Pre-breakfast	Pre exercise cap	15 min	30 min	45 min	60 min	75 min	post capillary
No.								
1	4.9	7.4	5.4	5.5	5.7	3.6	3.9	4.8
2	4.3	5.2	5.3	4.6	5.8	3.4	3.8	4.9
3	5.1	5.4	6.9	7.1	6.3	4.1	4.2	7.6
4	5.2	6.1	7.0	5.5	6.4	3.8	5.0	6.3
5	4.2	5.3	5.0	5.2	6.3	4.6	4.9	6.4
6	5.4	6.2	5.7	7.4	6.5	4.0	4.8	5.7
7	5.3	5.6	6.4	6.3	6.7	4.2	4.3	4.8
8	5.3	6.9	4.7	5.0	7.5	4.8	4.7	5.8
9	2.2	4.8	5.4	6.2	6.4	3.1	4.6	5.1
10	5.8	6.4	5.8	6.7	7.0	3.9	3.8	5.2
11	5.2	5.4	4.7	5.9	5.9	3.6	4.1	4.9
12	5.8	6.7	7.3	4.8	4.8	3.8	4.3	5.1
13	5.3	6.9	5.4	5.2	5.4	3.1	3.6	5.0
14	5.3	6.2	5.6	5.6	5.7	3.3	3.4	6.3
Mean	4.95	6.04	5.75	5.78	6.17	3.81	4.24	5.56
St Dev	0.91	0.77	0.84	0.85	0.69	0.51	0.50	0.83
SEM	0.24	0.21	0.22	0.23	0.18	0.14	0.13	0.22

Appendix K Passing raw data

Passing Speed	Placebo with Placebo gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	14.94	13.40	10.99	13.09	15.66	14.05
2	14.75	13.32	11.13	12.05	14.42	13.6
3	16.99	13.08	11.72	13.74	13.84	12.57
4	9.55	10.70	9.11	9.58	9.97	9.45
5	16.41	16.66	11.11	11.82	11.87	13.18
6	15.41	11.68	12.16	13.31	12.76	13.68
7	13.27	12.1	13.12	13.02	13.25	14.18
8	13.7	13.97	14.11	13.51	14.09	12.37
9	14.05	16.06	12.43	14.53	15.43	13.36
10	11.3	11.14	12.86	12.68	12.7	12.35
11	10.43	10.82	10.22	9.70	11.57	10.95
12	14.37	11.3	11.11	12.19	11.76	9.83
13	14.08	14.17	14.49	14.13	13.26	14.24
14	12.33	12.07	12.06	12.93	11.72	12.11
Mean	13.68	12.89	11.90	12.59	13.02	12.57
SD	2.15	1.86	1.46	1.46	1.59	1.54
SEM	0.57	0.50	0.39	0.39	0.42	0.41

Passing Speed	6% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	14.4	13.62	14.06	14.36	13.09	14.54
2	12.01	11.87	11.55	12.61	12.61	12.3
3	11	11.61	14.97	12.55	12.69	11.72
4	10.7	11.89	9.97	11.03	8.77	10.82
5	13.52	15.02	13.14	13.72	12.55	13.34
6	14.38	13.81	13.99	11.21	12.19	14.66
7	13.08	11.09	12.81	12.57	13.11	12.97
8	14.93	14.39	12.65	12.27	12.11	12.87
9	16.49	14.54	14.51	14.15	15.03	14.53
10	13.06	11.72	13.71	12.34	11.49	11.01
11	10.21	9.87	10.27	13.40	13.00	12.94
12	15	15.26	16.1	17.52	14.96	15.37
13	13.71	12.33	14.05	14.12	13.89	14.04
14	11.61	11.13	10.5	11.39	11.53	10.2
Mean	13.15	12.73	13.02	13.09	12.64	12.95
SD	1.84	1.69	1.85	1.68	1.55	1.59
SEM	0.49	0.45	0.50	0.45	0.41	0.43

Passing Speed	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	15.15	13.62	14.09	14.98	15.24	14.78
2	12.38	13.9	12.39	11.99	12.06	11.45
3	13.36	13.12	14.42	15.01	14.24	15.01
4	9.1	10.24	9.38	12.39	11.51	11.44
5	16.8	16.08	16.76	16.93	15.49	14.86
6	14.96	14.63	12.84	14.73	14.68	13.55
7	13.3	13.33	13.6	13.92	13.16	11.93
8	15.62	11.41	14.02	12.51	11.99	14.16
9	15.13	15.24	14.89	16.33	14.28	14.46
10	8.08	8.03	9.26	9.13	7.9	8.69
11	8.37	9.93	10.97	10.26	9.72	11.12
12	13.61	11.51	11.93	10.23	10.23	12.81
13	14.35	14.76	14.33	13.93	12.86	14.69
14	12.1	12.16	11.63	11	11.1	10.73
Mean	13.02	12.71	12.89	13.10	12.46	12.83
SD	2.76	2.28	2.12	2.40	2.24	1.97
SEM	0.74	0.61	0.57	0.64	0.60	0.53

Passing Precision	Placebo with Placebo gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	37.89	45.32	58.88	39.84	60.19	55.77
2	38.99	40.36	39.81	67.00	27.46	49.91
3	39.43	30.55	48.94	50.06	26.75	29.94
4	43.09	40.43	66.33	33.80	37.68	51.37
5	32.98	16.41	52.46	22.11	46.99	33.19
6	48.61	55.02	47.34	48.09	68.08	55.95
7	26.90	27.18	49.05	58.60	55.74	15.00
8	61.69	35.69	31.13	38.56	35.76	38.64
9	32.45	36.53	24.50	30.46	44.89	37.34
10	49.17	43.72	59.45	22.47	43.65	17.28
11	25.70	47.21	40.04	40.11	28.74	63.37
12	36.70	40.56	27.22	56.21	43.54	53.55
13	47.57	31.07	34.23	46.87	40.02	42.31
14	37.80	26.60	48.45	52.05	30.00	36.25
Mean	39.93	36.90	44.84	43.30	42.11	41.42
SD	9.60	9.95	12.58	13.31	12.60	14.54
SEM	2.57	2.66	3.36	3.56	3.37	3.89

Passing Precision	6% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	34.84	39.53	34.74	29.88	42.59	33.57
2	54.40	47.37	31.55	61.18	42.52	39.47
3	39.00	59.75	30.67	49.06	42.81	45.66
4	58.96	41.22	40.83	25.32	71.81	58.34
5	27.97	29.98	29.62	47.76	34.75	39.07
6	45.21	29.95	32.26	44.13	33.32	51.11
7	45.04	45.66	52.37	34.26	41.31	37.37
8	46.86	23.96	45.96	36.82	43.14	33.92
9	58.09	34.86	34.54	46.54	30.87	45.71
10	28.66	37.18	60.86	37.19	33.41	51.26
11	42.63	40.12	40.93	59.27	31.82	54.26
12	52.82	35.12	53.93	26.34	61.41	37.49
13	30.94	39.25	39.29	43.89	35.90	42.29
14	48.86	42.71	29.92	37.96	37.76	30.34
Mean	43.88	39.05	39.82	41.40	41.67	42.85
SD	10.44	8.73	10.02	10.99	11.61	8.47
SEM	2.79	2.33	2.68	2.94	3.10	2.26

Passing Precision	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	54.32	18.63	25.64	42.56	43.08	41.37
2	48.21	33.69	55.85	29.72	37.68	49.28
3	44.95	45.54	38.99	55.99	31.88	40.49
4	30.78	48.60	52.11	60.45	35.58	34.95
5	40.22	25.03	45.69	47.66	51.75	48.20
6	64.93	45.44	45.71	45.10	32.82	33.42
7	38.90	52.16	36.72	58.74	26.83	67.40
8	61.42	51.46	48.12	31.90	48.38	37.79
9	42.08	53.56	43.65	31.74	38.09	42.44
10	48.05	46.89	47.12	38.50	34.80	54.44
11	28.89	62.25	50.96	40.61	48.38	40.55
12	58.53	35.18	47.53	56.48	40.77	18.29
13	35.80	36.57	41.77	27.52	34.23	33.39
14	44.28	27.10	44.87	53.99	48.39	42.84
Mean	45.81	41.58	44.62	44.35	39.48	41.78
SD	10.96	12.49	7.42	11.49	7.52	11.35
SEM	2.93	3.34	1.98	3.07	2.01	3.03

Passing Success	Placebo with Placebo gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	37.5	75	100	37.5	75	87.5
2	75	62.5	87.5	75	75	100
3	37.5	87.5	100	87.5	75	87.5
4	62.5	75	50	62.5	62.5	75
5	87.5	87.5	75	100	75	87.5
6	62.5	100	75	75	87.5	75
7	50	62.5	62.5	75	62.5	50
8	62.5	87.5	75	62.5	100	87.5
9	87.5	75	100	87.5	87.5	87.5
10	87.5	75	87.5	100	50	50
11	75	62.5	50	50	37.5	62.5
12	62.5	62.5	75	87.5	87.5	75
13	75	100	75	100	100	50
14	100	87.5	62.5	75	75	100
Mean	68.75	78.57	76.79	76.79	75.00	76.79
SD	18.83	13.36	16.88	18.90	17.68	17.58
SEM	5.03	3.57	4.51	5.05	4.72	4.70

Passing Success	6% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	87.5	100	100	75	100	100
2	62.5	75	75	87.5	75	87.5
3	87.5	100	87.5	87.5	87.5	100
4	62.5	62.5	75	25	62.5	50
5	87.5	100	87.5	87.5	87.5	100
6	50	62.5	87.5	75	37.5	100
7	62.5	100	50	62.5	50	50
8	87.5	62.5	75	75	75	62.5
9	87.5	75	100	75	87.5	87.5
10	50	75	62.5	75	75	87.5
11	75	75	87.5	37.5	50	62.5
12	75	62.5	62.5	50	50	75
13	87.5	75	75	100	87.5	100
14	75	87.5	87.5	100	87.5	87.5
Mean	74.11	79.46	79.46	72.32	72.32	82.14
SD	14.26	15.20	14.38	22.02	19.10	18.81
SEM	3.81	4.06	3.84	5.89	5.11	5.03

Passing Success	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	62.5	75	75	75	87.5	87.5
2	87.5	87.5	87.5	75	100	100
3	75	87.5	87.5	87.5	75	75
4	50	37.5	50	50	75	50
5	75	100	100	87.5	100	100
6	75	50	87.5	87.5	75	87.5
7	75	75	62.5	62.5	75	87.5
8	50	75	62.5	37.5	100	87.5
9	62.5	75	87.5	100	87.5	75
10	75	50	75	87.5	12.5	87.5
11	62.5	62.5	75	75	87.5	50
12	75	62.5	62.5	87.5	75	87.5
13	100	62.5	87.5	87.5	100	87.5
14	100	100	75	100	100	100
Mean	73.21	71.43	76.79	78.57	82.14	83.04
SD	15.39	18.62	13.74	17.97	22.85	15.97
SEM	4.11	4.98	3.67	4.80	6.11	4.27

Passing SP Index			Placebo with Placebo gel			
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	97.96	87.63	71.51	85.77	101.82	91.50
2	96.65	87.28	72.94	78.16	94.96	88.76
3	111.34	86.02	76.52	89.67	91.17	82.69
4	62.49	70.09	59.11	62.92	65.38	61.64
5	107.82	110.23	72.44	78.01	77.56	86.59
6	100.63	76.09	79.44	86.93	82.74	89.09
7	87.41	79.69	85.66	84.71	86.29	93.88
8	89.03	91.69	92.78	88.57	92.47	81.09
9	92.33	105.37	81.96	95.56	100.90	87.62
10	73.77	72.88	83.64	83.68	83.09	81.68
11	68.73	70.69	66.96	63.55	76.15	71.12
12	94.27	74.02	73.17	79.38	76.94	64.07
13	91.98	93.17	95.15	92.33	86.88	93.21
14	80.85	79.51	78.76	84.32	77.10	79.46
Mean	89.66	84.60	77.86	82.40	85.25	82.32
SD	14.10	12.42	9.70	9.55	10.33	10.25
SEM	3.77	3.32	2.59	2.55	2.76	2.74

Passing SP Index	6% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	94.54	89.25	92.31	94.47	85.68	95.51
2	78.26	77.55	75.93	81.96	82.54	80.60
3	72.10	75.50	98.45	81.94	83.05	76.62
4	69.60	77.86	65.30	72.70	56.79	70.40
5	89.01	98.81	86.45	89.62	82.40	87.43
6	94.02	90.85	91.94	73.33	80.08	95.64
7	85.53	72.50	83.53	82.54	85.85	85.07
8	97.56	94.90	82.69	80.49	79.24	84.53
9	107.30	95.46	95.27	92.47	98.84	94.99
10	85.96	76.87	89.12	80.94	75.48	71.82
11	66.82	64.66	67.26	87.18	85.44	84.30
12	97.80	100.17	104.92	115.43	97.23	100.80
13	90.15	80.81	92.08	92.37	91.15	91.90
14	75.81	72.84	69.07	74.68	75.61	67.09
Mean	86.03	83.43	85.31	85.72	82.81	84.76
SD	12.04	11.25	12.09	11.09	10.23	10.47
SEM	3.22	3.01	3.23	2.96	2.74	2.80

Passing SP Index	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	98.72	90.03	92.86	98.05	99.73	96.78
2	80.85	91.30	80.69	78.88	79.09	74.75
3	87.36	85.77	94.51	97.75	93.60	98.32
4	59.84	66.87	61.17	80.55	75.54	75.10
5	110.06	106.00	109.57	110.59	101.03	97.05
6	97.11	95.65	83.94	96.32	96.46	89.01
7	87.18	86.93	89.22	90.56	86.68	77.37
8	101.52	74.43	91.57	82.23	78.30	92.85
9	99.05	99.33	97.42	107.35	93.63	94.65
10	52.77	52.47	60.50	59.85	51.87	56.62
11	55.09	64.52	71.57	67.21	63.48	72.84
12	88.55	75.56	77.94	66.61	67.00	84.69
13	94.18	96.84	93.82	91.73	84.45	96.50
14	79.14	80.09	76.05	71.69	72.49	70.22
Mean	85.10	83.27	84.34	85.67	81.67	84.05
SD	17.88	15.09	13.98	15.72	14.71	12.96
SEM	4.78	4.03	3.74	4.20	3.93	3.46

Passing SPS Index			6% CHO solution with Active gel			
subject	**0-15 min**	**15-30 min**	**30-45 min**	**45-60 min**	**60-75 min**	**75-90 min**
1	661.78	714.02	738.49	566.81	685.41	764.06
2	391.28	465.29	455.58	573.74	495.22	564.23
3	504.69	604.01	689.14	573.56	581.35	612.94
4	348.02	389.32	391.80	145.40	283.95	281.60
5	623.09	790.45	605.16	627.34	576.78	699.46
6	376.09	454.24	643.61	439.96	240.24	765.12
7	427.65	580.00	334.13	412.72	343.40	340.26
8	682.91	474.50	496.13	482.95	475.47	422.63
9	751.11	572.75	762.19	554.84	691.85	664.90
10	343.84	461.24	445.61	485.63	452.87	502.77
11	400.95	387.98	470.84	261.55	341.77	421.50
12	586.77	500.87	524.62	461.71	388.92	604.81
13	631.07	484.84	552.47	738.97	638.07	735.24
14	454.84	509.91	483.52	597.48	529.26	469.62
Mean	513.15	527.81	542.38	494.48	480.33	560.65
SD	139.20	115.17	129.07	151.02	146.00	158.11
SEM	37.20	30.78	34.50	40.36	39.02	42.26

Passing SPS Index	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	493.59	540.17	557.14	588.28	698.10	677.48
2	565.98	639.10	564.82	473.29	632.70	598.00
3	524.18	600.42	661.60	684.22	561.61	589.94
4	239.37	200.60	244.68	322.22	453.26	300.41
5	660.36	847.98	876.52	774.15	808.25	776.41
6	582.64	382.60	587.57	674.21	578.74	623.07
7	523.06	521.57	446.10	452.79	520.10	541.60
8	406.07	446.57	457.84	246.69	626.41	649.98
9	495.24	596.00	681.92	858.77	655.41	567.89
10	316.64	209.88	363.01	418.97	51.87	396.36
11	275.43	322.59	429.43	403.23	444.34	291.36
12	531.28	377.78	389.68	466.25	402.03	592.81
13	753.40	484.18	656.75	642.10	675.60	675.50
14	633.15	640.70	456.32	573.49	579.91	561.78
Mean	500.03	486.44	526.67	541.33	549.17	560.19
SD	147.23	178.92	161.35	173.96	180.06	140.38
SEM	39.35	47.82	43.12	46.49	48.12	37.52

Appendix L Dribbling raw data

Dribbling Speed			Placebo with Placebo gel			
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	2.44	2.36	2.45	2.62	2.73	2.93
2	2.52	2.73	2.73	2.31	2.68	2.66
3	2.14	2.83	2.71	2.92	2.66	2.66
4	1.96	2.24	2.05	2.16	2.38	2.64
5	2.73	2.88	2.43	2.55	2.60	2.67
6	2.60	2.72	2.80	2.66	2.61	2.49
7	2.36	2.41	2.37	2.60	2.63	2.39
8	2.94	2.54	2.93	2.45	2.88	3.05
9	2.73	2.84	2.44	2.82	2.86	2.81
10	2.29	2.14	2.00	2.27	2.25	2.34
11	2.16	2.18	2.38	2.51	2.62	2.59
12	2.61	2.89	2.89	2.45	2.36	2.60
13	2.42	2.50	2.52	2.35	2.50	2.32
14	2.64	2.83	2.66	2.58	2.65	2.81
Mean	2.47	2.58	2.53	2.52	2.60	2.64
SD	0.27	0.27	0.28	0.21	0.18	0.21
SEM	0.07	0.07	0.08	0.06	0.05	0.06

Dribbling Speed	6% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	2.28	2.34	2.27	3.08	3.03	3.08
2	2.56	2.69	2.72	2.63	2.41	2.80
3	2.87	3.21	2.99	2.81	3.44	3.53
4	1.88	2.06	2.28	2.58	2.69	2.69
5	2.48	2.87	2.48	1.94	1.84	1.91
6	2.78	2.79	2.85	2.64	2.74	2.85
7	2.31	2.54	2.35	1.96	2.40	2.25
8	2.72	2.50	2.54	2.55	2.84	2.97
9	2.81	2.81	2.62	2.62	3.08	2.73
10	2.27	2.45	2.42	2.67	3.09	3.22
11	2.26	2.02	2.08	2.01	2.20	2.10
12	2.61	2.58	2.38	2.85	2.60	2.89
13	2.53	2.48	2.40	2.36	2.55	2.45
14	2.74	2.84	2.85	2.35	2.16	2.23
Mean	2.51	2.58	2.52	2.50	2.65	2.69
SD	0.28	0.32	0.26	0.34	0.43	0.46
SEM	0.07	0.09	0.07	0.09	0.12	0.12

Dribbling Speed	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	2.16	2.37	2.46	2.50	2.79	2.69
2	2.86	2.86	2.81	2.77	2.83	3.10
3	3.08	3.03	3.12	2.25	2.13	2.29
4	2.15	2.44	2.48	2.38	2.55	2.52
5	3.07	2.98	2.50	2.50	2.36	2.73
6	2.58	2.55	2.81	2.49	2.49	2.52
7	2.50	2.69	2.42	2.74	3.13	2.69
8	2.86	3.27	2.86	2.32	2.26	2.12
9	3.05	3.08	3.00	3.07	2.73	2.21
10	2.20	2.22	1.97	2.07	1.94	2.39
11	2.29	2.28	2.08	2.21	2.14	2.70
12	2.61	2.77	2.56	2.80	2.93	2.93
13	2.40	2.38	2.31	2.77	2.47	2.26
14	2.77	2.82	2.73	2.07	2.21	2.10
Mean	2.61	2.70	2.58	2.50	2.50	2.52
SD	0.34	0.33	0.33	0.30	0.35	0.31
SEM	0.09	0.09	0.09	0.08	0.09	0.08

Dribbling Precision			Placebo with Placebo gel			
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	116.54	84.03	75.04	89.43	80.57	65.81
2	91.50	69.56	74.52	71.23	103.02	73.01
3	94.41	109.76	99.37	128.80	71.95	79.67
4	75.97	90.24	105.28	107.40	90.05	106.17
5	81.85	89.13	111.51	129.89	113.63	79.16
6	84.21	88.42	88.81	115.69	103.69	122.38
7	66.98	90.98	76.30	115.69	92.80	69.39
8	64.76	84.89	88.04	72.69	64.61	61.65
9	86.99	102.66	74.63	70.52	74.73	79.00
10	82.92	83.53	85.12	86.87	96.44	88.83
11	72.72	101.65	93.37	59.50	75.12	63.68
12	71.67	102.06	106.49	80.71	94.01	97.88
13	81.07	67.69	93.37	64.89	67.47	65.34
14	55.31	56.93	69.23	59.57	58.93	77.45
Mean	80.49	87.25	88.65	89.49	84.79	80.67
SD	14.94	14.79	13.59	25.32	16.61	17.67
SEM	3.99	3.95	3.63	6.77	4.44	4.72

Dribbling Precision	6% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	73.97	82.73	97.26	75.69	65.21	84.79
2	98.63	79.20	86.24	72.24	72.70	79.01
3	93.97	58.10	65.52	94.97	78.52	105.20
4	89.87	90.34	77.52	97.57	70.55	80.61
5	128.02	87.21	125.03	112.75	108.59	103.57
6	89.96	69.04	65.79	87.87	65.77	72.12
7	80.43	101.03	87.25	101.07	125.34	115.12
8	85.19	87.17	80.32	70.59	94.64	84.60
9	105.46	82.82	81.07	78.89	103.20	115.23
10	124.74	94.24	83.57	76.15	85.62	105.42
11	70.96	79.71	93.75	58.00	59.55	88.83
12	61.52	144.83	115.19	92.33	73.14	90.36
13	73.05	79.18	105.73	81.24	71.34	67.64
14	59.32	65.61	56.80	59.18	58.59	73.09
Mean	88.22	85.80	87.22	83.30	82.12	90.83
SD	20.96	20.40	19.11	16.35	20.30	16.47
SEM	5.60	5.45	5.11	4.53	5.63	4.57

Dribbling Precision	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	85.34	63.66	84.19	132.71	79.72	104.52
2	101.47	83.54	91.49	104.82	101.78	119.39
3	64.81	58.19	66.39	65.35	58.94	79.64
4	97.57	77.82	72.13	78.36	68.12	115.12
5	115.31	102.01	130.96	118.11	99.35	104.52
6	82.38	73.33	107.11	100.68	68.90	60.19
7	92.91	97.03	97.18	88.86	88.94	124.02
8	68.60	87.44	76.30	58.83	75.44	64.64
9	87.30	73.56	76.85	77.65	80.71	80.02
10	76.39	81.09	78.72	81.88	80.10	95.43
11	59.94	91.37	97.59	84.90	75.83	59.65
12	67.66	77.61	77.38	88.89	58.50	63.69
13	78.49	68.08	67.63	77.51	78.18	88.73
14	59.29	88.38	58.19	57.98	82.25	66.25
Mean	80.93	81.50	84.45	83.37	78.23	86.25
SD	17.30	12.00	19.83	17.55	13.25	23.50
SEM	4.80	3.33	5.50	4.87	3.67	6.52

Dribbling Success			Placebo with Placebo gel			
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	83.33	100.00	94.44	94.44	72.22	94.44
2	61.11	100.00	100.00	88.89	94.44	100.00
3	83.33	72.22	83.33	55.56	100.00	94.44
4	100.00	88.89	77.78	72.22	88.89	72.22
5	100.00	88.89	83.33	55.56	72.22	100.00
6	90.07	89.29	89.34	66.67	100.00	61.11
7	100.00	94.44	94.44	100.00	100.00	100.00
8	100.00	94.44	88.89	94.44	100.00	100.00
9	94.44	83.33	94.44	100.00	100.00	100.00
10	94.44	83.33	100.00	88.89	88.89	88.89
11	94.44	72.22	77.78	100.00	94.44	100.00
12	94.44	77.78	77.78	88.89	77.78	77.78
13	94.44	100.00	88.89	100.00	94.44	94.44
14	100.00	100.00	100.00	100.00	100.00	94.44
Mean	92.15	88.92	89.32	86.11	91.67	91.27
SD	10.59	9.99	8.29	16.56	10.39	12.27
SEM	2.83	2.67	2.21	4.43	2.78	3.28

Dribbling Success	6% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	94.44	71.90	95.30	100.00	77.78	100.00
2	100.00	94.44	77.78	100.00	100.00	88.89
3	46.44	100.00	100.00	77.78	88.89	66.67
4	88.89	77.78	88.89	77.78	94.44	88.89
5	61.11	88.89	61.11	66.67	83.33	77.78
6	83.33	100.00	100.00	83.33	100.00	88.89
7	100.00	83.33	94.44	83.33	66.67	72.22
8	94.44	88.89	88.89	100.00	77.78	88.89
9	83.33	100.00	100.00	94.44	83.33	77.78
10	61.11	88.89	100.00	66.67	100.00	83.33
11	100.00	88.89	77.78	100.00	94.44	77.78
12	100.00	50.00	61.11	77.78	94.44	83.33
13	100.00	83.33	66.67	88.89	83.33	100.00
14	100.00	94.44	100.00	100.00	100.00	88.89
Mean	86.65	86.49	86.57	86.90	88.89	84.52
SD	17.84	13.41	14.93	12.44	10.45	9.54
SEM	4.77	3.58	3.99	3.33	2.79	2.55

Dribbling Success	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	72.22	88.89	83.33	72.22	72.22	61.11
2	94.44	100.00	88.89	50.00	94.44	72.22
3	100.00	100.00	94.44	33.33	100.00	88.89
4	72.22	83.33	94.44	88.89	88.89	72.22
5	72.22	77.78	55.56	61.11	77.78	72.22
6	83.33	88.89	72.22	77.78	94.44	94.44
7	77.78	83.33	83.33	83.33	83.33	55.56
8	100.00	83.33	100.00	100.00	94.44	100.00
9	88.89	94.44	88.89	94.44	90.55	86.19
10	100.00	100.00	100.00	100.00	94.44	88.89
11	100.00	83.33	72.22	83.33	88.89	94.44
12	100.00	88.89	88.89	83.33	100.00	94.44
13	100.00	94.44	94.44	100.00	94.44	88.89
14	100.00	83.33	100.00	100.00	83.33	94.44
Mean	90.08	89.28	86.90	80.55	89.80	83.14
SD	11.97	7.38	12.82	20.41	8.11	13.89
SEM	3.20	1.97	3.43	5.46	2.17	3.71

Dribbling SP Index	Placebo with Placebo gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	15.57	15.21	15.84	16.85	17.61	19.00
2	16.20	17.68	17.65	14.95	17.17	17.21
3	13.74	18.09	17.38	18.56	17.21	17.17
4	12.67	14.41	13.12	13.82	15.31	16.89
5	17.61	18.53	15.52	16.20	16.60	17.24
6	16.75	17.50	18.02	16.97	16.71	15.86
7	15.30	15.50	15.31	16.59	16.90	15.48
8	19.07	16.36	18.86	15.85	18.69	19.81
9	17.58	18.19	15.78	18.26	18.49	18.14
10	14.76	13.79	12.88	14.62	14.44	15.06
11	13.97	13.97	15.29	16.32	16.94	16.81
12	16.89	18.52	18.49	15.81	15.16	16.68
13	15.61	16.20	16.19	15.25	16.20	15.05
14	17.19	18.41	17.23	16.77	17.23	18.15
Mean	15.92	16.60	16.25	16.20	16.76	17.04
SD	1.75	1.76	1.82	1.31	1.19	1.41
SEM	0.47	0.47	0.49	0.35	0.32	0.38

Dribbling SP Index	6% CHO solution with Active gel					
subject	**0-15 min**	**15-30 min**	**30-45 min**	**45-60 min**	**60-75 min**	**75-90 min**
1	17.26	17.07	16.42	17.57	11.68	16.65
2	14.68	15.60	16.92	16.80	15.12	15.56
3	19.27	18.52	19.49	18.91	18.68	19.04
4	13.52	13.17	14.47	13.28	14.33	13.53
5	17.85	17.59	16.42	18.81	17.95	17.95
6	15.61	18.22	17.69	14.42	16.76	16.48
7	13.77	15.88	15.09	13.81	15.11	11.49
8	16.76	17.30	17.60	19.53	18.35	17.46
9	18.24	17.32	17.71	17.52	17.74	11.49
10	11.46	15.28	16.19	16.04	16.03	11.52
11	15.80	16.52	14.16	16.53	13.93	14.91
12	15.38	16.09	16.69	16.27	16.74	17.19
13	14.62	16.68	15.85	16.24	16.11	15.17
14	16.88	16.09	17.18	17.73	20.30	17.29
Mean	15.79	16.52	16.56	16.68	16.34	15.41
SD	2.10	1.36	1.41	1.88	2.23	2.53
SEM	0.56	0.36	0.38	0.50	0.60	0.68

Dribbling SP Index	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	14.69	15.19	14.63	19.56	19.56	19.72
2	16.41	17.34	17.49	16.84	15.44	17.85
3	18.62	20.88	19.39	18.23	22.37	22.78
4	12.06	13.30	14.75	16.66	17.43	17.17
5	15.83	18.39	15.75	12.37	11.80	12.23
6	17.93	18.05	18.23	16.92	17.75	18.52
7	14.84	16.30	15.08	12.61	15.44	14.32
8	17.62	16.09	16.41	16.58	18.36	19.27
9	18.09	18.17	16.93	16.92	19.87	17.62
10	14.67	15.80	15.62	17.22	19.94	20.67
11	14.69	12.99	13.35	12.95	14.22	13.65
12	16.92	16.66	15.37	18.34	16.91	18.76
13	16.34	16.07	15.55	15.24	16.47	15.76
14	17.81	18.28	18.53	15.28	13.93	14.46
Mean	16.18	16.68	16.22	16.12	17.11	17.34
SD	1.83	2.08	1.70	2.19	2.83	2.96
SEM	0.49	0.56	0.45	0.59	0.76	0.79

Dribbling SPS Index			Placebo with Placebo gel			
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	12.97	15.21	14.96	15.92	12.72	17.95
2	9.90	17.68	17.65	13.29	16.21	17.21
3	11.45	13.06	14.48	10.31	17.21	16.21
4	12.67	12.81	10.21	9.98	13.61	12.20
5	17.61	16.47	12.94	9.00	11.99	17.24
6	14.89	15.63	16.10	11.32	16.71	9.69
7	15.30	14.63	14.46	16.59	16.90	15.48
8	19.07	15.45	16.76	14.97	18.69	19.81
9	16.60	15.16	14.90	18.26	18.49	18.14
10	13.94	11.49	12.88	12.99	12.84	13.38
11	13.20	10.09	11.89	16.32	15.99	16.81
12	15.95	14.40	14.38	14.05	11.79	12.97
13	14.74	16.20	14.39	15.25	15.30	14.21
14	17.19	18.41	17.23	16.77	17.23	17.14
Mean	14.68	14.77	14.52	13.93	15.41	15.60
SD	2.52	2.28	2.07	2.87	2.38	2.76
SEM	0.67	0.61	0.55	0.77	0.64	0.74

Dribbling SPS Index	6% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	16.30	12.27	15.65	17.57	9.08	16.65
2	14.68	14.73	13.16	16.80	15.12	13.83
3	8.95	18.52	19.49	14.71	16.60	12.70
4	12.01	10.24	12.86	10.33	13.53	12.03
5	10.91	15.63	10.03	12.54	14.96	13.96
6	13.01	18.22	17.69	12.02	16.76	14.65
7	13.77	13.23	14.25	11.51	10.08	8.30
8	15.83	15.37	15.64	19.53	14.27	15.52
9	15.20	17.32	17.71	16.54	14.78	8.93
10	7.00	13.58	16.19	10.70	16.03	9.60
11	15.80	14.69	11.01	16.53	13.15	11.60
12	15.38	8.05	10.20	12.65	15.81	14.33
13	14.62	13.90	10.57	14.43	13.42	15.17
14	16.88	15.20	17.18	17.73	20.30	15.37
Mean	13.60	14.35	14.40	14.54	14.56	13.05
SD	2.92	2.88	3.14	2.95	2.78	2.62
SEM	0.78	0.77	0.84	0.79	0.74	0.70

Dribbling SPS Index	10% CHO solution with Active gel					
subject	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min
1	10.61	13.50	12.19	14.12	14.12	12.05
2	15.49	17.34	15.54	8.42	14.58	12.89
3	18.62	20.88	18.31	6.08	22.37	20.25
4	8.71	11.09	13.93	14.81	15.49	12.40
5	11.43	14.30	8.75	7.56	9.18	8.83
6	14.94	16.04	13.17	13.16	16.76	17.49
7	11.55	13.58	12.57	10.51	12.87	7.96
8	17.62	13.41	16.41	16.58	17.34	19.27
9	16.08	17.16	15.05	15.98	17.66	15.18
10	14.67	15.80	15.62	17.22	18.83	18.38
11	14.69	10.82	9.64	10.79	12.64	12.89
12	16.92	14.81	13.66	15.28	16.91	17.71
13	16.34	15.18	14.69	15.24	15.55	14.01
14	17.81	15.23	18.53	15.28	11.61	13.66
Mean	14.68	14.94	14.15	12.93	15.42	14.50
SD	3.00	2.58	2.83	3.61	3.31	3.74
SEM	0.80	0.69	0.76	0.96	0.89	1.00

Appendix M Shooting raw data

Shooting Speed	Placebo with Placebo gel			6% CHO solution with Active gel			10% CHO solution with Active gel		
subject	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2
1	14.82	15.04	14.02	16.00	16.31	17.65	16.60	18.00	16.11
2	14.83	15.09	15.08	14.21	14.66	13.29	14.70	12.74	13.46
3	14.95	16.64	15.62	13.80	14.52	15.26	15.75	17.85	17.36
4	10.93	10.35	12.54	12.20	12.68	10.28	13.24	12.50	11.54
5	19.57	18.51	10.00	16.41	17.31	10.00	16.53	15.52	14.29
6	18.38	13.64	14.65	16.69	14.12	18.12	12.16	12.25	19.57
7	13.53	17.65	16.58	15.37	13.38	15.60	16.48	15.84	14.19
8	13.24	15.79	18.95	20.09	10.00	10.00	15.79	18.88	14.06
9	14.32	17.25	13.38	17.41	14.06	15.92	13.28	17.52	15.75
10	14.38	12.88	14.40	16.41	14.15	14.53	15.59	15.69	15.41
11	12.44	15.61	14.91	12.74	14.08	11.57	10.93	10.98	10.20
12	13.18	16.07	15.79	12.75	14.58	16.86	15.63	16.99	16.71
13	18.00	15.26	14.05	16.99	16.67	16.67	15.37	17.36	15.02
14	15.87	15.94	14.77	15.15	13.47	14.94	15.76	15.40	15.78
Mean	14.89	15.41	14.62	15.44	14.29	14.34	14.84	15.54	14.96
SD	2.39	2.07	2.02	2.17	1.79	2.85	1.76	2.49	2.34
SEM	0.64	0.55	0.54	0.58	0.48	0.76	0.47	0.67	0.63

Shooting Precision	Placebo with Placebo gel			6% CHO solution with Active gel			10% CHO solution with Active gel		
subject	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2
1	217.54	165.19	128.36	98.99	66.49	153.44	237.42	166.33	194.97
2	174.41	197.46	119.91	129.15	152.94	140.45	103.55	151.01	117.29
3	162.73	75.52	161.30	156.66	129.21	56.77	93.25	134.10	133.00
4	253.55	458.54	168.59	120.46	335.58	252.25	74.53	110.01	243.88
5	91.12	232.14	70.17	141.28	191.16	160.81	300.21	226.19	132.87
6	151.57	86.01	180.84	175.97	144.87	23.67	45.30	214.34	106.40
7	197.79	327.24	126.98	151.83	215.57	223.05	119.96	299.17	218.31
8	37.49	130.52	151.31	386.43	195.09	158.53	222.46	66.82	75.04
9	60.18	128.60	132.80	92.74	251.13	99.83	61.54	89.74	179.61
10	30.09	96.45	66.40	59.93	172.73	230.67	88.67	72.70	163.25
11	185.69	154.25	175.94	184.86	341.97	146.65	178.92	195.29	82.76
12	102.41	299.04	176.14	207.92	157.67	128.41	180.70	130.44	100.20
13	102.85	127.10	139.74	104.84	145.36	179.62	70.97	225.89	49.12
14	137.64	137.18	123.60	223.03	198.52	235.71	114.07	112.26	81.32
Mean	136.08	186.80	137.29	159.58	192.73	156.42	135.11	156.74	134.14
SD	67.99	108.54	36.04	79.74	75.64	66.73	76.56	67.84	58.25
SEM	21.02	29.01	9.63	21.31	20.21	17.83	11.19	18.13	15.57

Shooting success	Placebo with Placebo gel			6% CHO solution with Active gel			10% CHO solution with Active gel		
subject	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2
1	50	100	100	50	100	50	50	50	75
2	75	50	75	100	100	75	100	100	50
3	50	100	50	50	75	50	75	75	75
4	50	50	75	100	50	100	25	25	25
5	25	50	0	50	25	0	75	25	50
6	50	50	50	50	50	50	25	100	25
7	50	50	100	75	75	75	75	75	75
8	25	100	75	50	0	0	50	50	25
9	50	75	50	50	25	100	50	75	100
10	75	50	100	50	50	75	50	75	75
11	50	75	75	50	100	75	100	75	75
12	75	25	50	50	100	100	75	50	75
13	25	50	100	50	25	25	100	75	50
14	75	100	100	75	75	75	100	75	75
Mean	51.79	66.07	71.43	60.71	60.71	60.71	67.86	66.07	60.71
SD	18.25	25.21	29.18	18.90	33.56	33.56	26.73	23.22	23.44
SEM	4.88	6.74	7.80	5.05	8.97	8.97	7.14	6.21	6.26

Shooting SP Index	Placebo with Placebo gel			6% CHO solution with Active gel			10% CHO solution with Active gel		
subject	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2
1	96.40	98.31	92.04	105.38	107.83	115.55	107.76	117.68	105.02
2	96.89	98.36	99.09	93.28	95.98	87.13	96.75	83.40	88.47
3	97.78	109.90	102.18	90.32	95.32	101.01	103.81	117.08	113.93
4	70.84	65.92	81.97	80.16	81.57	66.64	87.42	82.23	74.85
5	129.01	120.22	66.08	107.57	112.88	65.42	106.67	100.84	93.76
6	120.35	89.97	95.64	109.01	92.53	120.43	80.62	79.68	128.75
7	88.17	113.63	108.86	100.64	87.04	101.41	108.31	102.22	92.27
8	87.84	103.63	124.09	128.69	65.19	65.43	102.68	124.83	92.88
9	94.75	113.24	87.79	114.75	91.15	104.84	87.86	115.53	102.81
10	95.50	84.86	95.20	108.58	92.48	94.39	102.77	103.64	100.80
11	81.17	102.18	97.38	83.13	90.53	75.80	71.36	71.60	67.29
12	86.77	103.72	103.13	83.00	95.41	110.68	102.03	111.49	110.07
13	118.50	100.19	92.12	111.83	109.23	108.84	101.53	112.80	99.49
14	104.08	104.54	97.01	98.48	87.77	97.00	103.65	101.29	104.15
Mean	97.72	100.62	95.90	101.06	93.21	93.90	97.37	101.74	98.18
SD	15.90	13.62	13.15	13.91	12.01	18.92	11.23	16.52	15.47
SEM	4.25	3.64	3.51	3.72	3.21	5.06	3.00	4.41	4.13

Shooting SPS Index	Placebo with Placebo gel			6% CHO solution with Active gel			10% CHO solution with Active gel		
subject	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2	Pre-ex	Post-1	Post-2
1	192.80	393.25	368.15	210.76	431.33	231.10	215.52	235.36	315.07
2	290.67	196.72	297.26	373.10	383.93	261.39	386.98	333.60	176.94
3	195.56	439.58	204.35	180.63	285.95	202.02	311.44	351.25	341.78
4	141.68	131.83	245.90	320.64	163.15	266.54	87.42	82.23	74.85
5	129.01	240.43	0.00	215.15	112.88	0.00	320.01	100.84	187.52
6	240.71	179.94	191.27	218.02	185.05	240.86	80.62	318.71	128.75
7	176.34	227.26	435.43	301.93	261.12	304.22	324.93	306.67	276.82
8	87.84	414.53	372.27	257.37	0.00	0.00	205.35	249.65	92.88
9	189.49	339.71	175.58	229.50	91.15	419.38	175.72	346.58	411.24
10	286.49	169.71	380.82	217.16	184.96	283.18	205.54	310.92	302.39
11	162.34	306.55	292.14	166.27	362.12	227.41	285.43	214.81	201.87
12	260.32	103.72	206.26	166.01	381.64	442.72	306.09	222.98	330.21
13	118.50	200.38	368.47	223.65	109.23	108.84	406.13	338.39	198.98
14	312.23	418.16	388.04	295.44	263.32	290.99	414.62	303.87	312.44
Mean	198.86	268.70	280.43	241.12	229.70	234.19	266.13	265.42	239.41
SD	69.83	114.62	117.69	61.21	129.76	129.09	107.81	86.90	101.95
SEM	18.66	30.63	31.45	16.36	34.68	34.50	28.81	23.23	27.25

Appendix N Abdominal discomfort raw data

	PLA				CHO6				CHO10			
Abdominal	**1st Half**		**2nd Half**		**1st Half**		**2nd Half**		**1st Half**		**2nd Half**	
Discomfort	**1cycle**	**6 cycle**	**1cycle**	**6 cycle**	**1cycle**	**6 cycle**	**1cycle**	**6 cycle**	**1cycle**	**6 cycle**	**1cycle**	**6 cycle**
No.												
1	0	0	0	0	0	0	0	0	1	1	0	0
2	0	0	0	0	0	0	0	0	0	3	0	0
3	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	3	0	0	0	0	0	0
7	0	5	0	0	0	0	0	2	0	1	0	0
8	0	0	0	0	0	0	0	0	0	0	0	3
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	1	0	0	0	0	0	0
11	0	0	1	0	0	1	0	0	0	2	3	0
12	0	0	0	0	0	0	0	0	1	4	1	5
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	2	0	0
Mean	0.00	0.36	0.07	0.00	0.00	0.36	0.00	0.14	0.14	0.93	0.29	0.64
SD	0.00	1.34	0.27	0.00	0.00	0.84	0.00	0.53	0.36	1.33	0.83	1.50
SEM	0.00	0.36	0.07	0.00	0.00	0.23	0.00	0.14	0.10	0.35	0.22	0.40