Carbohydrate gel ingestion significantly improves the intermittent endurance capacity, but not sprint performance, of adolescent team games players during a simulated team games protocol.

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Running Title: Carbohydrate gel and team games performance.

Abstract

The aim of this study was to investigate the influence of ingesting a carbohydrate (CHO) gel on the intermittent endurance capacity and sprint performance of adolescent team games players. Eleven participants (mean age 13.5 ± 0.7 years, height 1.72 ± 0.08 m, body mass (BM) 62.1 ± 9.4 kg) performed two trials separated by 3-7 days. In each trial, they completed four 15 min periods of part A of the Loughborough Intermittent Shuttle Test, followed by an intermittent run to exhaustion (part B). In the 5 min pre-exercise, participants consumed 0.818 $ml.kg^{-1}$ BM of a CHO or a non-CHO placebo gel, and a further 0.327 $ml.kg^{-1}$ BM every 15 min during part A of the LIST (38.0 ± 5.5 g $CHO.h^{-1}$ in the CHO trial). Intermittent endurance capacity was increased by 21.1% during part B when the CHO gel was ingested (4.6 ± 2.0 vs. 3.8 ± 2.4 min, $P < 0.05$, $r = 0.67$), with distance covered in part B significantly greater in the CHO trial (787 ± 319 vs. 669 ± 424 m, $P < 0.05$, $r = 0.57$). Gel ingestion did not significantly influence mean 15 m sprint time ($P = 0.34$), peak sprint time ($P = 0.81$), or heart rate ($P = 0.66$). Ingestion of a CHO gel significantly increases the intermittent endurance capacity of adolescent team games players during a simulated team games protocol.

Key Words: performance; nutrition; supplement; young people; LIST

Introduction

We have previously demonstrated a significant enhancement in the intermittent endurance running capacity (hereafter referred to as intermittent endurance capacity) of 12-14 year old team games athletes with ingestion of a 6% carbohydrate-electrolyte (CHO-E) solution during a modified Loughborough Intermittent Shuttle Test (LIST, Phillips et al 2010). This was achieved with a mean carbohydrate (CHO) intake of ~35 $g.h^{-1}$, or 0.78 $g.kg^{-1}$ body mass (BM), which is notably lower than the CHO intake in related adult work (~60-92 $g.h^{-1}$, Foskett et al 2008; Nicholas et al 1995; Welsh et al 2002). Young people display a different metabolic response to exercise than adults, characterised by an enhanced rate of fat metabolism and attenuated rate of endogenous CHO (CHO_{endo}) use (Riddell 2008; Timmons et al 2007), perhaps to preserve endogenous glycogen stores, which may be lower than adults (Aucouturier et al 2008). Despite this, young people appear able to oxidise exogenous CHO (CHO_{exo}) at BM-relative rates equal to, or greater than, adults for the same relative CHO ingestion rate (Timmons et al 2003). Therefore, CHO_{exo} requirements of young people may be different to those of adults, perhaps with a lower rate of CHO ingestion facilitating exercise enhancement (Phillips et al unpublished data). Coupled with the significant enhancement in intermittent endurance capacity reported in our previous study (Phillips et al 2010), this knowledge emphasises that findings from studies supplementing CHO during simulated team games in adults cannot be confidently applied to young people, and a greater research output into CHO supplementation during simulated team games in adolescents is therefore warranted.

In recent years, ingestion of CHO in the form of a gel has become more prevalent (Havemann et al 2008), due in part to the ability to manipulate CHO and fluid intake independently, and

to consume greater amounts of CHO, in gel compared with solution form (Pfeiffer et al 2010). Carbohydrate gel ingestion has been shown to improve prolonged steady-state cycling performance (Campbell et al 2008; Earnest et al 2004), with a negligible effect on half-marathon running performance (Burke et al 2005). However, the ~2.4% BM loss during the run, along with the presence of an order effect for performance time, may have negated the effect of the gel. Specific to team games exercise, Patterson and Gray (2007) showed a 45% improvement in intermittent endurance capacity when adult male soccer players ingested a CHO gel before and during the LIST. This is comparable to the improvement seen when consuming CHO-E solutions during the same or similar protocol (~33-52%, Foskett et al 2008; Nicholas et al 1995; Welsh et al 2002). To date, this remains the only study to investigate CHO gel supplementation during team games exercise.

The combination of our previous findings regarding the efficacy of a CHO solution during simulated team games in adolescents and the significant improvement in intermittent endurance capacity with CHO gel ingestion shown by Patterson & Gray (2007) suggests that ingestion of CHO gels during simulated team games may benefit adolescent team games players. Therefore, the aim of this study was to determine the influence of ingesting a CHO gel immediately before, and during, a simulated team games protocol on the intermittent endurance capacity and sprint performance of adolescent team games players. It was hypothesised that ingestion of the CHO gel would significantly improve intermittent endurance capacity, with no significant influence on sprint performance.

Methods

Participants

Eleven team games players (10 males and 1 female; mean age 13.5 ± 0.7 years, height 1.72 ± 0.08 m, BM 62.1 ± 9.4 kg) participated in the study. Participants were recruited from local schools and sports clubs. Inclusion criteria was to be between the ages of 12-14 years, regularly participating in competitive soccer, rugby or field hockey to at least club level, free from any muscle or joint injury, and not taking medication that influences the ability to exercise. All participants were in good health at the time of the study, as determined by completion of a pre-study medical questionnaire. Participants' were either frequent or occasional users of CHO containing sports drinks.

Prior to inclusion, comprehensive written and verbal explanation of the study was provided to participants and parents, and written parental informed consent was received. Subsequently, written child assent was gained. The study received ethical approval from the University of Edinburgh Ethics Committee.

Biological maturity status

Due to ethical and consensual restrictions regarding direct observational assessment of Tanner stages, biological maturity offset was assessed using the established, non-invasive equations of Mirwald et al (2002), as previously described (Phillips et al 2010). For the participants in this study, mean biological maturity offset was +0.94 years (range -1.77 - +2.68 years). Mean predicted age at peak height velocity for the female participant was 11.3

years and for the male participants was 12.6 years (range 11.8 – 13.8 years). This classifies the female participant as an average maturer, and the male participants as early maturers (Baxter-Jones et al 2005).

Preliminary Tests

Peak Running Velocity

All exercise intensities used in the main experimental protocol were based on percentages of peak running velocity (V_{peak}) as determined from a treadmill V_{peak} test. This is opposed to the more common calculation of speed based on percentage of $\dot{V}O_{2max}$, and is believed to more accurately reflect physiological demand during team games (Bangsbo 1994). The physiological responses to maximal treadmill and free range running have been reported to be similar (Crouter et al., 2001). Prior to undertaking the V_{peak} test, all participants walked at a self-selected speed on the treadmill (Ergo 55, Woodway, Germany) for 2 min, then completed the first four levels of the V_{peak} test as described below to familiarise themselves with the treadmill (Lavcanska et al 2005). Following this, participants sat quietly for 10 min to recover and allow any residual anxiety to dissipate before starting the test.

The V_{peak} test, adapted from Marino et al (2004), began at 8 $km.h^{-1}$ at a gradient of 1% for one minute, after which the speed was increased by 0.5 $km.h^{-1}$ in one-minute increments until the participant indicated that they could not continue despite strong verbal encouragement. A maximal effort was confirmed by observation of subjective symptoms of fatigue (facial flushing, unsteady gait, heavy sweating, hyperpnoea) and attainment of a heart rate (HR) $\geq$ 195 beats per min (Armstrong 2007). Peak running velocity and maximum HR (HR_{max}) were

calculated as the highest treadmill velocity maintained for 30 s and the highest 5 s average, respectively. After a 15 min seated recovery participants performed 15 min of the LIST, as described below, to familiarise themselves with the running speeds required and the data collection procedures.

Experimental Design

All participants completed two trials separated by a minimum of three, and maximum of seven, days. During each trial participants consumed either a 100% maltodextrin CHO gel (CHO trial) or a non-CHO artificially sweetened gel (placebo (PLA) trial), matched for taste, texture, and mouth-feel (High5 Ltd, Bardon, Leicestershire). All trials were randomised, counterbalanced, and double-blinded to control for order effects and experimenter bias. Each participant completed both trials at the same time of day, or as close to this as possible. The gel was consumed in amounts that enabled a standardised CHO intake of 0.78 $g.kg^{-1}$ BM for each participant, to enable a direct comparison with previous work from this laboratory (Phillips et al 2010). As the two gels were of slightly different colour they were prepared in non-transparent bottles by the individual in control of trial blinding, so that neither the investigator nor the participants could see the gel at any time. Participants were requested to refrain from heavy physical activity for 48 h before each trial. Additionally, they were asked to record their food and fluid intake, including the portion size of all food consumed and the volume of all fluid ingested, for 24 h before the first trial. This diet was replicated prior to trial two to standardise muscle and hepatic glycogen concentrations and hydration status. Participants were not requested to record food and fluid intake in the depth of detail that would have enabled a subsequent dietary composition analysis. Requesting this would have placed greater stress on extremely time-pressured participants and their parents, and may

have negatively affected adherence to the dietary record, and/or retention of participants through the full study.

Experimental Protocol

Standing height was measured using a free-standing adjustable stadiometer (Seca, model no. 2251821009, Germany). After voiding and urinating, if necessary, dry nude BM was recorded (Seca Digital, model no. 7052321009, Germany). After attaching the HR monitor chest strap and watch (Polar RS400, Polar Electro Oy, Finland) participants sat quietly for 5 min, then completed a standardised warm-up consisting of jogging, striding and dynamic stretching for 10 min. Immediately following the warm-up, participants sat and were instructed to consume the prescribed gel (0.818 $ml.kg^{-1}$ BM) followed by 5 $ml.kg^{-1}$ BM of water during the 5 min before commencing exercise. Water was ingested to offset the potential influence of dehydration (Patterson & Gray 2007), and was consumed in volumes that have previously been administered in this population during the same exercise protocol (Phillips et al 2010). Once the initial gel and water bolus had been consumed, participants were asked to state which gel they believed was being prescribed.

The LIST was conducted indoors, on a level rubber floor, as described elsewhere (Phillips et al 2010). Briefly, participants completed four blocks of part A of the LIST separated by 3 min seated recovery, followed by an intermittent run to exhaustion (part B). Participants consumed the solution (0.327 $ml.kg^{-1}$ BM) followed by water (2 $ml.kg^{-1}$ BM) in the recovery period between each 15 min block and in the recovery period before commencing part B. After the measurement of post-exercise BM, participants were asked again to state which gel they believed they had received during the protocol, to observe whether exercise exerted any

influence on their gel choice. Participants were clearly informed that they were free to change their mind from their pre-exercise gel choice, or to keep their selection the same.

Measurements

Heart rate was recorded at 5 s intervals throughout the V_{peak} test and the experimental protocol using short-range telemetry. Data was retrieved and downloaded onto a computer software program (Polar ProTrainer 5, Polar Electro Oy, Finland) for subsequent analysis. Ambient temperature and humidity were recorded immediately before the start of the protocol and at the end of each 15 min block in part A using a digital hygro-thermometer (Tako Astatic Technology, Malaysia). Ratings of perceived exertion (RPE) were measured during the first shuttle of the final walking phase of each 15 min block in part A and at exhaustion in part B using the Children's Omnibus Scale of Perceived Exertion (0-10 scale), which has been validated for use with participants of the age range in this study (Roemmich et al 2006). Gut fullness (GF) and gastric discomfort (GD) were assessed immediately on completion of each 15 min block in part A and at exhaustion in part B using anchored 10 point scales (1 = not at all, 10 = extremely). Sprint times were measured in one direction by two wireless infrared single-beam photoelectric cells (Speed Trap 2, Gill Athletics, Illinois) placed 15 m apart. If participants needed to urinate at any time from the onset of the protocol until completion of the measurement of post-exercise BM they did so into a measuring jug, with this volume incorporated into the BM loss calculation. Body mass loss was calculated from the difference between pre- and post-exercise nude BM, corrected for fluid intake and urine output. Sweat rate (SR; $L.h^{-1}$) was calculated using the equation: (Pre-exercise BM (kg) + fluid ingested (L) – urine output (L) – post-exercise BM (kg)) / protocol duration (min) x 60 (Edwards et al 2007). This calculation does not account for BM loss due to fuel oxidation

and respiratory fluid loss, but it is unlikely these would differ between trials (Edwards et al 2007).

Statistical Analysis

The Shapiro-Wilk test for normality was employed on all data sets. Paired *t*-tests compared between-trials differences in fluid, gel and CHO intake, pre-exercise BM, BM loss and SR, HR during part B, and HR, GF and GD at exhaustion. Distance covered in part A and B, time to exhaustion and RPE at exhaustion were analysed using the Wilcoxon matched-pairs test. Mean ambient temperature and relative humidity, sprint times and peak sprint times, and HR, GF and GD during part A were analysed with a 2 way (gel x time) ANOVA. Bonferroni pairwise comparisons were used to explore significant main effects with the exception of GF, where Wilcoxon matched-pairs tests with Bonferroni correction were used due to the grouped data displaying non-normal distribution. Friedman tests were used to analyse the main effect of time during part A within each trial for RPE. Wilcoxon matched-pairs tests, with Bonferroni correction, explored significant within-trials main effects. Chi-square analysis assessed the frequency distribution of gel choice responses. Effect sizes (ES) from ANOVA were calculated using partial eta squared (η^2) values, which were square rooted to give correlation coefficients (Field 2005). Effect sizes generated from *t* scores were calculated using the equation of Rosnow and Rosenthal (2005), and from *z* scores using the equation of Rosenthal (1991), to give correlation coefficients (Field 2005). Effect sizes were defined as small (r = 0.1-0.3), moderate (r = 0.3-0.5), large (r = 0.5-0.7), very large (r = 0.7-0.9), and nearly perfect (r = 0.9-1.0), based on the classifications of Hopkins (2006). Data are mean ± SD, and with the exception of analyses using the Bonferroni correction, significance was set at $P < 0.05$.

Results

Preliminary Tests

Mean V_{peak} attained in the incremental treadmill run to exhaustion was 14.6 ± 0.9 $km.h^{-1}$. Mean HR_{max} and RPE at exhaustion were 197 ± 6 beats per min and 9.2 ± 0.4, respectively.

Distance covered and time to exhaustion

By design, distance covered during part A was the same in the CHO and PLA trials (7.1 ± 0.2 km). Time to exhaustion during part B of the LIST for both trials is shown in Figure 1. Participants ran for 21.1% longer in the CHO compared to the PLA trial ($P < 0.05$, $r = 0.67$), corresponding with a significantly greater distance covered in the CHO trial (787 ± 319 vs. 669 ± 424 m, $P < 0.05$, $r = 0.57$).

PLEASE PLACE FIGURE 1 HERE

Sprint times

The mean time of all sprints, and the mean of participants' peak sprint time only, in each block of part A of the LIST is shown in Figure 2A and 2B, respectively. Sprint times throughout the LIST were faster in the CHO trial, but did not reach statistical significance ($F_{1, 10} = 1.1$, $P = 0.33$, $r = 0.31$). There was also no interaction effect (gel x time, $F_{3, 30} = 0.4$, $P = 0.75$, $r = 0.20$). There was a main effect of time on sprint duration ($F_{3, 30} = 25.1$, $P < 0.001$, $r = 0.85$). Sprint times in block 2 were significantly slower than block 1 ($P < 0.05$, $r =$

0.77) and in block 3 were significantly slower than block 2 ($P < 0.05$, $r = 0.80$). There was no significant difference in sprint time between blocks 3 and 4 ($P = 0.21$, $r = 0.68$). Mean peak sprint time was not significantly different between-trials ($F_{1, 10} = 0.06$, $P = 0.81$, $r = 0.08$) and there was no interaction effect ($F_{3, 30} = 0.4$, $P = 0.72$, $r = 0.21$). There was a main effect of time on peak sprint duration ($F_{3, 30} = 15.1$, $P < 0.001$, $r = 0.78$). Peak sprint times in block 3 were significantly slower than block 2 ($P < 0.05$, $r = 0.82$). There was no significant difference between blocks 1 and 2 ($P = 0.33$, $r = 0.52$) or 3 and 4 ($P = 1.0$, $r = 0.41$).

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Heart rate, ratings of perceived exertion, and gastric measures

Mean HR and RPE during part A of the LIST, and mean peak HR and mean RPE at exhaustion in part B are shown in Table 1. There was no significant treatment ($F_{1, 8} = 0.21$, $P = 0.66$, $r = 0.16$) or interaction ($F_{3, 24} = 1.34$, $P = 0.29$, $r = 0.38$) effect on HR during part A of the LIST. There was a main effect of time for HR in part A ($F_{1.32, 10.56} = 12.18$, $P < 0.005$, $r = 0.78$). Heart rate in block 2 was significantly greater than block 1 ($P < 0.001$, $r = 0.95$). There was no significant difference between blocks 2 and 3 ($P = 1.0$, $r = 0.14$) or 3 and 4 ($P = 0.97$, $r = 0.35$). Mean HR during part B of the LIST was greater in the CHO trial, but did not reach statistical significance (175 ± 5 vs. 173 ± 6 beats per min, $P = 0.42$, $r = 0.31$). Peak HR at exhaustion in part B was also higher in the CHO trial, but again this was not significant ($P = 0.56$, $r = 0.23$). Ratings of perceived exertion were very similar at all time points between trials, with no significant differences found. A main effect of time was present for the CHO ($\chi^2(3) = 29.8$, $P < 0.001$) and PLA ($\chi^2(3) = 31.1$, $P < 0.001$) trials. Ratings of perceived exertion increased significantly with each successive exercise block ($P < 0.001$, $r =$

0.89, 0.76 and 0.76, respectively) . There was no between-trials difference in RPE at exhaustion (P = 1.0, r = 0).

PLEASE INSERT TABLE 1 HERE

Mean GF and GD during part A of the LIST, and at exhaustion in part B, are shown in Table 2. Mean GF was greater in the CHO trial throughout part A of the LIST, but this was not statistically significant ($F_{1, 10}$ = 3.50, P = 0.09, r = 0.51). There was also no interaction effect ($F_{1.74, 17.36}$ = 0.65, P = 0.52, r = 0.25). There was a significant effect of time on GF ($F_{1.47, 14.71}$ = 7.72, P < 0.01, r = 0.66). Gut fullness in block 3 was significantly greater than block 2 (P < 0.01, r = 0.56). There was no significant difference between blocks 1 and 2 (P = 0.06, r = 0.40) or 3 and 4 (P = 1.0, r = 0). Gut fullness scores during part A of the LIST were modest. Gut fullness at exhaustion was higher in the CHO trial, but this was not statistically significant (P = 0.24, r = 0.37). There was no treatment ($F_{1, 10}$ = 0.14, r = 0.11) or interaction ($F_{3, 30}$ = 0.97, r = 0.30) effect on GD. Gastric discomfort increased significantly with time ($F_{1.45, 14.52}$ = 13.06, P < 0.005, r = 0.75), and was significantly greater in block 2 than block 1 (P < 0.05, r = 0.64) and block 3 than block 2 (P < 0.05, r = 0.54). There was no significant difference between blocks 3 and 4 (P = 1.0, r = 0.06). Gastric discomfort scores during part A were also moderate. Gastric discomfort at exhaustion was higher in the CHO trial, but this was not statistically significant (P = 0.59, r = 0.17).

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Body mass loss and sweat rate

Mean pre-exercise dry nude BM was not significantly different between the CHO and PLA trials (62.4 ± 9.1 and 62.9 ± 9.2 kg, respectively, $P = 0.27$, $r = 0.34$). Mean BM loss in the CHO and PLA trials was 1.0 ± 0.4 and 1.1 ± 0.3 kg, respectively ($P = 0.36$, $r = 0.29$), equating to a mean loss of 1.59 ± 0.53 and 1.67 ± 0.37% of pre-exercise BM ($P = 0.50$, $r = 0.22$). Mean SR was 0.77 ± 0.27 and 0.85 ± 0.27 $L.h^{-1}$ in the CHO and PLA trials, respectively ($P = 0.30$, $r = 0.33$), equating to a BM-relative mean sweat loss of 12.42 ± 4.16 and 13.44 ± 3.70 $ml.kg^{-1}$ $BM.h^{-1}$, respectively ($P = 0.39$, $r = 0.28$).

Blinding

After consuming the initial gel bolus immediately prior to exercise, four participants (36%) correctly identified both gels and seven (64%) failed to do so. Chi square analysis of the responses in the CHO trial found a non-significant deviation from the expected response frequency ($\chi^2(1) = 0.818$, $P = 0.37$). Post-exercise, only two participants correctly guessed both gels. In the PLA trial, five participants (46%) correctly guessed the PLA gel post-exercise when they had guessed incorrectly prior to exercise. In the CHO trial, no participants correctly guessed the CHO gel post-exercise after guessing incorrectly pre-exercise, but five participants (46%) incorrectly chose the PLA gel post-exercise, having guessed correctly pre-exercise.

Fluid and carbohydrate intake

Mean fluid intake was 811 ± 119 and 811 ± 120 ml for the CHO and PLA trials, respectively (P = 0.93, r = 0.03). Mean gel intake in the CHO trial was 132.6 ± 19.4 ml and in the PLA trial was 132.7 ± 19.6 ml (P = 0.92, r = 0.03). Combined fluid and gel intake was 943.6 ± 138.3 and 943.9 ± 139.4 ml (P = 0.92, r = 0.03) in the CHO and PLA trials, respectively. In the CHO trial, total CHO intake was 38.0 ± 5.5 $g.h^{-1}$, or 0.78 $g.kg^{-1}$ BM.

Ambient temperature and relative humidity

Mean ambient temperature and relative humidity during the LIST are shown in Table 3. Mean ambient temperature was not significantly different between ($F_{1, 10}$ = 3.59, P = 0.09, r = 0.51) or within ($F_{1.06, 10.58}$ = 0.32, P = 0.60, r = 0.18) trials. However, a significant gel x time interaction was present ($F_{1.67, 16.70}$ = 3.87, P < 0.05, r = 0.53). Mean relative humidity was not significantly different between ($F_{1, 10}$ = 3.89, P = 0.05, r = 0.57) or within ($F_{1.9, 18.9}$ = 1.38, P = 0.28, r = 0.35) trials, and there was no interaction effect ($F_{1.7, 17.4}$ = 1.08, P = 0.35, r = 0.31)

PLEASE PLACE TABLE 3 HERE

Discussion

This is the first study to demonstrate that ingestion of a CHO gel immediately before, and during, a simulated team games protocol significantly improves the intermittent endurance capacity of adolescent team games players. Carbohydrate gel ingestion did not significantly influence sprint performance during the protocol.

Time to exhaustion

The 21.1% improvement in intermittent endurance capacity in the current study is similar to the 24.4% improvement we recently demonstrated when adolescent team games players ingested equal BM-relative amounts of CHO via a 6% CHO-E solution before and during the same exercise protocol (Phillips et al 2010). Therefore, the current study serves to increase the knowledge base and provide further evidence for an ergogenic effect of CHO supplementation during simulated team games in adolescents. It could be inferred that the influence of CHO reported here may translate into actual team games performance by enabling participants to continue performing high-intensity exercise for longer, which is a recognised marker of performance and fatigue during team games (Carling et al 2008). Using self-paced protocols, such as that proposed by Ali et al (2009), may enable further quantification of this.

It appears that CHO gels and solutions of similar composition, when administered in volumes that deliver an equal amount of BM-relative CHO, have similar efficacies for adolescents during simulated team games. The observation of a similar time-course of CHO oxidation and peak CHO oxidation rate between CHO gels and drinks of the same

composition (Pfeiffer et al 2010) may help to explain this, but would need to be confirmed in adolescents.

The current findings mimic those of Patterson and Gray (2007), who found a 45% improvement in time to exhaustion at the end of the LIST in the only study to investigate CHO gel supplementation during simulated team games in adults. Patterson and Gray (2007) concluded that the increased intermittent endurance capacity was due to CHO-mediated sparing of muscle glycogen during exercise. The current study did not collect data that would enable direct quantification of enhancement mechanisms due to ethical and consensual restrictions regarding the employment of blood sampling and muscle biopsies in adolescents. However, as discussed in our previous study, metabolic distinctions between adolescents and adults exist that also support the hypothesis of muscle glycogen sparing with CHO ingestion in adolescents (Phillips et al 2010). It is crucial that future research manages to overcome ethical and consensual issues and provide data on the metabolic responses of adolescents during simulated team games with and without CHO ingestion.

The ~21% improvement in time to exhaustion in the current study is notably lower than the 45% improvement reported by Patterson and Gray (2007). Patterson and Gray (2007) used a PLA solution, matched for taste, colour, and temperature, as a comparison to the CHO gel. Despite matching for these criteria, it is possible that participants would still have been aware of whether they were consuming a gel or a solution, due to the different consistencies of these products. Reporting of blinding statistics would have been useful to validate the success of the single-blinding procedures used. In addition, depending on the amount of information the participants were provided with as to the aims and/or expectations of the study, the use of a PLA solution could have raised a significant potential for experimenter bias and/or

participant expectancy that may have greatly impacted the results. This may help to explain the difference in intermittent endurance capacity improvement compared with the current study. However, the different participant populations used in the two studies (adolescents versus adults) could also have contributed to this difference (Phillips et al 2010).

Sprint Duration

The finding that CHO gel supplementation did not significantly improve mean sprint or mean peak sprint performance during the LIST is in line with other work from this laboratory (Phillips et al., 2010), as well as previous adult work (Patterson & Gray 2007). Potential reasons for the lack of influence of CHO have been discussed previously (Phillips et al 2010), and the reader is referred here for further information.

The only significant attenuation in peak sprint time in the current study occurred between blocks 3 and 4, which also corresponded with a significant increase in both GF and GD measures. It may be that this increase in GF and GD inhibited sprint performance, which is further supported by the significant attenuation of mean sprint time over the same period. However, in our previous study, peak sprint time was significantly attenuated in block 3 with no significant corresponding increase in measures of GF or GD (Phillips et al 2010). Therefore, the parallel increases in these measures in the current study may be coincidental.

Heart rate, ratings of perceived exertion, and gastric measures

There were no significant between-trials differences for HR response, RPE, or gastric measures. This replicates findings from our previous study (Phillips et al 2010), and from

related adult work (Ali et al 2007; Nicholas et al 1995; Welsh et al 2002). In our previous study, we demonstrated a significantly greater peak HR at exhaustion in the CHO trial. This finding was not replicated in the current study, indicating that it may have been an artefact of the participant population employed in our previous work, rather than a mechanism of enhanced intermittent endurance capacity with CHO supplementation.

The lack of influence of CHO on RPE reinforces the notion that CHO supplementation during sub-maximal team games exercise has a negligible effect on the effort perception of adolescents. Along with the HR data, it can therefore be intimated that enhancements in intermittent endurance capacity with CHO ingestion in these participants are from a metabolic source. Potential causes of the progressive increase in RPE with time are discussed elsewhere (Phillips et al 2010).

It appears that a CHO gel of the composition and [CHO] used in this study is tolerated as well as an isoenergetic CHO-E solution by adolescents during simulated team games exercise (Phillips et al 2010). The greater concentration of the gel means that a lower volume is ingested to achieve a given CHO intake compared with a solution, which may explain the good tolerance of the gels (Noakes et al 1991). Potential reasons for the influence of time on gastric variables have been discussed previously (Phillips et al 2010).

Carbohydrate and fluid intake

As evidenced from the above discussion and the results of our previous study (Phillips et al 2010), CHO gels and solutions providing the same amount of CHO appear similarly efficacious for maintaining physiological function and improving intermittent endurance

capacity during team games exercise in adolescents. Clearly, the BM-relative and absolute CHO intake in our two studies is lower than adult research. It is also lower than that recommended by adult guidelines for performance enhancement (Jeukendrup 2004). However, a significant ergogenic effect was still reported. This evidence, from two studies using the same exercise protocol and CHO concentration ([CHO]), and similar participants, suggests that CHO_{exo} requirements are different for adolescents than adults, with perhaps a lower CHO intake able to promote significant exercise enhancement (Phillips et al unpublished data).

Body mass loss and sweat rate

The non-significant between-trials difference in BM loss in the current study is in agreement with Phillips et al (2010) and previous adult work (Ali et al 2007; Nicholas et al 1995), as is the similar between-trials mean SR (Phillips et al 2010). Together, this data suggests a similar degree of thermal stress, and thermoregulatory ability, between trials. These data represent the only published information currently available on the BM loss and SR of adolescents during simulated team games, therefore further comparative discussion is not possible.

Blinding

Analysis of the solution responses in the CHO trial demonstrated that the blinding procedures used in this study were successful. However, as discussed by Phillips et al (2010), it may be inappropriate to evaluate the success of blinding procedures simply by comparing them to chance (Boutron et al 2005). It appears that exercise did not provide any cues enabling

participants to more accurately choose both gels post-exercise. Analysis of the individual trials suggests that exercise made it easier for participants to recognise the PLA gel and harder to recognise the CHO gel, although the response rate was near to the 50% correct/incorrect response rate that could be expected to occur by chance alone (Boutron et al 2005).

Conclusion

Ingestion of a CHO gel immediately before, and during, a simulated team games protocol significantly improves the intermittent endurance capacity of 12-14 year old team games players. Carbohydrate gel ingestion does not significantly influence the sprint performance or physiological responses of adolescents during simulated team games.

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Conflict of Interest

The authors declare they have no conflict of interest regarding this study.

Ethical Declaration

The authors confirm that the conduct of this study complied fully with current Scottish law, and with the full ethical approval of the University of Edinburgh, Moray House School of Education Ethics Committee.

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Tables

Table 1 Mean heart rate (beats per min) and mean ratings of perceived exertion during part A of the LIST, and mean peak HR and mean ratings of perceived exertion at exhaustion in part B for both trials.

	Period of the LIST				
	Block 1	Block 2	Block 3	Block 4	Exhaustion
Mean heart rate (beats per min)					
CHO	158 ± 7	163 ± 7***	164 ± 7	163 ± 6	187 ± 5
PLA	158 ± 9	162 ± 10***	163 ± 9	162 ± 9	185 ± 5
Mean ratings of perceived exertion					
CHO	5.1 ± 1.4	6.4 ± 1.1***	7.2 ± 0.6***	8.1 ± 0.5***	9.4 ± 0.5
PLA	5.0 ± 1.1	6.3 ± 0.9***	7.3 ± 1.0***	8.2 ± 0.8***	9.4 ± 0.50

Data are mean ± SD (n = 9 for mean HR in part A, n = 8 for mean HR in part B, n = 11 for mean RPE)

CHO = carbohydrate trial; PLA = placebo trial

*** significantly greater than previous block, $P < 0.001$

Table 2 Mean gut fullness and gastric discomfort ratings during part A of the LIST, and at exhaustion in part B, for both trials.

	Period of the LIST				
	Block 1	Block 2	Block 3	Block 4	Exhaustion
Mean gut fullness ratings					
CHO	4.3 ± 1.9	4.4 ± 1.9	5.2 ± 1.6†	5.2 ± 1.8	5.3 ± 1.8
PLA	3.4 ± 1.3	4.0 ± 1.1	4.5 ± 1.4†	4.5 ± 1.5	4.7 ± 1.3
Mean gastric discomfort ratings					
CHO	3.0 ± 1.7	3.5 ± 2.0**	4.5 ± 2.0**	4.5 ± 2.3	5.5 ± 2.3
PLA	2.8 ± 1.6	3.9 ± 1.9**	4.3 ± 2.5**	4.3 ± 2.3	5.3 ± 2.0

Data are mean ± SD (n = 11)

CHO = carbohydrate trial; PLA = placebo trial

† significantly greater than previous block, P < 0.01

** significantly greater than previous block, $P < 0.05$

Table 3 Mean ambient temperature (^{o}C) and relative humidity (%) immediately before, and during, part A of the LIST in both trials.

	Period of the LIST				
	Pre-exercise	Block 1	Block 2	Block 3	Block 4
Mean ambient temperature (^{o}C)					
CHO	18.5 ± 1.2	18.5 ± 1.2	18.5 ± 1.3	18.5 ± 1.3	18.5 ± 1.3
PLA	18.8 ± 1.1	18.9 ± 1.1	18.9 ± 1.1	18.9 ± 1.1	18.9 ± 1.1
Mean relative humidity (%)					
CHO	39.5 ± 8.0	39.5 ± 8.1	39.4 ± 8.2	39.5 ± 8.6	39.2 ± 8.5
PLA	45.6 ± 7.5	44.8 ± 7.3	44.7 ± 7.1	44.6 ± 7.3	44.6 ± 7.3

Data are mean ± SD (n = 11)

CHO = carbohydrate trial; PLA = placebo trial

A significant interaction effect was reported for mean ambient temperature ($P < 0.05$)

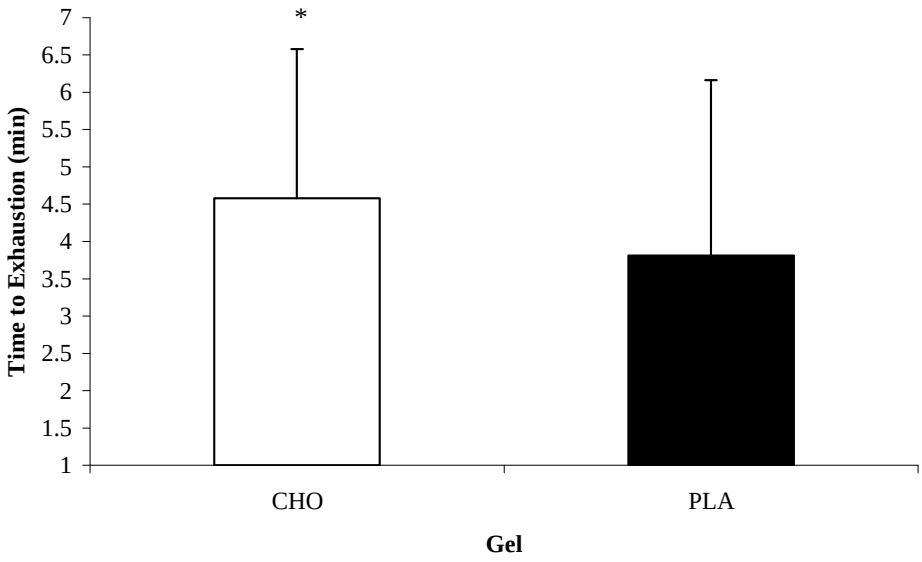

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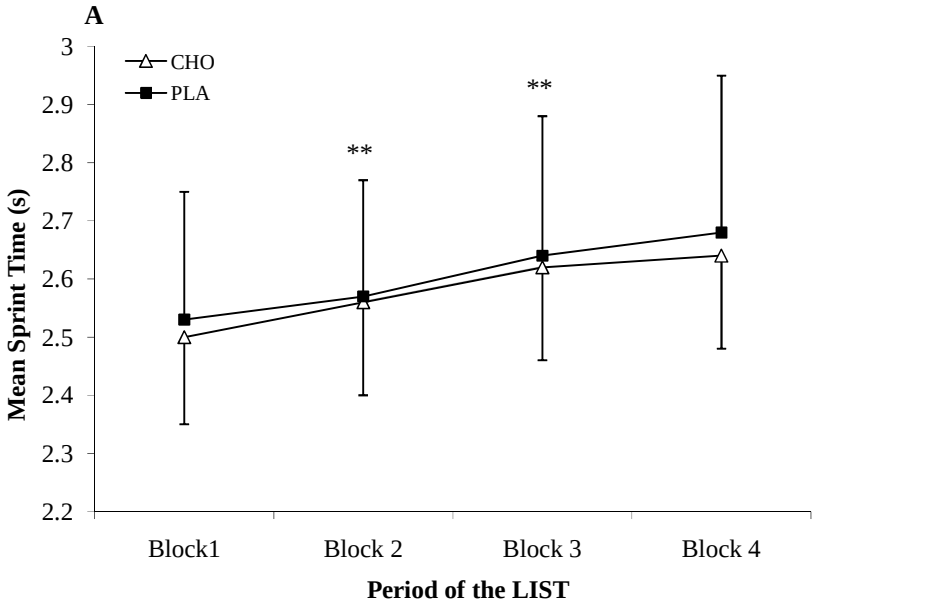
Figure 1 Time to exhaustion (min) during part B of the LIST in the CHO and PLA trial.

* significantly greater than the PLA trial, $P < 0.05$. (n=11).



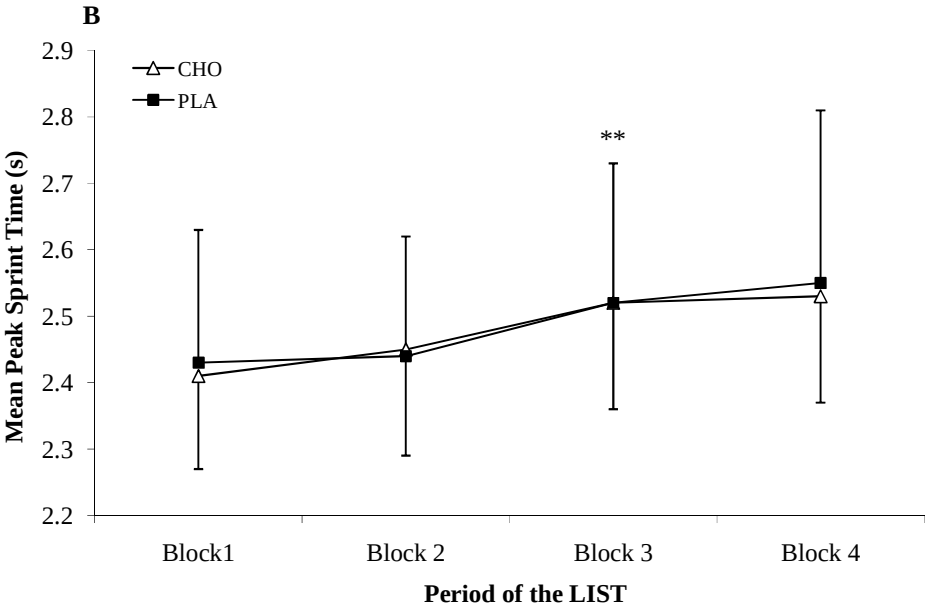


Figure 2 Mean sprint time (s, A) and mean peak sprint time (s, B) during part A of the LIST for both trials. ** significantly greater than previous block, $P < 0.05$. (n=11).