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

4

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23

24

25 **Running Title:** Carbohydrate gel and team games performance.

1 **Abstract**

2

3 The aim of this study was to investigate the influence of ingesting a carbohydrate (CHO) gel  
4 on the intermittent endurance capacity and sprint performance of adolescent team games  
5 players. Eleven participants (mean age  $13.5 \pm 0.7$  years, height  $1.72 \pm 0.08$  m, body mass  
6 (BM)  $62.1 \pm 9.4$  kg) performed two trials separated by 3-7 days. In each trial, they  
7 completed four 15 min periods of part A of the Loughborough Intermittent Shuttle Test,  
8 followed by an intermittent run to exhaustion (part B). In the 5 min pre-exercise, participants  
9 consumed  $0.818 \text{ ml.kg}^{-1}$  BM of a CHO or a non-CHO placebo gel, and a further  $0.327 \text{ ml.kg}^{-1}$   
10  $^1$  BM every 15 min during part A of the LIST ( $38.0 \pm 5.5 \text{ g CHO.h}^{-1}$  in the CHO trial).  
11 Intermittent endurance capacity was increased by 21.1% during part B when the CHO gel  
12 was ingested ( $4.6 \pm 2.0$  vs.  $3.8 \pm 2.4$  min,  $P < 0.05$ ,  $r = 0.67$ ), with distance covered in part B  
13 significantly greater in the CHO trial ( $787 \pm 319$  vs.  $669 \pm 424$  m,  $P < 0.05$ ,  $r = 0.57$ ). Gel  
14 ingestion did not significantly influence mean 15 m sprint time ( $P = 0.34$ ), peak sprint time  
15 ( $P = 0.81$ ), or heart rate ( $P = 0.66$ ). Ingestion of a CHO gel significantly increases the  
16 intermittent endurance capacity of adolescent team games players during a simulated team  
17 games protocol.

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22

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

24

## 1 **Introduction**

2

3 We have previously demonstrated a significant enhancement in the intermittent endurance  
4 running capacity (hereafter referred to as intermittent endurance capacity) of 12-14 year old  
5 team games athletes with ingestion of a 6% carbohydrate-electrolyte (CHO-E) solution  
6 during a modified Loughborough Intermittent Shuttle Test (LIST, Phillips et al 2010). This  
7 was achieved with a mean carbohydrate (CHO) intake of  $\sim 35 \text{ g}\cdot\text{h}^{-1}$ , or  $0.78 \text{ g}\cdot\text{kg}^{-1}$  body mass  
8 (BM), which is notably lower than the CHO intake in related adult work ( $\sim 60\text{-}92 \text{ g}\cdot\text{h}^{-1}$ ,  
9 Foskett et al 2008; Nicholas et al 1995; Welsh et al 2002). Young people display a different  
10 metabolic response to exercise than adults, characterised by an enhanced rate of fat  
11 metabolism and attenuated rate of endogenous CHO ( $\text{CHO}_{\text{endo}}$ ) use (Riddell 2008; Timmons  
12 et al 2007), perhaps to preserve endogenous glycogen stores, which may be lower than adults  
13 (Aucouturier et al 2008). Despite this, young people appear able to oxidise exogenous CHO  
14 ( $\text{CHO}_{\text{exo}}$ ) at BM-relative rates equal to, or greater than, adults for the same relative CHO  
15 ingestion rate (Timmons et al 2003). Therefore,  $\text{CHO}_{\text{exo}}$  requirements of young people may  
16 be different to those of adults, perhaps with a lower rate of CHO ingestion facilitating  
17 exercise enhancement (Phillips et al unpublished data). Coupled with the significant  
18 enhancement in intermittent endurance capacity reported in our previous study (Phillips et al  
19 2010), this knowledge emphasises that findings from studies supplementing CHO during  
20 simulated team games in adults cannot be confidently applied to young people, and a greater  
21 research output into CHO supplementation during simulated team games in adolescents is  
22 therefore warranted.

23

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

1 to consume greater amounts of CHO, in gel compared with solution form (Pfeiffer et al  
2 2010). Carbohydrate gel ingestion has been shown to improve prolonged steady-state cycling  
3 performance (Campbell et al 2008; Earnest et al 2004), with a negligible effect on half-  
4 marathon running performance (Burke et al 2005). However, the ~2.4% BM loss during the  
5 run, along with the presence of an order effect for performance time, may have negated the  
6 effect of the gel. Specific to team games exercise, Patterson and Gray (2007) showed a 45%  
7 improvement in intermittent endurance capacity when adult male soccer players ingested a  
8 CHO gel before and during the LIST. This is comparable to the improvement seen when  
9 consuming CHO-E solutions during the same or similar protocol (~33-52%, Foskett et al  
10 2008; Nicholas et al 1995; Welsh et al 2002). To date, this remains the only study to  
11 investigate CHO gel supplementation during team games exercise.

12

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

22

1 **Methods**

2

3 *Participants*

4

5 Eleven team games players (10 males and 1 female; mean age  $13.5 \pm 0.7$  years, height  $1.72 \pm$   
6  $0.08$  m, BM  $62.1 \pm 9.4$  kg) participated in the study. Participants were recruited from local  
7 schools and sports clubs. Inclusion criteria was to be between the ages of 12-14 years,  
8 regularly participating in competitive soccer, rugby or field hockey to at least club level, free  
9 from any muscle or joint injury, and not taking medication that influences the ability to  
10 exercise. All participants were in good health at the time of the study, as determined by  
11 completion of a pre-study medical questionnaire. Participants' were either frequent or  
12 occasional users of CHO containing sports drinks.

13

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

18

19 *Biological maturity status*

20

21 Due to ethical and consensual restrictions regarding direct observational assessment of  
22 Tanner stages, biological maturity offset was assessed using the established, non-invasive  
23 equations of Mirwald et al (2002), as previously described (Phillips et al 2010). For the  
24 participants in this study, mean biological maturity offset was  $+0.94$  years (range  $-1.77$  -  
25  $+2.68$  years). Mean predicted age at peak height velocity for the female participant was  $11.3$

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

4

#### 5 *Preliminary Tests*

6

#### 7 *Peak Running Velocity*

8

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

19

20 The  $V_{\text{peak}}$  test, adapted from Marino et al (2004), began at 8 km.h<sup>-1</sup> at a gradient of 1% for  
21 one minute, after which the speed was increased by 0.5 km.h<sup>-1</sup> in one-minute increments until  
22 the participant indicated that they could not continue despite strong verbal encouragement. A  
23 maximal effort was confirmed by observation of subjective symptoms of fatigue (facial  
24 flushing, unsteady gait, heavy sweating, hyperpnoea) and attainment of a heart rate (HR)  $\geq$   
25 195 beats per min (Armstrong 2007). Peak running velocity and maximum HR ( $HR_{\text{max}}$ ) were

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

5

## 6 *Experimental Design*

7

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



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

3

#### 4 *Experimental Protocol*

5

6 Standing height was measured using a free-standing adjustable stadiometer (Seca, model no.  
7 2251821009, Germany). After voiding and urinating, if necessary, dry nude BM was  
8 recorded (Seca Digital, model no. 7052321009, Germany). After attaching the HR monitor  
9 chest strap and watch (Polar RS400, Polar Electro Oy, Finland) participants sat quietly for 5  
10 min, then completed a standardised warm-up consisting of jogging, striding and dynamic  
11 stretching for 10 min. Immediately following the warm-up, participants sat and were  
12 instructed to consume the prescribed gel ( $0.818 \text{ ml.kg}^{-1} \text{ BM}$ ) followed by  $5 \text{ ml.kg}^{-1} \text{ BM}$  of  
13 water during the 5 min before commencing exercise. Water was ingested to offset the  
14 potential influence of dehydration (Patterson & Gray 2007), and was consumed in volumes  
15 that have previously been administered in this population during the same exercise protocol  
16 (Phillips et al 2010). Once the initial gel and water bolus had been consumed, participants  
17 were asked to state which gel they believed was being prescribed.

18

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

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

3

#### 4 *Measurements*

5

6 Heart rate was recorded at 5 s intervals throughout the  $V_{\text{peak}}$  test and the experimental  
7 protocol using short-range telemetry. Data was retrieved and downloaded onto a computer  
8 software program (Polar ProTrainer 5, Polar Electro Oy, Finland) for subsequent analysis.  
9 Ambient temperature and humidity were recorded immediately before the start of the  
10 protocol and at the end of each 15 min block in part A using a digital hygro-thermometer  
11 (Tako Astatic Technology, Malaysia). Ratings of perceived exertion (RPE) were measured  
12 during the first shuttle of the final walking phase of each 15 min block in part A and at  
13 exhaustion in part B using the Children's Omnibus Scale of Perceived Exertion (0-10 scale),  
14 which has been validated for use with participants of the age range in this study (Roemmich  
15 et al 2006). Gut fullness (GF) and gastric discomfort (GD) were assessed immediately on  
16 completion of each 15 min block in part A and at exhaustion in part B using anchored 10  
17 point scales (1 = not at all, 10 = extremely). Sprint times were measured in one direction by  
18 two wireless infrared single-beam photoelectric cells (Speed Trap 2, Gill Athletics, Illinois)  
19 placed 15 m apart. If participants needed to urinate at any time from the onset of the protocol  
20 until completion of the measurement of post-exercise BM they did so into a measuring jug,  
21 with this volume incorporated into the BM loss calculation. Body mass loss was calculated  
22 from the difference between pre- and post-exercise nude BM, corrected for fluid intake and  
23 urine output. Sweat rate (SR;  $\text{L}\cdot\text{h}^{-1}$ ) was calculated using the equation: (Pre-exercise BM (kg)  
24 + fluid ingested (L) – urine output (L) – post-exercise BM (kg)) / protocol duration (min) x  
25 60 (Edwards et al 2007). This calculation does not account for BM loss due to fuel oxidation

1 and respiratory fluid loss, but it is unlikely these would differ between trials (Edwards et al  
2 2007).

3

#### 4 *Statistical Analysis*

5

6 The Shapiro-Wilk test for normality was employed on all data sets. Paired *t*-tests compared  
7 between-trials differences in fluid, gel and CHO intake, pre-exercise BM, BM loss and SR,  
8 HR during part B, and HR, GF and GD at exhaustion. Distance covered in part A and B,  
9 time to exhaustion and RPE at exhaustion were analysed using the Wilcoxon matched-pairs  
10 test. Mean ambient temperature and relative humidity, sprint times and peak sprint times,  
11 and HR, GF and GD during part A were analysed with a 2 way (gel x time) ANOVA.  
12 Bonferroni pairwise comparisons were used to explore significant main effects with the  
13 exception of GF, where Wilcoxon matched-pairs tests with Bonferroni correction were used  
14 due to the grouped data displaying non-normal distribution. Friedman tests were used to  
15 analyse the main effect of time during part A within each trial for RPE. Wilcoxon matched-  
16 pairs tests, with Bonferroni correction, explored significant within-trials main effects. Chi-  
17 square analysis assessed the frequency distribution of gel choice responses. Effect sizes (ES)  
18 from ANOVA were calculated using partial eta squared ( $\eta^2$ ) values, which were square  
19 rooted to give correlation coefficients (Field 2005). Effect sizes generated from *t* scores were  
20 calculated using the equation of Rosnow and Rosenthal (2005), and from *z* scores using the  
21 equation of Rosenthal (1991), to give correlation coefficients (Field 2005). Effect sizes were  
22 defined as small ( $r = 0.1-0.3$ ), moderate ( $r = 0.3-0.5$ ), large ( $r = 0.5-0.7$ ), very large ( $r = 0.7-$   
23  $0.9$ ), and nearly perfect ( $r = 0.9-1.0$ ), based on the classifications of Hopkins (2006). Data  
24 are mean  $\pm$  SD, and with the exception of analyses using the Bonferroni correction,  
25 significance was set at  $P < 0.05$ .

26

## 1 **Results**

2

### 3 *Preliminary Tests*

4

5 Mean  $V_{\text{peak}}$  attained in the incremental treadmill run to exhaustion was  $14.6 \pm 0.9 \text{ km}\cdot\text{h}^{-1}$ .

6 Mean  $\text{HR}_{\text{max}}$  and RPE at exhaustion were  $197 \pm 6$  beats per min and  $9.2 \pm 0.4$ , respectively.

7

### 8 *Distance covered and time to exhaustion*

9

10 By design, distance covered during part A was the same in the CHO and PLA trials ( $7.1 \pm 0.2$   
11 km). Time to exhaustion during part B of the LIST for both trials is shown in Figure 1.

12 Participants ran for 21.1% longer in the CHO compared to the PLA trial ( $P < 0.05$ ,  $r = 0.67$ ),  
13 corresponding with a significantly greater distance covered in the CHO trial ( $787 \pm 319$  vs.  
14  $669 \pm 424$  m,  $P < 0.05$ ,  $r = 0.57$ ).

15

16 **PLEASE PLACE FIGURE 1 HERE**

17

### 18 *Sprint times*

19

20 The mean time of all sprints, and the mean of participants' peak sprint time only, in each  
21 block of part A of the LIST is shown in Figure 2A and 2B, respectively. Sprint times

22 throughout the LIST were faster in the CHO trial, but did not reach statistical significance

23 ( $F_{1,10} = 1.1$ ,  $P = 0.33$ ,  $r = 0.31$ ). There was also no interaction effect (gel x time,  $F_{3,30} = 0.4$ ,

24  $P = 0.75$ ,  $r = 0.20$ ). There was a main effect of time on sprint duration ( $F_{3,30} = 25.1$ ,  $P <$

25  $0.001$ ,  $r = 0.85$ ). Sprint times in block 2 were significantly slower than block 1 ( $P < 0.05$ ,  $r =$

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

8

9

**PLEASE PLACE FIGURES 2A and 2B HERE**

10

11 *Heart rate, ratings of perceived exertion, and gastric measures*

12

13 Mean HR and RPE during part A of the LIST, and mean peak HR and mean RPE at  
14 exhaustion in part B are shown in Table 1. There was no significant treatment ( $F_{1, 8} = 0.21$ ,  $P$   
15  $= 0.66$ ,  $r = 0.16$ ) or interaction ( $F_{3, 24} = 1.34$ ,  $P = 0.29$ ,  $r = 0.38$ ) effect on HR during part A  
16 of the LIST. There was a main effect of time for HR in part A ( $F_{1.32, 10.56} = 12.18$ ,  $P < 0.005$ ,  
17  $r = 0.78$ ). Heart rate in block 2 was significantly greater than block 1 ( $P < 0.001$ ,  $r = 0.95$ ).  
18 There was no significant difference between blocks 2 and 3 ( $P = 1.0$ ,  $r = 0.14$ ) or 3 and 4 ( $P$   
19  $= 0.97$ ,  $r = 0.35$ ). Mean HR during part B of the LIST was greater in the CHO trial, but did  
20 not reach statistical significance ( $175 \pm 5$  vs.  $173 \pm 6$  beats per min,  $P = 0.42$ ,  $r = 0.31$ ). Peak  
21 HR at exhaustion in part B was also higher in the CHO trial, but again this was not significant  
22 ( $P = 0.56$ ,  $r = 0.23$ ). Ratings of perceived exertion were very similar at all time points  
23 between trials, with no significant differences found. A main effect of time was present for  
24 the CHO ( $\chi^2(3) = 29.8$ ,  $P < 0.001$ ) and PLA ( $\chi^2(3) = 31.1$ ,  $P < 0.001$ ) trials. Ratings of  
25 perceived exertion increased significantly with each successive exercise block ( $P < 0.001$ ,  $r =$

1 0.89, 0.76 and 0.76, respectively) . There was no between-trials difference in RPE at  
2 exhaustion ( $P = 1.0$ ,  $r = 0$ ).

3

4

**PLEASE INSERT TABLE 1 HERE**

5

6 Mean GF and GD during part A of the LIST, and at exhaustion in part B, are shown in Table

7 2. Mean GF was greater in the CHO trial throughout part A of the LIST, but this was not

8 statistically significant ( $F_{1,10} = 3.50$ ,  $P = 0.09$ ,  $r = 0.51$ ). There was also no interaction effect

9 ( $F_{1.74, 17.36} = 0.65$ ,  $P = 0.52$ ,  $r = 0.25$ ). There was a significant effect of time on GF ( $F_{1.47, 14.71}$

10  $= 7.72$ ,  $P < 0.01$ ,  $r = 0.66$ ). Gut fullness in block 3 was significantly greater than block 2 ( $P$

11  $< 0.01$ ,  $r = 0.56$ ). There was no significant difference between blocks 1 and 2 ( $P = 0.06$ ,  $r =$

12  $0.40$ ) or 3 and 4 ( $P = 1.0$ ,  $r = 0$ ). Gut fullness scores during part A of the LIST were modest.

13 Gut fullness at exhaustion was higher in the CHO trial, but this was not statistically

14 significant ( $P = 0.24$ ,  $r = 0.37$ ). There was no treatment ( $F_{1,10} = 0.14$ ,  $r = 0.11$ ) or interaction

15 ( $F_{3,30} = 0.97$ ,  $r = 0.30$ ) effect on GD. Gastric discomfort increased significantly with time

16 ( $F_{1.45, 14.52} = 13.06$ ,  $P < 0.005$ ,  $r = 0.75$ ), and was significantly greater in block 2 than block 1

17 ( $P < 0.05$ ,  $r = 0.64$ ) and block 3 than block 2 ( $P < 0.05$ ,  $r = 0.54$ ). There was no significant

18 difference between blocks 3 and 4 ( $P = 1.0$ ,  $r = 0.06$ ). Gastric discomfort scores during part

19 A were also moderate. Gastric discomfort at exhaustion was higher in the CHO trial, but this

20 was not statistically significant ( $P = 0.59$ ,  $r = 0.17$ ).

21

22

**PLEASE PLACE TABLE 2 HERE**

23

24

1 *Body mass loss and sweat rate*

2

3 Mean pre-exercise dry nude BM was not significantly different between the CHO and PLA  
4 trials ( $62.4 \pm 9.1$  and  $62.9 \pm 9.2$  kg, respectively,  $P = 0.27$ ,  $r = 0.34$ ). Mean BM loss in the  
5 CHO and PLA trials was  $1.0 \pm 0.4$  and  $1.1 \pm 0.3$  kg, respectively ( $P = 0.36$ ,  $r = 0.29$ ),  
6 equating to a mean loss of  $1.59 \pm 0.53$  and  $1.67 \pm 0.37\%$  of pre-exercise BM ( $P = 0.50$ ,  $r =$   
7  $0.22$ ). Mean SR was  $0.77 \pm 0.27$  and  $0.85 \pm 0.27$  L.h<sup>-1</sup> in the CHO and PLA trials,  
8 respectively ( $P = 0.30$ ,  $r = 0.33$ ), equating to a BM-relative mean sweat loss of  $12.42 \pm 4.16$   
9 and  $13.44 \pm 3.70$  ml.kg<sup>-1</sup> BM.h<sup>-1</sup>, respectively ( $P = 0.39$ ,  $r = 0.28$ ).

10

11 *Blinding*

12

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

22

23

1 *Fluid and carbohydrate intake*

2

3 Mean fluid intake was  $811 \pm 119$  and  $811 \pm 120$  ml for the CHO and PLA trials, respectively  
4 ( $P = 0.93$ ,  $r = 0.03$ ). Mean gel intake in the CHO trial was  $132.6 \pm 19.4$  ml and in the PLA  
5 trial was  $132.7 \pm 19.6$  ml ( $P = 0.92$ ,  $r = 0.03$ ). Combined fluid and gel intake was  $943.6 \pm$   
6  $138.3$  and  $943.9 \pm 139.4$  ml ( $P = 0.92$ ,  $r = 0.03$ ) in the CHO and PLA trials, respectively. In  
7 the CHO trial, total CHO intake was  $38.0 \pm 5.5$  g.h<sup>-1</sup>, or 0.78 g.kg<sup>-1</sup> BM.

8

9 *Ambient temperature and relative humidity*

10

11 Mean ambient temperature and relative humidity during the LIST are shown in Table 3.

12 Mean ambient temperature was not significantly different between ( $F_{1, 10} = 3.59$ ,  $P = 0.09$ ,  $r =$   
13  $0.51$ ) or within ( $F_{1.06, 10.58} = 0.32$ ,  $P = 0.60$ ,  $r = 0.18$ ) trials. However, a significant gel x time  
14 interaction was present ( $F_{1.67, 16.70} = 3.87$ ,  $P < 0.05$ ,  $r = 0.53$ ). Mean relative humidity was  
15 not significantly different between ( $F_{1, 10} = 3.89$ ,  $P = 0.05$ ,  $r = 0.57$ ) or within ( $F_{1.9, 18.9} = 1.38$ ,  
16  $P = 0.28$ ,  $r = 0.35$ ) trials, and there was no interaction effect ( $F_{1.7, 17.4} = 1.08$ ,  $P = 0.35$ ,  $r =$   
17  $0.31$ )

18

19

**PLEASE PLACE TABLE 3 HERE**

20



1 **Discussion**

2

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

7

8 *Time to exhaustion*

9

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

21

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

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

3

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

16

17 The ~21% improvement in time to exhaustion in the current study is notably lower than the  
18 45% improvement reported by Patterson and Gray (2007). Patterson and Gray (2007) used a  
19 PLA solution, matched for taste, colour, and temperature, as a comparison to the CHO gel.  
20 Despite matching for these criteria, it is possible that participants would still have been aware  
21 of whether they were consuming a gel or a solution, due to the different consistencies of these  
22 products. Reporting of blinding statistics would have been useful to validate the success of  
23 the single-blinding procedures used. In addition, depending on the amount of information the  
24 participants were provided with as to the aims and/or expectations of the study, the use of a  
25 PLA solution could have raised a significant potential for experimenter bias and/or

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

5

#### 6 *Sprint Duration*

7

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

13

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

21

#### 22 *Heart rate, ratings of perceived exertion, and gastric measures*

23

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

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

6

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

13

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

20

### 21 *Carbohydrate and fluid intake*

22

23 As evidenced from the above discussion and the results of our previous study (Phillips et al  
24 2010), CHO gels and solutions providing the same amount of CHO appear similarly  
25 efficacious for maintaining physiological function and improving intermittent endurance

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

9

#### 10 *Body mass loss and sweat rate*

11

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

19

#### 20 *Blinding*

21

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

1 participants to more accurately choose both gels post-exercise. Analysis of the individual  
2 trials suggests that exercise made it easier for participants to recognise the PLA gel and  
3 harder to recognise the CHO gel, although the response rate was near to the 50%  
4 correct/incorrect response rate that could be expected to occur by chance alone (Boutron et al  
5 2005).

6

## 7 **Conclusion**

8

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

13

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2

3 The authors gratefully acknowledge the support of High5 Ltd, Bardon, Leicestershire, UK for  
4 the supply of CHO and PLA gels and drink bottles to enable completion of this study.

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1 **Conflict of Interest**

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

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1 **Ethical Declaration**

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

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1 **Tables**

2

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

|   | <b>Period of the LIST</b> |              |              |              |            |
|---|---------------------------|--------------|--------------|--------------|------------|
|   | Block 1                   | Block 2      | Block 3      | Block 4      | Exhaustion |
| <b>Mean heart rate (beats per min)</b>    |                           |              |              |              |            |
| CHO                                       | 158 ± 7                   | 163 ± 7***   | 164 ± 7      | 163 ± 6      | 187 ± 5    |
| PLA                                       | 158 ± 9                   | 162 ± 10***  | 163 ± 9      | 162 ± 9      | 185 ± 5    |
| <b>Mean ratings of perceived exertion</b> |                           |              |              |              |            |
| 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 |

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

8 CHO = carbohydrate trial; PLA = placebo trial

9 \*\*\* significantly greater than previous block, *P* < 0.001

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

|  | <b>Period of the LIST</b> |             |             |           |            |
|--|---------------------------|-------------|-------------|-----------|------------|
|  | Block 1                   | Block 2     | Block 3     | Block 4   | Exhaustion |
| <b>Mean gut fullness ratings</b>       |                           |             |             |           |            |
| 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  |
| <b>Mean gastric discomfort ratings</b> |                           |             |             |           |            |
| 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  |

3 Data are mean ± SD (*n* = 11)

4 CHO = carbohydrate trial; PLA = placebo trial

5 † significantly greater than previous block, *P* < 0.01

6 \*\* significantly greater than previous block, *P* < 0.05

7

8

9



- 1 **Table 3** Mean ambient temperature (°C) and relative humidity (%) immediately before, and  
 2 during, part A of the LIST in both trials.

|                                      | <b>Period of the LIST</b> |            |            |            |            |
|--------------------------------------|---------------------------|------------|------------|------------|------------|
|                                      | Pre-exercise              | Block 1    | Block 2    | Block 3    | Block 4    |
| <b>Mean ambient temperature (°C)</b> |                           |            |            |            |            |
| 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 |
| <b>Mean relative humidity (%)</b>    |                           |            |            |            |            |
| 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 |

- 3 Data are mean ± SD (*n* = 11)
- 4 CHO = carbohydrate trial; PLA = placebo trial
- 5 A significant interaction effect was reported for mean ambient temperature (*P* < 0.05)

1 **Figure Captions**

2

3 **Figure 1** Time to exhaustion (min) during part B of the LIST in the CHO and PLA trial. \*  
4 significantly greater than the PLA trial,  $P < 0.05$ . ( $n=11$ ).

5

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

8

9