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Ingesting a high-dose carbohydrate solution during the cycle section of a simulated Olympic-distance triathlon improves subsequent run performance

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Running Title: Carbohydrate ingestion and triathlon

ABSTRACT

Introduction: The well-established ergogenic benefit of ingesting carbohydrates during single-discipline endurance sports has only been tested once within Olympic-distance (OD) triathlon. The aim of the present study was to compare the effect of ingesting a 2:1 maltodextrin:fructose (CHO) solution with a placebo (PLA) on simulated OD triathlon performance. **Methods:** Six male and four female amateur triathletes (age, 25 ± 7 yr; body mass, 66.8 ± 9.2 kg; $\dot{V}O_{2peak}$, 4.2 ± 0.6 L·min^{-1}) completed a 1500-m swim time-trial and an incremental cycle test to determine $\dot{V}O_{2peak}$, before performing two simulated OD triathlons. The swim and cycle sections of the main trials were of fixed intensities, while the run section was completed as a time-trial. Two minutes prior to completing every quarter of the cycle participants consumed 202 ± 20 mL of either a solution containing 1.2 g·min^{-1} of maltodextrin + 0.6 g·min^{-1} of fructose at 14.4% concentration (CHO) or a sugar-free, fruit-flavored drink (PLA). **Results:** The time-trial was 4.0 ± 1.3% faster during the CHO versus PLA trial, with run times of 38 min 43 s ± 1 min 10 s and 40 min 22 s ± 1 min 18 s, respectively (*P* = 0.010). Blood glucose concentrations were higher in the CHO versus PLA trial (*P* < 0.001), while perceived stomach upset did not differ between trials (*P* = 0.555). **Conclusion:** The current findings show that a 2:1 maltodextrin:fructose solution (1.8 g·min^{-1} at 14.4%) ingested throughout the cycle section of a simulated OD triathlon enhances subsequent 10-km run performance in triathletes.

Key Words: exercise, metabolism, fructose, glucose, maltodextrin, gastro-intestinal discomfort, carbohydrate, sports nutrition, athlete performance

INTRODUCTION

Olympic-distance (OD) triathlon is a multi-disciplinary sport that involves a 1500-m swim, a 40-km cycle and a 10-km run performed in immediate succession. Research interest in triathlon has developed over recent years, with a number of review articles emerging since the turn of the millennium (Millet and Vleck 2000; Bentley et al. 2002; Jeukendrup et al. 2005; Bentley et al. 2008; Hausswirth and Brisswalter 2008; Peeling and Landers 2009). In contrast to the relative wealth of data regarding the effect of swim and/or cycling strategies on subsequent running and overall triathlon performance (Hausswirth et al. 2001; Vercruyssen et al. 2002; Bernard et al. 2003; Peeling et al. 2005; Vercruyssen et al. 2005; Suriano et al. 2007; Suriano and Bishop 2010), only one study has directly examined the effect of carbohydrate ingestion on OD triathlon (Millard-Stafford et al. 1990).

In their study, Millard-Stafford et al. (1990) prescribed the co-ingestion of ~ 0.5 $g \cdot min^{-1}$ of a glucose polymer and ~ 0.2 $g \cdot min^{-1}$ of fructose by means of a sports drink to a sample of trained, male triathletes throughout the cycle and run sections of a simulated OD race. Although there was a tendency for superior overall triathlon performance when consuming the carbohydrate drink compared with the placebo, the improvement was not significant ($P < 0.10$). Considering the convincing body of evidence supporting the ergogenic benefits of carbohydrate ingestion during single-discipline events (e.g. cycling or running) lasting ≥ 1 h (Wright et al. 1991; Tsintzas et al. 1996; Carter et al. 2003; Temesi et al. 2011), the lack of a statistically positive effect of carbohydrate ingestion on OD triathlon performance warrants further investigation.

The absence of a significant performance benefit identified by Millard-Stafford et al. (1990) following carbohydrate ingestion may be related to the relatively modest supplementation quantities used. Indeed, conventional wisdom at the time dictated that exogenous carbohydrate oxidation rates could not exceed 1 $g\cdot min^{-1}$, despite ingestion rates of > 2 $g\cdot min^{-1}$ (Jeukendrup and Jentjens 2000). However, more recent studies have since revealed a capacity for peak exogenous carbohydrate oxidation rates to reach 1.26 – 1.75 $g\cdot min^{-1}$ when ingesting high doses (i.e., 1.8 – 2.4 $g\cdot min^{-1}$) of mixed carbohydrates, such as glucose + fructose (Jentjens et al. 2004; Jentjens and Jeukendrup 2005). In addition, cycling endurance performance has been significantly improved following the consumption of a 2:1 glucose:fructose solution ingested at a rate of 1.8 $g\cdot min^{-1}$ and 14.4% concentration (Currell and Jeukendrup 2008). It is proposed that separate transporter proteins may enhance intestinal carbohydrate absorption when multiple types of carbohydrate are ingested simultaneously (Jentjens et al. 2004).

It remains to be established whether the recognized benefits of carbohydrate supplementation during cycling and running necessarily translate to similar effects when the separate disciplines are performed in sequence, as occurs during an OD triathlon. For example, the mechanisms through which exogenous carbohydrate can offset fatigue may differ between cycling and running, with an increased oxidation of blood glucose late in exercise observed during cycling and a decreased rate of muscle glycogen depletion throughout exercise observed during running (Tsintzas and Williams 1998). Based on these findings, there is clearly a need to confirm whether carbohydrate supplements represent an effective nutritional strategy for OD triathlon within the unique context of this multi-discipline event.

To this end, the aim of the current study was to investigate the ergogenic effects of ingesting a 2:1 glucose polymer (i.e., maltodextrin) + fructose solution in volumes providing 1.8 $g \cdot min^{-1}$ during the cycle section of a simulated OD triathlon. Based on the existing literature, it was hypothesized that ingesting 1.8 $g \cdot min^{-1}$ of a mixed carbohydrate solution would improve 10-km run time relative to a matched quantity of a sugar-free, fruit-flavored placebo drink.

MATERIALS AND METHODS

Participants

Ten amateur triathletes (mean ± SD: age, 25 ± 7 yr; body mass, 66.8 ± 9.2 kg; $\dot{V}O_{2peak}$, 4.2 ± 0.6 $L \cdot min^{-1}$), including four females (24 ± 5 yr; 59.8 ± 4.6 kg; 3.7 ± 0.4 $L \cdot min^{-1}$) and six males (26 ± 8 yr; 71.5 ± 8.6 kg; 4.5 ± 0.5 $L \cdot min^{-1}$), volunteered to participate in the study. All participants were training regularly (i.e., at least 5 $days \cdot week^{-1}$) and had previously competed in at least two sprint or OD triathlon races. Time to complete an actual OD triathlon race (n = 8) was 2 h 23 min 43 s ± 10 min 39 s (1500-m swim: 25 min 22 s ± 1 min 38 s; 40-km cycle: 1 h 13 min 22 s ± 6 min 36 s; 10-km run: 43 min 40 s ± 4 min 03 s). Individuals were fully informed of the procedures, requirements, benefits and risks associated with the study before providing written informed consent. The study was approved by the ethics committee of the Department for Health at the University of Bath, UK.

Experimental overview

Participants attended three testing sessions on separate days. The first session involved a preliminary 1500-m swim time-trial (STT) and an incremental cycle test to volitional exhaustion (RAMP). On both subsequent visits participants completed a simulated OD triathlon (1500-m swim, 40-km cycle and 10-km run), where the work rates during the swim and cycle sections were controlled and the run was treated as a time-trial (RTT). The two simulated triathlon trials were separated by 5 – 12 days and were performed at the same time in the morning to overcome any influence of circadian variance (Reilly and Brooks 1982). All swimming was conducted in a 50-m indoor pool, which was heated to a constant temperature of 27.5°C. Cycling was performed on a friction-braked cycle ergometer fitted with standard toe-strap pedals (Monark Ergomedic 824E, Varberg, Sweden). The RTT involved 5 x 2-km loops on a flat, asphalt surface within the University campus. Run distance was measured using a cycle-mounted global positioning system (Garmin Edge 305, Garmin International Inc., Olathe, KS).

Preliminary tests

The STT was used to determine individual swimming race pace. A standardized 500-m warm-up (WU) involving 200 m of freestyle swimming, 200 m with a pull buoy and 100 m of kicking was completed at a self-selected pace, followed by a 2-min recovery period, before a 1500-m race-pace swim commenced. Participants were instructed to swim at the maximal pace they could maintain within an OD triathlon (i.e., with a 40-km cycle and 10-km run to follow). No time feedback was provided throughout the swim and a signal was given (by submerging a kickboard beneath the water) prior to the final 100 m. The swim time was recorded using a hand-held stopwatch and was subsequently used to control the swim pace during the following two experimental trials.

The RAMP was completed 60 min after the STT in a laboratory where air temperature and pressure were 20.3 ± 1.7°C and 745.6 ± 8.5 mmHg, respectively. Upon arrival, body mass was measured to the nearest 0.1 kg and height was recorded to the nearest 0.1 cm using a balance beam scale (Seca 700, Birmingham, UK). The handlebar and saddle positions on the cycle ergometer were adjusted for individuals prior to testing and settings remained constant during subsequent trials. Cycling commenced at an initial power output of 80 – 120 W (based on estimated individual fitness) and was maintained at 85 $revs \cdot min^{-1}$. This cadence was selected based on previous findings using triathletes (Vercruyssen et al. 2001) and was used during all cycle components within the study.

The first stage of the RAMP was used as a warm-up and lasted 5 min. The flywheel resistance was increased by 0.5 kg (~ 40 W) every 3 min thereafter until volitional exhaustion. Expired air was collected for 60 s in Douglas bags after 1 min 45 s of each 3-min stage and cycle cadence was recorded during these periods. A 6 – 20 Borg scale was used to measure rating of perceived exertion (RPE) in the final minute of each stage and heart rate (HR) was measured continuously (Polar Electro, Kempele, Finland). Participants signaled to the experimenter if, mid-stage, they could only complete one further minute of exercise, at which point a final 60-s gas sample was collected. Standardized verbal encouragement was provided throughout the RAMP and the test was terminated at volitional exhaustion or when cadence dropped by 5 $revs \cdot min^{-1}$ following an initial warning.

Expired gas samples were analyzed for O_2 and CO_2 concentrations using an automated gas analyzer (Hitech GIR 250, Luton, UK), which was calibrated prior to each test using certified gases of known composition and volume. Total volumes expired were determined using a dry gas meter (Harvard Apparatus, Edenbridge, UK) and the temperatures of expired gases were measured with a digital thermometer (Edale Instruments Ltd., Cambridge, UK). The $\dot{V}O_{2peak}$ was identified as the highest $\dot{V}O_2$ value recorded throughout the test and maximal aerobic power (MAP) was defined as the highest average power output maintained for 1 min during the RAMP. The MAP was used to determine the work rate for the cycle section of the two simulated triathlon trials, which was fixed at 75% of MAP based on previous reports relating to OD triathlon (Hue et al. 1997; Delextrat et al. 2005).

Simulated Olympic-distance triathlons

Following the preliminary testing, two simulated OD triathlon trials were performed in a random order and a single-blind manner. Participants consumed either a 2:1 maltodextrin:fructose (CHO) mix based on the protocol of Currell and Jeukendrup (2008), providing 1.2 $g{\cdot}min^{-1}$ of maltodextrin + 0.6 $g{\cdot}min^{-1}$ of fructose, or a sugar-free, fruit-flavored placebo (PLA), as detailed in Table 1. The solutions were mixed in a plastic jug using cold tap water and decanted into an opaque 1-L sports bottle that was individually marked for each 25% dose. Participants matched their food consumption and low-intensity training load and avoided alcohol the day before each trial. They arrived at the testing venue on the morning of the trial having abstained from caffeine and eaten a pre-race breakfast of choice that was replicated for both trials.

INSERT TABLE 1 ABOUT HERE

Testing began with the standardized swimming WU followed by 2 min of rest and the simulated race ensued immediately. The pace of the 1500-m swim was fixed to within ± 5%

of the STT to ensure a constant pace across both trials. This was achieved by the experimenter giving visual signals after every 100 m advising the participant to slow down, speed up or continue at the same speed. A submerged kickboard indicated the final 100 m. Following the 1500-m swim there was a 3-min transition period before the commencement of the cycle section (Delextrat et al. 2005).

The cycle section was conducted on poolside and a standing floor fan was used to provide a cooling effect. The fan was positioned facing the cycle ergometer ~ 1 m in front of the participant and the speed of the air flow was ~ 2.5 $m \cdot s^{-1}$. Participants cycled at 75% of MAP maintaining a cadence of 85 $revs \cdot min^{-1}$ for a duration that approximated 40 km based on the following equation proposed by Nevill et al. (2006):

$$\text{Cycle speed } (km \cdot h^{-1}) = 5.1 \times (\text{MAP [W]})^{0.54} \times (\text{body mass [kg]})^{-0.26} \quad [1]$$

Therefore:

$$\text{Cycle duration (min)} = (40 / \text{cycle speed } [km \cdot h^{-1}]) \times 60 \quad [2]$$

Two minutes prior to completing every 25% (i.e., ~ 10 km) of the cycle duration participants ingested 25% of their total fluid volume, which was calculated as:

$$\text{Total fluid volume (mL)} = (1.8\ g \cdot min^{-1} \times \text{cycle duration [min]}) / 0.144 \quad [3]$$

In the CHO trial the carbohydrate (115 ± 10 g) was provided in a solution at a concentration of 14.4%, which provided 808 ± 81 mL of fluid, and in the PLA trial the sugar-free, fruit-flavored drink was matched to taste with approximately one part concentrate to three parts water. Fluid consumption was confined to the cycle section, as this has been recognized as the best opportunity to feed during OD triathlon events (Jeukendrup et al. 2005).

After every 12.5% (i.e., ~ 5 km) of the cycle duration a fingertip blood sample was collected and kept on ice until the end of the trial. Immediately after each trial the blood samples were analyzed for blood glucose ([GLU]) and lactate ([LAC]) concentrations using an automated blood analyzer (YSI 2300 STAT plus, YSI Ltd., Fleet, UK). The HR, RPE and perceived stomach upset (which was assessed using an adapted RPE scale to rate the level of discomfort) were also recorded after every 12.5% of the cycle duration. At the end of the cycle section participants were given a further 3-min transition period to prepare for the run.

Time and HR data were collected but concealed during the RTT and participants were followed closely throughout the run by a cycling researcher providing standardized encouragement. In order to avoid interference with the collection of ecologically valid performance data, no further physiological measures were made during the RTT. A perceived stomach upset rating was collected immediately after the RTT and a final blood sample was collected 3 min into the recovery period.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) was used to perform statistical procedures and an alpha level of $P < 0.05$ was accepted for significance. Differences in [GLU], [LAC], HR, RPE and perceived stomach upset throughout the cycle section were analyzed using a two-way (time x trial) analysis of variance (ANOVA) with repeated measures. The Greenhouse Geisser correction was used for epsilon < 0.75, while the Huynh-Feldt correction was adopted for less severe asphericity (> 0.75). Normality was checked using the Shapiro-Wilk test and differences between trials were localized using pair-wise comparisons with a Bonferroni adjustment. Paired t-tests were used to compare STT and RTT times, average HR during the run and post-run [GLU], [LAC] and perceived stomach upset data between the two trial conditions. A Wilcoxon Signed Rank Test was used when data were not normally distributed. The effect size (ES) for the change in run time was calculated using the SD of the PLA group, with threshold values for a small, moderate and large ES of 0.2, 0.5 and 0.8, respectively (Vincent 2005). Descriptive statistics are expressed as mean ± SD and tests of difference are reported as mean ± SEM.

RESULTS

Preliminary testing

The STT time was 24 min 51 s ± 3 min 27 s, which resulted in required 100-m split times during the simulated triathlons (i.e., ± 5%) of 1 min 34 s ± 13 s to 1 min 44 s ± 14 s. The cycling $\dot{V}O_{2peak}$ was 4.2 ± 0.6 $L \cdot min^{-1}$ (62.8 ± 9.3 $mL \cdot kg^{-1} \cdot min^{-1}$) and MAP was 305 ± 49 W, which resulted in required cycle durations for the 40-km cycle section (calculated from equations [1] and [2]) of 63 min 54 s ± 5 min 18 s.

Main trials: swim section

All participants completed the 1500-m swim section of both simulated triathlons within ± 5% of their individual STT time, as required, and swim times did not differ between the CHO and PLA conditions ($P = 0.546$).

Main trials: cycle section

The poolside air temperature was 27.1 ± 1.4°C and did not differ between trials ($P = 0.956$). Where the prescribed cycling power output could not be maintained (this occurred for two of the 10 participants), the resistance was reduced and these modifications were replicated during the second trial such that all participants could cycle for their calculated duration. The HR, RPE and perceived stomach upset data recorded mid-way through and at the end of the cycle section are displayed Table 2. There were no differences between trials for any of the three variables ($P > 0.05$). The [GLU] changed over time and was significantly higher in the CHO trial from ~ 15 km (i.e., 37.5% of the cycle duration) compared with the PLA trial ($P < 0.001$; Fig. 1a). The [LAC] did not change over time ($P = 0.097$) but was significantly higher in the CHO trial compared with the PLA trial after 50.0%, 62.5% and 100.0% of the cycle duration ($P < 0.05$; Fig. 1b).

INSERT TABLE 2 ABOUT HERE

INSERT FIGURE 1 ABOUT HERE

Main trials: run section

The outside air temperature during the RTT (15.9 ± 7.8°C) did not differ between trials (*P* = 0.917). The RTT was 4.0 ± 1.3% (1 min 40 s ± 34 s) faster (ES = 0.40) during the CHO trial compared with the PLA trial, with run times of 38 min 43 s ± 1 min 10 s and 40 min 22 s ± 1 min 18 s, respectively (*P* = 0.010; Fig. 2). Mean HR during the RTT (available for n = 5 only) was 171 ± 3 and 164 ± 3 beats·min^{-1} for the CHO and PLA trials, respectively (*P* = 0.149). Post-run [GLU] remained higher in the CHO trial compared with PLA (*P* = 0.007; Fig. 1a) while post-run [LAC] (*P* = 0.067; Fig. 1b) and perceived stomach upset (*P* = 0.742; Table 2) were not different between groups.

INSERT FIGURE 2 ABOUT HERE

DISCUSSION

The aim of the present study was to investigate the effects of ingesting a high-dose carbohydrate solution during cycling on subsequent running performance within the context of a simulated OD triathlon. Consistent with the hypothesis, running performance during the final section of the triathlon was significantly improved following ingestion of carbohydrate during the preceding cycling section compared with a placebo. In real-world terms, a 100-s improvement would have moved the second-placed male and female amateur athletes from silver- to gold-medal positions in the 2010 World Age-Group Championships in the 20 – 24 yr category (International Triathlon Union), which is the age-group category that seven of the 10 participants in the current study would have competed in.

Performance responses

The primary finding of this investigation is contrary to the only other study that has examined carbohydrate ingestion during an OD triathlon (Millard-Stafford et al. 1990), in which performance was not significantly improved. Since Millard-Stafford et al. (1990) provided carbohydrate at a rate of ~ 0.7 g·min^{-1}, compared with 1.8 g·min^{-1} in the present study, it may be that the quantity of carbohydrate required to elicit statistically significant improvements in performance is greater than that which has been shown to produce some degree of ergogenic effect during single-discipline events. Despite the unique multi-disciplinary challenge presented by triathlon, it appears that the recommendation for carbohydrate ingestion can be applied as for other single-discipline endurance events.

While a high carbohydrate dose is suggested here as a potential explanation for the improved run performance, this reasoning requires further specific examination to eliminate other possibilities. For example, additional methodological differences exist between the present study and that conducted by Millard-Stafford et al. (1990). These include environmental temperature differences (the earlier experiment was completed in the heat, at a dry bulb temperature of 30.0 ± 0.6°C), a mixture of sexes used within the present study and different pre-trial eating strategies, whereby a breakfast of choice was used in the present study to more accurately simulate race-day conditions. Although endurance exercise performed in a post-prandial state appears to affect metabolic responses when compared with overnight fasting, however, 10-km run time does not appear to be affected (Whitley et al. 1998). The current study also used a standardized relative cycling intensity as opposed to a free-paced cycle section. While a fixed power output was used during the cycle section to control the comparison of the subsequent run performance between trials, it would be useful to complement these data with future studies examining carbohydrate ingestion during a fully self-paced (i.e., race-specific) OD triathlon.

Metabolic responses

Higher concentrations of blood glucose were expected in the CHO trial compared with the PLA trial and the current results are in agreement with previous findings in relation to OD triathlon (Millard-Stafford et al. 1990). While measurements necessary to evaluate the specific derivation of substrate metabolism were not included in the current study, as it was considered a priority to provide an externally valid assessment of performance, a number of possibilities could explain the improved 10-km run time. The higher [GLU] following carbohydrate consumption may have led to a direct increase in the rate of carbohydrate oxidation by the working muscles, which has previously been shown to improve exercise performance and delay the onset of fatigue (Coyle et al. 1986; Coggan and Coyle 1989). However, since this explanation is speculative and the specific mechanisms by which carbohydrate ingestion improves performance are currently unclear (Karelis et al. 2010), further research is required to fully understand the enhanced performance observed in the present study.

Subjective responses

Considering the central mechanisms potentially associated with carbohydrate sensing and ingestion (Meeusen et al. 2006; Jeukendrup and Chambers 2010), the CHO trial may have been expected to elicit a lower perception of exertion throughout the cycle section compared with the PLA trial. However, no differences in RPE were identified between the two trials. This finding was combined with an anecdotal, post-facto inability of participants to successfully guess which trial they had just participated in, with only two participants confidently identifying the CHO solution. Perhaps more notable than RPE, at least from a practical perspective, perceived stomach upset did not differ between trials throughout the cycle section or at the end of the run. Due to common complaints among racing triathletes of gastro-intestinal discomfort from fluid consumption, particularly when carbohydrate concentrations are high (Jeukendrup et al. 2005; Bentley et al. 2008), this finding was unexpected. With no additional gastro-intestinal discomfort, a high-concentration carbohydrate solution would appear to be beneficial for competitive triathletes as it reduces the required volume of fluids, which may be advantageous when running after cycling. While it is possible that intestinal carbohydrate absorption was enhanced with the use of multiple types of carbohydrate, this remains to be examined.

Strengths and limitations of the study

Despite the majority of investigations recruiting male-only groups when examining the effects of carbohydrate metabolism on exercise, four of the 10 participants in the present study were female. Although avoidance of females is usually due to perceived difficulties associated with controlling for the menstrual cycle, evidence regarding the effects of menstrual phase on metabolism and performance appears equivocal (Hornum et al. 1997; Hackney 1999; Bailey et al. 2000; Campbell et al. 2001). Given that an effect of treatment was observed in the female participants (i.e., a 3.7% performance improvement) reflective of that observed for males (i.e., a 4.1% performance improvement), any error variance that was introduced by menstrual variability appears insufficient to have masked the effect of treatment in this instance.

Conclusion

The present study has shown that a 2:1 maltodextrin:fructose solution ingested at a rate of 1.8 $g \cdot min^{-1}$ and mixed to a concentration of 14.4% significantly improves running performance within a simulated OD triathlon when ingested throughout the cycle section. This is the first study to show significant improvements in any measure of triathlon performance with carbohydrate ingestion. Importantly, the relatively concentrated carbohydrate solution was not associated with an increase in gastro-intestinal discomfort compared with a placebo. As such, the findings of the current study advocate ingestion of 1.2 $g \cdot min^{-1}$ of maltodextrin + 0.6 $g \cdot min^{-1}$ of fructose at 14.4% concentration as opposed to non-caloric fluid throughout the cycle section of OD triathlon for the purpose of enhancing subsequent 10-km run performance.

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TABLES

Table 1: Details of the two drinks provided during the maltodextrin + fructose (CHO) and placebo (PLA) trials

CHO	Product:	EnergySource Fresh Citrus flavor, H5 Ltd., Leicestershire, UK
	Ingredients:	Maltodextrin, Fructose, Natural Flavors (Spray Dried Fruit Juice: Orange, Lemon, Lime), Citric Acid, Tri Sodium Citrate, Sodium Chloride, Potassium Citrate
	Nutritional content (per 100 g):	384 kcal, Protein 0 g, Carbohydrate 96 g (Maltodextrin 64 g, Fructose 32 g), Fat 0 g, Fiber 0 g
	Electrolyte content (per 100 g):	Sodium 0.7 g, Potassium 0.7 g
PLA	Product:	Robinsons Orange & Mango No Added Sugar, Britvic Soft Drinks Ltd, Chelmsford, UK
	Ingredients:	Water, Orange Fruit from Concentrate (11%), Mango Juice from Concentrate (1%), Citric Acid, Acidity Regulator (Sodium Citrate), Flavouring, Sweeteners (Aspartame, Saccharin), Preservatives (Potassium Sorbate, Sodium Metabisulphite), Stabiliser (E466), Colours (Anthocyanins, Beta-carotene), Vitamins (Niacin, Pantothenic Acid, B6, B12)
	Nutritional content (per 100 mL):	8 kcal, Protein 0.2 g, Carbohydrate 0.7 g (of which sugars 0.7 g), Fat 0 g, Fiber 0.3 g
	Electrolyte content (per 100 mL):	Sodium 0.1 g

Table 2: Mean ± SEM heart rate (HR), rating of perceived exertion (RPE) and perceived stomach upset during the cycle section and following the run section within the maltodextrin + fructose (CHO) and placebo (PLA) trials

		% of cycle duration		
		50%	100%	Post-run
HR (beats·min^{-1})	**CHO**	143 ± 6	142 ± 5	-
	PLA	144 ± 4	142 ± 4	-
RPE	**CHO**	14 ± 1	14 ± 1	-
	PLA	14 ± 1	15 ± 1	-
Perceived stomach upset	**CHO**	10 ± 1	11 ± 1	13 ± 1
	PLA	9 ± 1	10 ± 1	12 ± 1

No significant differences between CHO and PLA ($P > 0.05$)

FIGURES

Figure 1: Mean ± SEM a.) blood glucose concentration ([GLU]) and b.) blood lactate concentration ([LAC]) during the cycle section and following the run section within the maltodextrin + fructose (CHO) and placebo (PLA) trials. * Significantly different from the PLA trial ($P < 0.05$)

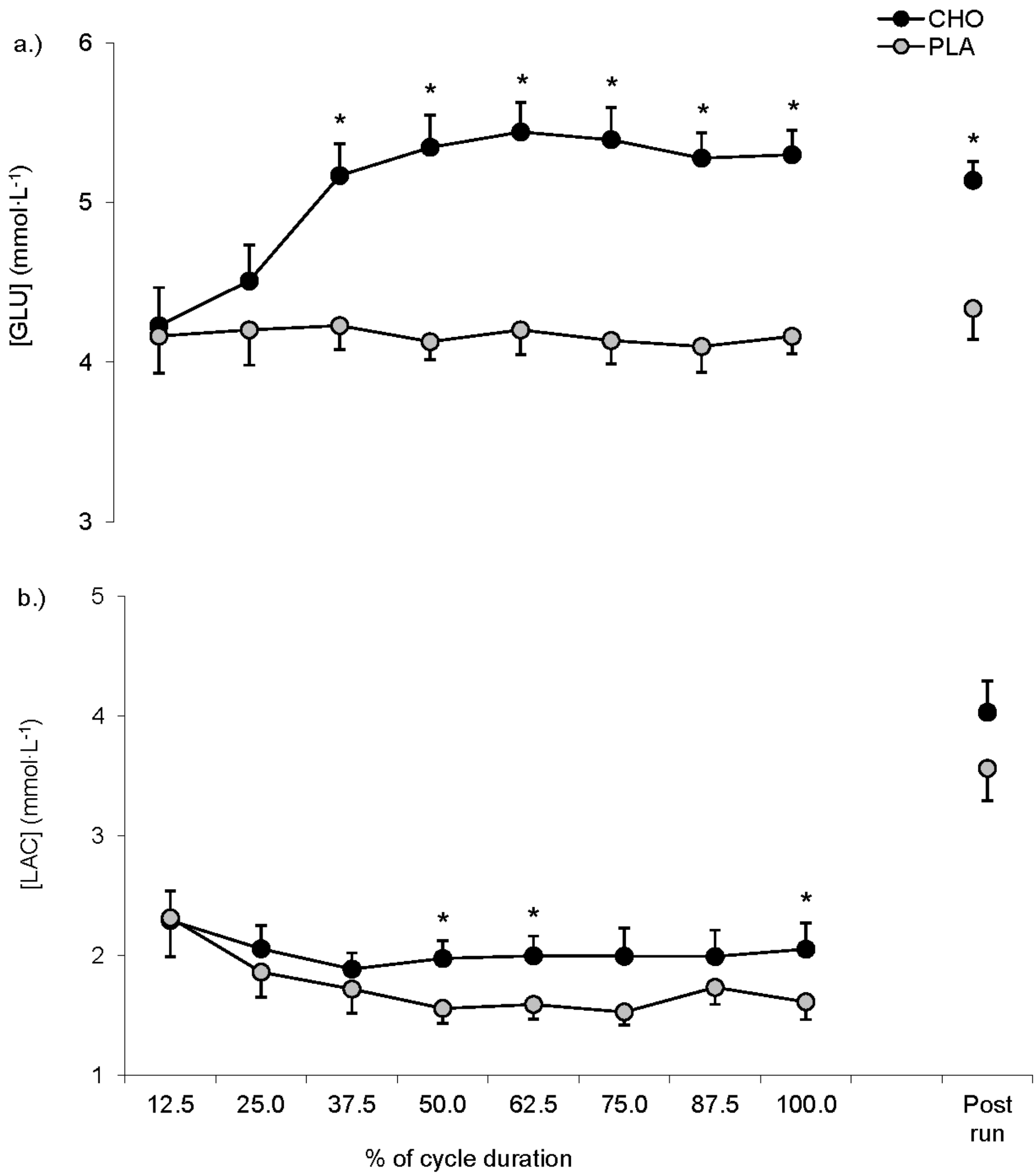

Figure 2: Run time-trial (RTT) performance within the maltodextrin + fructose (CHO) and placebo (PLA) trials; male participants marked with solid lines and females with dashed lines. * Significantly different from the PLA trial ($P < 0.05$)