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Ingesting a 12% carbohydrate-electrolyte beverage before each half of a soccer-match simulation facilitates retention of passing performance and improves high-intensity running capacity in academy players.

Paola Rodriguez-Giustiniani [a], Ian Rollo [b], Oliver C. Witard [a], Stuart D.R. Galloway [a]

[a] Physiology, Exercise and Nutrition Research Group, Faculty of Health Sciences and Sport University of Stirling, United Kingdom.

[b] Gatorade Sports Science Institute, PepsiCo Global Nutrition R&D, United Kingdom.

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Corresponding author:

Dr Stuart Galloway

Physiology, Exercise and Nutrition Research Group

Faculty of Health Sciences and Sport

University of Stirling

Stirling

FK9 4LA

Telephone: +44 (0) 1786 466494

E-mail: s.d.r.galloway@stir.ac.uk

Abstract

This study investigated the influence of ingesting a 12% carbohydrate plus electrolyte (CHO-E) solution providing 60 g of carbohydrate before each half of a 90-min soccer match simulation (SMS) protocol on skill performance, sprint speed and high-intensity running capacity. Eighteen elite academy (age 18±2 y) soccer players ingested two 250 mL doses (pre-exercise and at half-time) of a 12% CHO-E solution or electrolyte placebo administered in a double-blind randomised cross-over design. During an indoor (artificial grass pitch) SMS, dribbling, passing and sprint performance were assessed, and blood was drawn for glucose and lactate analysis. High-intensity running capacity was assessed following the SMS. Dribbling speed/accuracy and sprint speed remained unchanged throughout the SMS. Conversely, passing accuracy for both dominant (mean % difference (95% CI): 9 (3-15)) and non-dominant (mean % difference (95% CI): 13 (6-20)) feet was better maintained during the SMS on CHO-E ($p<0.05$), with passing speed better maintained in the non-dominant foot (mean % difference (95% CI): 5.3 (0.7 to 9.9), $p=0.032$). High-intensity running capacity was greater in CHO-E vs. placebo (mean % difference (95% CI): 13 (6 to 20), $p=0.010$). Capillary blood glucose concentration was higher in CHO-E than placebo at half-time (CHO-E: 5.8±0.5 mM vs. placebo: 4.1±0.4 mM, $p=0.001$) and following the high-intensity running capacity test (CHO-E: 4.9±0.4 mM vs. placebo: 4.3±0.4 mM, $p=0.001$). Ingesting a 12% CHO-E solution before each half of a match can aid in the maintenance of soccer-specific skill performance, particularly on the non-dominant foot, and improves subsequent high-intensity running capacity.

Keywords: Carbohydrate, skill, exercise, metabolism, football

Introduction

Soccer is characterized by prolonged intermittent activities involving multiple sprints, high intensity actions and technical motor skills. As a result, fatigue in soccer is a complex phenomenon underpinned by central and physiological mechanisms, and is most prominent during the latter stages of a match (Mohr et al., 2005; Reilly, 1997). At the metabolic level, the decline in muscle glycogen content during a soccer match (Krustrup et al 2006) is associated with a reduced work rate (Ostojic and Mazic, 2002). Since the brain is dependent on a supply of blood glucose (Duelli and Kuschinsky, 2001), enhancing exogenous carbohydrate availability could preserve central nervous system integrity (Meeusen and Decroix, 2018) and help to attenuate the loss of motor skill performance (Russell et al, 2012). Moreover, the benefit of carbohydrate feeding on peripheral fatigue during intermittent exercise is evidenced by the previously reported better maintenance of high-intensity running capacity (McGregor et al 1999).

Several studies have demonstrated that consuming carbohydrate beverages before and at regular intervals during sporting activities improves subsequent high-intensity exercise capacity (Phillips et al. 2012; Nicholas et al. 1995; Davis et al. 2000; Kingsley et al 2014) and can also aid the retention of skill performance (Harper et al. 2017). This benefit of carbohydrate feeding has been demonstrated in soccer (Ali et al., 2007; Currell et al., 2009; Russell et al., 2012) and in other skill-based sports such as tennis (McRae and Galloway, 2012) and squash (Bottoms et al 2007) where weaker shots on the backhand side were most affected. In relation to soccer, from a practical perspective, carbohydrate beverages can only be supplied to players during the warm-up, and during scheduled breaks in play (Clarke, 2008). Thus, opportunities available for soccer player to ingest sufficient carbohydrates (~30-60g/h) are limited (Ali and Williams, 2009; Cermak and van Loon, 2013).

A potential strategy to overcome the limited opportunities to consume carbohydrate during soccer match-play is to administer highly concentrated carbohydrate beverages. In this context, the negative consequences of ingesting concentrated carbohydrate solutions on gastro-intestinal comfort (Clarke, 2008) can be partially alleviated by the ingestion of maltodextrin plus fructose combinations (O'Brien and Rowlands, 2001; Jeukendrup, 2010). Accordingly, a recent study simulated a real-world soccer context by providing soccer players with a highly concentrated (12%) maltodextrin:fructose formulation at the end of the warm-up and at half-time (Harper et al 2017). Skill performance and intermittent endurance performance were improved on the 12% carbohydrate trial compared with placebo, as evidenced by the maintenance of dribbling speed, and self-paced soccer-specific exercise performance during the latter stages of the soccer match simulation (Harper, 2017). Crucially, players reported minimal gastro-intestinal discomfort despite the provision of a 12% concentrated carbohydrate solution.

While an excellent study, the work of Harper et al. (2017) does raise several applied questions. First, the impact of carbohydrate ingestion *per se* was not isolated since players also were dehydrated by ~2% body mass during both trials. Second, participants ingested only a small standardised breakfast ~135-min before exercise, and performed the match simulation in the morning rather than in the afternoon when professional youth team games or senior fixtures are normally scheduled in Scotland. Third, participants were University standard soccer players rather than young professionals and no assessment of skill performance was performed on dominant and non-dominant feet. To follow-up the preliminary work of Harper et al. (2017) we set out to control for many of these additional factors i.e. maintain body mass loss within 1%, adopt pre-match feeding guidelines prior to an afternoon kick-off, assess outcomes in professional youth players, and distinguish between potential effects in dominant and non-dominant feet. Therefore, the primary aim of the present study was to provide further practical insight into the influence of ingesting a 12% carbohydrate-electrolyte beverage on soccer skill performance and high-intensity running capacity in professional youth academy soccer players. We hypothesised that ingesting 250 ml of a 12% carbohydrate-electrolyte beverage before kick-off and during the half-time period, versus the ingestion of an equivalent volume of a placebo-electrolyte beverage, would improve the retention of soccer-specific skills (dribbling speed and accuracy; passing speed and accuracy), sprint speed, and anaerobic endurance running capacity during and after a 90-min soccer match simulation (SMS) conducted in a cool environment.

Methods

Participants

Eighteen male well-trained soccer players (7 midfielders, 6 defenders and 5 strikers) were recruited from local football academies to participate in this investigation. *A priori*, we conducted a power calculation (GPower version 3 software) of appropriate sample size based on previously published data (Harper et al., 2017). This calculation revealed that 14 participants (using a crossover design) are required for 80% power with a mean difference in skill performance score of 0.8×SD and significance set at $p<0.05$. All players had 5 or more years of playing experience, had been training consistently for one year or more and were free from injury at the time of the recruitment and testing (age: 18±2 years, body mass: 73.4±6.0 kg, stature: 177.7±4.8 cm, body mass index: 23.1±1.0 $kg \cdot m^{-2}$, estimated VO_{2max}: 55.9±1.5 $ml \cdot kg^{-1}$). The experimental procedures were approved by the University of Stirling Research Ethics Committee.

Study Design

Players attended two preliminary study visits (VO_{2max} estimation and full trial familiarisation) before undertaking two main trials (carbohydrate-electrolyte; CHO-E; and placebo) with beverages administered in a double-blind randomised, crossover manner. All visits were separated by 7-14 days. A shuttle running test protocol was used to estimate VO_{2max} (Yo-Yo IR1; Bangsbo et al., 2008), with the level obtained used to determine the speed corresponding to 40%, 50%, 85% and 90% of VO_{2max} for use during and after the soccer match simulation (SMS) protocol. Players followed 48-h habitual diets (avoiding caffeine and alcohol) and recorded food consumed (analysed retrospectively; Nutritics, Nutritics Ltd., Dublin, Ireland) before the familiarisation visit. The pre-familiarisation trial diet was replicated for both main trials. Players refrained from strenuous exercise 24-h before the familiarisation trial and main trial days. On the familiarisation visit, players undertook a 10-min warm-up (incorporating light aerobic activity, dynamic stretches, 20-m sprints), before completing the 90-min SMS protocol (Russell et al., 2011) followed by a high intensity (90% VO_{2max}) running test to exhaustion. All testing sessions were performed on an indoor artificial grass pitch.

Experimental trials

Experimental trials were scheduled to start in the afternoon to reflect times at which this cohort typically engages in soccer matches (Figure 1A). At the training ground, researchers provided players with a standardised breakfast (2 eggs, 2 slices of bread, 1 medium-sized banana providing 423 kcal, 46g carbohydrate, 26g protein, 14g fat) and then a pre-trial standardised meal 2-h before beginning the main trials providing 459 ± 97 kcal, 2g carbohydrate $\cdot$ kg^{-1} of body mass (pasta in a tomato sauce) plus 500 ml of water.

Soccer players performed the 90-min SMS that incorporates six blocks of activity equally split across two 45-min periods (Figure 1B). To assess dribbling performance, players dribbled a ball between 6 cones (3-m apart) towards a camera as fast and precisely as possible. For the sprint assessment, players ran as fast as possible through timing gates (Brower, USA) placed 15-m apart, with a 1-m run-in. At the end of each of the 12 blocks of activity, players directed alternate passes towards target zones (2.0-m × 1.0-m) placed to the left and right at a distance of 7.9 m. The passing target was divided into three equally sized areas, with the center area worth 10 points and the two areas at either side worth 5 points. Passes that missed the areas on the target were scored as zero. The bouts of passing consisted of 8 passes (4 with the dominant foot followed by 4 with the non-dominant foot).

Digitisation (Kinovea version 0.8.15; Kinovea Org., France) yielded dribbling speed, dribbling precision, passing accuracy and passing speed. Dribbling, sprint, and passing performance were expressed as means for each 15-min of the protocol. After the SMS protocol was completed, players performed a fixed high-intensity running capacity test to the point of volitional fatigue. The test consisted of 20-m shuttles at a speed corresponding to 90% of their VO_{2max} until volitional exhaustion (the duration of the test ranged from 1 min 21 sec to 1 min 42 sec). Exhaustion was defined as the inability to maintain the required pace for two consecutive shuttles. Running capacity performance was expressed as the total running distance completed during the test. Following completion of exercise, body mass loss was calculated from the difference between pre and post-exercise body mass (SECA Quadra 808), corrected for fluid intake and urine output. Abdominal discomfort ratings (nausea, fullness, bloatedness) were assessed routinely by asking players to place a vertical line on a 100-mm visual analogue scale (VAS).

Beverages (250 ml) were ingested on two separate occasions. First, 15-min before beginning the SMS and second, immediately upon completing the first half (15 min before beginning the second half). The CHO-E and placebo beverages were ready-to-drink formulations (PepsiCo International Ltd., USA) matched for flavor, color and texture containing comparable amounts of Na^+ (41 mg · 100 ml^{-1}). The CHO-E drink was a 12% solution (blend of maltodextrin and sucrose, 60 g · 500 ml^{-1}, Gatorade Football Energy, PepsiCo Inc) delivering 40 g of carbohydrate per hour during the SMS. The placebo drink was non-caloric and taste-matched using artificial sweeteners. Although water was made available *ad libitum* no player consumed any water during either trial.

Analytical Procedures

Capillary blood samples (30-µl aliquots) were dispensed into 300 µl of ice cold 0.3-N perchloric acid and shaken vigorously before being placed in an ice bath. On completion of the trial, samples were centrifuged and stored at –70°C until analysis. Analysis of blood glucose and lactate concentrations were completed using the method of Maughan (1982). Urine samples were collected into a 0.5-L plastic container and total mass (to the nearest 0.1 g) assessed to determine urine volume. A 5-mL aliquot was then dispensed into a plain screw-capped tube and stored at 4°C until analysis of osmolality on the evening of the trial days (freezing point depression method, Löser Micro-Digital Osmometer M15).

Statistical Analysis

Data are presented as mean (SD) with 95% confidence intervals for mean differences shown in the text. Statistical significance was set at $p<0.05$. Effect sizes based on using Cohen's d with threshold values for trivial, small, moderate, large, very large, and extremely large effects set at <0.2, 0.2. 0.6, 1.2, 2.0, and 4.0 (Hopkins et al 2009) were reported along with a written description. Performance variables were analyzed using two-way repeated measures analysis of variance (ANOVA) whenever data contained multiple time points. When a significant time × trial interaction was observed, post-hoc pairwise comparisons with Bonferroni confidence-interval adjustment were performed to identify at what time point(s) differences existed between conditions. If no time × trial interaction was observed, main time or trial effects only were reported. Paired samples t-tests were used to examine mean differences between trials when data were collected at one time point only (e.g. high-intensity anaerobic endurance running capacity).

Results

No significant trial order effect was observed for any performance variable, hence any differences between conditions were considered to be due to treatment effects. Two out of the 18 participants correctly identified the order of the treatments. Dietary analysis revealed no difference in nutritional intake between CHO-E (total energy: 2120±532 kcal · d^{-1}; carbohydrates: 290±63 g · d^{-1}; proteins: 101±47 g · d^{-1}; fats: 70±17 g · d^{-1}) and placebo (total energy: 2345±437 kcal · d^{-1}; carbohydrates: 293±62 g · d^{-1}; proteins: 89±27 g · d^{-1}; fats: 87±27 g · d^{-1}; all $p>0.05$) trials in the 48-h period before the main experimental trial days. Ambient temperature (CHO-E: 6±1 °C, placebo: 6±1 °C) and humidity (CHO-E: 59±10 %, placebo: 61±13 %) were similar between trials ($p>0.05$).

Physiological responses to soccer match simulation

There was no significant time × trial interaction for heart rate (HR), ratings of perceived exertion (RPE) and hydration status responses to the SMS ($p>0.05$). HR increased from the 15-min time point (144±9 bpm, CHO-E and placebo trials combined) throughout the SMS protocol (time effect: $p=0.01$), rising to 158±6 bpm (CHO-E and placebo combined) by the end (90 min) of the SMS protocol, with no difference between trials ($p=0.42$). Likewise, RPE scores increased from the 15-min time point (10±2, CHO-E and placebo trials combined) throughout the SMS protocol (time effect: $p=0.01$), rising to 15±3 (CHO-E and placebo combined) by the end (90 min) of the SMS protocol, with no difference between trials ($p=0.17$). No differences were observed for any of the fluid balance and hydration status variables recorded pre and post the SMS protocol (Pre-trial urine osmolality: 513±159 mOsm · kg^{-1}; Post-trial urine osmolality: 464±137 mOsm · kg^{-1}; Body mass loss: 0.7±0.4%, all $p>0.05$ for CHO-E and placebo trials combined).

Dribbling speed and accuracy

Dribbling speed did not decline throughout the SMS on both CHO-E and placebo trials (Figure 2A), with no time × trial interaction ($p=0.42$), time ($p=0.49$) or trial ($p=0.38$) effects. The mean difference (95% CI) in dribbling speed between CHO-E and placebo trials was 0.03 (-0.24 to 0.09) $m \cdot s^{-1}$ with an effect size (Cohen's d) of 0.2 (small effect). Likewise, dribbling accuracy did not change over time in either CHO-E or placebo trials (Figure 2B) and the was no time ($p=0.54$), trial ($p=0.41$) or time × trial interactions ($p=038$). The mean difference (95% CI) in dribbling accuracy between trials was -0.03 (-0.23 to 0.16) m with an effect size (Cohen's d) of 0.1 (trivial effect).

Passing accuracy and speed

There was a significant time × trial interaction (p=0.02) on passing score (accuracy) for both feet. Passing accuracy was greater in CHO-E than placebo at 15 min (p=0.005) and 90 min (p=0.02) timepoints for the dominant foot (Figure 3A) and at 60 min (p=0.012) and 75 min timepoints (p=0.001) for the non-dominant foot (Figure 3C). Passing accuracy, calculated as mean scores measured during the SMS, also was greater in CHO-E than placebo when passes were completed with either the dominant (Figure 3B) or non-dominant (Figure 3D) foot. The mean difference (95% CI) in passing score for the dominant foot between CHO-E and placebo trials was 5 (1 to 9) points, with an effect size (Cohen's d) of 0.7 (moderate effect). The mean difference (95% CI) in passing score for the non-dominant foot between trials was 6 (3 to 10) points with an effect size (Cohen's d) of 0.8 (moderate effect).

Passing speed was similar on both trials for the dominant foot with no time, trial, or time × trial interaction effects observed (all p>0.05) (Figure 4A). The mean difference (95% CI) in passing speed between trials for the dominant foot was 0.4 (-0.1 to 0.9) km/h with an effect size (Cohen's d) of 0.2 (trivial effect). In contrast, for the non-dominant foot, a significant time × trial interaction was observed (p=0.032). Post-hoc analyses revealed that passing speed was better maintained from 75-min onwards in CHO-E trial compared with placebo (p=0.001; Figure 4C). Mean passing speed was greater in CHO-E than placebo for the non-dominant foot only (p = 0.04; Figure 4B and D). The mean difference (95% CI) in passing speed for the non-dominant foot between trials was 0.6 (0.1 to 1.2) km/h. The effect size (Cohen's d) was 0.4 (small effect).

Sprint Speed

Sprint speeds did not decline throughout the SMS with no time (p=0.38), trial (p=0.47) or time × trial interactions (p=0.31) detected. In addition, average sprint speed during the 90-min SMS was similar between trials. The mean difference (95% CI) in sprint speed for the non-dominant foot between trials was 5.9 (5.8 to 6.1) km/h. The effect size (Cohen's d) was 0.2 (small effect).

High-intensity anaerobic endurance running capacity

Anaerobic endurance capacity, expressed as running distance completed at 90% of the VO_{2max}, was 11.8% better on the CHO-E trial than placebo (p=0.01; Figure 5). The mean difference (95% CI) in running capacity between trials was 54 (15 to 94) meters, with an effect size (Cohen's d) of 0.4 (small to moderate effect).

Gastrointestinal comfort

VAS scores recorded for nausea were low and remained constant (15-min time point: 12±15, 90-min time point: 21±16) throughout the SMS with no time (p=0.536), trial (p=0.11) or time × trial (p=0.37) effects. There was a significant main effect of trial (p = 0.014) and a time × trial interaction for fullness (p = 0.007), with participants reporting greater fullness scores in the CHO-E condition pre-trial (39±22) and at the end (90 min) of the SMS protocol (37±25). Perceived feelings of bloatedness increased during the SMS, with participants feeling more bloated after ingesting the second drink at half time (45±23), compared to pre-trial feelings (30±22), on both trials. However, there was no time × trial (p=0.78) interaction for bloatedness scores.

Blood analytes

There was a significant time × trial interaction (p=0.001), main time effect (p=0.001) and main trial effect (p=0.002) for capillary blood glucose concentration. Whereas a 26% decline in glucose concentration from half-time to the first 15-min of the second half in the CHO-E condition was observed, glucose concentrations remain constant in placebo. Glucose concentrations were greater in CHO-E than placebo at half-time and after completing the high intensity running capacity test (Figure 6A). No significant time × trial interaction effect (p=0.12) or main trial effect (p=0.27) was observed for blood lactate concentrations over the course of the SMS (Figure 6B). However, lactate values increased above baseline at 15-min and, with the exception of half-time, values remained constant during the 90-min SSM. Lactate concentrations increased after the high-intensity anaerobic endurance running capacity test.

Discussion

The primary aim of this study was to investigate the influence of ingesting 60 g of carbohydrate as a 12% CHO-E solution, prior to and at half-time during a 90-min SMS, on soccer-specific skill performance, speed and high-intensity running capacity in academy soccer players. The SMS protocol was performed on an indoor artificial grass surface 2-h following intake of a pre-match meal, compliant with recommended carbohydrate guidelines. We demonstrated that ingesting the 12% CHO-E solution vs. an electrolyte-matched placebo better maintained passing accuracy in both the early and latter stages of the SMS protocol and passing speed during the latter stages of the SMS protocol with minimal impact on gut comfort. Although there was no benefit of ingesting the 12% CHO-E solution on dribbling speed and accuracy, or sprint speed, compared with placebo, post-match high-intensity running capacity was improved on the CHO-E trial. In terms of practical application, these data suggest that ingesting a 12% CHO-E solution before and during a soccer match may benefit soccer-specific skill performance and anaerobic endurance capacity.

A recent study reported the better maintenance of ball dribbling speed during the final 30-min of a SMS when ingesting a 12% CHO-E solution pre-match and during half-time vs. an electrolyte or water placebo condition (Harper et al., 2017). In contrast, we demonstrated no influence of ingesting a 12% CHO-E solution on dribbling speed vs. an electrolyte-matched placebo. We speculate that this discrepant finding may be attributed to several methodological factors. Unlike previous studies, our experimental trials were performed on an artificial grass surface and players wore their own soccer boots, which may have facilitated the better execution of skills. Moreover, we chose to perform the trials in the early afternoon instead of the morning with the aim to better reflect competitive practices of this group of players in Scotland. In accordance with published carbohydrate recommendations for exercise (Williams and Rollo, 2015; Thomas et al., 2016), we also provided a standardised breakfast containing 46 g of carbohydrate in addition to a pre-match meal consisting of 2 g carbohydrate per kg of body mass ingested 2-h prior to starting the SMS protocol. In contrast, Harper et al. (2017) provided soccer players with a breakfast containing 10% of daily energy requirement (~35 g of carbohydrate) ingested ~135-min before exercise. Interestingly, whereas Harper et al. (2017) reported a statistically significant decline in dribbling speed over time, in the present study dribbling speed remained constant throughout the 90-min protocol. Although muscle glycogen concentration was not measured in our study, we speculate that including a carbohydrate-rich pre-match meal prevented the decline in muscle glycogen content that has previously been associated with impaired performance (Mohr et al., 2005). Hence, the benefit of ingesting a 12% CHO-E solution on ball dribbling performance appears to be context-specific, e.g. when it is not possible to comply with pre-match carbohydrate intake guidelines, and/or only when fatigue has a markedly detrimental impact on dribbling performance.

In the present study, whereas ingesting the 12% CHO-E solution resulted in the better maintenance of passing accuracy in both dominant and non-dominant feet, passing speed was better maintained with carbohydrate ingestion during the latter stages of the SMS protocol in the non-dominant foot only. To our knowledge, this is the first study to differentiate between dominant and non-dominant feet when measuring soccer passing performance. Previous work demonstrates that if a task is familiar to an individual, then there will be an element of automaticity, and fewer central nervous system (CNS) resources are required for optimal performance (McMorris and Graydon, 1997). Conversely, when a task becomes more complex, the task outcome is more likely to be influenced by arousal (McMorris and Graydon, 1997). Thus, it is intuitive that performing the passing test with the non-dominant foot required a greater allocation of CNS resources than when performing the passing test with the dominant foot. It also has been proposed that fatigue is associated with a decrement in central control (Welsh et al., 2002), thus it can be inferred that the non-dominant side would demand more activity from the CNS and therefore be more susceptible to fatigue. Previous work has demonstrated that carbohydrate ingestion enhances CNS activity and motor control (Liu et al., 2000; Welsh et al., 2002). In this regard, Bottoms et al. (2007) showed that when compared to placebo the ingestion of a carbohydrate solution resulted in skill retention specifically in the backhand drive (weaker shot) in squash players. Hence, it is intuitive that ingesting the 12% CHO-E solution had a more profound effect on passing performance with the non-dominant foot than with the dominant foot. Consistent with this proposed mechanism, it appears from our data that the impact of carbohydrate feeding is observed primarily with the non-dominant foot, particularly towards the end of the SMS.

Studies showing a deterioration in soccer specific skills (Ostojic and Mazic, 2002; Ali et al., 2007; Ali and Williams, 2009) when players did not consume carbohydrates have argued that lowered glucose concentrations are associated with declines in skill performance. In the present study, blood glucose concentrations at half-time, and at the end of the full protocol were significantly higher when ingesting the 12% CHO-E solution vs. placebo. However, ingesting the 12% CHO-E solution failed to prevent the decline in blood glucose concentration 15-min into the second half of the SMS, likely reflecting increased glucose disposal at the onset of the second half of the SMS. Others (Russell et al., 2012) have reported skill performance decline in placebo condition versus carbohydrate consumption despite mean blood glucose concentration remaining euglycemic. Taken together, it appears that blood glucose concentration *per se* is not a key driver for the changes in skill performance detected between trials.

Blood lactate concentration during the SMS protocol was similar on both trials and reflects typical match intensity responses (Krustrup et al., 2006). Although marginal, the higher lactate concentrations in the CHO-E trial following the high-intensity anaerobic running test likely reflects greater capacity for flux through glycolysis in the face of additional substrate availability on that trial. Although sprint speed over 15-m did not decline throughout the SMS, mean values were comparable to those reported during actual match-play (Krustrup et al. 2006). Interestingly, Balsom et al. (1992) previously demonstrated that 15-m sprints could be performed at 30-s intervals without impaired performance in the absence of carbohydrate supplementation. In the present study, 18 × 15-m sprints were performed over the 90-min SMS protocol separated by a minimum period of 5 min, during which lower intensity exercise intervals were performed. This protocol would suggest there was sufficient time for phosphocreatine resynthesis between sprints, thus preventing a decline in sprint speed over the SMS on both trials. We reported that high-intensity running capacity following the SMS was significantly better in the 12% CHO-E vs placebo trial. Similar results were reported by Alghannam, (2011) and Nicholas et al. (1995), supporting the argument that carbohydrate ingestion exhibits an ergogenic benefit on anaerobic endurance capacity after prolonged intermittent exercise.

In conclusion, ingesting a 12% CHO-E solution before a SMS protocol and at half-time aided the retention of soccer-specific skill performance, particularly passing performance towards the end of the SMS protocol, and enhanced high-intensity running capacity after simulated match-play. Soccer players typically experience fatigue towards the end of the match (Mohr et al., 2005; Bradley et al., 2009) and the number of goals conceded increases during the latter stages of the game (Reilly, 1997). The current study adds to the evidence base that optimisation of carbohydrate ingestion strategies appears to have a practically relevant benefit on key skill (passing) and physiological (high-intensity running capacity) related factors that likely influence performance towards the end of a soccer match.

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Figures

Figure 1. Schematic diagram of study protocol (A) and outline of the Soccer Match Simulation (SMS) protocol (B).

Figure 2. Dribbling speed (A) and dribbling accuracy (B) during the soccer match simulation on placebo and CHO-E (carbohydrate-electrolyte) trials. No main effects of trial, time or trial × time were observed.

Figure 3. Passing score (A) during the soccer match simulation and mean passing score (B) for the dominant foot. Passing score (C) during the soccer match simulation and mean passing score (D) for the non-dominant foot. Significant main effects of trial ($p<0.05$) and trial x time ($p<0.05$) were observed. $^{\alpha}$ indicates time points at which significant differences were evident between placebo and CHO-E (carbohydrate-electrolyte) trials. * indicates significant difference in mean passing score.

Figure 4. Passing speed (A) during the soccer match simulation and mean passing speed (B) for the dominant foot. Passing speed (C) during the soccer match simulation and mean passing speed (D) for the non-dominant foot. Significant main effects of trial ($p<0.05$) and trial x time ($p<0.05$) were observed on non-dominant foot only. $^{\alpha}$ indicates time points at which significant differences in passing speed were evident between placebo and CHO-E

(carbohydrate-electrolyte) trials. * indicates a significant decrease in passing speed compared to 15-minute value on PLACEBO trial only. $^{\beta}$ indicates significant difference in mean passing speed.

Figure 5. High intensity anaerobic endurance running capacity on completion of the soccer match simulation on placebo and carbohydrate-electrolyte drink (CHO-E) ingestion trials. $^{\alpha}$ significant effect ($p<0.05$) with greater running capacity on CHO-E than PLACEBO.

Figure 6. Blood glucose (A), lactate (B) concentration during the soccer match simulation on placebo and carbohydrate-electrolyte drink (CHO-E) ingestion trials. BL – Baseline - HT – half time; F – final trial sample taken following running capacity test. *significant difference ($p<0.05$) from 0 time point. $^{\alpha}$-significant difference between trials at half time and final time point

Figure 1

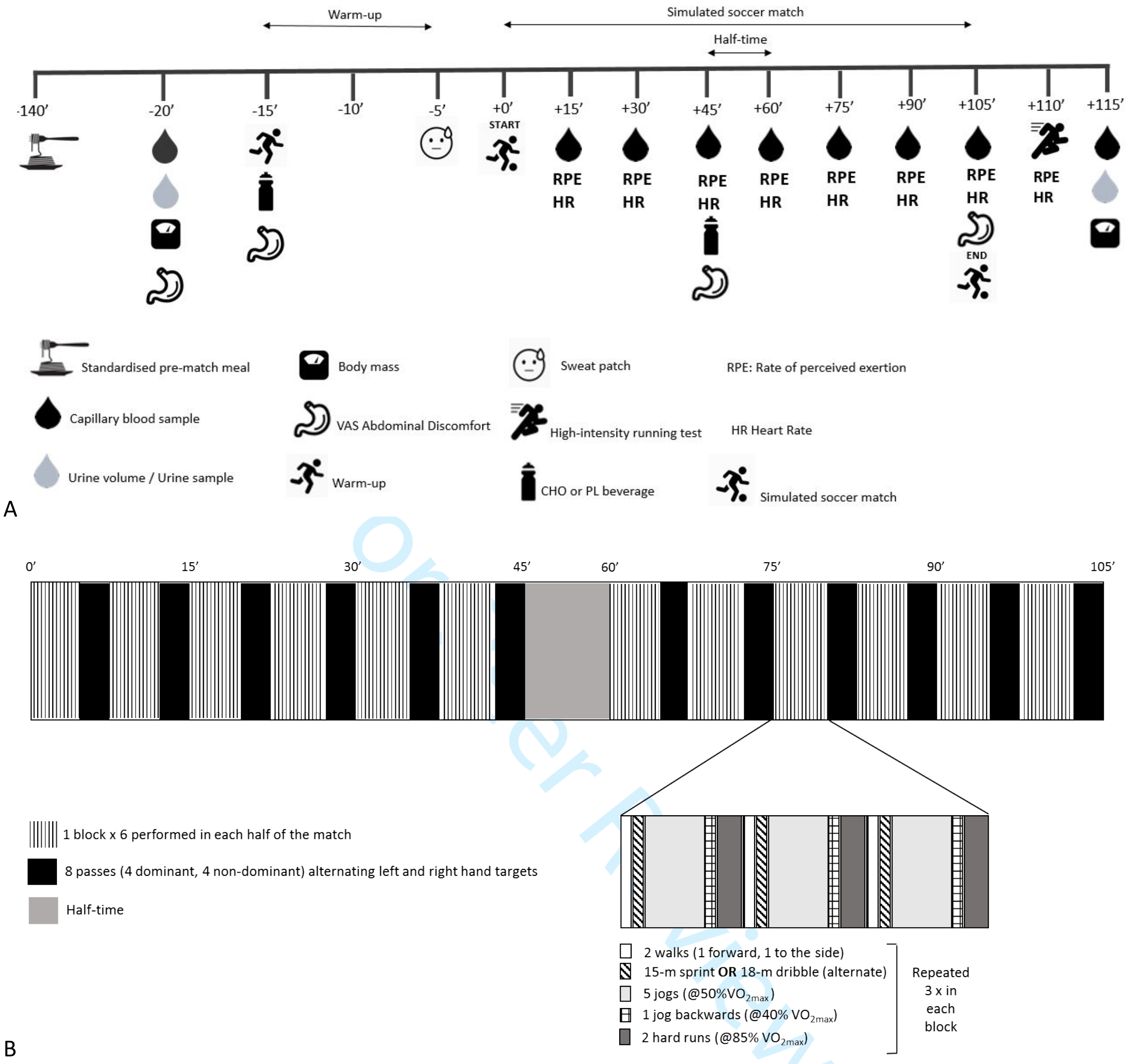
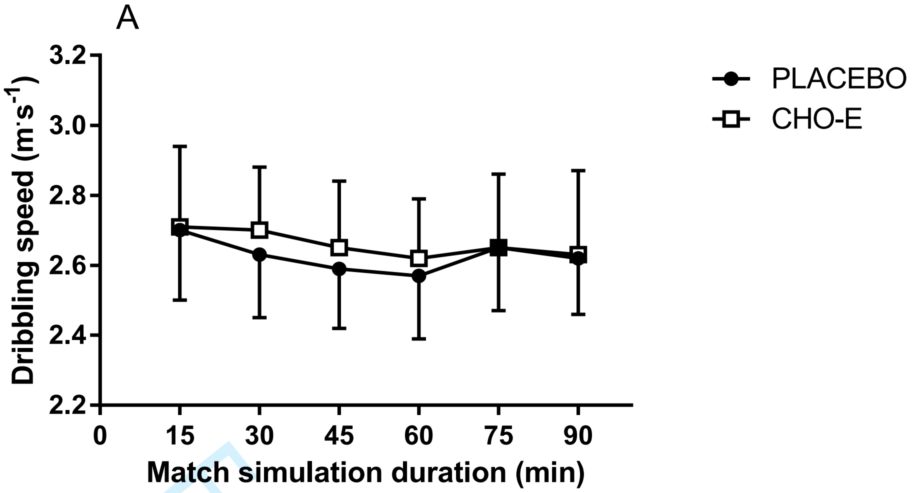

Warm-up
Simulated soccer match
Half-time
-140'
-20'
-15'
-10'
-5'
+0'
START
+15'
+30'
+45'
+60'
+75'
+90'
+105'
+110'
+115'
RPE
HR
END
Standardised pre-match meal
Body mass
Sweat patch
RPE: Rate of perceived exertion
Capillary blood sample
VAS Abdominal Discomfort
High-intensity running test
HR Heart Rate
Urine volume / Urine sample
Warm-up
CHO or PL beverage
Simulated soccer match
A
0'
15'
30'
45'
60'
75'
90'
105'
1 block x 6 performed in each half of the match
8 passes (4 dominant, 4 non-dominant) alternating left and right hand targets
Half-time
2 walks (1 forward, 1 to the side)
15-m sprint OR 18-m dribble (alternate)
5 jogs (@50%VO2max)
1 jog backwards (@40% VO2max)
2 hard runs (@85% VO2max)
Repeated 3 x in each block
B

Figure 2


A
3.2
3.0
2.8
2.6
2.4
2.2
Dribbling speed (m·s^{-1})
0
15
30
45
60
75
90
Match simulation duration (min)
PLACEBO
CHO-E

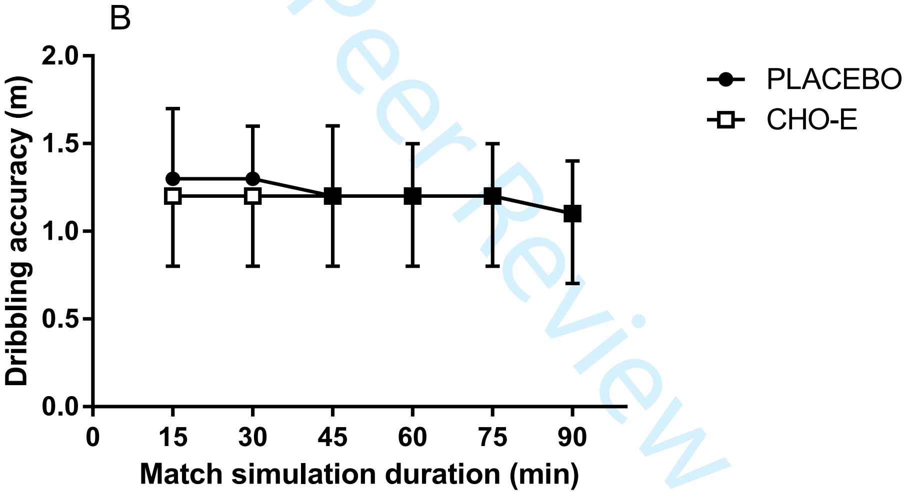

B
2.0
1.5
1.0
0.5
0.0
Dribbling accuracy (m)
0
15
30
45
60
75
90
Match simulation duration (min)
PLACEBO
CHO-E

Figure 3

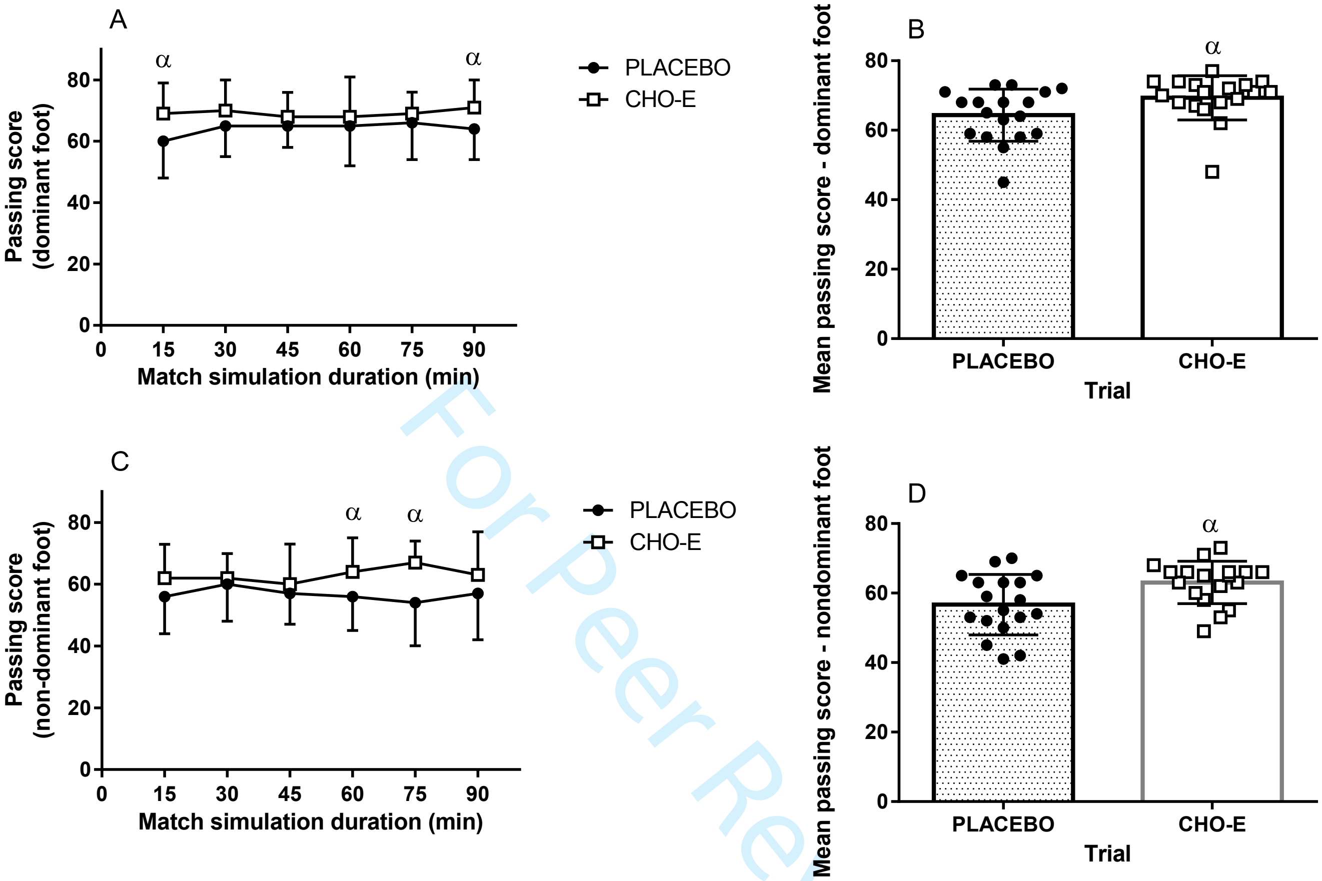

A
Passing score (dominant foot)
0
20
40
60
80
α
α
0
15
30
45
60
75
90
Match simulation duration (min)
PLACEBO
CHO-E
B
Mean passing score - dominant foot
0
20
40
60
80
α
PLACEBO
CHO-E
Trial
C
Passing score (non-dominant foot)
0
20
40
60
80
α
α
0
15
30
45
60
75
90
Match simulation duration (min)
PLACEBO
CHO-E
D
Mean passing score - nondominant foot
0
20
40
60
80
α
PLACEBO
CHO-E
Trial

Figure 4

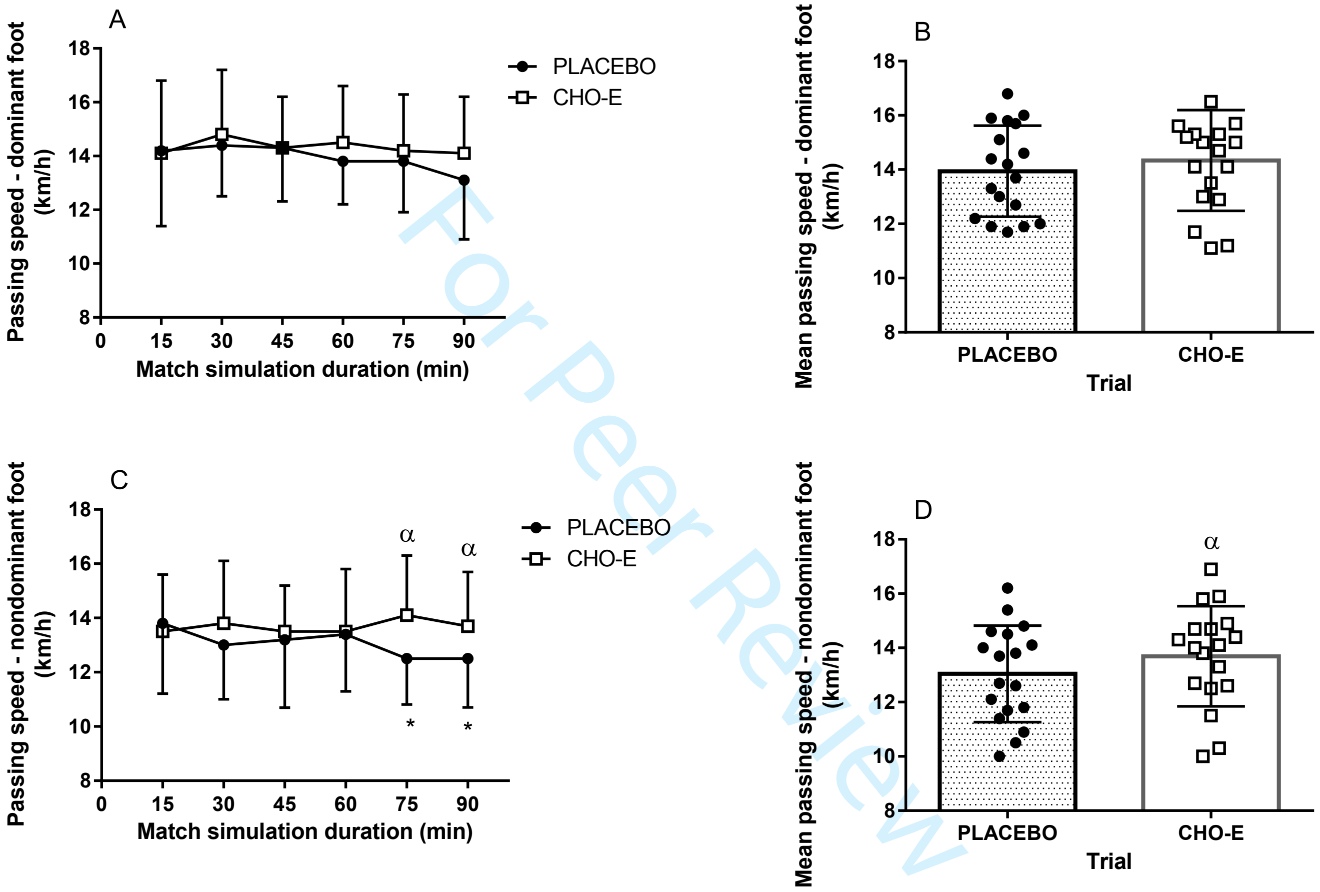

A
Passing speed - dominant foot (km/h)
18
16
14
12
10
8
0
15
30
45
60
75
90
Match simulation duration (min)
PLACEBO
CHO-E
B
Mean passing speed - dominant foot (km/h)
PLACEBO
CHO-E
Trial
C
Passing speed - nondominant foot (km/h)
α
α
*
*
Match simulation duration (min)
PLACEBO
CHO-E
D
Mean passing speed - nondominant foot (km/h)
α
PLACEBO
CHO-E
Trial

Figure 5

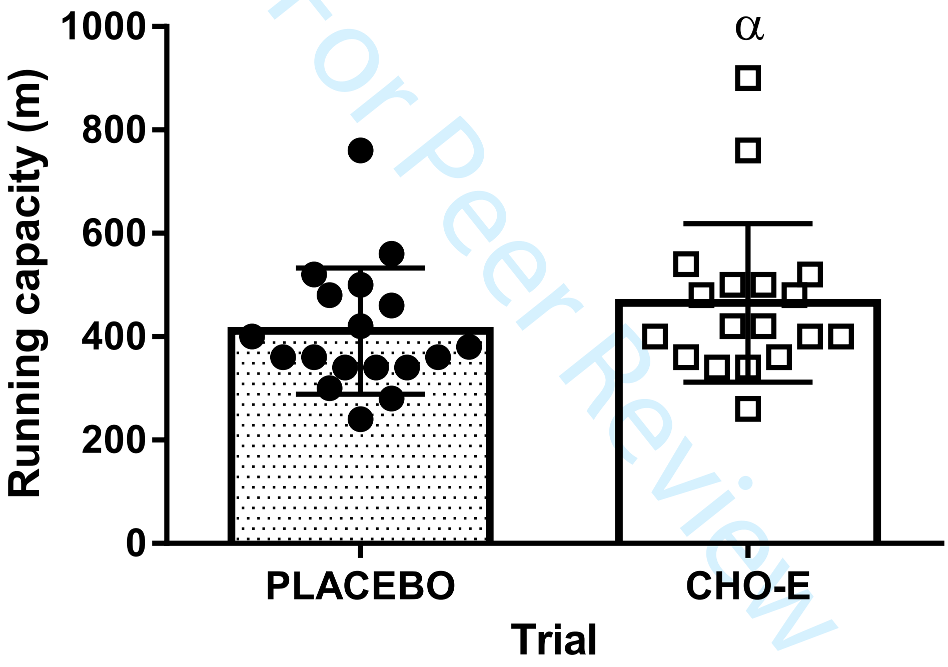
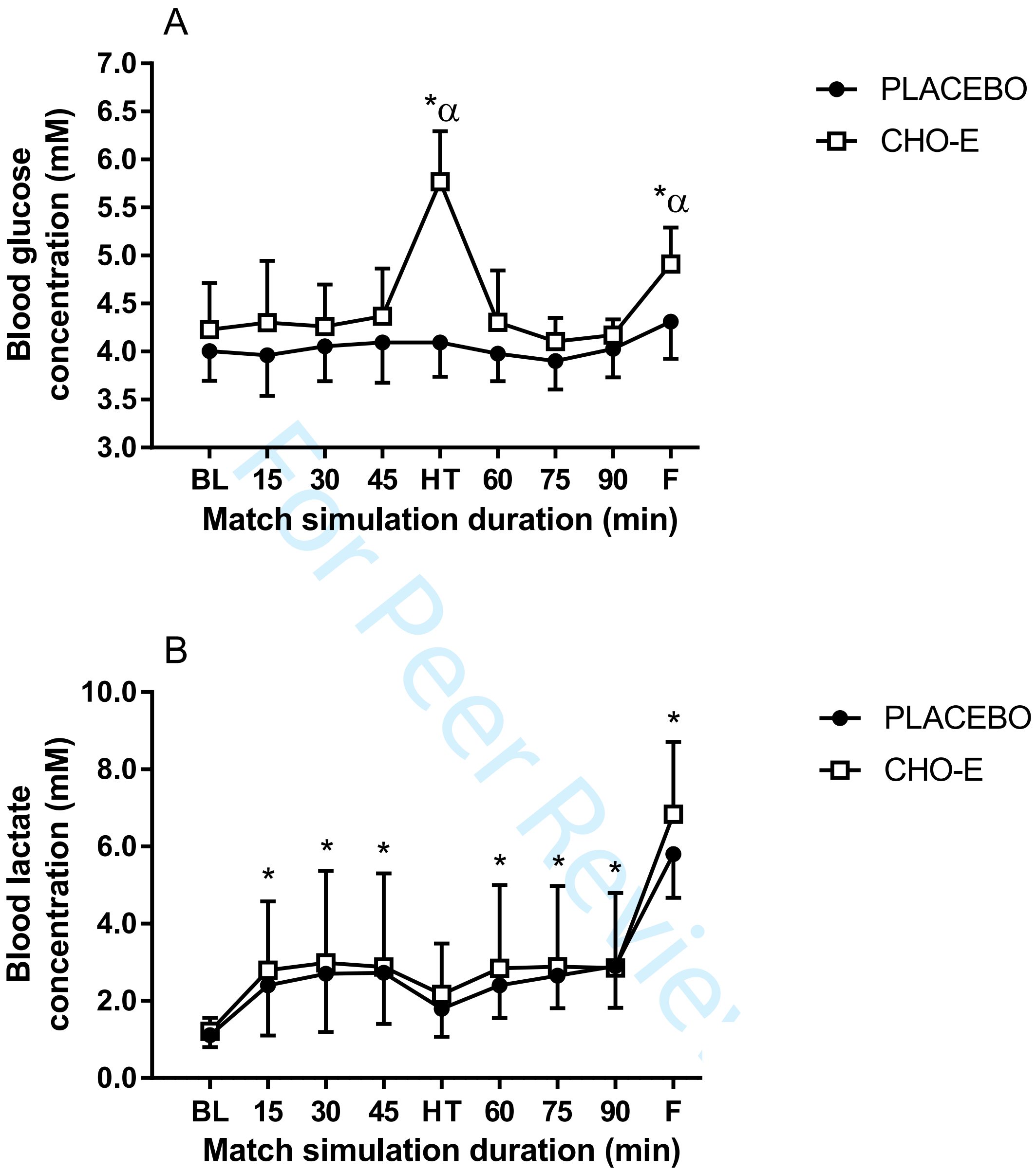

α
Running capacity (m)
1000
800
600
400
200
0
PLACEBO
CHO-E
Trial

Figure 6


A
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
Blood glucose concentration (mM)
*α
*α
BL
15
30
45
HT
60
75
90
F
Match simulation duration (min)
PLACEBO
CHO-E
B
10.0
8.0
6.0
4.0
2.0
0.0
Blood lactate concentration (mM)
*
*
*
*
*
*
*
BL
15
30
45
HT
60
75
90
F
Match simulation duration (min)
PLACEBO
CHO-E