The Effects of Sports Drinks Containing Caffeine and Carbohydrate on Soccer-Specific Skill Performance During Match-Induced Fatigue

by

Marc Jacobson
B.Sc., University of Victoria, 2009

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of

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in the School of Exercise Science, Physical and Health Education

Supervisory Committee

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Abstract

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A ninety minute competitive soccer match consists of many intermittent sprints resulting in fatigue, and consequently, a reduction in skill performance. The combination of caffeine and carbohydrate (CHO) has been shown to have ergogenic effects which help maintain skill measures during fatiguing states, however, there has been little research investigating this combination on soccer performance. Therefore, the aim of this study was to examine the effects of three sports drinks, including a placebo (PLA), a 6% CHO drink, and CHO + caffeine (CCAF; 5 mg/Kg body mass (BM)) on soccer-specific skills, throughout a fatigue-inducing soccer match. Twelve male soccer players completed three ninety minute intersquad matches played outdoors on a grass field in a randomized crossover design. Players consumed 5 ml/kg BM 45 minutes prior to kickoff and 3 ml/kg BM every 15 minutes during match play. Soccer passing skill was measured using the Loughborough Soccer Passing Test (LSPT), shot speed, and 20m sprint performance were measured pre-match, immediately at halftime and immediately post-match. Countermovement jump (CMJ) was measured pre-match and post-match. Heart rate (HR) was measured continuously. Blood lactate, rating of perceived exertion (RPE), and perceived fatigue were assessed every fifteen minutes throughout the match. Urine was collected pre-match for analysis of urine specific gravity (USG). BM was measured pre-match and post-match. LSPT total performance time was significantly better in the CCAF trial compared to the PLA trial at halftime (55.3 ± 10.3 s vs 66.5 ±8.7 s, p = .027). There were also significant improvements in penalty time (CCAF 8.2 ± 7.6 s vs. PLA 16.6 ± 7.8 s, p = .042) and movement time (CCAF 8.2 ± 7.6 s vs. PLA 16.6 ± 7.8 s, p = .028) during the CCAF trial in comparison to the PLA at halftime. HR and blood lactate was elevated throughout the PLA trial in comparison to the CHO trial. There were no other significant findings. Most players (50% - 83%) started all three matches in a dehydrated state (USG > 1.020). The CHO trial had significantly lower sweat rates (0.83 ± 0.25 L/hr) than both the PLA trial (1.06 ± 0.26 L/hr, p = .038) and the CCAF trial (1.11 ± 0.19 L/hr, p = .009). The addition of caffeine to a CHO sports drink significantly improved passing performance (quicker completion time and fewer penalties accumulated) over a PLA. All three sports drinks appeared to be equally as effective in preventing deterioration of soccer skill performance during a game situation. This suggests that the total volume of fluid consumed is of greater importance than the type of fluid. Caffeine appeared to have limited ergogenic effects on skill performance without any negative consequences.

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Acknowledgments

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Chapter 1: Introduction

In competitive sports such as soccer, athletes are always striving to gain an advantage over their opponents. For ergogenic effects they turn to nutritional supplements such as sports drinks, which are legal, affordable, easily accessible, and often contain mixtures of carbohydrates (CHO), electrolytes (E), and caffeine (CAF) (Ali, Gardiner, Foskett & Gant, 2010).

Over the duration of a ninety-minute competitive soccer match, professional male players cover an average total distance of 10.7 km (Bradley et al., 2009), including many high-intensity intermittent sprints. The subsequent accumulated fatigue has been shown to have a detrimental effect on all parts of play, both with and without the ball (Bradley et al.), including short passing ability (Rampinini et al., 2008) and sprint performance (Ali et al., 2010; Mohr, Krustrup & Bangsbo, 2003). The impaired performance has been attributed to low glycogen concentrations in a considerable number of individual muscle fibres (Krustrup et al., 2006).

Exogenous CHO is commonly used by athletes during events to enhance performance through maintenance of muscle and liver glycogen stores and plasma glucose levels even after ninety minutes of exercise (Ali & Williams, 2009; Ali, Williams & Fosket, 2007; Backhouse et al., 2007; Clarke, Drust, Maclaren & Reilly, 2008; Ostojic & Mazic, 2002). CHO sports drinks have been shown to preserve leg force (Coso, Estevez, Baquero & Mora-Rodriguez, 2008), increase run time to fatigue, increase speed and agility, and decrease average

20 m sprint times during shuttle-running (Welsh, Davis, Burke & Williams, 2002) in comparison to water alone.

Zeederberg et al. (1996) investigated CHO ingestion on soccer performance and found no significant difference in the effects of ingesting CHO or water in tackling, heading, dribbling or shooting ability during two soccer matches. Abbey and Rankin (2009) also failed to find any significant differences in soccer-skill performance between a drink containing CHO and a placebo (PLA). However, numerous studies have reported enhanced dribbling speed, passing ability, kicking accuracy, agility, sprint performance and percent maximal oxygen consumption (VO_{2max}) during consumption of CHO in comparison to a PLA when fatigue was a factor (Ali & Williams, 2009; Ali et al., 2007a; Currell, Conway & Jeukendrup, 2009; Ostojic & Mazic, 2002).

Caffeine can be detected in the blood within 15 to 45 minutes from ingestion with peak concentrations evident within one hour and a half-life of three to ten hours in human adults (Goldstein et al., 2010; Paluska, 2003; Robertson, Wade, Workman, Woosley & Oates, 1981). Caffeine can freely cross the blood-brain barrier where its primary mode of action appears to be adenosine antagonism in the central nervous system (CNS) (Paluska). This has been shown to increase wakefulness, vigilance, alertness and motor activity, and reduce rating of perceived exertion (RPE) (Foskett, Ali & Gant, 2009; Graham et al., 2008; Paluska; Stuart, Hopkins, Cook & Cairns, 2005; Watson, 2008).

Caffeine doses between 3 to 6 mg/kg body mass (BM) have been shown to enhance endurance performance, increase mean peak power during sprints and reduce sprint time over 30 m (Glaister et al., 2008; Graham & Spriet, 1995; Schneiker, Bishop, Dawson & Hackett, 2006). During a soccer-specific exercise protocol, caffeine has been shown to improve passing performance and functional leg power in fatigued subjects compared to a placebo (Foskett et al., 2009).

Caffeinated sports drinks typically also contain CHO and electrolytes. The combination of CHO, electrolytes, and caffeine has been shown to improve time trial (TT) cycling performance through maintenance of blood glucose and muscle glycogen and a caffeine attributed attenuation of muscular and mental fatigue (Cox et al., 2002; Cureton et al., 2007; Hulston & Jeukendrup, 2008; Kovacs, Stegen & Brouns, 1998).

The endurance demands of soccer, combined with the need for power, agility, accuracy and decision making may be best supported through the combination of CHO and caffeine. Guttierres, Natali, Alfenas and Marins (2009) found a CCAF drink to significantly increase jump height compared to a CHO-only drink during soccer-specific performance. Similarly, Gant, Ali and Foskett (2010) found a CCAF drink significantly enhanced jump height, 15 m sprint times, and ratings of pleasure in comparison to a CHO-only drink. However, they found no significant differences between drinks for passing ability, RPE or blood lactate.

The studies by Guttierres et al. (2009) and Gant et al. (2010) failed to include a CHO-free placebo which would have allowed for a greater understanding of how each substance (caffeine and CHO) contributes to physiological processes related to soccer performance. Consequently, further research assessing the effects of a CHO and caffeine sports drink on soccer-specific skills should be undertaken to help athletes and coaches make informed decisions about hydration and nutrition practices to support optimal performance (for further details see Appendix A: Related Literature Review).

Purpose

The purpose of this study was to examine the effects of three sports drinks varying in content of CHO and caffeine (PLA, CHO, CHO+CAF) on soccer-specific skills, with a specific focus on caffeine, when soccer match-induced fatigue limits game performance.

Research Questions

During a 90 minute match, does:

1) a CHO-containing sports drink limit a fatigue-induced decline in soccer skill performance, sprint performance, jump power and shot power over a CHO and caffeine-free placebo?

2) caffeine enhance the effects of a CHO containing sports drink on soccer skill performance, sprint performance, jump power and shot power, by further reducing the effects of match-induced fatigue?

Hypothesis (H_1)

The impact of three sports drinks on soccer performance (passing skills, ball control, dribbling, sprinting, jump power, shot power) over a ninety minute soccer match:

$$\text{Placebo} < \text{CHO} < \text{CCAF}$$

Assumptions

1) Players attended all exercise testing sessions consistently hydrated and well-nourished with no ingestion of caffeine, alcohol or having participated in intense exercise for 24 hours prior to testing.

2) Players were not able to detect any difference between drinks for sweetness, electrolytes, texture, colour, taste and flavour.

3) Players' intensity/work rate was equivalent across all three trials and was performed to the best of their ability over the full ninety minutes during each match and all test protocols.

4) Players honestly, consistently and accurately recorded food and fluid intake, with no recall bias, under reporting, or changes in intake.

Delimitations

1) Participants were University aged males (18-23 years of age).

2) Participants were Canadian Interuniversity Sport level athletes.

3) Athletes represented players of all field positions in soccer (defenders, midfielders, forwards).

Limitations

1) Caffeine metabolism may differ between individuals.

2) Motivation level of the participants to provide maximal effort during all tests.

3) No caffeine-only drink was included in the research design, therefore caffeine's role on performance enhancement was assumed based on the CCAF sports drink's effects compared with the CHO-only drink.

4) The first two matches were played in the evening (6 pm), however the third match was conducted in the morning (10 am).

5) There were some time delays (up to 10 minutes) in some players between match play and blood lactate, RPE and fatigue measurements taken at halftime and post-match which may have resulted in reduced values not indicative of the actual game intensity.

6) Ambient conditions varied between matches.

Operational Definitions

Match-induced fatigue	*Decreases in endurance running, sprinting and ball skills, and an increase in RPE and fatigue as a consequence of ninety minutes of competitive soccer match play.*
Soccer-specific skills (Soccer performance)	*The skills (dribbling, passing accuracy, shooting power, jump height, ball control, sprinting ability) involved in typical soccer-match play.*

Habitual caffeine consumption	*Caffeine consumption equal to or greater than 1 cup of coffee per day (approximately 125 mg caffeine).*
Trial	*Includes the ninety-minute match and all activities associated with the data collection on a given day (physiological measures, soccer performance measures). This study was comprised of three trials.*

Chapter 2: Methods

Participants

Twelve participants were recruited from the University of Victoria varsity men's Vikes soccer team (Victoria, BC). Participants were healthy, university aged males of Canadian Interuniversity Sport (CIS) level soccer skill, who provided informed, written consent to the experiments conducted in accordance to protocols and ethics obtained from the Human Research Ethics Committee at the University of Victoria.

Pre-experimental Protocol

Each participant completed an informed consent form (Appendix B) and PAR-Q for medical screening during a session prior to the beginning of the testing protocol. All 12 participants also completed five familiarization attempts at the LSPT, and practiced the shot speed, countermovement jump, and 20m sprint protocols seven days prior to the first test day. During this familiarization session players were introduced to the 15-point Borg Scale of perceived exertion (RPE; Borg, 1970; see Appendix C), the Perceived Fatigue Scale (PFS; see Appendix D), and were provided clear directions on how to use these to represent their perceptions of work effort and fatigue respectively during a game situation.

Players were asked to complete a dietary questionnaire (Appendix E) to assess their habitual caffeine consumption and monitor their fluid and food intake for 48 hours prior to each trial. They were instructed to prepare for the first testing session as they would for a competitive match, taking diet, sleep, and physical activity into consideration, and replicate this prior to the remaining two trials. Participants were directed to refrain from caffeine, alcohol and intense exercise during the 24 hours prior each exercise trial.

Experimental Design and Protocols

A double-blind, randomized, crossover “quasi-experimental” research design was implemented over the three trials where participants consumed one of three different sports drinks over three days of testing separated by at least 36 hours (PLA, CHO, CCAF). A diagrammatic representation of the experimental exercise protocol is presented in Figure 1 (Appendix F). Participants competed in three inter-squad matches and were equally dispersed between the two teams and matched for skill (by the coach). Teams remained consistent with the same players playing on the same team across all three matches. All matches and skill tests were performed outdoors on the same grass field during a winter month (November). The first two matches were played in the evening (6 pm kickoff) with an ambient temperature of 7-8˚C, 55-60% humidity, 756-761 mmHg barometric pressure, and an average wind speed of 5-10 km/hr. The third match was played in the morning (10 am kickoff) with an ambient temperature of 1-3˚C, 50% humidity, 754 mmHg barometric pressure, and an average wind speed of 16-34 km/hr.

Pre-Match Protocols

Upon arriving at the field, participants were asked to void their bladders and collect a urine sample mid-stream. Each sample was labelled upon collection and placed on ice. A small aliquot was analysed for urine specific gravity by a handheld refractometer (Atago Pocket Refractometer, Atago Inc., USA) within 30 minutes of collection, with the remainder refrigerated for later analysis of caffeine concentration via electrospray ionization mass spectrometry to confirm overnight abstinence. Near-nude body weight was measured, and HR monitors (Polar Team^2 Pro, Kempele, Finland) attached. Blood lactate (Lactate Pro, Arkray Ltd., Kyoto, Japan), 15-point RPE (Borg, 1970), and PFS was assessed.

The three conditions were: PLA, 6% CHO, 6% CHO + 5 mg/kg BM CAF (See Appendix G for more details about the sports drinks used in this study). Anhydrous caffeine was purchased from a local pharmacy, weighed on an analytical balance (Mettler Toledo PC 400, Mississauga, Canada), dissolved in a commercially available CHO sports drink (Powerade Ion4, Coca-Cola Canada, Toronto, Canada) and refrigerated for 24 hours prior to ingestion. The two remaining drinks were a CHO-free placebo (Powerade Zero Ion4, Coca-Cola Company, Atlanta, USA) and a CHO sports drink (Powerade Ion4, Coca-Cola Canada, Toronto, Canada). All drinks were matched for temperature, electrolyte content, colour, and flavour.

Forty-five minutes prior to commencement of exercise, participants consumed 5 ml/kg BM of a randomly assigned, double-blind sports drink. After fluid consumption the players performed a 15 minute standardized pre-match warm-up.

Sweat Loss

While sweat was not collected, sweat loss was estimated from net BM loss (not corrected for respiratory and metabolic water loss) during match play, and corrected for total fluid intake (litres). This estimation relied on the assumption that 1L = 1Kg. Predicted sweat rates (litres per hour) were then calculated as (Casa et al., 2000; Edwards et al., 2007):

$$\text{Sweat rate}\left(\frac{L}{hr}\right) = \frac{\text{(Pre-BM (kg) + fluid ingested (L) - post-BM (kg)}}{90\text{ min} \times 60\text{ min/1hr}}$$

HR Measurement

HR was monitored continuously (1 sec recordings) throughout the protocol and the data were downloaded at the end of each testing session. HR measures were used to determine exercise intensity, which has been shown to be a valid indicator of soccer-specific exercise intensity (Hoff, Wisløff, Engen, Kemi & Helgerud, 2002).

Percentage of age-predicted maximal HR (220-age) was used to determine the time spent in four modified sport intensities (ACSM, 1998):

- Light 0-59 % HR Max
- Moderate 60-74 % HR Max
- Hard 75-89 % HR Max
- Very Hard 90-100% HR Max

<u>Loughborough Soccer Passing Test (LSPT)</u>

All testing protocols were carried out on a well-groomed grass soccer field with grids and distances measured accurately and marked out with cones and paint. The skill tests were run simultaneously pre-match, during halftime and immediately post-match with players consistently rotating through the skill stations in the same order throughout all three trials. Before each match, during the halftime break, and after the match, participants completed the LSPT (Figure 2; for more information see Ali et al., 2007).

The LSPT consists of 16 passes performed within a circuit of cones and grids (12 m x 9.5 m grid) as quickly and accurately as possible. There were four coloured target areas measuring 30 cm x 60 cm, each with an inner coloured target measuring 30 cm x 10 cm. These targets were attached to benches to allow rebounding of the ball. The player started with the ball in the centre grid, and then had to dribble into the passing area, pass the ball against the target, control the ball when it came back and then dribble back into the centre grid before carrying out the next pass. The passing sequence was randomly assigned (Appendix H) and the colour signalled by the operator prior to the current pass. In total there were 8 long and 8 short distance passes, with players allowed 43 seconds for test completion before they were penalized.

Penalty and bonus time were accumulated according a pre-set criterion (Ali et al., 2007):

- 5 s for missing the bench completely or passing to the wrong bench
- 3 s for missing the target area (60 cm x 30 cm)
- 3 s for handling the ball
- 2 s for passing the ball from outside of the designated area
- 2 s for not crossing two inner lines
- 2 s if the ball touches any cone
- 1 s for every second over the allocated 43 s to complete the test
- 1 s was *deducted* from the total time if the ball hits the 10-cm strip in the middle of the target

Three indices of performance were calculated from the LSPT:

1) *Movement Time*: Time necessary to complete the 16 passes and to return to the central box without the penalties accumulated, as recorded by a stopwatch (220 Sport Timer Stopwatch, Sportline, NY, USA).

2) *Penalty Time*: Penalties calculated from the errors committed and the bonuses scored by each player during the test execution.

3) *Total Performance Time*: Time necessary to complete the test after adjusting for penalties and bonus time.

Shot Speed

Concurrent with the LSPT, the shot speed protocol was performed before the match, during the halftime break, and after the match. Five regulation soccer balls (size 5) were arranged 10 m from a soccer goal with participants striking each ball one at a time (each shot separated by 5 seconds) with maximal speed (players had to strike the ball using 1 stride). Ball speed (peak speed measured throughout the entire motion of the ball) was measured with a sports radar gun (Stalker Sport 2 Digital Sports Radar, Stalker/Applied Concepts, Plano, TX, USA) with the best speed recorded (Ali et al., 2007).

Countermovement Jump (CMJ)

The CMJ was performed before and after the match on an electronic jump mat (Just Jump Mat, Probotics Inc., Huntsville, AL, USA) where participants performed two attempts with the best height recorded (Guttierres et al., 2009). Players used a full arm-swing motion during the jump, consistent to soccer-related jumping.

Running Sprints

20m sprint times were measured in one direction by dual-beam electronic timing lights (Brower Timing Systems, Utah, USA) (See Appendix I and J for sample data collection sheets).

Timing of Skill Tests

Immediately following the completion of the initial skill tests the inter-squad match began. Every 15 minutes throughout each half 3 ml/kg BM of fluid (one of the three sports drinks per trial) was consumed, blood lactate was measured and RPE and PFS were assessed. Each half was 45 minutes with a 15 minute halftime break during which the LSPT, shot speed protocol, and 20 m running sprint were assessed as well as blood lactate collected, and RPE and PFS surveyed. 3 ml/kg BM of the sport drink used that trial was consumed during the halftime break.

Post-Study Survey

On completion of the final match, participants were asked to complete a questionnaire (Appendix K) to indicate any differences or similarities they had noticed between the three sports drinks given during each trial.

Statistical Analyses

SPSS (version 19.0, SPSS Inc., Chicago, IL) was used to carry out a two-way (Treatment x Time), within-subject, repeated-measures, two-tailed analysis of variance (ANOVA) on skill performance scores. Mauchly's test for sphericity was used, and when sphericity was violated, the Greenhouse-Geisser correction was used. Paired t-tests were used for post hoc analysis of significant main effects to determine the source of variance. Adjustment for the multiple comparisons was made through the application of the Bonferroni correction method. Significance was set at $p < 0.05$. All data are reported as mean (SD).

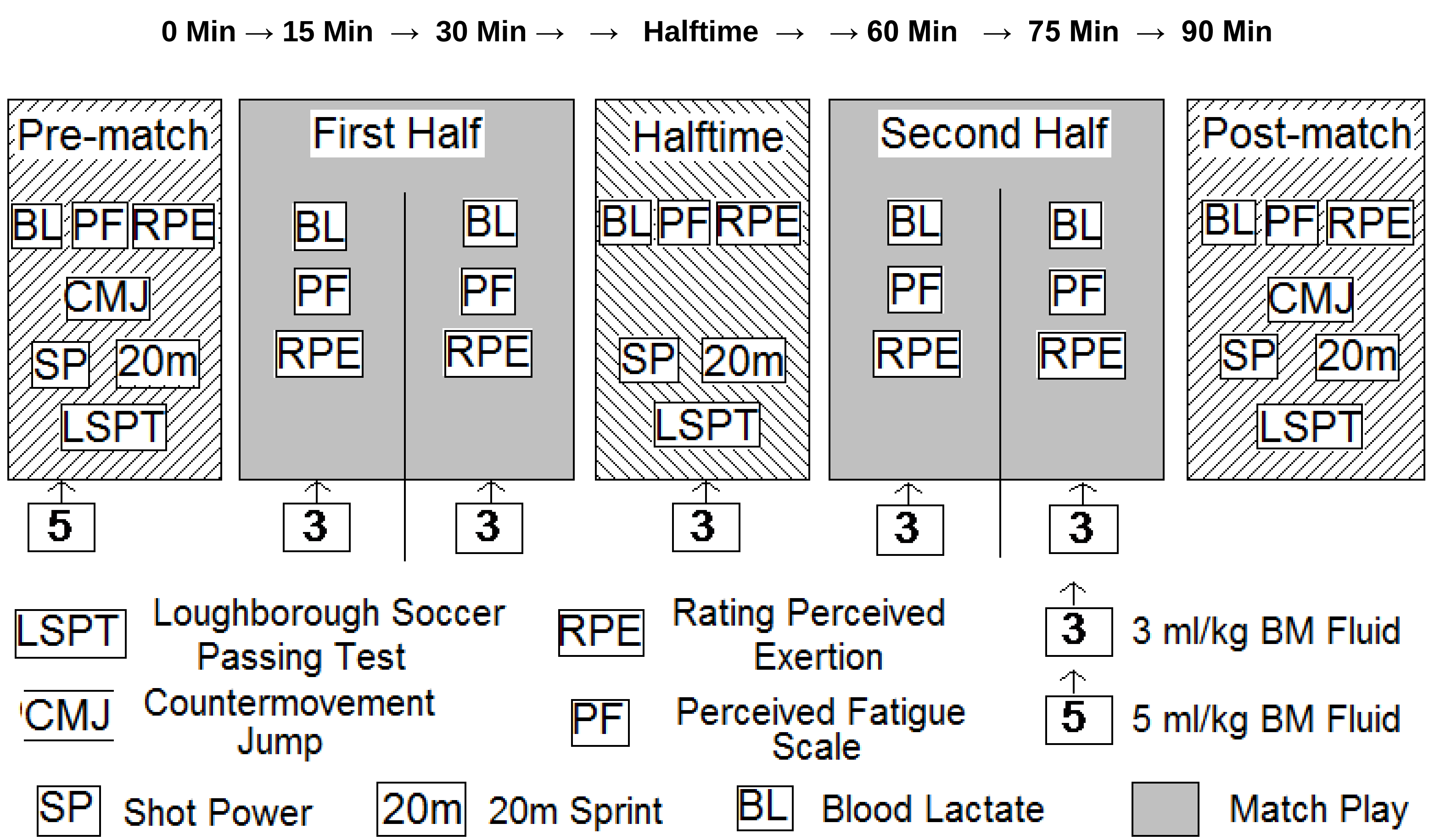

Figure 1. **Schematic representation of the exercise protocol.**

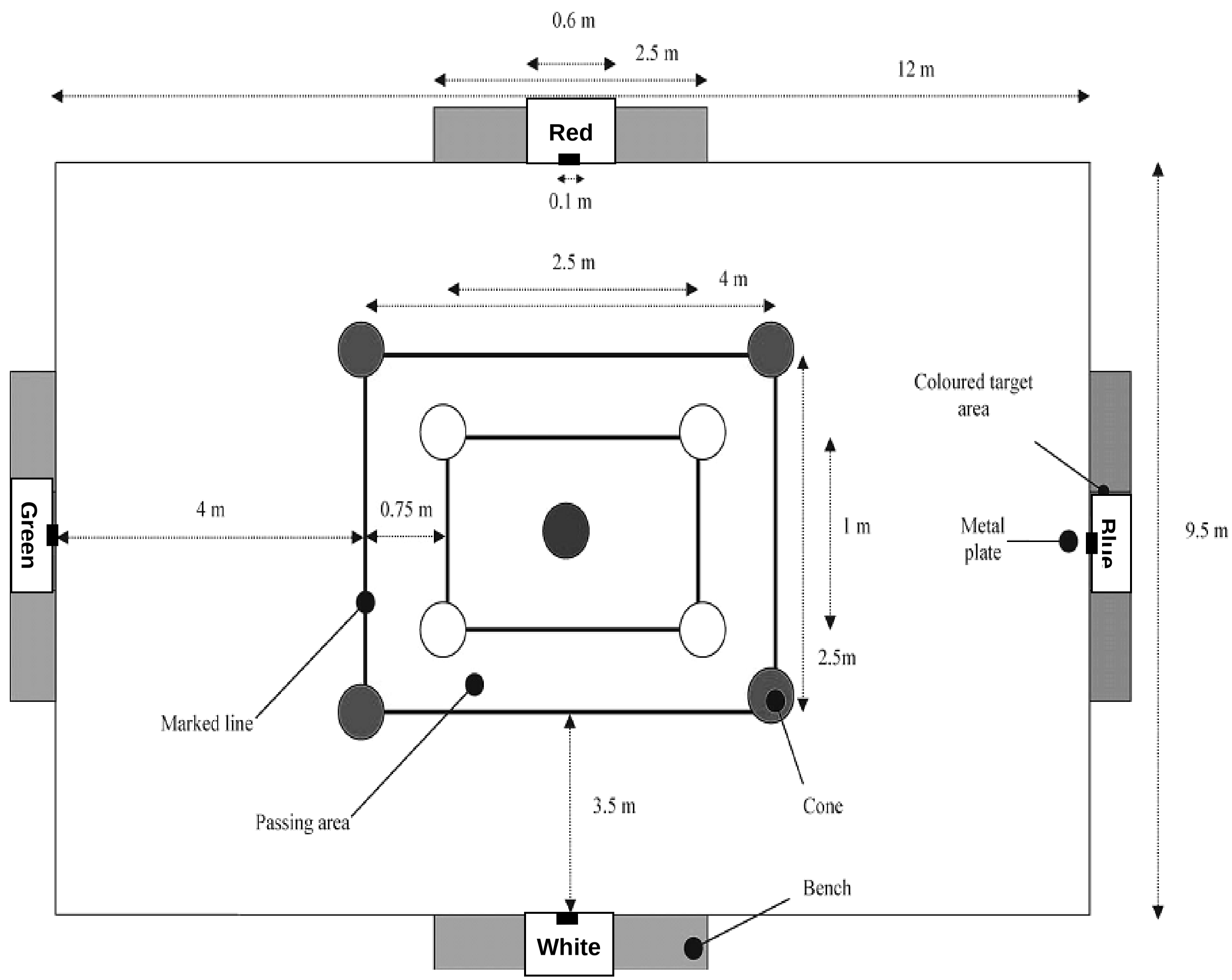

Figure 2. Schematic representation of the Loughborough Soccer Passing Test (LSPT). (Ali, Foskett & Gant, 2008).

Chapter 3: Results

All data are reported as mean (SD) and presented in graphical form, with error bars indicating 1 SD around the mean. All 12 players (age 19.4 (1.8) years, BM 73.2 (7.8) kg) completed each of three matches and all of the associated performance tests. Results include data from all subjects (n = 12), unless otherwise stated.

No player had measurable caffeine concentrations at the start of each match across all three trials, as measured from the pre-match urine samples.

LSPT Passing Performance

Soccer passing performance, as assessed through LSPT completion time, penalty time (including bonuses scored), and overall performance time (completion time + penalty time) on the LSPT, is reported as average scores in Table 1. Average completion time in the CCAF trial was significantly quicker during half time than pre-game (p = .018), and significantly quicker than PLA during halftime (p = .028). There was a significant main effect for penalties accumulated in the PLA trial (p = .041), with less penalties accumulated post-match than pre-match during the CHO trial (p = .001). At halftime there was also a significant penalty difference between trials, with fewer penalties accumulated during the CCAF trial than the PLA trial (p = .042).

In terms of overall performance time, the post-match average scores were significantly better than pre-match average scores (p = .015) in the CHO trial. There was a significant 17% improvement in overall performance during the

CCAF trial at halftime compared to the PLA trial (*p* = .027), which was due to fewer penalties (time deducted for accumulated penalties, rather than the "penalty time") being accumulated in the CCAF trial versus the PLA trial (15.3 secs vs 23.5 secs respectively) since bonus points scored (based on hitting the central metal target) in each trial were similar (7.2 secs vs 6.9 secs respectively).

Table 1

Loughborough Soccer Passing Test Performance Scores Measured Pre-match, Halftime, and Post-Match Across Three Hydration Trials

		LSPT Performance		
	Drink	**Pre**	**Halftime**	**Post-Match**
Movement time (s)	CCAF	50.0 (3.6)^	47.2 (3.6)*^	47.3 (4.2)
	CHO	50.3 (5.7)	48.2 (3.7)	49.3 (6.7)
	PLA	51.3 (4.6)	49.9 (3.1)*	49.5 (4.2)
Penalty time (s)	CCAF	11.4 (8.2)	8.2 (7.6)*	7.5 (8.6)
(Accumulated	CHO	15.5 (10.5)^	10.2 (9.3)	8.6 (9.5)^
penalties - bonus time)	PLA	16.8 (8.6)	16.6 (7.8)*	10.0 (5.2)
Total performance	CCAF	61.4 (10.5)	55.3 (10.3)*	54.8 (10.6)
time (s)	CHO	65.8 (12.8)^	58.3 (11.3)	57.8 (14.6)^
(Movement time + Penalty time)	PLA	68.1 (12.2)	66.5 (8.7)*	59.5 (8.3)

** Matching symbols indicate a significant difference between trials ($p < 0.05$)*

^ Matching symbols indicate a significant difference within trials ($p < 0.05$)

Shooting Performance

Figure 3 displays average peak shot speed across the three hydration trials. During the CCAF trial halftime shot speed was significantly faster than pre-match shot speed (*p* =.036). Shot speeds were significantly slower during the CHO trial pre-match than during the PLA trial (*p* = .040), and during halftime than the PLA trial (*p* = .002) and the CCAF trial (*p* = .010).

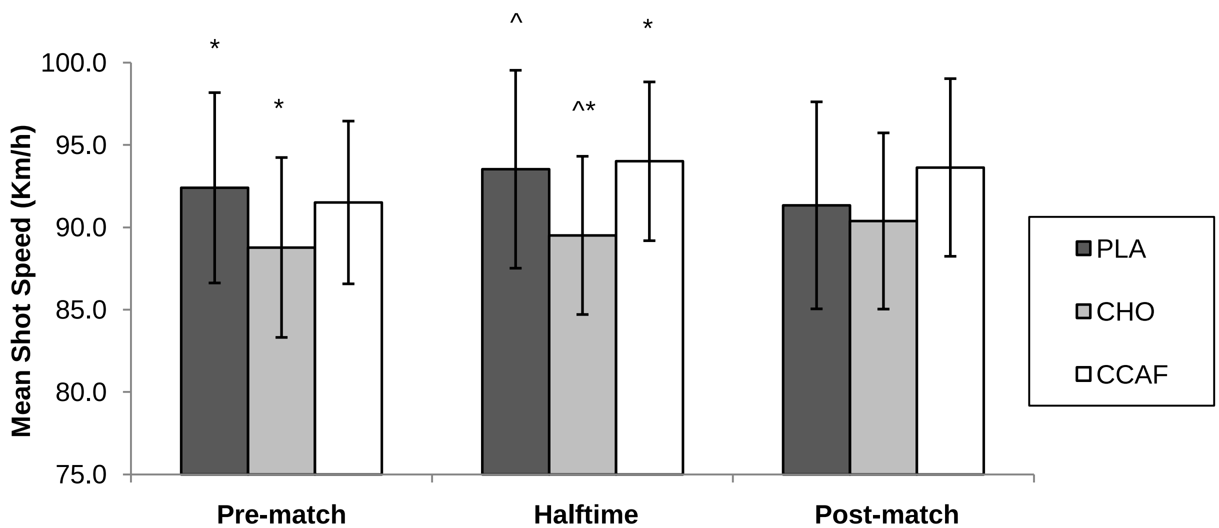

Figure 3. Average shot speed measured pre-match, halftime, and post-match across three hydration trials. (Note: matching symbols indicate significant difference between trials within each time period, $p < 0.05$).

Sprint Performance

There were no significant effects within any of the hydration trials for 20m sprint performance (Figure 4.). Between trials, the CHO trial was significantly slower than the PLA trial (*p* = .001) and CCAF trial (*p* = .033) at halftime.

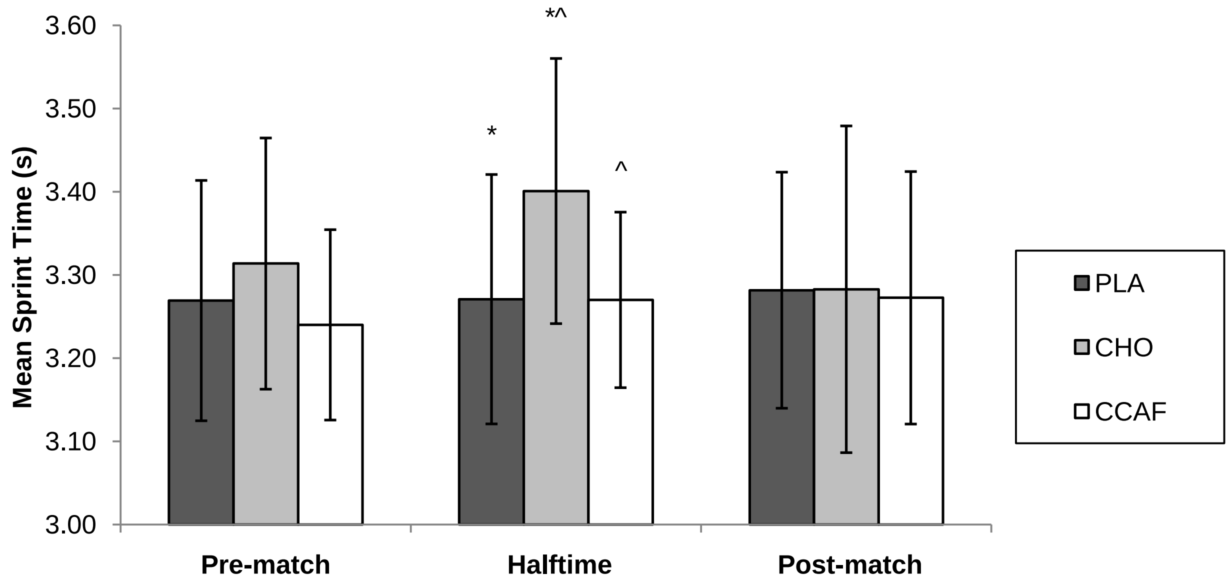

Figure 4. Average sprint time measured pre-match, halftime, and post-match across three hydration trials. (Note: matching symbols indicate significant difference between trials within each time period, $p < 0.05$).

Countermovement Jump Performance

CMJ performance is displayed in Figure 5 as average jump height. Due to technical difficulties with the equipment, some data were missing during the CCAF trial which led to reduced sample sizes: pre-match CCAF (n = 9), post-match CCAF (n = 8), all other CMJ results (n = 12). There were no significant improvements within trials. However, the average CCAF jump height was significantly less than the PLA jump heights (p = .016) and CHO jump heights (p = .021) pre-match.

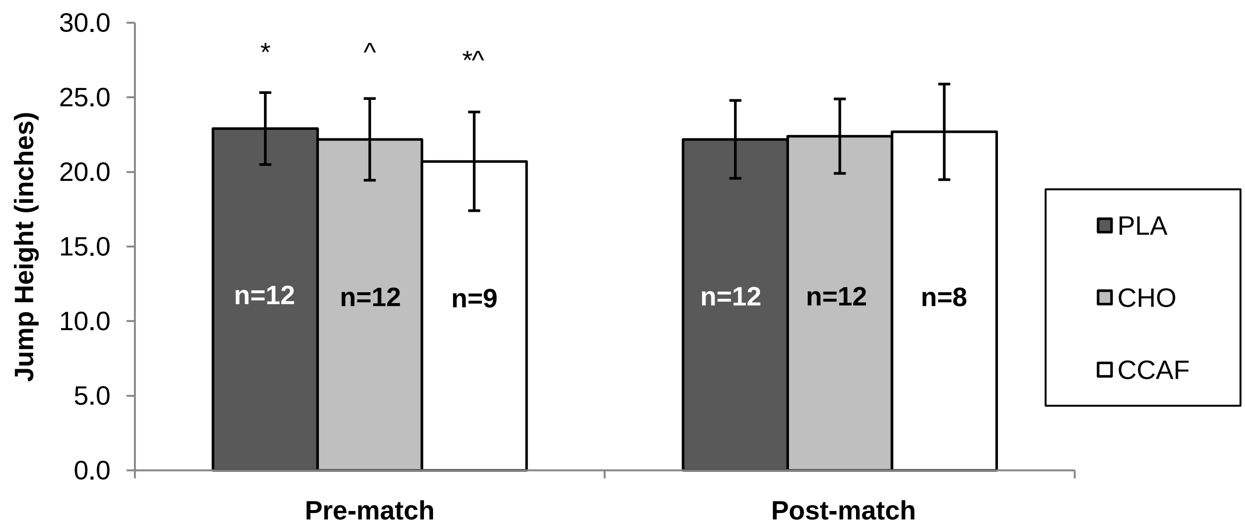

Figure 5. Average countermovement jump height measured pre-match and post-match across three hydration trials. (Note: matching symbols indicate significant difference between trials within each time period, $p < 0.05$).

Match Intensity

Match intensity was determined through HR, RPE, lactate and fatigue. HR data are presented as 15 minute averages (Figure 6). The percent of match time spent at different HR zones determined through percent of HR maximum (Figure 7).

The average HR value for the PLA trial was 157.1 (8.7) bpm, for the CHO trial was 149.1 (7.6) bpm, and for the CCAF trial was 154.4 (10.0) bpm. There was a significant difference between the mean HR for the PLA and CHO trials ($p = .004$). During the PLA trial HR averages for the first 15 min of the match were significantly higher than during the 30-45 minute ($p = .031$), 45-60 minute ($p = .000$), 60-75 minute ($p = .001$), and 75-90 minute ($p = .000$) averages. During the CCAF trial 0-15 minute HR averages were significantly higher than

60-75 minute averages (*p* = .023), and 15-30 minute averages were significantly higher than 30-45 minute (*p* = .003), 45-60 minute (*p* = .014), and 60-75 minute averages (*p* = .006).

There was a main effect for the CHO trial when comparing 15 minute averages (*p* = .010, n = 11). Across trials, average HR values over the first 15 minutes of the match were significantly greater in the PLA trial than the CHO trial (*p* = .018) and the CCAF trial (*p* = .009). During 15-30 minutes the CHO trial HRs were significantly lower than the PLA trial (*p* =.049) and the CCAF trial (*p* =.004). The PLA trial HR values were significantly greater than the CHO trial (*p* = .003). There was significance among trials for HR averages over the last 15 minutes of matches (*p* = .026). There was significantly less time spent in the moderate HR zone for the PLA trial compared to the CHO trial (*p* = .010) and CCAF trial (*p* = .021). There was a significantly greater percent of time spent in the hard HR zone during the PLA trial compared to the CHO trial (*p* = .011), and a greater percent of time spent in the very hard HR Zone during the PLA trial compared to the CHO trial (*p* = .023) and CCAF trial (*p* = .025) (Figure 7).

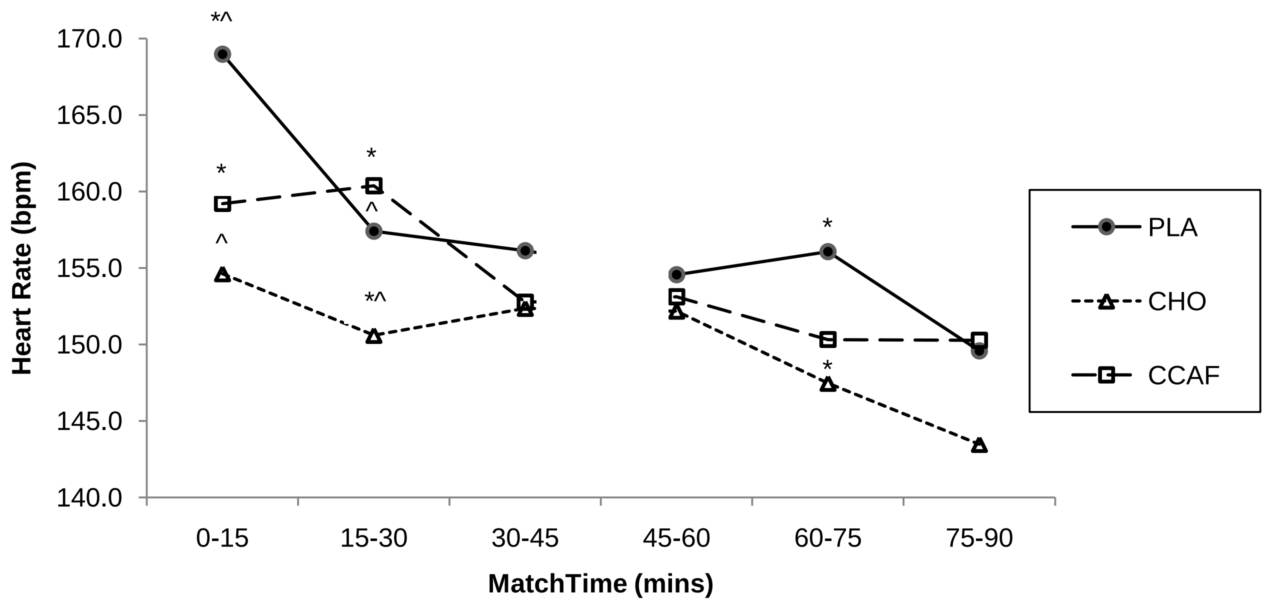

Figure 6. Average 15 minute interval heart rates measured across three hydration trials. (Note: matching symbols indicate significant difference between trials within each time period, $p < 0.05$).

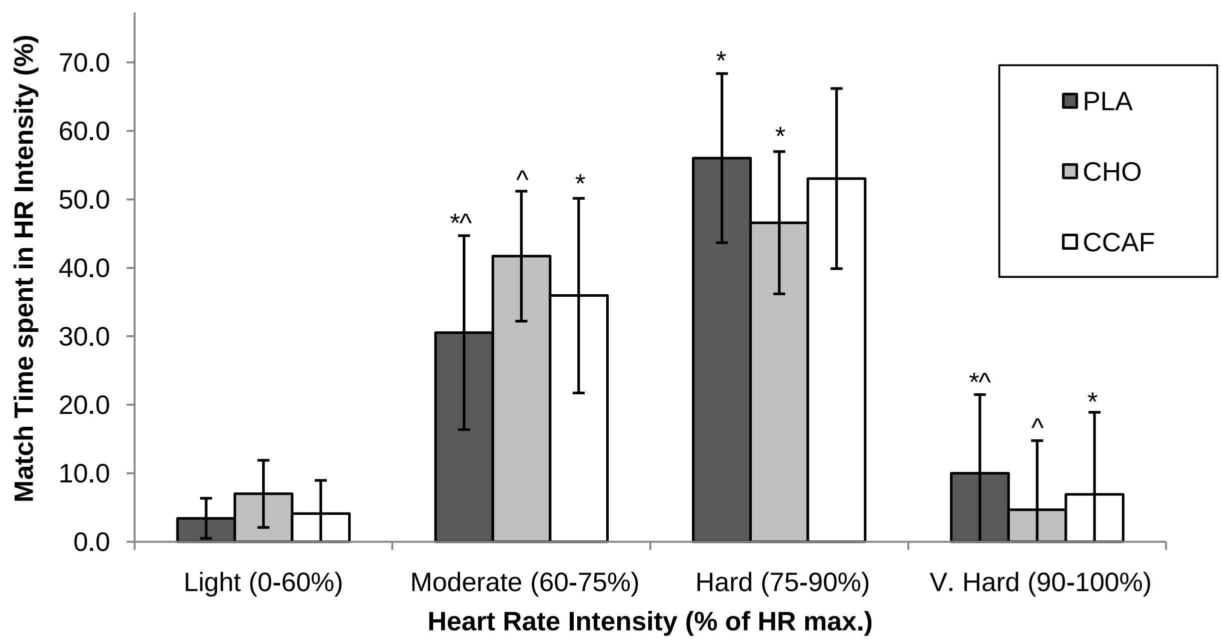

Figure 7. Percent of match time spent in each of four heart rate intensities measured across three hydration trials. (Note: matching symbols indicate significant difference between trials within each time period, $p < 0.05$).

A significant difference was seen between pre-match perceived fatigue scores and those measured during match play in all trials with perceived fatigue being higher at all time points compared to pre-match measures (Figure 8). In the PLA trial there was also significant difference between 45-minute and 75-minute scores (p = .002). In the CCAF trial the 15 minute score was significantly less than the score measured at 30 minutes (p = .000), 60 minutes (p = .006), 75 minutes (p = .012), and 90 minutes (p = .001), and between the average 45 minute score and the 90 minute score (p = .018). During the CHO trial there was significant difference between the perceived fatigue scores at 15 and 30 minutes (p = .032). There were no significant differences between trials for perceived fatigue.

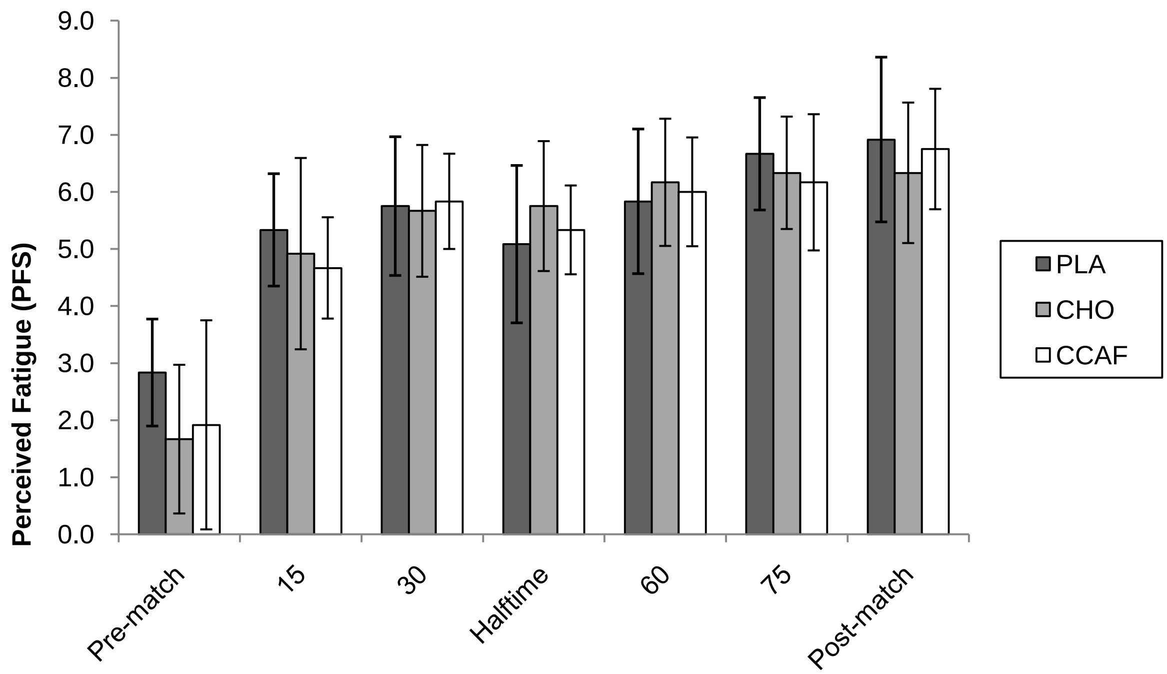

Figure 8. Perceived fatigue (0-10 scale) measured every 15 minutes during each match across three hydration trials.

Pre-match RPE averages, similar to perceived fatigue scores, were significantly different than RPE measures during match play (Figure 9). There were no significant differences between drinks for RPE.

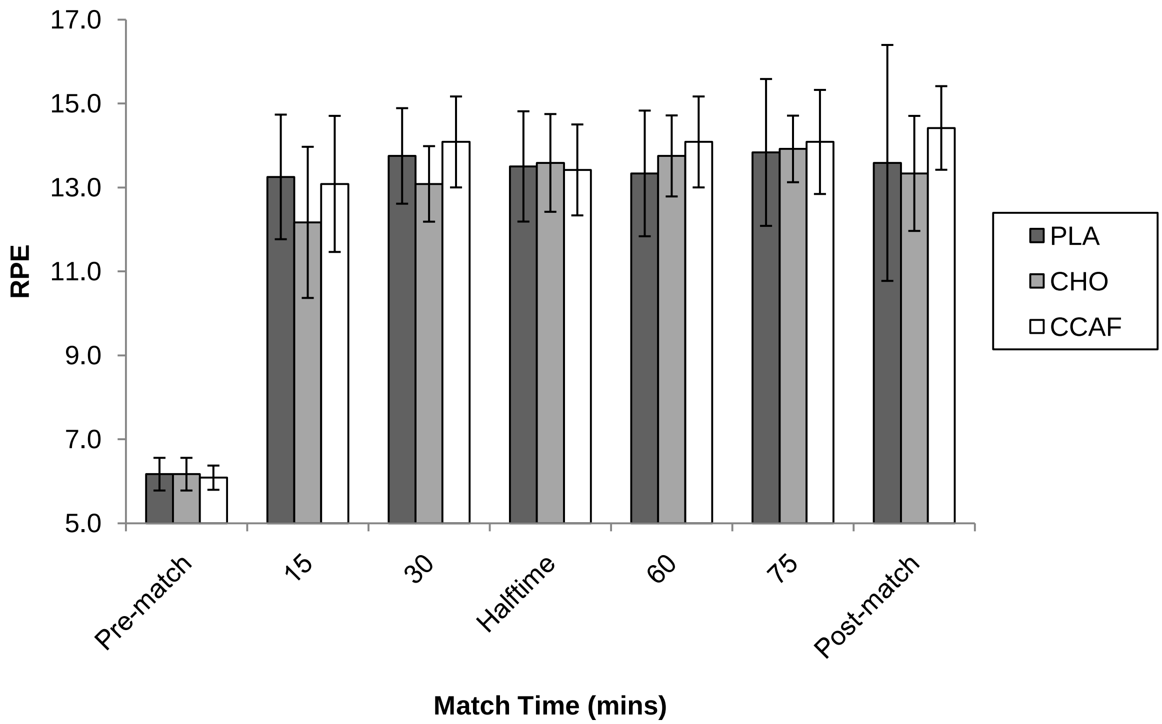

Figure 9. RPE (Borg's 6-20 scale) measured every 15 minutes during each match across three hydration trials.

Average blood lactate measurements are presented in Figure 10. In the PLA trial the pre-match measurements were significantly lower than those measured at 15 minutes (p = .001). Additionally, the measure taken at 90 minutes in the PLA trial was significantly less than that taken at 15 minutes (p = .013) and 75 minutes (p = .014). The pre-match lactate measurements taken during the CCAF trial were significantly less than the 15 minute (p = .021), the 30 minute (p = .021) and the 90 minute (p = .029) measures. Between hydration trials, the PLA trial had significantly elevated lactate values over the CHO trial at 15 minutes (*p* = .027) and 60 minutes (*p* = .023). At 60 minutes the CHO+CAF trial also had significantly greater lactate values than the CHO trial (*p* = .006). When all lactate values measured throughout the match were averaged, it was determined that the PLA trial overall had higher lactate values than the CHO trial (*p* = .031).

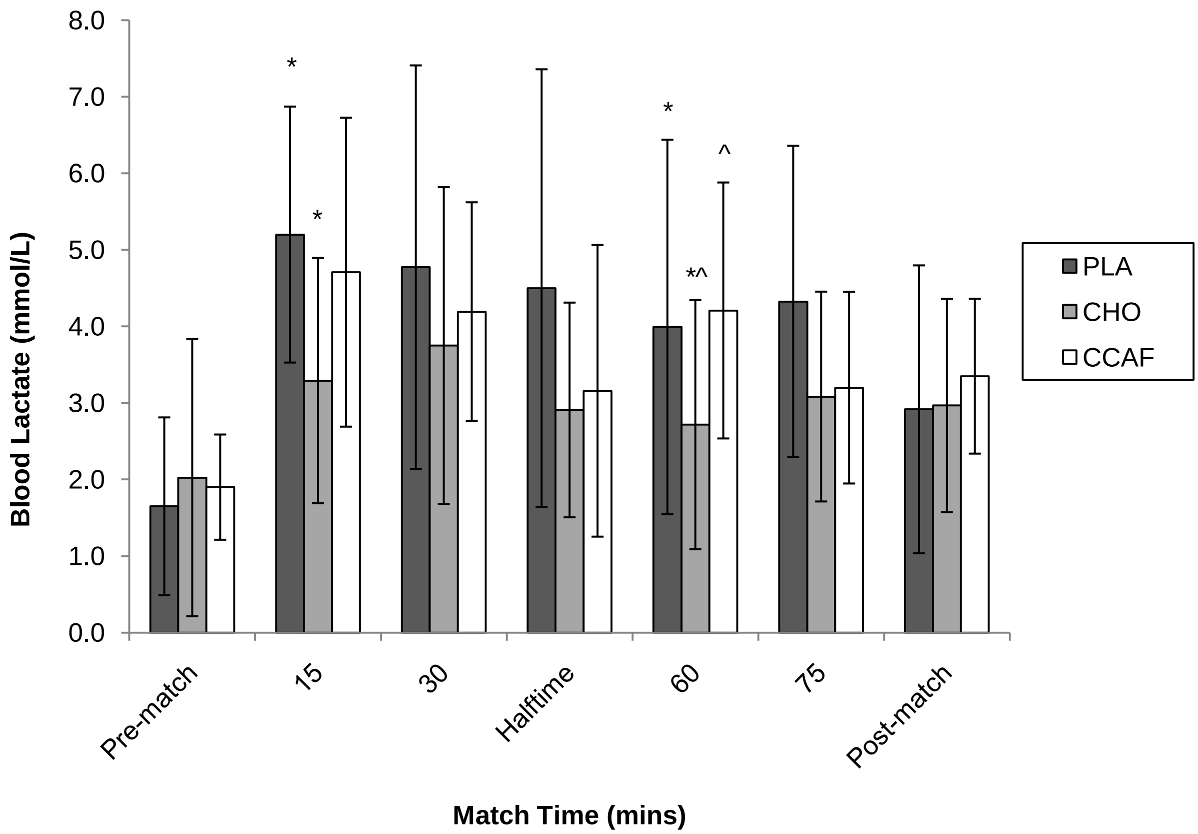

Figure 10. Average blood lactate measured every 15 minutes during each match across three hydration trials. (Note: matching symbols indicate significant difference between trials within each time period, $p < 0.05$).

Subjective Drink Responses

Although blind to which drink was consumed for each of the match sessions, nine participants (75 %) identified the CCAF sports drink as providing the feeling of more energy, and one participant identified the PLA as providing more energy. Based on the post-study questionnaire, all 12 participants reported that the CCAF sports drink was different than the other two drinks. Five participants (42%) thought the PLA and CHO drinks were either similar or the same drink, and the remaining 8 participants (67%) felt the PLA and CHO drinks were different sports drinks. It should be noted that players did not actually identify the drinks in the questionnaire.

Hydration Status

Figure 11 shows that, on average, players arrived in a mildly dehydrated state only prior to the commencement of match play in the CHO trial. However, upon further inspection of the data it was determined that for the PLA trial 67% (8 players) of players arrived to the trial in a dehydrated state. For the CHO trial, 83% (10 players) presented with USG values greater than 1.020, and in the CCAF trial 50% (6 players) had values greater than 1.020. Examination of individual data demonstrated that a small number of players were extremely well hydrated (USG < 1.012 mmol/L) in comparison to the rest of the group. The USG values for these few players substantially reduced the group mean USG values masking the fact that most players were less than optimally hydrated. When those players (n = 1-3) with values of less than 1.012 mmol/L were removed, the corrected values indicated that most players started each trial in a mildly hypohydrated state, with mean values of: PLA - 1.023 (.002) mmol/L, CHO - 1.024 (.003) mmol/L, CCAF - 1.020 (.005) mmol/L.

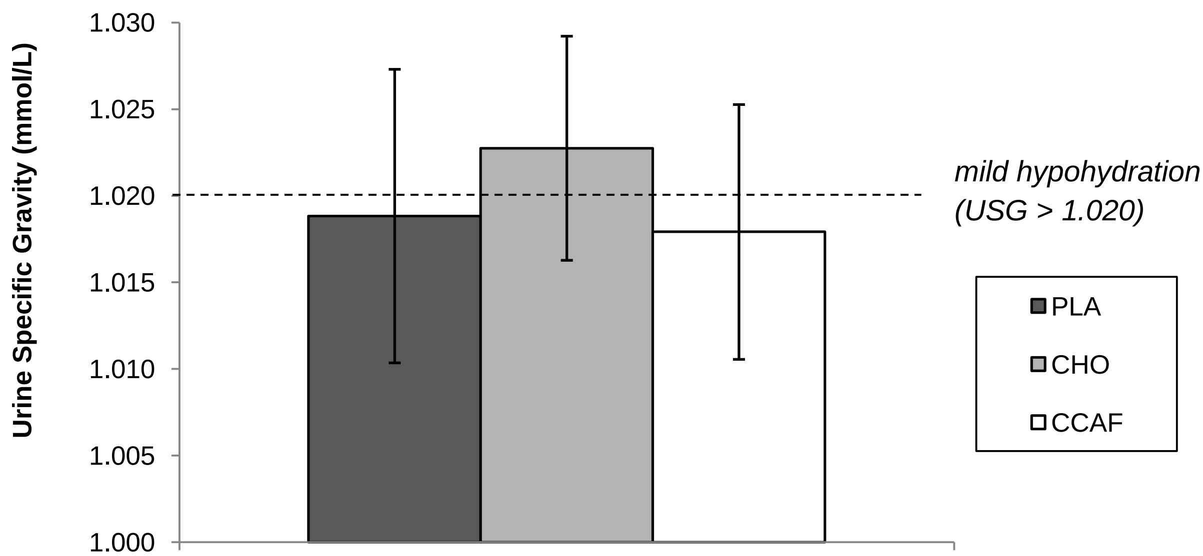

Figure 11. Average urine specific gravity measured pre-match across three hydration trials.

Sweat rates (litres per hour), as shown in Figure 12, were calculated as net BM loss during match play plus total fluid intake (Casa et al., 2000; Edwards et al., 2007). The CHO trial had significantly lower sweat rates than both the PLA trial (p = .038) and the CCAF trial (p = .009).

BM (Figure 13) was significantly lower post-match compared to pre-match in only the CCAF trial (p = .015). Between trials, the CHO and CCAF trials were significantly different (p = .013). When comparing percent BM loss, the CHO trial was significantly lower than both the PLA trial (p = .043) and the CCAF trial (p =

.014). In fact, on average the players gained weight in the CHO trial post-match. Players on average consumed 1.46 L of fluids during each trial.

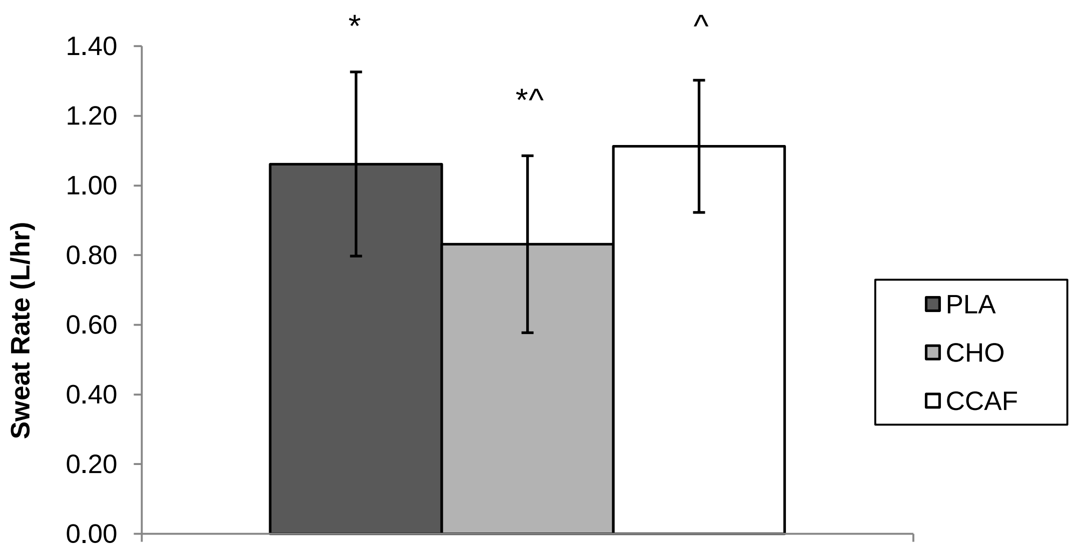

Figure 12. Sweat rate across three hydration trials. (Note: matching symbols indicate significant difference between trials, $p < 0.05$).

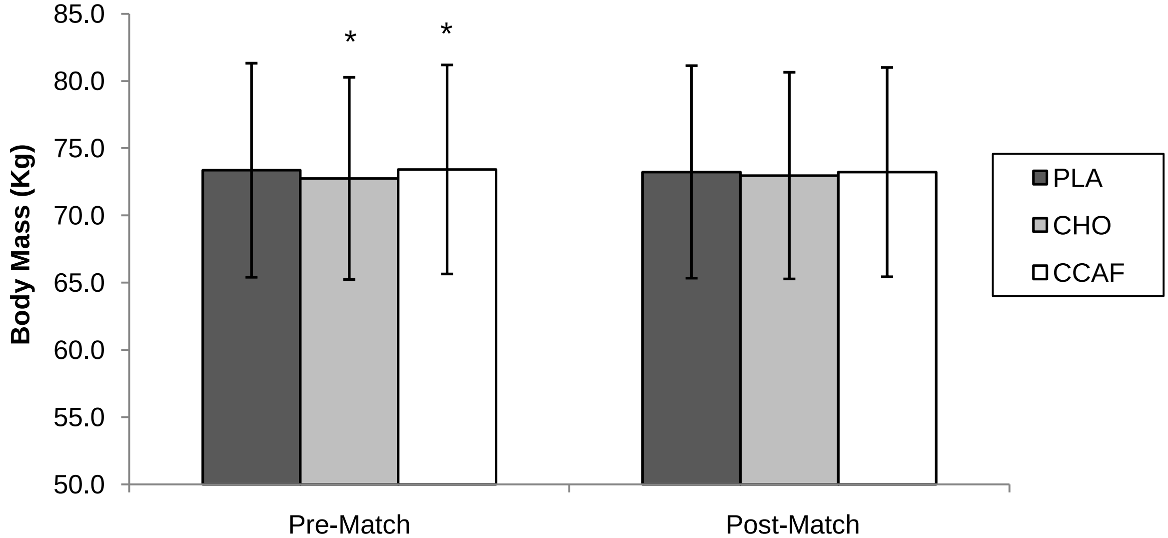

Figure 13. Body mass measured pre and post-match across three hydration trials. (Note: matching symbols indicate significant difference between trials within each time period, $p < 0.05$).

Chapter 4: Discussion

The main finding of the present study is that all three sports drinks appeared to prevent deterioration in soccer skill performance as a consequence of fatigue. Furthermore, the addition of caffeine (5 mg/kg BM) to a 6% CHO solution improved passing performance, as measured by the LPST, compared to the placebo over ninety minutes of match play, but did not improve 20m sprint times, shot speed, jump height, RPE, or feelings of fatigue. The CHO sports drink did not appear to have any performance enhancing effects over the placebo drink.

The inclusion of a caffeine only solution (no CHO) would have been beneficial to distinguish between the effects of caffeine and the combination of CCAF. However due to logistics of this research, only three trials were conducted. It was assumed that any effects of caffeine would be manifested through significant differences between the CCAF drink in comparison to the CHO and the PLA sports drinks assessed.

Passing Performance

The LSPT is a validated performance test assessing passing accuracy, dribbling ability, decision making, and ball control. This is the first study to report on the LSPT in an outdoors setting on a grass field, most realistic to a typical competitive match setting. There was a statistically significant 17% improvement in overall performance with the consumption of caffeine in a CHO sports drink over the placebo drink at the halftime assessment. This was based on a significant improvement in both the number of penalties accumulated and the time taken to complete the 16 passes. The reduction in the penalty score was due to less penalty time accumulated (less inaccurate passing and/or poor ball control) rather than increased accuracy from striking the central metal target (bonus of 1 sec), which may be indicative of caffeine's ability to increase arousal at the central nervous system (CNS) so the players were more alert in their decision making when passing and dribbling around the coned area. This study is unique in discussing the differentiation between the bonus time and penalty time which make up the overall penalty score. The CCAF drink was responsible for a 7% improvement in overall passing performance at 90 minutes compared to the PLA drink, which also corresponded to a quicker completion time and a reduced number of penalties accumulated, although this was not statistically significant. Foskett, Ali and Gant (2009) had similar findings that caffeine decreased the penalties accumulated, leading to a significantly improved overall performance time in comparison to a placebo. They attributed this improvement to increased passing accuracy based on caffeine's ability to enhance fine motor skills involved in typical soccer skills such as control and passing accuracy, in addition to improving the complex cognitive-processing of tasks in the brain, such as decision making. In their study, they gave either a placebo or caffeine pill to the participants prior to the 90 minute LIST, and provided a designated amount of water throughout the protocol. While the protocol of Foskett et al. (2009) study was different to this present study, there are similarities in that fluids were given throughout the entire protocol, which appears to be key in helping prevent performance losses due to fatigue. Although there were no statistically significant differences when comparing passing performance between the consumption of the CHO sports drink and the PLA sports drink, there was a 7% improvement in overall performance time, a 30% reduction in penalties accumulated, and a 2% decrease in completion time during consumption of the CHO sports drink. Ali and Williams (2009) also found no significant differences between a 6.4% CHO drink and a PLA (8 ml/kg BM pre-exercise and 3 ml/kg BM every 15 min), but did note that providing a CHO drink over a PLA was able to help offset the decline in performance (3 ± 12% decline with CHO compared to 14 ± 24% decline with PLA). Another Ali et al. (2007a) study similarly found no significant difference in passing performance on the LSPT when comparing a 6.4% CHO drink to a placebo (5 ml/kg BM pre-exercise and 2 ml/kg BM every 15 min), however, they also stated that total performance time appeared to be better maintained in the CHO trial. Zeederberg et al. (1996) found no improvement in passing, dribbling or ability to control the ball between a 6.9% CHO drink or an artificially sweetened placebo, attributing this to no evidence of post-match hypoglycaemia in either ninety minute trial.

In the present study, as the matches progressed, there was an improvement in overall passing performance due to fewer penalties accumulated. Zeederberg et al. (1996) reported similar findings with increased successful pass completion and better ball control in the second half of a match compared to the first half. They associated this to a decrease in work rate later in the match. A theory by Easterbrook (1959, as cited in Ali & Williams, 2009) suggests a relationship between arousal and performance in the shape on an inverted-U. At rest when arousal is low, performance is equally low (bottom of the inverted-U). However, during match play there is an increase in arousal (top of the inverted-U) associated with peak cognitive and motor performance, which may explain the increase in passing performance seen in this study as the match progressed. The theory continues that fatigue may further increase arousal which is actually counterproductive and thus returns performance to baseline levels. Ali and Williams (2009) found a decrease in passing performance during the last 15 minutes (of their ninety minute soccer-specific exercise protocol) which they attributed to increased penalty accrual, and may be indicative of the last portion of Easterbrook’s U-shaped theory. Their protocol consisted of a glycogen depleting exercise protocol the evening before followed by a 12-hour fast, which most likely magnified the resulting fatigue and thus explained the reduction in passing performance. Lyons, Al-Nakeeb and Nevill (2006) also found a reduction in passing performance on a modified version of the LSPT when they induced fatigue through alternate split squats. They found the best performance with moderate fatigue over a rest condition, and the poorest performance with high-intensity fatigue. There did not appear to be any major fatigue after 90 minutes in the present study, suggesting that the players remained at the peak of Easterbrook’s inverted-U which may explain the increases in passing performance later in the match. Additionally, Rampinini et al. (2008) saw a reduction in passing performance (mainly from increases in penalty time) on the LSPT later in the match in sixteen teenage players competing in two matches.

They also found a decrement in passing performance after short bursts of high-intensity intermittent shuttle running. It therefore appears that there was not sufficient fatigue accumulation in the players in the current study to see declines in passing performance.

Shooting Performance

There were no significant improvements in shooting performance during either the CCAF trial or the CHO trial over the PLA trial. There were also no significant decreases in shot speeds across each trial (i.e. at 15 mins vs 75 mins), indicating that fatigue is either not a factor when striking a ball, or there was not sufficient fatigue accumulated after 90 minutes of match play to significantly affect shot speed. While accuracy was not measured, only those shots on target (into the goal) were recorded. Ali et al. (2007a) used the Loughborough Soccer Shooting Test (LSST) in their study comparing a PLA and a 6.4% CHO sports drink. The LSST is a valid test which factors in ball control, decision making, shot speed, and shot accuracy to provide an overall score similar to the LSPT (see Ali et al., 2007b). Similar to the present findings in this study, Ali et al. (2007a) found no difference in mean shot speed between the two drinks, however they reported an increase in shooting performance with the CHO-E drink and a decrease in performance with the PLA drink when comparing overall scores. They attributed this to the speed-accuracy trade-off which involves a reduction in movement and shot speed in order to maintain accuracy during a fatigued state when gross motor movements are compromised.

Similarly, Currell, Conway and Jeukendrup (2009) assessed shooting accuracy by splitting a regular sized goal into nine targets. They found a 7.5% CHO drink to enhance shooting accuracy over a PLA drink, and also noticed a decrease in kicking accuracy throughout the ninety minute soccer-specific exercise protocol. Zeederberg et al. (1996) also assessed shooting ability through video match analysis of two matches, but did not see any significant differences between a 6.9% CHO drink and a PLA. Due to the adverse weather conditions present during the CHO trial the shot speeds were consequently significantly lower during this trial than the other two trials. The decreased shooting performance was most likely due to the ball speed being reduced from opposing wind forces, and the striking of a near-frozen ball due to the low outdoor temperatures. It is therefore difficult to compare the shooting results for the CHO drink to the PLA drink in this study with the results from other studies. Furthermore, none of the above-mentioned research used the same shooting performance protocol which makes it difficult to compare the results.

This is the first study to assess the effect of caffeine on shooting performance, so comparisons to other soccer-related research cannot be made. There was a significant increase in shot speed from the pre-match measurement to the halftime measurement in the CCAF trial, which could possibly be due to caffeine's ability to either increase alertness which may have an effect on technique when striking the ball. Although not directly measured in the present study, the enhanced shot speed may have been due to an increase in mean peak power output of the leg muscles as has been shown in other studies investigating other powerful leg movements during short-duration sprints (Glaister et al., 2008; Schneiker, Bishop, Dawson & Hackett, 2006). Schneiker et al. hypothesize this could be due to adenosine antagonism, leading to stimulation of the CNS which in turn could recruit additional motor units or increase the frequency of motor unit activation. They also propose caffeine's ability to mobilize intramuscular calcium, which may facilitate excitation-contraction coupling to increase muscle contraction efficacy.

Sprint Performance

There were no significant improvements seen with either the CHO or CCAF drinks compared to the PLA drink. Previous research has shown mixed findings, with some encountering improved sprint performance with CHO ingestion over a PLA (Ali et al., 2007a; Gant, Leiper & Williams, 2007; Welsh, Davis, Burke & Williams, 2002), and some studies finding no significant differences in sprint performance between a CHO sports drink and a PLA (Ali & Williams, 2007; Foskett, Williams, Boobis & Tsintzas, 2008). The same is true when investigating caffeine's effects on sprint performance, with some observing an improvement over a PLA (Glaister et al., 2008; Schneiker, Bishop, Dawson, Hackett, 2006), and another study seeing no improvements in sprint performance with caffeine over a placebo (Foskett et al., 2009). Gant et al. (2010) found the decline in sprint performance was less with a CCAF drink over a placebo during a ninety minute LIST protocol, which they attributed to a possible reduction in perception of fatigue and increase in pleasure from the caffeine.

In the present study, the only significant difference for 20-m sprint performance was an increase in sprint times for the CHO trial, which as mentioned previously, was most likely due to environmental conditions of the opposing wind speeds slowing down sprints. Other than this discrepancy, there did not appear to be any signs of fatigue on sprint performance in any of the trials, which may be due to insufficient accumulated fatigue throughout ninety minutes of match play. These studies differ from that of Krustrup et al. (2006) who found a decline in sprint performance after a ninety minute match as well as after intense periods of play in both the first and second halves when investigating 31 Danish fourth division players over three matches.

Jump Performance

There were no significant improvements with either caffeine or CHO over the PLA, however, due to technical difficulties with the equipment, the validity of the data from the CCAF trial must be considered cautiously.

The literature has shown mixed findings regarding the effects of caffeine and CHO on jump performance. Zeederberg et al. (1996) found no improvement in heading ability with a 6.9% CHO drink over a PLA, however their results are based on the number of successful headers as opposed to jump height or power. Welsh et al. (2002) and Currell et al. (2009) also reported no difference between a CHO drink and a PLA in vertical jump performance. Foskett et al. (2009) published findings of elevated CMJ performance with 6 mg/kg BM of caffeine over a PLA, which they speculated could be attributed to caffeine's ability to act as an adenosine antagonist to increase activation at the CNS and subdue the inhibition in the motor cortex. The combination of caffeine and CHO combined into a sports drink has also shown improved vertical jump performance over a PLA (Guttierres, Natali, Alfenas & Marins, 2009). Due to the relative lack of research on caffeine and jump performance more investigation needs to be performed.

Physiological Measures

Heart rate combined with blood lactate, RPE and perceived fatigue was used in this study to measure the work intensity of the players during each of the three matches. Heart rate remained elevated from resting values in all three trials during the full duration of the ninety minute matches, with mean values similar to those reported in the literature during friendly outdoor matches (Krustrup et al., 2006). Mean HR from the PLA trial was significantly greater than the CHO trial, and players spent a larger proportion of match time in a very hard sport zone (90-100% of HR max) during the PLA trial than the other two trials. On average, players worked around 80% of HR max during the PLA trial, at 74% of HR max during the CHO trial, and at 77% HR max during the CCAF trial. The adverse weather conditions during the CHO trial may have resulted in the observed decreased work rate. Additionally, there appeared to be a decrease in HR during the last 15 minutes of the match (75-90 mins) in both the PLA and CHO trials, while HR was maintained during the last 15 minutes in the CCAF trial which showed overall significance. The players reported in the post-study questionnaire that they felt like they had more energy during the trial were caffeine was given, which may explain the maintenance of intensity during the final 15 minutes of match play.

The blood lactate response was similar to that of heart rate. Blood lactate was elevated during match play from pre-match values. There was also a significant decrease in the mean post-match lactate values in the PLA trial which may be indicative of reduced work rate later in the match. Another possible reason for the reduced values may be the time delay for some players between the match ending and the blood lactate measurement being taken, however, only the PLA trial exhibited a drop in values post-match. The blood lactate values during the CHO trial were significantly lower, thus supporting the HR data in that the exercise intensity appears to be lowest during the CHO trial. The blood lactate values observed in this study are similar to other studies which also found no difference between trials (CHO vs PLA) when employing a soccer-specific exercise protocol (Ali et al., 2007a; Ali & Williams, 2009). Blood lactate has been reported to be elevated with the consumption of caffeine (Hulston & Jeukendrup, 2008; Schneiker et al., 2006), but this was not apparent in this study. The underlying mechanism behind this is not clearly understood but Hulston and Jeukendrup hypothesized the elevated blood lactate may be due to reduced lactate clearance with the consumption of caffeine.

Although blood glucose was not measured in this study, the assumption is that blood glucose would have been elevated in the trials with exogenous CHO provided, as shown in others studies (Ali et al., 2007a; Ali & Williams, 2009;

Hulston & Jeukendrup, 2008). A review by Mohr, Krustrup and Bangsbo (2005) determined that fatigue at the end of soccer games may be caused by glycogen depletion of individual muscle fibres, and therefore providing a source of CHO is important. Additionally, caffeine in combination with CHO has been reported to have a sparing effect on blood glucose and muscle glycogen to help preserve energy stores for later use, however, research is extremely mixed (Graham, 2001). Analogous to this, caffeine has also been reported to enhance fat oxidation which in turn can preserve CHO stores, however this has similarly been refuted with little evidence to support this hypothesis (Graham et al., 2008).

Subjective feelings

RPE and PFS results show a similar trend where mean values were elevated throughout the match from pre-match values. There were no differences between trials for either measure, which has been shown with RPE in other studies comparing CHO to PLA (Ali & Williams, 2009), caffeine to PLA (Crowe et al., 2006; Foskett et al., 2009; Schneiker et al., 2006), or CCAF to CHO (Gant et al., 2010). The following studies also found an increase in RPE as exercise progressed, which was not seen in this study, with RPE remaining fairly consistent within each trial after 15 minutes. Conversely, one of caffeine’s reported ergogenic effects is to reduce RPE which can correspondingly enhance workload, endurance, or exercise intensity (Doherty & Smith, 2005), and has been shown in studies investigating caffeine’s effects on cycling performance (Cureton et al., 2007; Hulston & Jeukendrup, 2008). The enhanced effects of caffeine in these studies was either to prolong time trial cycling performance or improve the total amount of sprint work performed cycling. The game of soccer is more complex, involving many physical actions and mental decision making processes which may explain why reductions in RPE involving soccer-related research has not been previously observed (Foskett et al., 2009; Gant et al., 2010).

The PFS used in this study has not been validated previously, and fatigue scales are rarely used. However, it appeared relevant to include such a measure to help the players differentiate between perceived fatigue and perceived exertion, and get a measure of both of these cognitive perceptions.

Hydration

Between 6 and 10 of the 12 players (50% - 84%) came to the matches in a dehydrated state (USG ≥ 1.020 mmol/L). Maughan et al. (2007) found 11 of 32 elite male soccer players (34%) showed up to a competitive match in a dehydrated state (mean osmolality for each team was 640 and 725 mOsm/kg). Kurdak et al. (2010) found only 3 of 19 male soccer players (16%) commencing a match in a dehydrated state (mean USG 1.012 mmol/L). Additionally, Palmer, Logan and Spriet (2010) found between 10 and 11 of 14 teenage ice hockey players (71% - 79%) arrived to practice in various stages of hypohydration. Pre-match hydration status is important to help prevent declines in performance. If players are starting in a dehydrated state, then this will become exaggerated earlier in the match leading to reductions in endurance and skill utilization, especially in warmer environments. A wide range of pre-match hydration status is reported in the literature, but the current study suggests that players need to be educated in nutrition and fluid consumption so they arrive to games in well-nourished and hydrated states.

The mean percentage of BM lost (-0.27% - 0.28%) suggests that players in the current study were able to match their fluid losses (mean sweat rate was estimated at 0.83 L/hr - 1.11 L/hr) with consumed fluid (mean fluid consumed was 1.46L per trial). Maughan et al. (2007) reported a mean sweat loss of 1.68 L (1.12 L/hr) in English Premier League players playing in similar temperatures to the current study, equating to a BM loss of 1.1%. This study monitored a competitive reserve match, and therefore players could only consume fluids (mean fluid intake of 0.84 L) before the match, during halftime and post-match which may explain the greater percentage BM loss. During the ninety minute indoor LIST, player BM losses have been reported as 1.8% BM (Ali et al., 2007) 2% BM (Gant et al., 2010) and 1kg BM (Foskett et al., 2009) even when players were consuming fluids every 15 minutes. Additionally, when a match was played in an outdoor, warm environment, players lost 3.1 L of sweat and were about 2.2% lighter after the game when they had access to fluids (0.7-2.4 L fluid was consumed). A review by Edwards and Noakes (2009) found typical sweat rates during match-play to range between 0.8-1.5 L/h across most environmental conditions; consequently, the results seen in this study are comparable to the reported values in the literature. Furthermore, Edwards et al. (2007) found that moderate dehydration corresponding to a loss of 2% BM was detrimental to soccer performance. BM losses of this magnitude were not seen in this study which was most likely due to the players being given fairly large quantities of fluid to consume every fifteen minutes. However, even in a cold environment, the players lost almost all fluid weight consumed. Furthermore, the players in this study were not used to drinking such quantities of fluid during a match and often reported discomfort while playing, which illustrates the importance of creating individualized hydration plans for players so they can be accustomed to taking in the appropriate quantities of fluids both before and during a competitive match. The significantly lower percent body mass loss (players gained weight) in the CHO trial was most likely due to the statistically reduced fluid loss during this match because of the colder weather compared to the other two trials. It should also be noted that the estimated sweat rates, which were calculated solely based on BM lost in this study, may be over-calculated as players may have urinated during half time (which was not reported), and we assumed all fluid losses were in the form of sweat.

The reported hydration findings suggest that all three sports drinks (PLA, CHO, CCAF) were equally as effective at maintaining BM loss when ingested before and during a match, and furthermore caffeine did not appear to have any negative consequences on fluid balance, which is supported in findings by Gant et al. (2010).

Significant Practical Implications

The results from this study suggest that athletes participating in high-intensity intermittent team sports should try to consistently consume fluids throughout exercise to maintain fluid balance. This present study showed that even in a cooler environment, athletes still lost large quantities of fluid, mostly in the form of sweat, which if not replaced has been shown to result in performance deficits (Edwards et al., 2007). The protocol used in the present research allowed players to drink every fifteen minutes throughout match-play; however, this is usually not permitted during most competitive sports, making it vital to consume liquids whenever possible. Furthermore, this study showed that the addition of electrolytes (potassium and sodium) and CHO may help replace lost ions and glycogen respectively, to help prevent fatigue-induced performance deterioration.

The addition of caffeine to a sports drink did not appear to have any negative effects on endurance capacity or skill performance, and in fact had a mild ergogenic effect on passing ability and improved player's perceived energy. Caffeine's effects were evident after 45 minutes of match play, so it could therefore be considered beneficial to consume caffeine at least 30 minutes prior to commencement of exercise, and consuming it in the form of a sports drink throughout the activity may improve fluid balance and maintain adequate caffeine levels for ergogenic enhancements.

Conclusion

All three sports drinks appeared to be equally as effective in preventing deterioration of soccer skill performance. The addition of caffeine to a CHO sports drink improved passing performance, with no apparent negative consequences in any endurance or skill measure from consumption of caffeine. Due to caffeine’s ability to easily cross both the blood brain barrier and most other cellular tissues, it is difficult to pinpoint caffeine’s exact mode of action, whether that be neural or muscular in nature. Furthermore, if caffeine’s primary mode of action is via adenosine antagonism, most tissues in the body have adenosine receptors, including the CNS and musculature, which all add to the difficulty of determining caffeine’s exact mode of action (Graham, 2001).

In conclusion, caffeine may have ergogenic benefits on soccer performance, but more importantly it is the total volume of fluid consumed which can help prevent performance decrements from accumulated fatigue. Further research needs to be undertaken to try and determine caffeine’s exact mode of action and how this may beneficial to soccer players.

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Appendix A: Literature Review

Introduction

In soccer, fatigue affects performance both with and without the ball (Bradley et al., 2009). Over the duration of a ninety minute match an average total distance of 10.7 km is covered by elite, professional, male players (Bradley et al.) and average player has a mean rate of energy expenditure estimated to be around 16 kcal/min, corresponding to an oxygen consumption of about 75% of maximum (Mohr, Krustrup & Bangsbo, 2005).

A review of fatigue in soccer by Mohr et al. (2005) found reduced performance in both halves after short-term intense periods, in the initial phase of the second half, and towards the end of a match, suggesting fatigue occurs both acutely during the game and as a result of ninety minutes of prolonged intermittent exercise. Furthermore, video analysis of professional soccer players during competitive matches found that in the last fifteen minutes of a match the amount of high-intensity running is decreased by 35-45% (Mohr, Krustrup & Bangsbo, 2003). This decline in performance has also been shown in adolescent male (Rampinini et al., 2008) and female (Krustrup, Zebis, Jensen & Mohr, 2010) players. Fatigue at the end of a game appears to be caused by low glycogen concentrations in a considerable number of individual muscle fibres (Krustrup et al., 2006; Mohr et al.), while temporary fatigue after short, intense exercise bursts has been possibly attributed to disturbances in muscle ion (possibly an accumulation of extracellular potassium) homeostasis and impaired excitation of the sarcolemma (Mohr et al.). Edwards and Noakes (2009) argue that there is no single metabolic factor causing fatigue and instead suggest an individualized self-pacing plan to explain the decreased intensity at the end of a game. They propose players subconsciously modulate their effort during a match according to strategy based on both pre-match and dynamic considerations during the game.

Cometti, Maffiuletti, Pousson, Chatard and Maffulli (2000) found professional soccer players differed from amateur players in terms of knee flexor muscle strength, sprint speed over 10 m, and hamstring-quadriceps strength ratio; however, there were no significant differences in sprint speed over 30 m and ball speed recorded during shooting. Additionally, highly elite soccer players (those playing for elite European club teams in addition to their respective national teams) performed 28% more high-intensity running (15-30 km/h) and 58% more sprinting (30 km/h) than moderately-elite players (those playing for a team in the top Danish league in additional to representing their national teams) during matches, and highly-elite players performed on average an additional 11% on the Yo Yo Intermittent Recovery Test Level 1 (YYIRTL1) than moderately elite professionals (Mohr et al., 2003). Of the playing positions in soccer, center backs cover the least distance during a match, while wide and central midfielders cover the greatest total distance and the greatest distance in high-intensity running. Attacking players and full-backs cover the greatest distances sprinting (Bradley et al., 2009; Mohr et al., 2003).

In competitive sports such as soccer, athletes are always striving to gain an advantage over their opponents. For ergogenic effects they turn to nutritional supplements such as sports drinks, which are legal, affordable, easily accessible, and often contain mixtures of carbohydrates (CHO), electrolytes, and more recently, caffeine. There is evidence to suggest consumption of a carbohydrate-electrolyte sports drink (CES) can improve performance compared to a placebo beverage (Coombes & Hamilton, 2000), therefore, this review of literature will examine the ergogenic effects of different sports drink contents on soccer performance. Furthermore, the scientific background and rationale behind the addition of caffeine to sports drinks will be discussed.

Dehydration and Performance

A moderately dehydrated state (~2% body mass (BM) loss) has been shown to impair performance (Edwards et al., 2007), therefore understanding fluid loss during play, as well as effective fluid replacement strategies is important.

A comprehensive review of the literature in dehydration in soccer was undertaken by Edwards and Noakes (2009). Some key findings were that under most environmental conditions fluid loss (~1-2% BM loss), metabolite accumulation, and core temperature during match-play remain fairly constant, and typical match-play sweat rates ranged between 0.8-1.5 L/h. Ali, Gardiner, Foskett and Gant (2010) showed this in female soccer players with a 2.7% deterioration in sprint performance when no fluid was provided in comparison to water ingestion during 90 minutes of shuttle running. Additionally, core temperature, HR, lactate concentration and RPE were also elevated when fluid was restricted, reiterating the importance of fluid consumption during exercise.

Maughan et al. (2007) investigated elite male soccer players throughout a competitive match played in a cool environment and found a large individual variability in hydration status, sweat losses and drinking behaviour, leading them to suggest the need for individualized assessment of hydration status for optimal fluid-replacement strategies. Kurdac et al. (2010) found a strong relationship between pregame hydration status and fluid volume consumed in 22 male players over the course of two matches played in a warm environment. Additionally, when players were given the choice of water or a CES during a match they consumed the same volume (half as CES and half as water) as they had done in the previous match when only water was available, replenishing about 55% of the sweat volume losses (~3.1L, 45 mmol sodium) accumulated over the course of the match. Palmer, Logan and Spriet (2010) found similar results in junior elite ice hockey players with similar amounts of fluid consumed when players were offered both CES and water.

The goal for players is to be in a euhydrated state before commencing exercise (Shirreffs, 2009), and to take in adequate fluids and electrolytes (through a combination of sports drinks and water) during match play and half time to limit fluid BM losses and restore water balance.

Commercial Sports Drinks

Most commercial sports drinks contain between 6 and 8% CHO, with the monomers glucose and fructose, the dimer sucrose, and the synthetic polymer maltodextrins most commonly being used. The increased use of maltodextrins in recent years improves palatability and allows for a constant CHO content even with relatively high concentrations of electrolytes. Additionally, most CES contain 2 to 3% fructose along with glucose to enhance gastric emptying (Coombes & Hamilton, 2000), and around 20–25 mmol/l sodium. The addition of sodium can stimulate sugar and water uptake in the small intestine, maintain extracellular fluid volume, maintain the drive to drink by keeping plasma osmolality high, and replenish sodium lost in sweat (Shirreffs, 2009).

Sports drinks containing CHO and electrolytes appear to empty from the stomach at a similar total fluid volume to placebos during high-intensity intermittent shuttle running (Gant, Leiper & Williams, 2007; Leiper, Nicholas, Ali, Williams & Maughan, 2005). Additionally, it appears that hypertonic CES (≥10%) are as effective as hypotonic CES (<10%) at restoring fluid balance (Evans, Shirreffs, & Maughan, 2009). However, a low-CHO hypotonic solution or isotonic solution (< 280 mOsm/kg) is recommended if rapid rehydration is required (Coombes & Hamilton; Shirreffs, 2009). Clarke et al. (2008) investigated the volume and timing of fluid intake during ninety minutes of exercise and found that while the sensation of gut fullness was significantly less during more frequent, smaller CHO feedings than fewer, larger feedings, the total volume consumed is of more importance than the timing.

Recently, Watson et al. (2008) found skimmed milk to be an effective post-exercise rehydration drink and was actually more efficient at replacing sweat losses than a CES following exercise-induced dehydration. Chocolate milk has been found to have similar effects (Karp et al., 2006; Thomas, Morris &

Stevenson, 2009). A further benefit of milk is to provide protein for post-exercise recovery.

Carbohydrate For Performance

The role of CHO metabolism during performance is well defined in the literature (see review by Jeukendrup, 2004). Exogenous CHO consumption can maintain body glycogen stores and blood glucose (Foskett, Willims, Boobis & Tsintzas, 2008).

The Loughborough Intermittent Shuttle Test (LIST) (see Nicholas, Nuttall & Williams, 2000) is a commonly used controlled field-based test which has been shown to simulate soccer match-level running intensities (Magalhães et al., 2010). Foskett et al. (2008) had participants run the LIST for ninety minutes, while consuming either a 6.4% CES or a placebo. They found increased run to exhaustion times and higher plasma glucose concentrations at fatigue in the CES trial, and a significantly lower muscle glycogen in the placebo trial at exhaustion, suggesting higher plasma glucose concentrations towards the end of exercise may provide energy for muscle metabolism and the CNS. The LIST was also used by Gant et al. (2007) who found shorter cumulative sprint times during consumption of a CES over a placebo, and Backhouse et al. (2007) who witnessed significantly elevated perceived activation with a CES over a placebo.

Other research have also found CES to have ergogenic effects over water alone, including decreased average 20 m sprint times, increased speed and agility (Welsh, Davis, Burke & Williams, 2002), preserved leg force during prolonged exercise in the heat (Coso, Estevez, Baquero & Mora-Rodriguez, 2008), and greater fat and CHO oxidation rates (Clarke et al., 2008).

Carbohydrate Sports Drinks and Soccer Performance

Muckle (1973) was one of the first researchers to investigate exogenous CHO intake on soccer performance. They found ingestion of glucose syrup with added mineral salts prior to soccer match improved both team and individual performance as assessed by the number of goals scored and conceded, and the total number of scoring efforts and ball-contacts compared to non-glucose controls. A number of studies have since been undertaken employing more rigorous soccer-specific skill tests to investigate ergogenic effects.

Ostojic and Mazic (2002) had 22 professional male soccer players compete in two matches then complete four soccer-specific skills. After a ninety minute soccer match, they found consumption of a 7% CHO drink (2-5 ml/kg BM) resulted in a higher blood glucose concentration, a lower RPE, and had an enhanced effect on dribbling speed and ball precision over a placebo. However, this study failed to include baseline measures of skill performance and did not have a crossover design which may have led to the enhancements being down to difference in skill between the players rather than the effects of the drinks. Ali, Williams and Foskett (2007) found improvements in shooting performance on the Loughborough Soccer Shooting Test (LSST), enhanced sprint performance and maintenance of blood glucose when consuming a 6.4% CES compared to a placebo in university male soccer players running the LIST. However, there appeared to be no difference in passing performance on the Loughborough

Soccer Passing Test (LSPT). A second study by Ali and Williams (2009) found that providing a CHO drink over a PLA showed a tendency to help offset the decline in passing performance (3 ± 12% decline with CHO compared to 14 ± 24% decline with PLA) over ninety minutes of intermittent shuttle running, although this result was not statistically significant. Ali, Foskett and Gant (2008) demonstrated the LSPT to be a valid and reliable protocol to assess soccer skill performance in both male and female players of all skill levels) and RPE was unchanged. Currell, Conway and Jeukendrup (2009) found a 7.5% CES significantly improved performance for kicking accuracy, dribbling and agility, but compared to the placebo there was no difference for heading over ninety minutes of simulated soccer exercise.

In contrast, Zeederberg et al. (1996) found that compared to a placebo, a 6.9% glucose polymer solution given at 5 ml/kg BM before the match and at halftime was not able to improve tacking, heading, dribbling or shooting ability during two soccer matches. Abbey and Rankin (2009) had similar findings when they compared a 6% CHO sports drink (1 g/kg CHO consumed before and during halftime) to a placebo drink and a honey drink and failed to find any differences in performance between trials on soccer-skill tests (agility, high-intensity running, ball-shooting) performed throughout a soccer-simulated exercise protocol.

It has been well documented in the literature that exogenous CHO intake can help maintain blood glucose and preserve stored glycogen in longer duration endurance exercise in addition to high-intensity intermittent exercise, however the ability of CHO-electrolyte sports drinks to enhance soccer-specific skill performance has provided mixed results. The many different exercise and skill assessment protocols employed makes it difficult to compare results across studies and there is a need for more tests similar to the LSPT and LIST to measure other aspects of soccer-specific skill performance. However, the use of CES to replace lost CHO and electrolytes (sodium and potassium primarily) can be extremely beneficial for players over the duration of ninety minutes of high intensity intermittent activities, even if only for rehydration purposes.

Caffeine For Performance

Mode of Action

Caffeine can be detected in the blood within 15 to 45 minutes from ingestion with peak concentrations evident within one hour, and a half-life of three to ten hours in human adults (Goldstein et al., 2010; Paluska, 2003; Robertson, Wade, Workman, Woosley, & Oates, 1981). Caffeine freely crosses the blood-brain barrier due to its lipid solubility (Watson, 2008) and is an antagonist to adenosine receptors associated with intracellular pathways (see review by Graham et al., 2008). Adenosine acts as both a neuromodulator and a neurotransmitter in the CNS to inhibit the release of many excitatory neurotransmitters such as dopamine and norepinephrine, which as a result can decrease wakefulness, vigilance and lower motor activity (Watson, 2008). Caffeine exerts its effects through a combination of actions on various tissues; for example, it is hypothesized that caffeine’s effect on skeletal muscle may be related to antagonism of the A_1 receptor thus elevating cAMP (Graham et al., 2008).

Two additional proposed physiological mechanisms of caffeine include mobilization of intracellular calcium from the sarcoplasmic reticulum to enhance muscular contraction, increase peak force generation and improve neuromuscular transmission. However, the large quantity of caffeine required for significant enhancements also produces secondary adverse effects (Paluska, 2003). Additionally, caffeine may inhibit the enzyme phosphodiesterase, which is responsible for breaking down cyclic monophosphate (cAMP). The resulting increase in muscle cAMP appears to stimulate epinephrine release, leading to lipolysis stimulation and promotion of free fatty acid release in order to preserve stored glycogen which can then be later used to prolong exercise (Essig, Costill, & Van Handel, 1980). However, this “caffeine-induced glycogen sparing” hypothesis has extremely mixed conclusions, attesting that caffeine’s primary action is probably not through glycogen sparing (Hulston & Jeukendrup, 2008; Graham et al., 2000; Graham et al., 2008; Greer, Friars, & Graham, 2000). Due to caffeine’s ability to easily cross the blood brain barrier in addition to most other cellular tissues it is too complex to pinpoint caffeine’s exact mode of action, however, research does support caffeine’s primary mode of action through antagonism to adenosine (Foskett, Ali & Gant, 2009; Graham et al., 2008; Paluska, 2003; Stuart, Hopkins, Cook & Cairns, 2005).

The optimal caffeine dose is between 3-6 mg/kg BM, with higher doses having similar ergogenic effects and adverse consequences (Paluska, 2003). Additionally, caffeine does not appear to have any significant effects on hydration status while exercising, either during shorter high-intensity performance, or prolonged endurance exercise (Goldstein et al., 2010; Graham, Hibbert, & Sathasivam, 1998; Paluska, 2003), and has been shown to increase alertness (Stevenson, Hayes & Allison, 2009). Caffeine appears to have ergogenic effects, however its exact mode of action is still largely unknown due to caffeine's ability to have diverse effects based on the target tissue and the dosage.

Caffeine and Exercise

An early study by Graham and Spriet (1995) looking at treadmill performance in well-trained male endurance athletes found that either 3 or 6 mg/kg BM of caffeine enhanced endurance performance by 22% over a placebo, but 9 mg/kg had no significant performance enhancing effect. Additionally, only the 6 and 9 mg/kg BM doses of caffeine had an effect on plasma epinephrine, and only the 9 mg/kg BM caffeine bolus resulted in subsequent increases in glycerol and FFA, suggesting that caffeine has altered interactions on different tissues at different concentrations. Caffeine has also been shown to have an effect on mean peak power output during cycling sprints. Schneiker, Bishop, Dawson and Hackett (2006) observed around a 7.0% increase in output when 10 male team-sport athletes consumed 6 mg/kg BM caffeine over a placebo. Similarly, Glaister et al. (2008) presented a 1.4% improvement in fastest running sprint time over 30 m in 21 physically active males completing multiple sprints when consuming 5 mg/kg BM caffeine over a placebo.

Conversely, Crowe, Leicht and Spinks (2006) found no positive effects on cognition, peak power, work output, RPE or peak HR with ingestion of 6 mg/kg BM of caffeine compared to a placebo during two sixty-second maximal cycling bouts; in fact a slower time to peak power was observed in the caffeine trial. However, this protocol only consisted of two 60 second short bursts of maximal power output which when associated with caffeine has previously produced mixed results (Greer, McLean & Graham, 1998).

In terms of skill performance, Stuart et al. (2005) investigated the impact of consuming 6 mg/kg BM caffeine on simulated rugby performance. Compared to the placebo, the consumption of caffeine 70 minutes prior to the 80 minute exercise protocol resulted in increased rugby-related performance measures (sprints, passing, peak power generation), including improved passing accuracy. The maintenance of sprint speed performance later in the placebo condition combined with the inability of caffeine to improve this measure led the authors to speculate that caffeine influences several processes in the CNS to reduce fatigue.

Caffeine and Soccer-Specific performance

There have been few studies investigating the effects of caffeine ingestion on soccer skill performance. Foskett, Ali and Gant (2009) had 12 premier level male soccer players complete the LIST and LSPT while consuming either mg/kg BM of caffeine or a placebo. They found improved performance on the LSPT and enhanced functional leg power during jump performance in the caffeine trial. However, there were no differences between trials for sprint performance, HR or RPE. The authors concluded that improvements in the LSPT were attributable to decreased error rate (fewer penalties accumulated) which may suggest an enhancement of fine motor skills, such as ball control and accuracy. More research needs to be undertaken to investigate possible ergogenic effects of caffeine on skill performance, especially in soccer.

Caffeine and Carbohydrate

Caffeinated Sports Drinks and Exercise

Cureton et al. (2007) examined caffeinated sports drinks on 16 highly-trained cyclists riding at 60% to 75% $VO2_{max}$ for 120 minutes on a cycle ergometer followed by a fifteen minute all-out performance ride in a warm environment. They found 15-23% greater work output during the performance ride, reduced RPE, and limited maximum voluntary contraction (MVC) strength loss while consuming a 7% CHO and 195 mg/L caffeine sports drink in comparison to a 6% CES or a placebo. Similarly, Hulston and Jeukendrup (2008) found a 4.6% enhancement of a 45 minute timed trial (TT) performance when consuming a 6.4% CHO + 5.3 mg/kg BM caffeine drink compared to a 6.4% CES and a 9% enhancement in comparison to the placebo. Significant improvements in TT performance have also been reported by Kovacs, Stegen & Brouns (1998) and Cox et al. (2002).

Caffeinated Sports Drinks and Soccer

Two studies to date have published results on the ergogenic effects of caffeinated sports drinks on soccer performance. Guttierres, Natali, Alfenas and Marins (2009) assessed 18 junior male soccer players over two competitive matches. They found the CHO-caffeine drink (7% CHO and 250 mg/L caffeine) significantly increased jump height compared with the 7% CES, but neither drink was able to improve performance on the Illinois agility test after the match, leading the authors to conclude that the combination of CHO and caffeine can increase explosive strength in the lower limbs.

Gant, Ali and Foskett (2010) compared a CES (1.8 g/kg BM CHO) to a CHO-caffeine sports drink (3.7 mg/kg BM caffeine, 1.8 g/kg BM CHO) in fifteen male soccer players performing the LIST. They found the CHO-caffeine drink significantly enhanced jump height, 15 m sprint performance and ratings of pleasure over the CHO drink, however, there were no significant differences between trials for passing ability (LSPT) and RPE. This led the authors to conclude that the performance enhancements were most likely due to altered subjective perceptions of exercise intensity and fatigue.

Caffeinated, CHO containing sports drinks appear to be as effective in providing energy during prolonged exercise, but more effective than either CHO alone or a placebo in improving endurance performance and attenuating muscle fatigue. This combination may also benefit individuals playing sports requiring elements of skill and mental concentration, such as soccer, however there is currently limited evidence to draw strong conclusions on any ergogenic effects.

Conclusion

Match-induced fatigue impacts many aspects of soccer skill performance, such as decreasing passing accuracy and reducing the amount of high-intensity running at the end of a game. To counteract this, athletes have turned to ergogenic sports drinks to stay hydrated, maintain blood glucose and muscle glycogen, and improve cognitive performance, such as alertness and decision making. Exogenous CHO intake has been shown to improve both endurance and sprint performance over water alone, as well as maintain soccer-specific skills. Caffeine is a CNS stimulant which has improved cycling endurance and sprint power, and more recently was proven to enhance ball control and passing accuracy in soccer. The combination of caffeine and CHO has a superior ergogenic effect over either supplement consumed alone, and when combined into a sports drink, fulfills the need to maintain fluid balance during exercise. Consequently, further research assessing the combination of CHO and caffeine in a sports drink on soccer-specific skills should be performed to enhance the current body of literature.

Table 2

Summary of Research Investigating Exogenous Carbohydrate Consumption During Exercise

Study (year)	**Carbohydrate**	**Population Sample**	**Findings (effects of CHO)**
Zeederberg et al., 1996	5 ml/kg BM at 6.9%	2 pre-professional male soccer teams	No change in performance
Ostojic & Mazic, 2002	5 mL/kg BM before and 2 mL/kg BM every 15 mins of 7%	22 professional male soccer players	↑ soccer-specific skill performance
Welsh, Davis, Burke & Williams, 2002	5 mL/kg BM of 6% CHO before 15 min warm-up and 3 mL/kg BM before each quarter. 5 mL/kg BM of 18% CHO at halftime	10 University aged male basketball and soccer players	↑ motor skill performance
Ali, Williams & Fosket, 2007	5 mL/kg BM before and 2 mL/kg BM every 15 min of 6.4%	16 male, university soccer players	↑ sprint performance; maintenance of skill
Backhouse, Ali, Biddle & Williams, 2007	8 ml/kg BM prior to LIST and 3 ml/kg BM during rest periods of 6.4% CHO	17 male university soccer players	↑ perceived activation; plasma glucose maintained
Clarke, Drust, Maclaren, & Reilly, 2008	7 ml/kg BM of CHO before and at half-time	12 male university soccer players	↑ plasma glucose concentrations; greater fat and CHO oxidation rates
Foskett, Williams, Boobis, & Tsintzas, 2008	8 ml/kg BM prior to LIST and 3 ml/kg BM during rest periods of 6.4% CHO	6 males (LIST running)	↑ endurance capacity

Hulston & Jeukendrup, 2008	5.5 mL/kg BM at onset and 2 mL/kg BM every 15 minutes of 6.4%	Ten endurance-trained male cyclists	↑ time-trial performance
Currell, Conway & Jeukendrup, 2009	6 mL/kg BM 30 mins prior to exercise then 1 mL/kg BM every 12 mins of 7.5 % CHO	11 university male soccer players	↑ kicking accuracy, dribbling and agility performance
Guttierres, Natali, Alfenas & Marins, 2009	5 ml/kg BM 20 min before the game and 3 ml/kg BM every 15 minutes of 7% CHO	18 junior male soccer players	No changes in skill performance
Stevenson, Hayes & Allison, 2009	5 mL/kg BM consumed preround and 2.5 mL/kg BM at holes 6 and 12 of 6.4 g CHO per 100 mL	20 male golfers	↑ putting performance; ↑ feelings of alertness

Table 3

Summary of Research Investigating Exogenous Caffeine Consumption During Exercise

Study (year)	**Caffeine**	**Population Sample**	**Findings (effects of CHO+CAF)**
Kruk et al., 2001	5 mg/kg BM	9 male soccer players	↑ psychomotor performance
Stuart, Hopkins, Cook & Cairns, 2005	6 mg/kg BM	9 male rugby players	↑ peak power, mean performance measures and ability to pass the ball

Crowe, Leight & Spinks, 2006	6 mg/kg BM	12 males and 5 females (cycling)	no ergogenic effect on repeated maximal cycling bouts
Schneiker, Bishop, Dawson & Hackett, 2006	6 mg/kg BM	10 male team-sport athletes (cycling)	↑ performance of prolonged, intermittent-sprint ability
Bassini-Cameron et al., 2007	5 mg/kg BM	22 professional male soccer players	↑ WBC count
Cureton et al., 2007	5 mg/kg BM	16 male cyclists	↑ work output, ↓ RPE, ↓ MVC strength loss
Glaister et al., 2008	5 mg/kg BM	21 males	↑ sprint time performance
Hulston & Jeukendrup, 2008	5 mg/kg BM	10 male cyclists	↑ time-trial performance
Foskett, Ali & Gant, 2009	6 mg/kg BM	12 premier level male soccer players	↑ LSPT performance; ↑ functional leg power
Guttierres, Natali, Alfenas & Marins, 2009	250 mg/L	18 junior male soccer players	No changes in skill performance
Machado, Breder, Ximenes, Simões, & Vigo, 2009	5.5 mg/kg BM	15 male professional soccer players	No change
Stevenson, Hayes & Allison, 2009	1.6 mg/kg BM	20 male golfers	↑ putting performance; ↑ feelings of alertness
Gant, Ali, Foskett, 2010	1.8 g/kg BM CHO and 3.7 mg/kg BM CAF consumed pre-LIST at 8 ml/kg and during each break at 3 ml/kg	15 male soccer players	↑ sprint performance; ↑ CMJ; ↑ subjective experiences

Appendix B: Participant Consent Form

University of Victoria | School of Exercise Science, Physical & Health Education

PARTICIPANT CONSENT FORM

Project Title: The Effects of Sports Drinks Containing Caffeine and Carbohydrate on Soccer-Specific Skill Performance During Match-Induced Fatigue.

Researcher(s): Marc Jacobson, Graduate Student, School of Exercise Science, Physical and Health Education (EPHE), University of Victoria, (250) 508-6854, marcj@uvic.ca

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Purpose(s) and Objective(s) of the Research:

- The purpose of this study is to examine the effects of three sports drinks (placebo, carbohydrate, carbohydrate-caffeine) on soccer-specific skills when fatigue limits performance.

- The research questions are associated with examining the effects of fatigue over the duration of a ninety minute match, and assessing if:
  - A carbohydrate-containing sports drink limits declining soccer skill performance, sprint performance, jump power and shot power over water alone?
  - Caffeine enhances the effects of a carbohydrate sports drink on soccer performance, sprint performance, jump power and shot power?

This Research is Important because:

- There is currently a paucity of research assessing the impact of sports drinks containing a combination of both carbohydrate and caffeine on soccer, and more specifically soccer-specific skill performance. There is substantial evidence that caffeine can enhance endurance performance in general. However, there is little evidence of it's impact on reducing the effects of performance-related fatigue (ie game-related) on skill throughout an endurance event that requires a maintenance of skill (ie in team sports). Therefore this study will extend the scientific literature in this area and potentially lead to improved nutritional and hydration practices in team sports requiring both endurance and skill, such as soccer**.**

Participation:

- The target population for this study is elite male soccer players.
- Participation in this project is entirely voluntary.
- Whether you choose to participate or not will have no effect on your position on the team or how you will be treated.
- If a potential participant is a known diabetic they should not participate without their doctor's approval as blood sugar levels are affected by sports drinks.

Procedures:

The study will be a double-blind, randomized crossover design consisting of 3 separate trials where participants act as their own control. The study will include collecting data from selected volunteers from the Vikes men's soccer team during a team scrimmage. Each trial consists of an intersquad match where the 2 groups of team players will remain the same for each trial, and skill tests will be performed throughout the match. Prior to the first day of testing, participants will attend a familiarization session with the methods/protocols so they are comfortable performing these protocols for the subsequent trials.

1) Participants will be directed to complete a questionnaire where they will record fluid,food, and supplement intake for 48 hours prior to testing and replicate their dietary intake prior to each trial. Some medical information will also be collected using the par q form.

2) Upon arriving in the laboratory, participants will void and a urine sample will be collected for later analysis of urine specific gravity by a handheld refractometer, and a small aliquot will be frozen and stored for later analysis of caffeine content (collected samples will only be analyzed for caffeine). Nude body weight will then be self-measured in a private room. Following this, HR monitors will be attached to the chest using standard procedure. Saliva samples will also be collected and frozen for later analysis of caffeine content.

3) 45 minutes prior to commencement of exercise, participants will consume 5 ml/kg BM of a randomly assigned, double-blind sports drink (placebo, 6% carbohydrate, 6% carbohydrate + 5 mg/kg body mass caffeine). All drinks will be matched for sweetness, electrolytes, texture, colour, taste and flavour.

4) After consumption of the sports drink participants will perform a 40 minute standardized warm-up and stretching period, during which HR will be monitored. Prior to the match beginning, blood lactate will be measured and the 15-point Rating of Perceived Exertion (RPE), and a Perceived Fatigue Scale will be completed. All testing protocols will be carried out on a grass soccer field with test-related grids and distances marked out with cones.

5) Before beginning the match, during the halftime break, and after the match, participants will complete the Loughborough Soccer Passing Test (LSPT), which consists of 16 passes against targets, performed within a circuit of cones and grids (12 x 9.5 m grid) as quickly and accurately as possible. Participants will be observed and results for accuracy, penalty accumulation and time to completion will be recorded.

6) Concurrently with the LSPT, the shot power test protocol will be performed before the match, during the halftime break and after the match. Five balls will be lined up 10 m away from a soccer goal, and participants will have to hit all five balls with maximal power, consecutively. Ball speed will be measured with a sports radar gun with the best speed recorded. 20 m sprint times will be measured in one direction by dual-beam electronic timing lights concurrently with the LSPT (before the match, during half-time and post-match). The countermovement jump will be performed before and after the match on an electronic jump mat where participants will get 2 attempts with the best height recorded.

7) After completion of the initial skill tests the match will begin, during which HR will continuously recorded and downloaded onto a computer at the end of the session. Every 15 minutes 3 ml/kg BM of fluid (predetermined and consistent throughout the process, one of the three sports drinks) will be consumed, blood lactate will be measured and RPE and PFQ will be assessed. Two designated tables will be set up at the side of the field where blood lactate will be measured (table 1) and fluids will be provided (table 2) to players during games. Blood lactate will be collected by the pi, supervisor or trained ra (gloves will be worn and both the table and participant’s finger will first be sanitized with an alcohol swab before being pricked) using an auto-lancet and analyzed with a lactate pro. Used materials will be disposed of in a designated biohazard/sharps container.

8) Each match half will be 45 minutes in duration with a 15 minute halftime break during which the LSPT and shot power protocol will be assessed as well as blood lactate, RPE and PFQ. Another 3 ml/kg BM of the specified sports drink will also be consumed.

9) On the completion of the last trial, participants will be asked to indicate whether they could identify which sports drink they had been given during each exercise testing trial.

- **Duration:** Participants will perform three trials involving coming in an hour prior to a ninety minute soccer match, then completing skill tests after the match (approximately 3 hours for each trial). Additionally, participants will familiarize themselves with the testing protocol prior to the trials (approximately 1.5 hours). The total time requirement will therefore be approximately 10.5 hours, however, this will only be an additional 4.5 hours to regular team practices, during which the study will be run.

- **Location:** UVic Centennial stadium (Team locker room and field) and adjacent field.

- **Inconveniences:**
  1) Participants will be required to complete the testing protocols (lspt, countermovement jump, 20 m sprint, shot power) and also have their finger pricked a total of 7 times per test session for lactate measurement which will be only minor stresses compared to that experienced during a regular training session or intersquad scrimmage.

  2) Respondent burden to complete food and hydration diaries. Participants may find recording all food and beverages to be time consuming.

  3) Participants will have to refrain from alcohol, caffeine and intense exercise for 24 hours prior to testing and must replicate their dietary intake 24 hours prior to each trial for every trial.

  4) Participants will be asked to provide urine and saliva samples, and a nude body weight measurement prior to each match.

Benefits:

1) The results from this study will help the participants to understand the importance of hydration prior to and during soccer games. Additionally, the results will help the participants select a sports drink which maximizes personal performance.

2) Understanding the potential effects of caffeine combined with carbohydrate in a hydration solution (sports drink) will help soccer players at all levels, as well as athletes in other sports, to maximize their full potentials by potentially reducing fatigue.

3) There is currently a lack of research, especially with soccer, investigating the effects of caffeine and carbohydrate combined in a sports drink. This research will therefore help to build the body of knowledge surrounding this topic.

Risks:

- There are no known or anticipated risks to you by participating in this research over and above regular training sessions.

- **Risk(s) will be addressed by:** Researchers, the soccer coach, and a student physiotherapy aid (associated with the athletic team and not part of the research team) will be present in the case of any injuries, and the participant will be helped to reduce and prevent further injury. Participants will also be provided with plenty of fluid throughout the protocol to help reduce fatigue.

Withdrawal of Participation:

- You may withdraw at any time without explanation or consequence.
- Should you withdraw, with your written permission, your data will be used partially in determination of the results if you complete at least two of the three trials. If you complete less than 2 complete trials then your data will not be used in the analysis and will be destroyed.
- Agreement will be obtained through the consent form which will be provided prior to each trial. In this document will be information regarding participant withdrawal and their choice of data usage.

Continued or On-going Consent:

- At the start of each visit, participants will be reminded they are free to withdraw from the study during any point in time, with no consequences or explanation required.

Anonymity and Confidentiality:

- Names and personal information will not be released to anybody other than the investigators. Once the data has been collected the participants' data and samples will be identified only with a numerical code. From this point on, no data will contain names, and all samples and results will be interpreted and displayed as group data and individual data by their assigned code. Only the PI and graduate supervisor will have the ability to identify the individual participant codes**.** All data will be stored either on a password protected computer or in a locked filing cabinet in dr gaul's office for 5 years following completion of the study. after this time data will be destroyed by either shredding paper files or permenantly deleting computer files.

- Due to the nature of the study where participants will be performing the protocols in close proximity to each other it is not possible to prevent participants from viewing their teammates, however, participants will not be given other participants scores. Secondly, since the members of the UVic men's soccer team will be involved in the study, either as participants or bystanders playing in the match it will also be likely that confidentiality will not be fully protected due to the size of the sample from which participants are drawn. Lastly, the UVic men's coach will be helping to coordinate the games in each trial which may also limit confidentiality.

- To help limit breaches of confidentiality, scores for all participants will be kept private between the researchers. A letter will be send to the coach (Bruce Wilson) informing him that athletes must be given the option of participation and cannot ethically be forced into participation against their will, and their participation in the study will have no repercussions on their ranking or selection onto the team.

- Urine and saliva samples will only be analyzed for caffeine content. After these two analyses, samples will be disposed of in an appropriate manner as directed by biosafety regulations. All samples will be labeled by code.

Research Results will be Used/Disseminated in the Following Ways:

- Findings will be used to publish papers in peer-reviewed journals. Abstracts will be submitted to appropriate academic conferences for dissemination of results.
- Findings will be used for the primary investigator's graduate thesis and will be available for viewing on the internet at the uvic library's d space.
- Each participant will get a copy of their own scores and results.

Questions or Concerns:

- Contact the researcher(s) using the information at the top of page 1;
- Contact the Human Research Ethics Office, University of Victoria, (250) 472-4545, ethics@uvic.ca

<u>Consent:</u>

Your signature below indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers.

______________________	______________________	____________
Name of Participant	*Signature*	*Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Visually Recorded Images/Data: Participant to provide initials:

- Photos may be taken of me for: Dissemination* ________
- Videos may be taken of me for: Dissemination* _________

*Even if no names are used, you may be recognizable if visual images are shown as part of the results.

Appendix C: RPE Scale

Instruction on RPE and RPE Scale

You are now going to be participating in a soccer match, throughout which we will measure several physiological and skill-specific parameters. We would also like you to tell us how *hard* you think you are working. We call this your **rating of perceived exertion** (or RPE). By this we mean the total amount of exertion, combining sensations and feelings of physical stress and effort. Do not concern yourself with any one factor such as leg fatigue, shortness of breath, or the work intensity, but rather please concentrate on your *total inner feelings of exertion*. We will ask you for your ratings of perceived exertion prior to the match, every 15 minutes during the match, during halftime and after the match. At these times, we will show you a chart and you may indicate your perception of effort by pointing to the appropriate value.

Rating of Perceived Exertion

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

Appendix D: Fatigue Scale

Instruction on Fatigue and Fatigue Scale

You are now going to be participating in a soccer match, throughout which we will measure several physiological and skill-specific parameters. We would also like you to tell us how *fatigued* you think you are **RIGHT NOW**. By this we mean the total amount of physical and mental fatigue. We will ask you for your level of fatigue prior to the match, every 15 minutes during the match, during halftime and after the match. At these times, we will show you a chart and you may indicate your level of fatigue by pointing to the appropriate value.

0	Not at all fatigued
1	
2	
3	
4	
5	Moderately fatigued
6	
7	
8	
9	
10	As fatigued as I have ever been

Appendix E: Nutrition Survey and Food Recording Forms

PLAYER CONTACT INFORMATION:

Player's Name		**Date of Birth**	1-Jan-00
Home Address			
Phone		**Fax**	
Mobile phone		**Email**	

MEDICAL HISTORY (Injuries, Kidney, Heart, Diabetes etc):

Comment on any medical history		
TYPE	**DATES**	**DETAILS**

SUPPLEMENT USE:

Are you currently taking any vitamins, herbs, caffeine, creatine, amino acids or other dietary supplements (i.e. powders, pills, foods, or drinks)? Please list:		
Name of supplement	**Amount**	**Frequency of Use**
Caffeine		

DAILY HYDRATION PRACTICE:

On a regular day, what types (i.e. juice, water, milk, coffee, alcohol, energy drinks) and how much liquid do you consume (i.e. 1 cup)? Please list:

Name of Liquid	Amount

SPORT NUTRITION PRACTISE:

Pre-training Eating Plan

- Do you hydrate before a game or hard training session? Yes or No

  Explain how much you drink and when you drink it and what you drink:

  ____

- What you typically eat before a game or long training session? (eg. favorite meal?)

Game Time: ____________ Eating Time: _____________

Food Amount

______________________________________ ____________

______________________________________ ____________

During Exercise

- Do you drink during practice? Yes No If yes, how much and what do you drink?_______________
- Do you drink during a game? Yes No If yes, how much and what do you drink?_______________

Recovery Eating Plan

- Do you drink after practice? Yes No If yes, how much and what do you drink?
- What you typically eat after a game or hard practice, how much and how soon after completing exercise:

Time After Game Finish Time: _________

Food Item Amount Carb Content (use

attached table)

(ex. Granola bar) *2* *23g*

____________________________________ ____________ ____________

____________________________________ ____________ ____________

Have you ever had problems with muscle cramping Yes No

Sample Form 1 (full forms included a total of 6 days)

FOOD RECORDING FORMS:

Using the following forms on the next 6 pages to track everything you ate and drank over the 2 days prior to the first day of testing. This food and fluid intake should be matched for the 2 days prior to the next two days of testing.

PRE-TRIAL 1: DAY #1 FOOD and FLUID INTAKE:

DATE OF FOOD RECORDING:

TIME	FOODS	Approx Amount
Eg. 8:00am	Bagel with cream cheese and orange juice	1 large bagel with 1 cup juice

Appendix F: Data Collection Schedule

Pre-Match:

- Collection of Urine sample – analysis via handheld refractometer and stored in containers
- Collection of Saliva – stored in salivettes
- Measurement of nude body weight
- Attachment of HR monitors and accelerometers
- Consumption of 5 ml/kg BM of a randomly assigned sports drink
- Blood lactate, PFS, RPE will be measured (pairs [1 player from each team] will be placed in order for measurement)
- Players will warm-up
- Players will perform:
  - CMJ (1 person), Shot Power (2 people), 20 m Sprint (2 people), LSPT (2 people per grid x 2 = 4 people [possibly 3 people per grid]). Order will be determined for pairs.

Match:

- Every 14-17 minutes:
  - Take 2 players at one time (1 from each team) approx 30 secs for each pair. 6 Pairs = 3 mins total. Order has to remain the same as pre-match.
  - Blood lactate (12 tips) (2 people), PFS, RPE (2 people) will be measured
  - Consumption of 3 ml/kg BM sports drink (3 people)

Half-time:

- Blood lactate (12 tips), PFS, RPE will be measured (ordered)
- Consumption of 3 ml/kg BM sports drink
- Players will perform:
  - Shot Power (2 people), 20 m Sprint (2 people), LSPT (2 people per grid x2 = 4 people). Same order as pre-match.

Post-Match:

- Blood lactate (12 tips), PFS, RPE will be measured (ordered)
- Players will perform:
  - CMJ (1 person), Shot Power (2 people), 20 m Sprint (2 people), LSPT (2 people per grid x2 = 4 people). Same order as pre-match.
- HR monitors and accelerometers removed
- Measurement of nude body weight

Appendix G: Sports Drink Nutritional Information

Powerade Zero Ion 4

Mixed Berry (PLA):

MIXED BERRY

flavor + other natural flavors

Nutrition Facts

Serving Size: 8 fl oz (240 mL)
Servings Per Container: 4

Amount Per Serving	
Calories 0	
	% Daily Value*
Total Fat 0g	**0%**
Sodium 100mg	**4%**
Potassium 25mg	**1%**
Total Carbohydrate 0g	**0%**
Protein 0g	
Vitamin B3 10% •	Vitamin B12 10%
Vitamin B6 10% •	Magnesium †

† Not a significant source of calories from fat, saturated fat, trans fat, cholesterol, dietary fiber, sugars, vitamin A, vitamin C, calcium and iron.

* Percent Daily Values are based on a 2,000 calorie diet.

MIXED BERRY FLAVOR + OTHER NATURAL FLAVORS

Powerade Ion 4 Mixed

Berry (CHO/CHO+CAF):

Nutrition Facts

Serving Size 8 fl oz (240 mL)
Servings Per Container 4
Calories 50 (Energy)

Amount Per Serving	% Daily Value*
Total Fat 0g	**0%**
Sodium 100mg	**4%**
Potassium 25mg	**1%**
Total Carbohydrate 14g	**5%**
Sugars 14g	
Protein 0g	

Vitamin B3 10% • Vitamin B6 10%
Vitamin B12 10% • Magnesium †

† Not a significant source of calories from fat, saturated fat, trans fat, cholesterol, dietary fiber, vitamin A, vitamin C, calcium and iron.

*Percent Daily Values are based on a 2,000 calorie diet

FOR 32 FL OZ PACKAGE

Appendix H: Post Testing Questionnaire

Did you notice any differences or similarities between the three sports drinks consumed during each trial (e.g. flavour, texture on tongue, colour, sweetness)?

After consumption of each of the three sports drinks did you notice any psychological or physiological differences in your performance (e.g. more energy, less fatigued, concentration levels, perceived performance)?

Appendix I: LSPT Target Order

	1	2	3	4
1	blue	blue	green	white
2	blue	white	white	blue
3	white	green	green	blue
4	red	blue	white	white
5	white	white	red	red
6	red	green	white	red
7	red	white	green	white
8	green	green	blue	blue
9	green	blue	green	red
10	white	red	blue	green
11	green	white	blue	green
12	green	blue	red	red
13	blue	green	blue	white
14	red	red	red	green
15	white	red	white	blue
16	blue	red	red	green

	5	6	7	8
1	Red	White	Blue	Green
2	Green	Blue	Red	White
3	White	White	Blue	Blue
4	White	Blue	Blue	White
5	Red	Red	White	Blue
6	Blue	Green	Green	Red
7	White	Blue	Red	Blue
8	Red	White	Red	Red
9	Green	Blue	Green	Green
10	Red	Red	White	Green
11	Blue	Green	Green	White
12	Green	Red	White	Red
13	Blue	Red	Blue	White
14	White	Green	White	Red
15	Green	White	Red	Green
16	Blue	Green	Green	Blue

Appendix J: Sample LSPT Data Collection Sheet

Player	Scoring Criteria		Completion time (s)
*	ball hits **CONE**		
	outside **PASSING ZONE**		
	CROSS 2 inner **LINES**		
	HAND ball		
*	ball hits **CONE**		
	outside **PASSING ZONE**		
	CROSS 2 inner **LINES**		
	HAND ball		
	ball hits **CONE**		
	outside **PASSING ZONE**		
	CROSS 2 inner **LINES**		
	HAND ball		
	ball hits **CONE**		
	outside **PASSING ZONE**		
	CROSS 2 inner **LINES**		
	HAND ball		
	ball hits **CONE**		
	outside **PASSING ZONE**		
	CROSS 2 inner **LINES**		
	HAND ball		
	ball hits **CONE**		
	outside **PASSING ZONE**		
	CROSS 2 inner **LINES**		
	HAND ball		

Appendix K: Sample Data Collection Sheet

Player	Pre-match			15 mins			30 mins			Halftime		
	Lac.	RPE	Fat.	Lac.	RPE	Fat.	Lac.	RPE	Fat.	Lac.	RPE	Fat.
	60 mins			75 mins			90 mins					
	Lac.	RPE	Fat.	Lac.	RPE	Fat.	Lac.	RPE	Fat.			

Appendix L: Sample Participant Results Form

University of Victoria | School of Exercise Science, Physical & Health Education

THE EFFECTS OF SPORTS DRINKS CONTAINING CAFFEINE AND CARBOHYDRATE ON SOCCER-SPECIFIC SKILL PERFORMANCE DURING MATCH-

About Your Results:

Thank you for your participation in this study. Your personal results and the study averages (all participants) are summarized in this report. Trial 1 (Tuesday) was the Placebo Trial (Powerade Zero Mixed Berry), Trial 2 (Thursday) was the Caffeinated-Carbohydrate Trial (Powerade Mixed Berry plus caffeine), and Trial 3 (Saturday) was the Carbohydrate Trial (Powerade Mixed Berry). All sports drinks appeared to be adequate at preventing fatigue and maintaining fluid balance. The addition of caffeine did not appear to have any negative effects on performance, and may in fact have beneficial effects such as increasing one's feelings of energy levels. Importantly, taking in enough fluid is more critical than the type of fluid ie. caffeinated sports drink vs regular sports drinks vs water.

The following data is your own personal data and will not be shared with anybody else. Your coach, Bruce Wilson will only be receiving team averages for all of the following scores.

If you have any questions about your results, please feel free to contact the study investigators: Marc Jacobson (marcj@uvic.ca) or Dr. Kathy Gaul (kgaul@uvic.ca).

Skill Test Results

Skill Test Results		
Skill Test	**Your Results**	**Team Average**
20 m Sprint	secs	3.29 secs
Shot Power	km/hr	91.7 km/hr
Vertical Jump	inches	22.1 inches
Loughborough Soccer Passing Test	secs	60.8 secs

About Skill Test Results:

1. You have been provided with your best result across all 3 trials.

2. The **Team Average** is a mean of all 12 players across all 3 trials.

Hydration Results

Hydration Results			
		Your Results	**Team Average**
Pre-Match USG	*Game 1*	mmol/L	1.019 mmol/L
	Game 2	mmol/L	1.018 mmol/L
	Game 3	mmol/L	1.023 mmol/L
Sweat Rate	*Game 1*	L/hr	1.06 L/hr
	Game 2	L/hr	1.11 L/hr
	Game 3	L/hr	0.83 L/hr
Average Body Mass		Kg	73 Kg
Average Fluid Consumption per Trial		L	1.46 L
% Body Mass	*Game 1*	%	0.2%

Loss	*Game 2*	%	0.3%
	Game 3	%	-0.3%

About Hydration Results:

1. USG (Urine Specific Gravity) is a marker of your hydration status. Athletes with a USG > 1.020 should aim to consume more fluid regularly (water and/or milk are best!) BEFORE practice or matches. Urine colour can help you indentify your hydration status (Light colour - hydrated; Dark - potentially dehydrated). Guidelines recommend 5-7 ml per kg of body weight at least 4 hours prior to exercise. If urine colour is still dark, drink 3-5 ml per kg body weight of water, milk or sport drink about 2 hours before exercise (this is about 1 cup or 250-300 ml of fluid). You should aim to constantly sip fluids towards the start of the practice/match, using urine colour as an indicator of hydration status. **With very few exceptions, everybody on the team was considered to be dehydrated during all 3 games**.

2. Percent (%) Body Mass Loss represents the amount of sweat lost and replaced during the match. Research has shown losing more than 2.0% of body mass during exercise can result in performance decrements. Athletes losing 1.0% or more should increase their fluid (water, diluted juice or sport drink) consumption DURING exercise. Aim for 150-250 ml per 20-30 mins of exercise.

3. Sweat Rate (L/hour) represents the amount of sweat lost and replaced (through drinking) during each match. Athletes with high sweat rates combined with high percent body mass loss should aim to drink more during exercise. While the amount of fluid you consumed during each trial may have seemed excessive, this is actually the minimal amount you should all be drinking during a competitive match.

Exercise Intensity Testing Results

Exercise Intensity Results				
		Your Results	**Team Average**	**Comment**
Mean Heart Rate	*Game 1*	bpm	157 bpm	*Your estimated HR Max =* bpm
	Game 2	bpm	154 bpm	*You were working between*: %-% of your HR Max
	Game 3	bpm	149 bpm	*Team average work rate*: 74%-80% of HR Max
Percent of Time Spend in Different Intensity Zones				
Very Hard	*Game 1*	%	10%	90-100% HR Max
	Game 2	%	7%	
	Game 3	%	5%	
Hard	*Game 1*	%	56%	75-90% HR Max
	Game 2	%	53%	
	Game 3	%	47%	
Moderate	*Game 1*	%	31%	60-75% HR Max
	Game 2	%	36%	
	Game 3	%	42%	
Light	*Game 1*	%	3%	0-60% HR Max
	Game 2	%	4%	
	Game 3	%	7%	

About Exercise Intensity Results:

1. Mean Heart Rate represents your average heart rate (beats per minute) over each match. The higher the value, the harder your average work rate during the practice session. Resting heart rate is usually around 60-80 beats per minute.

2. Percent of Time Spent in Different Intensity Zones represents the accumulated (not continuous) time spent at different intensity levels based on a percentage of your personal maximum heart rate (predicted by 220 bpm - age).