No Placebo Effect From Carbohydrate Intake During Prolonged Exercise

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The purpose of this study was to investigate the possibility of a placebo effect from carbohydrate (CHO) intake during prolonged exercise. Ten endurance-trained male cyclists performed 3 experimental trials consisting of 120 min of steady-state cycling at 61% \( \text{VO}_{2\text{max}} \) followed by a time trial (TT) lasting approximately 60 min. During exercise participants ingested either plain water (WAT), artificially colored and flavored water (PLA), or a 6% carbohydrate-electrolyte solution (CES). PLA and CES were produced with identical color and taste. To investigate the possibility of a placebo effect from CHO intake, participants were told that both flavored solutions contained CHO and that the purpose of the study was to compare CHO drinks with water. Mean power output during TT was 218 \( \pm \) 22 W in WAT, 219 \( \pm \) 17 W in PLA, and 242 \( \pm \) 27 W in CES. Performance times were 66.35 \( \pm \) 6.15, 65.94 \( \pm \) 5.56, and 59.69 \( \pm \) 2.87 min for WAT, PLA, and CES, respectively. Therefore, CES ingestion enhanced TT performance by 11.3% compared with WAT \((p < .05)\) and 10.6% compared with PLA \((p < .05)\), with no difference between PLA and WAT. In conclusion, during a prolonged test of cycling performance, in which participants were not fully informed of the test conditions, there was no placebo effect when participants believed they had ingested CHO. In contrast, the real effect of CHO intake was a 10.6% improvement in TT cycling performance.

Keywords: nutrition, supplements, time trial, cycling, performance

The placebo effect is a favorable outcome arising purely from the belief that one has received a beneficial treatment (Clark, Hopkins, Hawley, & Burke, 2000). Our current understanding of this phenomenon is largely based on observations in clinical research. However, the placebo effect can also influence physical performance during exercise in response to potentially ergogenic aids. For example, studies have reported improvements in strength or endurance in participants who believed they had ingested substances such as anabolic steroids (Ariel & Saville, 1972; Maganaris, Collins, & Sharp, 2000), caffeine (Beedie, Stuart, Coleman, & Foad, 2006; Foad, Beedie, & Coleman, 2008), or carbohydrate (CHO; Clark et al.).

In studies with a placebo control, CHO ingestion during prolonged exercise (lasting more than 2 hr) delays the onset of fatigue and improves exercise

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performance (Coggan & Coyle, 1987, 1989; Coyle, Coggan, Hemmert, & Ivy, 1986; Coyle et al., 1983; Febbraio, Chiu, Angus, Arkinstall, & Hawley, 2000). This ergogenic effect of CHO has been attributed to the maintenance of plasma glucose concentrations and high rates of CHO oxidation late in exercise, when muscle and liver glycogen stores are low (Coggan & Coyle, 1989). Given the widespread use of CHO supplements in endurance sports and the widely advertised benefits of using CHO products, however, participants taking part in CHO-feeding studies are well aware of the potential benefits for performance. Therefore, it is reasonable to suggest that the placebo effect might contribute to the ergogenic effect of CHO intake during exercise.

Clark et al. (2000) reported a 4% improvement in 40-km time-trial cycling performance (test duration ~ 1 hr) when participants ingesting a placebo solution were told it contained CHO. In contrast, they reported that the real effect of CHO was a slight decrease in performance (0.3%). These findings suggest that the placebo effect might account for the ergogenic effect of some nutritional supplements. Clark et al. made several recommendations for future placebo-effect research, including protocols of different exercise duration. Indeed, it seems unlikely that placebo effects remain constant under varied test conditions, and whether a placebo effect of CHO intake can influence performance during prolonged exercise remains unknown. Therefore, the purpose of the current study was to investigate the placebo effect of CHO intake during a prolonged test of cycling performance (test duration ~ 3 hr). We hypothesized that a placebo effect would be present but that it would be significantly less than the real effect of CHO intake.

**Methods**

**Participants**

Ten endurance-trained male cyclists (age 28 ± 8 years, body mass 74.1 ± 9.0 kg, maximal oxygen uptake \([\text{VO}_{2\text{max}}]\) 61.7 ± 7.3 ml · kg\(^{-1}\) · min\(^{-1}\), maximal power output 336 ± 31 W; \(M \pm SD\)) volunteered to participate in this study. Participants were informed of the potential risks involved with the experimental procedures before providing their written consent. The study was approved by the School of Sport and Exercise Sciences’ Safety and Ethics Committee (University of Birmingham, UK).

**General Design**

Each participant completed three experimental trials consisting of 120 min of steady-state cycling at 50% maximal power output (\(W_{\text{max}}\)) followed by a time trial (TT) lasting approximately 60 min. Throughout exercise, participants ingested either plain water (WAT), artificially colored and flavored water (PLA), or a 6% carbohydrate-electrolyte solution (CES), which contained glucose and fructose in a 2:1 ratio. Trials were performed in random order, using a double-blind crossover design, and separated by at least 7 days. PLA and CES were produced with identical color and taste. To investigate the possibility of a placebo effect with CHO
feeding participants were told that both flavored solutions contained CHO and that the purpose of the study was to compare CHO drinks with water.

**Preliminary Testing**

One week before the start of the experiment, participants performed an incremental test to exhaustion on an electromagnetically braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands) to determine their VO$_{2\max}$ and W$_{\text{max}}$. Briefly, participants began cycling at 95 W, followed by 35-W increments every 3 min thereafter. Breath-by-breath measurements were performed throughout exercise using an automated online gas-analysis system (Oxycon Pro, Jaeger, Wuerzburg, Germany). W$_{\text{max}}$ values were used to determine 50% and 70% W$_{\text{max}}$, which were later employed in the experimental trials.

**Diet and Activity Before Testing**

Participants were asked to record their food intake and physical activity for 2 days before the first trial and were then instructed to follow the same diet and activities before all remaining trials. They were also asked to refrain from strenuous exercise and alcohol and caffeine intake for 24 hr before all trials. They were given standardized forms for this purpose. All 10 participants provided detailed food records as required. These records included the timing of food intake, portion size (weighed when possible but estimated otherwise), brand of food, and method of cooking. One of the researchers checked the records (for sufficient detail) before handing them back to the participants to guide them in standardizing their food intake before subsequent visits. We are satisfied that all 10 participants understood the importance of this procedure and complied with the diet control.

**Experimental Trials**

Participants reported to the laboratory after a 3-hr fast. To avoid the influence of circadian variation, each participant performed all trials at the same time of day. After they sat quietly for 10–15 min a Teflon catheter (Venflon, Becton Dickinson, Plymouth, UK) was inserted into an antecubital vein of the arm and a resting blood sample (10 ml) was obtained. Participants then began cycling at 50% W$_{\text{max}}$ (168 ± 15 W) for 120 min. At the onset of exercise, they ingested 600 ml of one of the three experimental beverages (WAT, PLA, or CES), followed by a further 150 ml every 15 min thereafter. Further blood samples (10 ml) were obtained every 15 min, along with measures of VO$_2$ and VCO$_2$ using an automated online gas-analysis system (Oxycon Pro, Jaeger, Wurzburg, Germany). Heart rate was recorded continuously (15-s intervals) throughout exercise using a radiotelemetry heart-rate monitor (Polar 625X, Kemepele, Finland).

On completion of steady-state exercise, the ergometer was adjusted to the cadence-dependent (linear) mode, and participants were required to complete a set amount of work (847 ± 78 kJ) as fast as possible. The total amount of work to be performed was calculated using the following formula:

$$\text{Total work (J)} = 0.70 \times W_{\text{max}} \times 3,600 \text{ s}$$
The linear factor was individually adjusted so that 70% $W_{max}$ was obtained when the participant pedaled at his preferred cadence. Preferred cadence was determined during the preliminary testing session and was considered to be the average cadence freely adopted during the VO$_{2max}$ test. In addition, participants were asked to report their preferred cadence, and in all cases this was similar to that observed during the VO$_{2max}$ test. Preferred cadence was between 90 and 95 rpm for all participants. The only information available to the participants during TT was elapsed work and percentage of work performed (i.e., 0% at the start and 100% on completion). Furthermore, they were not given any feedback on their performance until completion of the entire study. At set intervals throughout the TT (25%, 50%, and 75% work completed) participants ingested a further 150 ml of one of the experimental beverages (W AT, PLA, or CES). The total fluid intake during steady-state exercise and TT (total duration ~ 3 hr) was 2,250 ml. During the CES trial this provided 135 g of CHO (0.75 g/min, or 45 g/hr). Heart rate was recorded continuously throughout the test, but no blood or respiratory measures were taken. With the exception of providing drinks, every effort was taken to ensure that participants were not disturbed. A screen was placed around each participant to separate him from the investigator, and participants were not given any verbal encouragement. These are standard testing procedures in our laboratory (Currell & Jeukendrup, 2008).

**Analyses**

Blood samples were collected into prechilled Vacutainers containing K$_3$EDTA and stored on ice for approximately 15–20 min before centrifugation at 2,300 g for 10 min at 4 °C. After centrifugation, aliquots of the plasma were immediately frozen in liquid nitrogen and stored at –25 °C until further analysis. Plasma samples were analyzed using commercially available spectrophotometric assays for glucose (Glucose HK, ABX Diagnostics, UK) and lactate (Lactic Acid, ABX Diagnostics) using a semiautomatic analyzer (Cobas Mira Plus, ABX).

**Calculations**

Rates of total CHO and fat oxidation were calculated using stoichiometric equations (Jeukendrup & Wallis, 2005), with the assumption that protein oxidation was negligible:

$$\text{CHO oxidation (g/min)} = (4.210 \times VCO_2) - (2.962 \times VO_2)$$

$$\text{Fat oxidation (g/min)} = (1.695 \times VO_2) - (1.701 \times VCO_2)$$

**Statistical Analysis**

All data are expressed as $M \pm SD$. One-way (trial) analysis of variance (ANOVA) for repeated measures was performed to study differences in substrate metabolism (averaged over the 120-min steady-state period) and TT performance. Two-way (Trial $\times$ Time) ANOVA for repeated measures was performed to study differences in plasma metabolite concentrations during steady-state exercise and power output during the TT. Significant effects were followed up by post hoc comparisons.
Data analysis was performed using SPSS for Windows, version 13.0 software (Chicago, IL), or by hand. Significance was accepted at $p < .05$.

**Results**

**Performance Data**

Mean power output during TT was 218 ± 22 W in WAT, 219 ± 17 W in PLA, and 242 ± 27 W in CES (Figure 1). Performance times were 66.35 ± 6.15, 65.94 ± 5.56, and 59.69 ± 2.87 min for WAT, PLA, and CES, respectively. Therefore, CES enhanced performance by 11.3% compared with WAT ($p < .05$, 95% confidence interval 4.7–17.9%) and 10.6% compared with PLA ($p < .05$, 95% confidence interval 4.4–16.8%). Ingesting PLA resulted in a small (0.4%), nonsignificant improvement in performance compared with WAT (95% confidence interval −3.4% to 4.2%).

Power output decreased throughout TT in WAT and PLA, whereas power output was maintained throughout TT in CES (Figure 2; $p < .05$). Average power output during the last 25% was significantly higher in CES than in WAT (Figure 2; $p < .05$). Average power output during the last 50% was significantly higher in CES than in PLA (Figure 2; $p < .05$).

**VO$_2$, Respiratory-Exchange Ratio, CHO, and Fat Oxidation**

Expired-gas measurements and substrate oxidation are displayed in Table 1. There was no difference in VO$_2$ between trials. Therefore, relative exercise intensity was similar in all trials (~61% VO$_{2\text{max}}$). Ingesting CES resulted in significantly higher respiratory-exchange ratios than WAT and PLA ($p < .05$). Accordingly, total CHO

![Figure 1](image) — Average power output during the time trial, $M \pm SD (N = 10)$. WAT = water; PLA = placebo; CES = carbohydrate-electrolyte solution. *Significantly different from WAT, $p < .05$. †Significantly different from PLA, $p < .05$. 

(Tukey’s honestly significant difference).
oxidation was significantly higher \( (p < .05) \) and total fat oxidation significantly lower \( (p < .05) \) in CES than in WAT and PLA.

**Plasma Metabolites**

Plasma glucose and lactate concentrations at rest and during exercise are shown in Figure 3(a) and (b), respectively. Resting plasma glucose concentrations were not significantly different between trials \( (4.5–4.8 \text{ mmol/L}) \). Ingesting CES resulted in significantly higher plasma glucose concentrations than WAT and PLA at several time points throughout exercise. Resting plasma lactate concentrations were not
significantly different between trials (1.15–1.25 mmol/L). Average plasma lactate concentrations were significantly higher in CES (1.54 ± 0.38 mmol/L) than in WAT (1.35 ± 0.30 mmol/L) and PLA (1.35 ± 0.25 mmol/L; *p* < .05).

**Discussion**

The purpose of the current study was to investigate the possibility of a placebo effect from CHO intake during prolonged exercise. Based on the recommendations of Beedie and colleagues (Beedie, Coleman, & Foad, 2007; Trojan & Beedie, 2008) we designed a three-condition study (PLA, CES, and water), which allowed comparison between the placebo and real treatment, as well as comparison with a true baseline measure (in this case, ingestion of water). Participants
were told that PLA and CES contained CHO and that the purpose of the study was to compare the CHO drinks with water. This novel aspect of the study design meant that participants had similar expectations for PLA and CES in terms of their potential for performance benefits. The main finding of the current study was that CHO ingestion improved performance by 10.6% compared with PLA, and PLA ingestion did not improve performance compared with water (Figure 1).

The lack of a placebo effect is somewhat surprising given that participants believed that PLA contained CHO, which seems in contrast to at least one previous study (Clark et al., 2000). However, this observation is most likely a result of the intensity and duration of exercise and hence the mechanism by which CHO improves performance. As previously mentioned, Clark et al. reported a 4% improvement in 40-km time-trial cycling performance (test duration ~ 1 hr) when participants ingesting a placebo solution were told it contained CHO. In that study, the real effect of CHO intake was a slight decrease in performance. Because CHO availability is not thought to be limiting during relatively short-duration high-intensity exercise, the placebo effect might account for the ergogenic effect of supplements’ having little or no real mechanism of action.

Fatigue during prolonged submaximal exercise (like that of the current study) coincides with the depletion of glycogen stores and reduced blood glucose concentrations (Coyle et al., 1986). Although this is speculative, we suggest that signals of metabolic fatigue associated with prolonged exercise would override any positive psychological factors manifesting as a result of believing one has received a beneficial treatment. Hence, under these conditions, one might expect similar performances in WAT and PLA trials. Regardless of the exact reason for similar performances between PLA and WAT, the current study demonstrates that simply believing one has received CHO does not improve performance during prolonged exercise.

Five participants responded to PLA ingestion with an improvement in performance when compared with WAT (mean improvement of 4.5%). This could represent day-to-day variation in our performance measure, but the variation of this test is typically less than 2% (unpublished observations), and previous studies have also reported individual differences in placebo responsiveness (Beedie et al., 2006). It is not yet known why some individuals appear more responsive to placebo effects than others, but pacing could play a role. For example, if participants ride submaximally during a baseline performance measure, it is entirely possible that they raise their effort (either consciously or subconsciously) when a potentially ergogenic aid is administered. Given that we did not observe a placebo effect, this could indicate that our well-trained participants gave a true all-out effort during the baseline WAT trial. Of course this is difficult to know for sure. Nonetheless, researchers should be encouraged to recruit highly motivated well-trained participants with competitive experience when investigating potential ergogenic aids. It has also been suggested that there might be a relationship between training status and placebo responsiveness, with moderately trained athletes being more responsive than highly trained athletes (Clark et al., 2000). In the current study, we cannot confirm or dismiss this possibility because of the relatively small sample size (N = 10) and similar training status of the cyclists recruited.
As mentioned previously, a unique aspect of the current study was that participants received CHO, PLA, and WAT but were only told they would receive CHO and WAT. In more traditional placebo-controlled research, participants receive the placebo and real treatments in a blind manner but are fully informed that at some point they will receive a placebo. One of the limitations of this traditional approach is that uncertainty of trial order can increase the variation of the performance measure (Clark et al., 2000). Another limitation is that participants might respond to subtle cues that help them correctly identify the treatment and placebo conditions. These cues could be knowledge of their current versus previous performance or identification of symptoms or side effects associated with receiving an active substance (Foad et al., 2008). Considering these points, we suggest that not fully informing participants of the treatments they receive might be a useful method of reducing the placebo effect and improving the reliability of performance testing. In addition, in the current study we chose not to measure ratings of perceived exertion during steady-state exercise, which is often standard practice in this type of study. The reason for this is that simply asking participants to rate their perceived exertion could give away treatment and placebo conditions and therefore influence the performance outcome. Researchers should be aware of this possibility when deciding whether to include ratings of perceived exertion in future studies of potential ergogenic aids. Furthermore, researchers should determine the placebo effect under the specific conditions of their intervention by including a true baseline measure, as well as a placebo, as originally suggested by Beedie and colleagues (Beedie et al., 2007; Trojan & Beedie, 2008).

In summary, during a prolonged test of cycling performance in which participants were not fully informed of the test conditions, there was no placebo effect when participants believed they had ingested CHO. In contrast, the real effect of CHO intake was a 10.6% improvement in TT cycling performance.

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References


