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### **Beverage carbohydrate concentration influences the intermittent endurance capacity of adolescent team games players during prolonged intermittent running**

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1 **Beverage carbohydrate concentration influences the intermittent endurance capacity of**  
2 **adolescent team games players during prolonged intermittent running.**

3

4

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25

1 **Abstract**

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This study investigated the influence of consuming a 2, 6, and 10% carbohydrate-electrolyte (CHO-E) solution on the intermittent endurance capacity and sprint performance of adolescent team games players. Seven participants (five males and two females; mean age  $13.3 \pm 0.5$  years, height  $1.71 \pm 0.05$  m, body mass (BM)  $62.0 \pm 6.3$  kg) performed three trials separated by 3 to 7 days. In each trial, they completed four 15 min periods of part A of the Loughborough Intermittent Shuttle Test (LIST) followed by an intermittent run to exhaustion (part B). Participants consumed  $5 \text{ ml.kg}^{-1}$  BM of the solution during the 5 min pre-exercise period, and a further  $2 \text{ ml.kg}^{-1}$  BM every 15 min during part A of the LIST. Intermittent endurance capacity increased by 34% with ingestion of the 6% CHO-E solution compared with the 10% solution ( $5.5 \pm 0.8$  vs.  $4.1 \pm 1.5$  min,  $P < 0.05$ ), equating to a distance of  $931 \pm 172$  vs.  $706 \pm 272$  m ( $P < 0.05$ ). There was no significant difference between the 2% ( $4.8 \pm 1.2$  min) and 6% ( $P = 0.10$ ) or the 2% and 10% solutions ( $P = 0.09$ ). Carbohydrate concentration did not significantly influence mean 15 m sprint time ( $P = 0.38$ ). These results suggest that the carbohydrate concentration of an ingested solution influences the intermittent endurance capacity of adolescent team games players with a 6% solution significantly more effective than a 10% solution.

**Key Words:** Team games; performance; nutrition; young people; LIST

## 1 **Introduction**

2

3 We recently reported a significant 24% improvement in intermittent endurance running  
4 capacity (hereafter referred to as intermittent endurance capacity) when 12-14 year old team  
5 games athletes ingested a 6% carbohydrate-electrolyte (CHO-E) solution before and during a  
6 modified Loughborough Intermittent Shuttle Test (LIST, Phillips et al 2010). This was  
7 achieved using the same body mass (BM)-standardised ingestion volumes and timings as the  
8 original adult work of Nicholas et al (1995). The lack of a significant treatment effect on  
9 heart rate (HR), ratings of perceived exertion (RPE), sweat rate (SR) or BM loss in our  
10 previous study also mirrored the findings of most relevant adult studies (Ali et al 2007; Davis  
11 et al 1999; Nicholas et al 1995; Welsh et al 2002). This suggests that the relative  
12 physiological responses to intermittent endurance running with carbohydrate (CHO)  
13 supplementation appear similar between adolescents and adults.

14

15 Most previous adult studies that demonstrated improved intermittent endurance capacity with  
16 CHO ingestion during intermittent endurance running used a CHO concentration ([CHO]) of  
17 6.0-6.9% (60-69 g.L<sup>-1</sup> of solution, Davis et al 1999; Nicholas et al 1995; Welsh et al 2002).  
18 This is similar to existing guidelines for CHO supplementation during prolonged steady-state  
19 exercise for adults, i.e. a recommendation of ~1.0-1.1 g.min<sup>-1</sup> (60-70 g.h<sup>-1</sup>, Jeukendrup 2004)  
20 to maximise exogenous CHO (CHO<sub>exo</sub>) oxidation. However, it cannot be assumed that these  
21 guidelines for steady-state exercise also apply to CHO ingestion during participation in team  
22 games. Christmass et al (1999) demonstrated a 1.2 times higher ( $P < 0.05$ ) rate of  
23 endogenous CHO (CHO<sub>endo</sub>) oxidation during 90 min of sustained intermittent compared with  
24 continuous running at the same overall  $\dot{V}O_2$ . This suggests that the requirement for CHO  
25 may be greater during intermittent compared with continuous exercise. Some studies have

1 investigated the influence of [CHO] on endurance capacity during prolonged intermittent  
2 exercise (Murray et al., 1987). However, protocol issues make drawing conclusions on the  
3 influence of [CHO] difficult, and also preclude the application of the findings to team games.  
4 To date, no published research has investigated the influence of consuming different [CHO]  
5 during intermittent endurance running. Ali and Williams (2009) reported no benefit of  
6 ingesting CHO at a rate of 52 g.h<sup>-1</sup> on sprint performance during the LIST, but did report a  
7 significant improvement in sprint performance with ingestion of 32 g CHO.h<sup>-1</sup> (Ali et al  
8 2007). However, intermittent endurance capacity, where CHO ingestion most consistently  
9 exerts an effect during intermittent endurance running, was not assessed in these studies.  
10  
11 Due to a lack of empirical research, no published guidelines exist for CHO supplementation  
12 during team games exercise in adolescents. The findings of Phillips et al (2010) were  
13 generated despite one fewer drink period compared with adult work, as adolescents  
14 commonly play team games for a shorter duration than adults (60 min vs. 90 min, Ekblom  
15 1986). As a result, mean CHO intake was 0.56 g.min<sup>-1</sup> compared with ~0.79-1.3 g.min<sup>-1</sup> in  
16 adult work (Nicholas et al 1995; Welsh et al 2002). While the shorter duration of adolescent  
17 team games may suggest a lesser depletion of CHO<sub>endo</sub> stores, and therefore question the  
18 efficacy of CHO supplementation, it should be considered that adolescents may have lower  
19 endogenous glycogen stores than adults (Aucouturier et al 2008), which may offset the  
20 sparing effect of a shorter exercise bout. Furthermore, BM-relative CHO<sub>exo</sub> oxidation rates  
21 may be significantly greater in young people compared to adults (Timmons et al 2003),  
22 despite the preferential use of fat as a fuel source in young people (Timmons *et al* 2007).  
23 This is likely a mechanism to preserve the lower CHO<sub>endo</sub> stores (Riddell 2008). The  
24 different metabolic response of young people to exercise indicates that adult guidelines  
25 regarding CHO supplementation before and during exercise may not be appropriate for this

1 population. It would be of interest to study the influence of different rates of CHO ingestion  
2 by young people during intermittent endurance running. This would enable observation of  
3 whether their ability to readily oxidise CHO<sub>exo</sub> elicits a dose-response relationship to CHO  
4 provision in terms of enhancing exercise performance (Jeukendrup et al 1999), and to begin  
5 the process of forming guidelines for the ingestion of CHO during intermittent endurance  
6 running in this population.

7

8 Manipulating CHO<sub>exo</sub> intake could be achieved by ingesting different volumes of a 6%  
9 solution; however, ingesting larger volumes may lead to gastrointestinal distress (Shi et al  
10 2004). Furthermore, this practice would not translate well to actual field-based team games,  
11 where there are limited opportunities to drink during matches (Clarke et al 2008).

12 Manipulating the [CHO] of the ingested solution may also increase the risk of gastrointestinal  
13 distress (Shi et al 2004), but the minimal understanding of CHO tolerance during team games  
14 in adolescents, along with the absence of any CHO intake guidelines, provides a rationale for  
15 using different [CHO].

16

17 The aim of this study is to determine the influence of ingesting a 2, 6, and 10% CHO-E  
18 solution immediately before, and during, an intermittent endurance running protocol on the  
19 intermittent endurance capacity and sprint performance of adolescent team games players. It  
20 was hypothesised that [CHO] would significantly influence intermittent endurance capacity,  
21 but would not significantly impact sprint performance during prolonged intermittent running.

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## 1 **Methods**

2

### 3 *Participants*

4

5 Seven team games players (five males and two females; mean age  $13.3 \pm 0.5$  years, height  
6  $1.71 \pm 0.05$  m, BM  $62.0 \pm 6.3$  kg) participated in the study. Participants were recruited from  
7 local schools and sports clubs. Inclusion criteria were that they had to be between the ages of  
8 12-14 years, regularly participating in competitive soccer, rugby or field hockey to at least  
9 club level, free from any muscle or joint injury, and not taking medication that influences the  
10 ability to exercise. All participants were in good health at the time of the study, as  
11 determined by completion of a pre-study medical questionnaire. Participants' were either  
12 frequent or occasional users of CHO containing sports drinks.

13

14 Prior to inclusion, comprehensive written and verbal explanation of the study was given to  
15 participants and parents, and written parental informed consent was received. Each  
16 participant then gave their written assent. The study received ethical approval from the  
17 University of Edinburgh Ethics Committee.

18

### 19 *Biological maturity status*

20

21 Biological maturity was not assessed using direct observational assessment of Tanner Stages  
22 (Tanner 1962), due to ethical and consensual restrictions. Instead, biological maturity offset  
23 was assessed using the established, non-invasive equations of Mirwald et al (2002), as  
24 previously described (Phillips et al 2010). For the participants in this study, mean biological  
25 maturity offset was +1.25 years (range +0.70 to +2.68 years). Mean predicted age at peak

1 height velocity for females was 11.3 years (range 0 years) and for males was 13.0 years  
2 (range 12.3 to 13.8 years). This classifies the participants in this study as average 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 in contrast to  
11 the more common calculation of speed based on percentage of  $\dot{V}O_{2\text{max}}$ , and is believed to  
12 more accurately reflect physiological demand during team games (Bangsbo 1994). The  
13 physiological responses to incremental maximal treadmill running and free-range running  
14 have been reported to be similar (Crouter et al., 2001). Prior to undertaking the  $V_{\text{peak}}$  test, all  
15 participants walked at a self-selected speed on the treadmill (Ergo 55, Woodway, Germany)  
16 for 2 min, then completed the first four levels of the  $V_{\text{peak}}$  test as described below, to  
17 familiarise themselves with the treadmill (Lavcanska et al 2005). This also acted as a  
18 standardised warm-up. Following this familiarisation, participants sat quietly for 10 min to  
19 recover and allow any excessive anxiety to dissipate before starting the test.

20

21 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  
22 one-minute, after which the speed was increased by 0.5 km.h<sup>-1</sup> in one-minute increments until  
23 the participant indicated they could not continue, despite strong verbal encouragement. A  
24 maximal effort was confirmed by observation of subjective symptoms of fatigue (facial  
25 flushing, unsteady gait, heavy sweating, hyperpnoea) and attainment of a HR  $\geq$  195 beats per



1 min (Armstrong 2007). Peak running velocity and maximum HR ( $HR_{max}$ ) were calculated as  
2 the highest treadmill velocity maintained for 30 s and the highest 5 s average, respectively.  
3 After a 15 min seated recovery, participants performed 15 min of the LIST, as described  
4 below, to familiarise themselves with the running speeds required and the data collection  
5 procedures.

6

### 7 *Experimental Design*

8

9 All participants completed three trials separated by a minimum of three, and maximum of  
10 seven, days, in a randomised, counterbalanced, double-blind fashion. The three trials were as  
11 follows:

12

13 A. 2% CHO-E solution (low CHO trial – LCHO)

14 B. 6% CHO-E solution (moderate CHO trial – MCHO)

15 C. 10% CHO-E solution (High CHO trial – HCHO)

16

17 The [CHO] of both the LCHO and MCHO solutions was similar to that of commercially  
18 available CHO-E drinks. Furthermore, the [CHO] of the MCHO solution was the same as  
19 that used in previous research from this laboratory (Phillips et al 2010) and was similar to  
20 solutions used in the majority of adult work (Davis et al 1999; Nicholas et al 1995; Welsh et  
21 al 2002). The HCHO solution was employed, as solutions with a [CHO] >10% are rarely  
22 used in contemporary research due to current adult guidelines regarding fluid and CHO  
23 intake during prolonged, steady-state exercise (Jeukendrup 2004). No such guidelines  
24 currently exist for young people. Therefore, the use of a [CHO] greater than 10% currently

1 has no empirical support and, due to the lack of knowledge of CHO tolerance during  
2 prolonged intermittent exercise in young people, no ethical basis.

3

4 The CHO was 100% maltodextrin (High5 Ltd, Bardon, UK). Commercially available  
5 electrolyte tablets (High5 Ltd, Bardon, UK) were used in all solutions (one tablet dissolved  
6 per 500 ml of solution), yielding the following electrolyte concentrations per L: sodium, 250  
7 mg; magnesium, 60 mg; potassium, 90 mg; calcium, 20 mg. The electrolyte tablets also  
8 contained a flavouring (citrus, berry, or cherry-orange). Prior to the first trial, each  
9 participant was asked which flavour they would prefer. The participants' chosen flavour was  
10 then used for all three of their trials. Therefore, within-participants, all solutions were  
11 matched for colour, taste, texture, and feeling within the mouth. Participants were requested  
12 to refrain from heavy physical activity for 48 h before each trial. They were also asked to  
13 record their food and fluid intake, including the portion size of all food consumed and the  
14 volume of all fluid ingested, for 24 h before the first trial. This diet was replicated prior to  
15 trials two and three to standardise muscle and hepatic glycogen concentrations and hydration  
16 status. Participants were not requested to record food and fluid intake in the depth of detail  
17 that would have enabled a subsequent dietary composition analysis. Requesting this would  
18 have placed greater stress on extremely time-pressured participants and their parents, and  
19 may have negatively affected adherence to the dietary record, and retention of participants  
20 through the full study.

21

## 22 *Experimental Protocol*

23

24 Standing height was measured using a free-standing adjustable stadiometer (Seca, model no.  
25 2251821009, Germany). After voiding and urinating, if necessary, dry nude BM was

1 recorded (Seca Digital, model no. 7052321009, Germany). Participants were then fitted with  
2 a HR monitor chest strap and watch (Polar RS400, Polar Electro Oy, Finland) and sat quietly  
3 for 5 min, after which a standardised warm-up consisting of jogging, striding and dynamic  
4 stretching was undertaken for 10 min. Immediately following the warm-up, participants sat  
5 and were instructed to consume the prescribed solution ( $5 \text{ ml.kg}^{-1} \text{ BM}$ ) during the 5 min  
6 before commencing exercise (Nicholas et al 1995). Once this initial bolus had been  
7 consumed, participants were asked to state which solution they believed was being  
8 prescribed.

9  
10 The LIST was conducted indoors, on a level rubber floor, as described elsewhere (Phillips et  
11 al 2010). Briefly, participants completed four blocks of part A of the LIST separated by 3  
12 min seated recovery, followed by an intermittent run to exhaustion (part B). Participants  
13 consumed the solution ( $2 \text{ ml.kg}^{-1} \text{ BM}$ ) in the recovery period between each 15 min block and  
14 in the recovery period before commencing part B. After the measurement of post-exercise  
15 BM, participants were asked again to state which solution they believed they had received  
16 during the protocol. This was done in order to compare their response with their pre-exercise  
17 choice, and observe whether their experiences during the exercise bout prompted them to  
18 change their mind about which solution they had consumed during the protocol. Participants'  
19 were clearly informed that they were free to change their mind from their pre-exercise  
20 solution choice, or to keep their selection the same.

21  
22 *Measurements*

23  
24 Heart rate was recorded at 5 s intervals throughout the  $V_{\text{peak}}$  test and the experimental  
25 protocol using short-range telemetry. Data was retrieved and downloaded onto a computer

1 software program (Polar ProTrainer 5, Polar Electro Oy, Finland) for subsequent analysis.

2 Ambient temperature and relative humidity were recorded immediately before the start of the

3 protocol and at the end of each 15 min block in part A using a digital hygro-thermometer

4 (Tako Astatic Technology, Malaysia). Ratings of perceived exertion were recorded during

5 the first shuttle of the final walking phase of each 15 min block in part A and at exhaustion in

6 part B using the Children's Omnibus Scale of Perceived Exertion (0-10 scale). This scale has

7 been validated for use with participants of the age range in this study (Roemmich et al 2006).

8 Gut fullness (GF) and gastric discomfort (GD) were assessed immediately on completion of

9 each 15 min block in part A and at exhaustion in part B via anchored 10 point scales (1 = not

10 at all, 10 = extremely; van Nieuwenhoven et al 2005). Sprint times were measured in one

11 direction by two wireless infrared single-beam photoelectric cells (Speed Trap 2, Gill

12 Athletics, Illinois) placed 15 m apart. If participants needed to urinate at any time from the

13 onset of the protocol until completion of the measurement of post-exercise BM, they did so

14 into a measuring jug, with this volume incorporated into the BM loss calculation. No

15 participant needed to urinate during the protocol in the current study. Body mass loss was

16 calculated from the difference between pre- and post-exercise nude BM, corrected for fluid

17 intake and urine output. Sweat rate ( $L \cdot h^{-1}$ ) was calculated using the equation: (Pre-exercise

18 BM (kg) + fluid ingested (L) – urine output (L) – post-exercise BM (kg)) / protocol duration

19 (min) x 60 (Edwards et al 2007). This calculation does not account for BM loss due to fuel

20 oxidation and respiratory fluid loss, but it is unlikely these would differ between trials

21 (Edwards et al 2007).

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1 *Statistical Analysis*

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The Shapiro-Wilk test for normality was employed on all data sets. One-way repeated measures ANOVA compared between trials differences in fluid and CHO intake, pre-exercise BM, BM loss and SR, and time to exhaustion, HR, RPE, GF and GD at exhaustion in part B. Bonferroni pairwise comparisons and simple contrast analysis were used to explore main effects of fluid and CHO intake and time to exhaustion, respectively. Two way (solution x time) ANOVA analysed mean relative humidity, mean sprint times and mean peak sprint times, HR, RPE, GF and GD during part A. Bonferroni pairwise comparisons explored the main effect for RPE, and paired t-tests with Bonferroni correction explored main effects for mean sprint times, mean peak sprint times, HR, GF and GD. Friedman tests with Bonferroni correction analysed between trials differences in mean ambient temperature at all time points, with a Friedman's test employed to analyse the main effect of time for the grouped trials data. Chi-square analysis assessed the frequency distribution of solution choice responses. Effect sizes (ES) were calculated using partial eta squared ( $\eta^2$ ) values, which were square rooted to give correlation coefficients (Field 2005). Where post-hoc paired t-tests with Bonferroni correction were performed, ES was calculated using the equation of Rosnow and Rosenthal (2005) to produce correlation coefficients. 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  $\pm$  SD. With the exception of analyses using the Bonferroni correction, significance was set at  $P < 0.05$ .

## 1 **Results**

2

### 3 *Preliminary Tests*

4

5 Mean  $V_{\text{peak}}$  attained in the incremental treadmill run to exhaustion was  $14.4 \pm 1.2 \text{ km}\cdot\text{h}^{-1}$ .

6 Mean  $\text{HR}_{\text{max}}$  and RPE at exhaustion were  $196 \pm 6$  beats per min and  $9.3 \pm 0.5$ , respectively.

7

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

9

10 By design, distance covered during part A was the same in all three trials ( $7.1 \pm 0.3 \text{ km}$ ).

11 Time to exhaustion was significantly influenced by solution ( $F_{2, 12} = 6.1$ ,  $P < 0.05$ ,  $r = 0.71$ ),

12 and was 34% greater in the MCHO trial compared with the HCHO trial ( $5.5 \pm 0.8$  vs.  $4.1 \pm$

13  $1.5 \text{ min}$ ,  $P < 0.05$ ,  $r = 0.76$ ), and by 14.6% compared with the LCHO trial ( $4.8 \pm 1.2 \text{ min}$ ),

14 although this was not statistically significant ( $P = 0.10$ ,  $r = 0.63$ ). Time to exhaustion in the

15 LCHO trial was 17.1% greater than the HCHO trial, but was not statistically significant ( $P =$

16  $0.09$ ,  $r = 0.63$ ). Distance covered in part B was significantly greater in the MCHO trial

17 compared with the HCHO trial ( $931 \pm 172$  vs.  $706 \pm 272 \text{ m}$ ,  $P < 0.05$ ,  $r = 0.76$ ), but not the

18 LCHO trial ( $811 \pm 230 \text{ m}$ ,  $P = 0.09$ ,  $r = 0.63$ ). Distance covered was not significantly

19 different between the LCHO and HCHO trials ( $P = 0.11$ ,  $r = 0.61$ ).

20

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1 *Sprint times*

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3 The mean time of all sprints, and the mean of participants' peak sprint time only, in each  
4 block of part A of the LIST are shown in figure 1A and 1B, respectively. There was a trend  
5 for mean sprint times to be slower throughout exercise in the HCHO trial compared with the  
6 other two trials, but no main effect of solution was present ( $F_{2, 10} = 1.1, P = 0.38, r = 0.42$ ).  
7 Similarly, there was no interaction effect (solution x time,  $F_{2.1, 10.3} = 0.89, P = 0.44, r = 0.39$ ).  
8 There was a main effect of time ( $F_{1.1, 5.5} = 8.6, P < 0.05, r = 0.79$ ), with sprint time increasing  
9 significantly with each successive exercise block ( $P < 0.05, r = 0.56, 0.82$  and  $0.55,$   
10 respectively). Peak sprint time for each exercise block showed a trend for slower times in the  
11 HCHO trial compared with the other two trials, but no main effect of solution ( $F_{2, 10} = 1.1, P$   
12  $= 0.37, r = 0.42$ ) or interaction ( $F_{6, 30} = 0.6, P = 0.72, r = 0.33$ ) was found. There was a main  
13 effect of time ( $F_{3, 15} = 8.3, P < 0.005, r = 0.79$ ), with peak sprint time significantly slower in  
14 block 3 than block 2 ( $P < 0.001, r = 0.75$ ). There was no significant difference between  
15 blocks 1 and 2 ( $P = 0.22, r = 0.30$ ) or 3 and 4 ( $P = 0.60, r = 0.10$ ).

16

17 **PLEASE PLACE FIGURE 1A and 1B HERE**

18

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

20

21 Mean HR and RPE during part A of the LIST, and mean peak HR and RPE at exhaustion in  
22 part B are shown in table 1. Heart rate was lower in the LCHO trial at all time points in part  
23 A, but there was no significant treatment ( $F_{2, 8} = 1.8, P = 0.23, r = 0.56$ ) or interaction ( $F_{6, 24}$   
24  $= 1.7, P = 0.62, r = 0.40$ ) effect. There was a main effect of time for HR in part A ( $F_{3, 12} =$   
25  $32.1, P < 0.001, r = 0.94$ ). Heart rate in block 2 was significantly greater than block 1 ( $P <$

1 0.01,  $r = 0.98$ ). There was no significant difference between blocks 2 and 3 ( $P = 0.48$ ,  $r =$   
2 0.76) or 3 and 4 ( $P = 1.0$ ,  $r = 0.22$ ). Peak HR at exhaustion in part B was not significantly  
3 different between trials ( $F_{1.1, 6.8} = 0.67$ ,  $P = 0.46$ ,  $r = 0.32$ ). Ratings of perceived exertion  
4 were similar at all time points between trials, with no significant differences found ( $F_{2, 12} =$   
5 1.3,  $P = 0.32$ ,  $r = 0.42$ ). No interaction effect was present ( $F_{6, 36} = 0.3$ ,  $P = 0.53$ ,  $r = 0.35$ ).  
6 There was a main effect of time ( $F_{1.1, 6.5} = 36.0$ ,  $P < 0.005$ ,  $r = 0.93$ ), with RPE significantly  
7 greater in block 2 than block 1 ( $P < 0.05$ ,  $r = 0.97$ ) and in block 4 than block 3 ( $P < 0.001$ ,  $r$   
8  $= 0.99$ ). There was no significant difference between blocks 2 and 3 ( $P = 0.41$ ,  $r = 0.95$ ), and  
9 no significant between trials difference in RPE at exhaustion ( $F_{1, 6} = 1.0$ ,  $P = 0.36$ ,  $r = 0.38$ ).

10  
11 **PLEASE PLACE TABLE 1 HERE**

12  
13 Mean GF and GD during part A of the LIST and at exhaustion in part B are shown in table 2.  
14 Mean GF was not significantly influenced by solution ( $F_{2, 12} = 1.1$ ,  $P = 0.36$ ,  $r = 0.40$ ), and  
15 there was no interaction effect ( $F_{6, 36} = 1.0$ ,  $P = 0.43$ ,  $r = 0.38$ ). There was a significant effect  
16 of time on GF ( $F_{3, 18} = 3.3$ ,  $P < 0.05$ ,  $r = 0.59$ ). This main time effect was just under the  
17 stated alpha figure of  $P < 0.05$ , and specific differences between time points could not be  
18 determined using *post hoc* analyses. Effect sizes for the differences between blocks 1 and 2,  
19 2 and 3, and 3 and 4 were  $r = 0.10$ , 0.22 and 0.48, respectively. Gut fullness at exhaustion  
20 was not significantly different between trials ( $F_{2, 12} = 2.2$ ,  $P = 0.16$ ,  $r = 0.51$ ). Despite the  
21 significant main effect of time, GF scores during part A of the LIST were modest. There was  
22 no treatment ( $F_{2, 12} = 0.4$ ,  $P = 0.68$ ,  $r = 0.25$ ) or interaction ( $F_{6, 36} = 1.8$ ,  $P = 0.14$ ,  $r = 0.48$ )  
23 effect on GD, but there was a main effect of time ( $F_{3, 18} = 3.9$ ,  $P < 0.05$ ,  $r = 0.63$ ). As with  
24 GF, specific differences could not be determined *post hoc*. Effect sizes for the differences  
25 between blocks 1 and 2, 2 and 3, and 3 and 4 were  $r = 0.46$ , 0.10 and 0.40, respectively.



1 Gastric discomfort at exhaustion was similar across all trials ( $F_{2, 12} = 0.27$ ,  $P = 0.77$ ,  $r =$   
2 0.21). Gastric discomfort scores during part A of the LIST were moderate.

3

4

## PLEASE PLACE TABLE 2 HERE

5

### *Body mass loss and sweat rate*

7

8 Mean pre-exercise dry nude BM was not significantly different between trials ( $F_{2, 12} = 0.1$ ,  $P$   
9  $= 0.92$ ,  $r = 0.11$ ). Mean BM loss was  $1.0 \pm 0.2$ ,  $1.0 \pm 0.2$ , and  $1.0 \pm 0.4$  kg in the LCHO,  
10 MCHO and HCHO trials, respectively ( $F_{2, 12} = 0.11$ ,  $P = 0.90$ ,  $r = 0.13$ ), equating to a mean  
11 loss of  $1.62 \pm 0.37$ ,  $1.63 \pm 0.24$ , and  $1.54 \pm 0.49\%$  of pre-exercise BM, respectively ( $F_{2, 12} =$   
12  $0.24$ ,  $P = 0.79$ ,  $r = 0.19$ ). Mean SR was  $0.78 \pm 0.15$ ,  $0.78 \pm 0.13$ , and  $0.76 \pm 0.28$  L.h<sup>-1</sup> in the  
13 LCHO, MCHO and HCHO trials, respectively ( $F_{2, 12} = 0.03$ ,  $P = 0.97$ ,  $r = 0.07$ ), equating to a  
14 BM-relative mean sweat loss of  $12.63 \pm 2.81$ ,  $12.53 \pm 1.75$ , and  $12.18 \pm 3.86$  ml.kg<sup>-1</sup> BM.h<sup>-1</sup>,  
15 respectively ( $F_{2, 12} = 0.09$ ,  $P = 0.91$ ,  $r = 0.12$ ).

16

### *Blinding*

18

19 After consuming the initial bolus of the solution immediately prior to exercise, one  
20 participant (14%) correctly identified all solutions and six (86%) failed to do so. Chi square  
21 analysis of the responses in the MCHO trial found a non-significant deviation from the  
22 expected response frequency ( $\chi^2(1) = 3.6$ ,  $P = 0.16$ ). Post-exercise, only one participant  
23 correctly guessed all three solutions, and this was the same participant who guessed all three  
24 correctly pre-exercise. In the LCHO and MCHO trials, one participant (14%) changed their  
25 mind post-exercise and correctly guessed the solution when they had guessed incorrectly

1 prior to exercise. In the HCHO trial, no participant identified the correct solution post-  
2 exercise after having chosen incorrectly pre-exercise.

3

#### 4 *Ambient temperature and relative humidity, fluid and carbohydrate intake*

5

6 Mean ambient temperature and relative humidity during the LIST are shown in table 3. Mean  
7 ambient temperature was not significantly different between trials at any time point, therefore  
8 the data for all three trials was grouped for analysis of a main effect of time. Mean ambient  
9 temperature rose from  $18.0 \pm 1.7^\circ\text{C}$  immediately pre-exercise to  $18.3 \pm 1.7^\circ\text{C}$  at the end of  
10 part A of the LIST ( $\chi^2(4) = 39.3, P < 0.001$ ). Mean relative humidity was not significantly  
11 different between ( $F_{2, 12} = 0.06, P = 0.94, r = 0.10$ ) or within ( $F_{1.6, 9.6} = 4.1, P = 0.06, r =$   
12  $0.64$ ) trials, and there was no interaction effect ( $F_{2.2, 2.4} = 0.90, P = 0.46, r = 0.36$ ).

13

14 Mean fluid intake was  $811 \pm 83, 810 \pm 82, \text{ and } 810 \pm 84 \text{ ml}$  ( $F_{2, 12} = 0.05, P = 0.95, r = 0.09$ )  
15 in the LCHO, MCHO and HCHO trials, respectively. Absolute CHO intake in the LCHO,  
16 MCHO and HCHO trials was  $12.7 \pm 1.3, 37.6 \pm 3.7, \text{ and } 64.0 \pm 7.3 \text{ g}\cdot\text{h}^{-1}$  ( $F_{1.0, 6.1} = 497.0, P$   
17  $< 0.001, r = 0.99$ ), or  $0.21 \pm 0.02, 0.63 \pm 0.06, \text{ and } 1.07 \pm 0.02 \text{ g}\cdot\text{min}^{-1}$  ( $F_{1.0, 6.1} = 481.6, P <$   
18  $0.001, r = 1.0$ ). Body mass-relative CHO consumption was 0.26, 0.78, and  $1.3 \text{ g}\cdot\text{kg}^{-1} \text{ BM}$  in  
19 the LCHO, MCHO and HCHO trials, respectively.

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**PLEASE PLACE TABLE 3 HERE**

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24

## 1 **Discussion**

2

3 This study demonstrates that ingestion of a 6% CHO-E solution significantly improves the  
4 intermittent endurance capacity of adolescent team games players during intermittent  
5 endurance running compared with a 10% solution. A non-significant trend for improved  
6 intermittent endurance capacity with the 6% compared with a 2% solution, and the 2%  
7 compared with a 10% solution, was also found. No significant influence of [CHO] was  
8 found for sprint performance during the protocol.

9

### 10 *Time to exhaustion*

11

12 The greatest intermittent endurance capacity was achieved in the MCHO trial. This suggests  
13 that adult guidelines for CHO ingestion during prolonged moderate- to high-intensity  
14 exercise (Jeukendrup 2004) do not apply to adolescent team games athletes during  
15 intermittent endurance running. In support of this adult-child difference, Nassis et al (1998)  
16 failed to find a significant improvement in intermittent endurance capacity in adults during  
17 prolonged intermittent treadmill running with ingestion of CHO at very similar rates to that of  
18 the MCHO trial in the current study ( $0.6 \text{ g}\cdot\text{min}^{-1}$ ;  $34 \text{ g}\cdot\text{h}^{-1}$ ).

19

20 The minimum absolute rate of CHO ingestion that has been demonstrated to enhance  
21 endurance capacity during prolonged cycling in adults is  $16 \text{ g}\cdot\text{h}^{-1}$  (Jeukendrup 2004), equating  
22 to  $0.26 \text{ g}\cdot\text{min}^{-1}$ , whereas any further CHO ingestion above a rate of  $\sim 1\text{-}1.1 \text{ g}\cdot\text{min}^{-1}$  does not  
23 further increase the rate of  $\text{CHO}_{\text{exo}}$  oxidation, provided the composition of ingested CHO  
24 remains the same (Jeukendrup 2004). In the current study, the rate of CHO ingestion in the  
25 LCHO trial may not have facilitated absorption of sufficient CHO into the systemic

1 circulation to enable exercise enhancement (Rogers et al 2005) The reasons behind the  
2 inferior intermittent endurance capacity in the HCHO trial are unclear. It does not appear that  
3 CHO ingestion simply exceeded the maximal rate of CHO absorption and/or oxidation of the  
4 participants, as in this case a similar intermittent endurance capacity between the HCHO and  
5 MCHO trials would have been expected. This requires further study, perhaps by focussing  
6 initially on potential modulators of CHO<sub>exo</sub> oxidation (Jeukendrup 2004; Shi & Passe 2010).  
7 However, it should also be noted that there was a larger variation in time to exhaustion values  
8 for the HCHO trial, perhaps representing a greater individual variation in response to this  
9 CHO dose. Conversely, this may also have been due to the relatively small sample size.  
10 While this study was not designed to identify enhancement mechanisms due to ethical and  
11 consensual restrictions, it does provide initial indirect support for the existence of low and  
12 high CHO ingestion thresholds during intermittent endurance running in adolescents, below  
13 and above which the efficacy of CHO does not appear to be maximised, in line with adult  
14 findings (Jeukendrup 2004). Interestingly, these thresholds appear to be at different ingestion  
15 rates for adolescents than adults. Clearly, more work is required to confirm the relative  
16 influence of different [CHO] during intermittent endurance running in adolescents, and to  
17 provide data on the metabolic response to these [CHO], which may help to explain the  
18 performance data.

19

### 20 *Sprint Performance*

21

22 The lack of influence of CHO on sprint performance, along with a progressive, treatment-  
23 independent increase in sprint duration with time, in the current study is in line with previous  
24 work from this laboratory (Phillips et al 2010), and the reader is referred here for further  
25 discussion on these findings. When the results of these two studies are combined, it can be

1 inferred that CHO supplementation across a range of ingestion rates does not significantly  
2 influence the sprint performance of adolescent team games players during intermittent  
3 endurance running, in line with most adult work (Davis et al, 1999; Nicholas et al., 1995).

4  
5 The mean increase in sprint time from the first to the last block of part A in all trials is greater  
6 than that recorded in some adult work (0.08 sec for both trials; Ali et al 2007), in line with  
7 Phillips et al (2010). This provides further confirmation that adolescent team games players  
8 do not appear to display a greater fatigue resistance than adults during sprinting in the LIST,  
9 as may have been expected (Ratel et al 2002).

10

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

12

13 The lack of a treatment effect on HR during part A of the LIST in the current study agrees  
14 with our previous findings (Phillips et al 2010) and most adult research (Ali et al 2007;  
15 Nicholas et al 1995; Welsh et al 2002). Mean HR during part A of the LIST was in  
16 agreement with values reported during outdoor 11-a-side and indoor 5-a-side soccer matches  
17 in recreational and elite young players (Castagna et al., 2007; Strøyer et al., 2004).

18

19 Heart rate at exhaustion in part B of the current study is in contrast to our previous  
20 investigation, which reported a significantly greater HR at exhaustion in the CHO trial  
21 (Phillips et al 2010). It is possible that this was simply an artefact of the particular participant  
22 population used in that study and not, as suggested at the time, a mechanistic indicator of a  
23 metabolic and/or perceptual response to CHO supplementation. Alternatively, a perceptual  
24 mechanism of CHO efficacy in adolescent team games players may exist, but may be  
25 participant-dependent. More work should be undertaken to clarify this.

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Data from the current study lends further support to our previous finding that CHO supplementation does not modulate RPE during intermittent endurance running in adolescents (Phillips et al 2010), although it should be considered that a non-CHO trial was not included in the current study. This suggests that CHO supplementation does not elicit centrally-mediated alterations in adolescents that modulate effort perception during exercise, and may further indicate that enhancements in intermittent endurance capacity with CHO ingestion in this population are of a metabolic nature. However, as mentioned in the previous paragraph, it may be too early to rule out a possible influence of CHO on effort perception at exhaustion.

No increase in RPE was observed in block 3 of part A of the LIST. Both mean sprint and mean peak sprint times significantly slowed during block 3 of the LIST, which may have had an attenuating influence on RPE in block 3. However, a slower sprint time may relate to a less favourable metabolic condition for sprinting (Bangsbo et al 2006), not necessarily a reduced effort from participants. Furthermore, in our previous study mean sprint and mean peak sprint time slowed significantly in block 3 of the LIST, with no corresponding attenuation in RPE (Phillips et al 2010). The non-significant increase in RPE in block 3 of the LIST in the current study may be a result of the low participant number, which is supported by the almost perfect ES for this time point.

The current study indicates that 2, 6, and 10% CHO-E solutions are equally well tolerated by adolescents during intermittent endurance running. This conforms to previous findings from this laboratory regarding tolerance to CHO-E solutions and CHO gels in adolescents during prolonged intermittent exercise (Phillips et al 2010; Phillips et al unpublished data).

1 Mechanisms behind the influence of time on gastric variables are discussed elsewhere  
2 (Phillips et al 2010).

3

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

5

6 When the results of the current, and our previous, study are considered, it appears that  
7 ingestion of CHO across a range of concentrations does not alter the BM loss or SR responses  
8 of adolescents to intermittent endurance running. The BM loss and SR data from the current  
9 study and that of Phillips et al (2010) currently represent the only published data of its kind in  
10 adolescents during intermittent endurance running, therefore comparison of values with other  
11 related work is not possible at this time.

12

#### 13 *Blinding*

14

15 It appears that the blinding procedures used in this study were effective. Furthermore, the  
16 data indicates that exercise did not provide any cues enabling participants to more accurately  
17 identify the three solutions. Interestingly, however, it does appear that some cues were  
18 provided to the participants during exercise that led them to falsely believe that they had not  
19 received the HCHO solution. It is impossible to speculate as to what these cues may have  
20 been, and whether they were perceived as positive or negative, without knowing what the  
21 individual participants' beliefs were pre-exercise regarding the HCHO solution. Therefore,  
22 the influence of intermittent endurance running exercise on adolescents' perceptions of CHO  
23 administration should be investigated further, considering the potential influence of an  
24 individuals perception of the treatment they believe they have received on their subsequent  
25 exercise performance (Beedie et al 2007).

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*Preliminary tests: peak running velocity and maximum heart rate*

The mean  $V_{\text{peak}}$  of 14.4 km.h<sup>-1</sup> in the current study is very similar to that reported in our previous work (Phillips et al 2010), and suggests our participants were of a notably higher training status than international population means (Sandercock et al 2008), although protocol differences should be considered when interpreting  $V_{\text{peak}}$  data between studies. The mean  $HR_{\text{max}}$  and RPE values recorded in the current study are again similar to our previous work, and indicate our participants provided a maximal effort during the incremental test (Armstrong, 2007). The similar  $V_{\text{peak}}$ , HR and RPE data in the current study compared with our previous work (Phillips et al 2010) indicates that the participants used in these two studies were of a similar training status, strengthening the comparisons made throughout this discussion.

**Conclusion**

Ingestion of a 6% CHO-E solution significantly improves the intermittent endurance capacity of adolescent team games players during intermittent endurance running compared with a 10% solution. A non-significant trend for greater intermittent endurance capacity was reported with ingestion of the 6% compared with the 2% solution, and the 2% compared with the 10% solution. Carbohydrate concentration did not significantly influence sprint performance or physiological responses to intermittent endurance running. Future research should build on these findings in order to further develop guidelines for optimal CHO ingestion by adolescents during team games.



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2

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6 College, Edinburgh, for their invaluable participation in, and support of, this research project.

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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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25

1 **Reference List**

2

3 Ali A, Williams C (2009) Carbohydrate ingestion and soccer skill performance during  
4 prolonged intermittent exercise. *J Sports Sci* 27: 1499-1508.

5

6 Ali A, Williams C, Nicholas W, Foskett A (2007) The influence of carbohydrate-electrolyte  
7 ingestion on soccer skill performance. *Med Sci Sports Exerc* 39: 1969-1976.

8

9 Armstrong N (Ed) (2007) *Paediatric Exercise Physiology*. Churchill Livingstone Elsevier,  
10 Philadelphia.

11

12 Aucouturier J, Baker JS, Duché P (2008) Fat and carbohydrate metabolism during  
13 submaximal exercise in children. *Sports Med* 38: 213-238.

14

15 Bangsbo J (1994) The physiology of soccer with special reference to intense intermittent  
16 exercise. *Acta Physiol Scand (Suppl)* 619: 1-155.

17

18 Bangsbo J, Mohr M, Krstrup P (2006) Physical and metabolic demands of training and  
19 match-play in the elite football player. *J Sports Sci* 24: 665-674.

20

21 Baxter-Jones ADG, Eisenmann JC, Sherer LB (2005) Controlling for maturation in pediatric  
22 exercise science. *Pediatr Exerc Sci* 17: 18-30.

23 Beedie CJ, Coleman DA, Foad AJ (2007) Positive and negative placebo effects resulting  
24 from the deceptive administration of an ergogenic aid. *Int J Sport Nutr Exerc Metab* 17: 259-  
25 269.

1 Castagna C, Belardinelli R, Impellizzeri FM, Abt GA, Coutts AJ, D'Ottavio S (2007)  
2 Cardiovascular responses during recreational 5-a-side indoor-soccer. *J Sci Med Sport* 10:  
3 89-95.  
4  
5 Christmass MA, Dawson B, Passeretto P, Arthur PG (1999) A comparison of skeletal muscle  
6 oxygenation and fuel use in sustained continuous and intermittent exercise. *Eur J Appl*  
7 *Physiol* 80: 423-435.  
8  
9 Clarke ND, Drust B, Maclaren DPM, Reilly T (2008) Fluid provision and metabolic  
10 responses to soccer-specific exercise. *Eur J Appl Physiol* 104: 1069-1077.  
11  
12 Crouter S, Foster C, Esten P, Brice G, Porcari JP (2001) Comparison of incremental treadmill  
13 exercise and free range running. *Med Sci Sports Exerc* 33: 644-647.  
14  
15 Davis JM, Welsh RS, De Volve KL, Alderson NA (1999) Effects of branched-chain amino  
16 acids and carbohydrate on fatigue during intermittent, high-intensity running. *Int J Sports*  
17 *Med* 20: 309-314.  
18  
19 Edwards AM, Mann ME, Marfell-Jones MJ, Rankin DM, Noakes TD, Shillington DP (2007)  
20 Influence of moderate dehydration on soccer performance: physiological responses to 45 min  
21 of outdoor match-play and the immediate subsequent performance of sport-specific and  
22 mental concentration tests. *Br J Sports Med* 41: 385-391.  
23  
24 Ekblom B (1986) Applied physiology of soccer. *Sports Med* 3: 50-60.  
25

1 Field A (2005) *Discovering Statistics Using SPSS* (2<sup>nd</sup> ed). Sage, London.

2

3 Hopkins WG (2006) *A Scale of Magnitudes for Effect Statistics*. Sportsscience.

4 <http://sportsci.org/resource/stats/>. Accessed 19 January 2011.

5

6 Jeukendrup A (2004) Carbohydrate intake during exercise and performance. *Nutrition* 20:

7 669-677.

8

9 Jeukendrup AE, Wagenmakers AJM, Stegen JHCH, Gijzen AP, Brouns F & Saris WHM

10 (1999) Carbohydrate ingestion can completely suppress endogenous glucose production

11 during exercise. *J Physiol* 276: E672-E683.

12

13 Lavcanska V, Taylor NF & Schache AG (2005) Familiarization to treadmill running in young

14 unimpaired adults. *Hum Mov Sci* 24: 544-557.

15

16 Marino FE, Lambert MI, Noakes TD (2004) Superior performance of African runners in

17 warm humid but not in cool environmental conditions. *J Appl Physiol* 96: 124-130.

18

19 Mirwald RL, Baxter-Jones ADG, Bailey DA, Beunen GP (2002) An assessment of maturity

20 from anthropometric measurements. *Med Sci Sports Exerc* 34: 689-694.

21

22 Murray R, Eddy DE, Murray TW, Seifert JG, Paul GL, Halaby GA (1987) The effect of fluid

23 and carbohydrate feedings during intermittent cycling exercise. *Med Sci Sports Exerc* 19:

24 597-604.

25

1 Nassis GP, Williams C, Chisnall P (1998) Effect of a carbohydrate-electrolyte drink on  
2 endurance capacity during prolonged intermittent high-intensity running. *Br J Sports Med*  
3 32: 248-252.  
4

5 Nicholas CW, Williams C, Lakomy HKA, Phillips G, Nowitz A (1995) Influence of  
6 ingesting a carbohydrate-electrolyte solution on endurance capacity during intermittent, high-  
7 intensity shuttle running. *J Sports Sci* 13: 283-290.  
8

9 Phillips SM, Turner AP, Gray S, Sanderson MF, Sproule J (2010) Ingesting a 6%  
10 carbohydrate-electrolyte solution improves endurance capacity, but not sprint performance,  
11 during intermittent, high-intensity shuttle running in adolescent team games players aged 12-  
12 14 years. *Eur J Appl Physiol* 109: 811-821.  
13

14 Ratel S, Bedu M, Hennegrave A, Doré E, Duché P (2002) Effects of age and recovery  
15 duration on peak power output during repeated cycling sprints. *Int J Sports Med* 23: 397-  
16 402.  
17

18 Riddell MC (2008) The endocrine response and substrate utilization during exercise in  
19 children and adolescents. *J Appl Physiol* 105: 725-733.  
20

21 Roemmich JN, Barkley JE, Epstein LH, Lobarinas CL, White TM, Foster JH (2006) Validity  
22 of PCERT and OMNI walk/run ratings of perceived exertion. *Med Sci Sports Exerc* 38:  
23 1014-1019.  
24

1 Rogers J, Summers RW, Lambert GP (2005) Gastric emptying and intestinal absorption of a  
2 low-carbohydrate sport drink during exercise. *Int J Sport Nutr Exerc Metab* 15: 220-235.  
3  
4 Rosnow RL, Rosenthal R (2005) *Beginning Behavioural Research: A Conceptual Primer* (5<sup>th</sup>  
5 ed). Pearson/Prentice Hall, New Jersey.  
6  
7 Sandercock G, Voss C, Gladwell V (2008) Twenty-metre shuttle run test performance of  
8 English children aged 11 – 15 years in 2007: comparisons with international standards. *J*  
9 *Sports Sci* 26: 953-957.  
10  
11 Shi X, Horn MK, Osterberg KL, Stofan JR, Zachwieja JJ, Horswill CA, Passe DH, Murray R  
12 (2004) Gastrointestinal discomfort during intermittent high-intensity exercise: effect of  
13 carbohydrate-electrolyte beverage. *Int J Sport Nutr Exerc Metab* 14: 673-683.  
14  
15 Shi X, Passe DH (2010) Water and solute absorption from carbohydrate-electrolyte solutions  
16 in the human proximal small intestine: A review and statistical analysis. *Int J Sport Nut*  
17 *Exerc Metab* 20: 427-442.  
18  
19 Strøyer J, Hansen L, Klausen K (2004) Physiological profile and activity pattern of young  
20 soccer players during match play. *Med Sci Sports Exerc* 36: 168-174.  
21  
22 Tanner JM (1962) Growth at Adolescence. Oxford: Blackwell Scientific Publications.  
23  
24 Timmons BW, Bar-or O, Riddell MC (2003) Oxidation rate of exogenous carbohydrate  
25 during exercise is higher in boys than in men. *J Appl Physiol* 94: 278-284.  
26

1 Timmons BW, Bar-Or O, Riddell MC (2007) Influence of age and pubertal status on  
2 substrate utilization during exercise with and without carbohydrate intake in healthy boys.  
3 *Appl Physiol Nutr Metab* 32: 416-425.  
4  
5 van Nieuwenhoven MA, Brouns F, Kovacs EMR (2005) The effect of two sports drinks and  
6 water on GI complaints and performance during an 18-km run. *Int J Sports Med* 26: 281-  
7 285.  
8  
9 Welsh RS, Davis JM, Burke JR, Williams HG (2002) Carbohydrates and physical/mental  
10 performance during intermittent exercise to fatigue. *Med Sci Sports Exerc* 34: 723-731.  
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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 peak heart rate and ratings of perceived exertion at exhaustion in part B  
 5 for all trials.

	Period of the LIST				
	Block 1	Block 2	Block 3	Block 4	Exhaustion
<b>Mean heart rate (beats per min)</b>					
LCHO	159 ± 7	164 ± 7***	165 ± 7	165 ± 7	189 ± 3
MCHO	162 ± 6	168 ± 5***	170 ± 6	169 ± 5	190 ± 4
HCHO	162 ± 5	168 ± 6***	168 ± 6	168 ± 5	190 ± 4
<b>Mean ratings of perceived exertion</b>					
LCHO	4.6 ± 1.1	6.0 ± 0.82*	7.4 ± 0.98	7.6 ± 1.1**	9.4 ± 0.53
MCHO	4.4 ± 0.98	6.1 ± 0.70*	6.7 ± 0.95	8.0 ± 0.82**	9.3 ± 0.49
HCHO	4.4 ± 0.98	6.0 ± 1.0*	7.1 ± 0.70	8.0 ± 0.82**	9.3 ± 0.49

6 Data are mean ± SD (*n* = 7)

7 LCHO = low CHO trial; MCHO = moderate CHO trial; HCHO = high CHO trial

8 \*\*\* significantly greater than block 1, *P* < 0.01; \* significantly greater than previous block,

9 *P* < 0.05; \*\* significantly greater than previous block, *P* < 0.001

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

	Period of the LIST				
	Block 1	Block 2	Block 3	Block 4	Exhaustion
<b>Mean gut fullness ratings</b>					
LCHO	4.1 ± 1.7	4.7 ± 1.3	4.7 ± 1.1	5.3 ± 1.3	5.1 ± 1.1
MCHO	4.1 ± 1.6	3.9 ± 1.9	4.0 ± 1.7	4.7 ± 1.7	5.3 ± 1.3
HCHO	3.7 ± 1.4	3.7 ± 1.1	4.3 ± 1.6	4.3 ± 1.1	4.7 ± 0.80
<b>Mean gastric discomfort ratings</b>					
LCHO	2.1 ± 1.1	3.1 ± 1.2	3.0 ± 1.3	3.1 ± 1.5	4.0 ± 1.5
MCHO	2.9 ± 1.3	3.3 ± 1.4	3.3 ± 1.6	3.4 ± 1.7	4.3 ± 1.8
HCHO	2.3 ± 1.9	2.4 ± 1.1	2.9 ± 1.2	4.0 ± 1.9	4.1 ± 2.0

3 Data are mean ± SD (*n* = 7)

4 LCHO = low CHO trial; MCHO = moderate CHO trial; HCHO = high CHO trial

5 A main effect of time was found for GF and GD (*P* < 0.05)

6

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

	Period of the LIST				
	Pre-exercise	Block 1	Block 2	Block 3	Block 4
<b>Mean ambient temperature (°C)</b>					
LCHO	18.0 ± 1.8	18.1 ± 1.9	18.1 ± 1.9	18.2 ± 1.9	18.2 ± 1.9
MCHO	17.8 ± 1.4	17.9 ± 1.4	18.0 ± 1.4	18.0 ± 1.3	18.1 ± 1.3
HCHO	18.3 ± 2.2	18.4 ± 2.1	18.4 ± 2.1	18.5 ± 2.1	18.5 ± 2.1
<b>Mean relative humidity (%)</b>					
LCHO	40.6 ± 5.5	40.1 ± 6.1	39.9 ± 6.1	39.4 ± 5.9	39.0 ± 6.0
MCHO	40.7 ± 8.4	40.4 ± 8.4	40.1 ± 8.6	39.7 ± 8.6	39.6 ± 9.2
HCHO	40.6 ± 9.0	41.0 ± 8.3	41.1 ± 8.2	41.0 ± 8.3	40.0 ± 8.8

3 Data are mean ± SD (*n* = 7)

4 LCHO = low CHO trial; MCHO = moderate CHO trial; HCHO = high CHO trial

5 A main effect of time was found for the grouped mean ambient temperature data (*P* < 0.01)

6

1 **Figure Captions**

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4 **Figure 1** Mean sprint time (A) and mean peak sprint time (B) during part A of the LIST for

5 allboth trials. \* significantly greater than previous block,  $P < 0.05$ ; \*\* significantly greater

6 than previous block,  $P < 0.001$ . ( $n = 6$ ).

7