Carbohydrate Mouth Rinsing in the Fed State: Lack of Enhancement of Time-Trial Performance

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It has been reported previously that mouth rinsing with a carbohydrate-containing solution can improve cycling performance. The purpose of the current study was to investigate the impact of such a carbohydrate mouth rinse on exercise performance during a simulated time trial in a more practical, postprandial setting. Fourteen male endurance-trained athletes were selected to perform 2 exercise tests in the morning after consuming a standardized breakfast. They performed an ~1-hr time trial on a cycle ergometer while rinsing their mouths with either a 6.4% maltodextrin solution (CHO) or water (PLA) after every 12.5% of the set amount of work. Borg’s rating of perceived exertion (RPE) was assessed after every 25% of the set amount of work, and power output and heart rate were recorded continuously throughout the test. Performance time did not differ between treatments and averaged 68.14 ± 1.14 and 67.52 ± 1.00 min in CHO and PLA, respectively (p = .57). In accordance, average power output (265 ± 5 vs. 266 ± 5 W, p = .58), heart rate (169 ± 2 vs. 168 ± 2 beats/min, p = .43), and RPE (16.4 ± 0.3 vs. 16.7 ± 0.3 W, p = .26) did not differ between treatments. Furthermore, after dividing the trial into 8s, no differences in power output, heart rate, or perceived exertion were observed over time between treatments. Carbohydrate mouth rinsing does not improve time-trial performance when exercise is performed in a practical, postprandial setting.

Keywords: exercise, cycling, mouthwash, maltodextrin

It has been well established that carbohydrate ingestion during prolonged, moderate- to high-intensity endurance-type exercise can delay the onset of fatigue and enhance exercise performance (Coggan & Coyle, 1987; Coyle, Coggan, Hemmert, & Ivy, 1986; Foskett, Williams, Boobis, & Tsintzas, 2008; Jeukendrup, 2004; Tsintzas & Williams, 1998; Yaspelkis et al., 1993). The ergogenic properties of carbohydrate ingestion during exercise have been attributed to the maintenance of high carbohydrate oxidation rates throughout the later stages of exercise (Coggan & Coyle, 1987; Coyle et al., 1986; Jeukendrup, 2004; Jeukendrup et al., 2004).
Moreover, several studies have shown that carbohydrate intake during exercise spares endogenous muscle glycogen stores (Stellingwerff et al., 2007; Tsintzas & Williams, 1998; van Loon, Jeukendrup, Saris, & Wagenmakers, 1999; Yaspelkis, Patterson, Anderla, Ding, & Ivy, 1993). Several studies have reported that carbohydrate ingestion can also improve performance during more intense exercise of short duration—less than 45–60 min (Anantaraman, Carmines, Gaesser, & Weltman, 1995; Ball, Headley, Vanderburgh, & Smith, 1995; Below, Mora-Rodriguez, Gonzalez-Alonso, & Coyle, 1995; Carter, Jeukendrup, Mundel, & Jones, 2003; el-Sayed, Balmer, & Rattu, 1997; Jeukendrup, 2004; Jeukendrup, Brouns, Wagenmakers, & Saris, 1997; Neufer et al., 1987). However, there is no apparent metabolic explanation for this observation, because endogenous carbohydrate stores should not limit exercise performance during short exercise tasks (Jeukendrup et al., 1997; McConell, Canny, Daddo,ance, & Snow, 2000). To examine exogenous and endogenous glucose kinetics during high-intensity cycling exercise, Carter, Jeukendrup, Mann, and Jones (2004) tested 6 endurance athletes for 1 hr at 75% Wmax while infusing either 20% glucose or 0.9% saline. Despite greater plasma glucose availability in the glucose-infusion trial, total carbohydrate oxidation rates did not differ between treatments. Moreover, no performance benefits were observed after intravenous glucose administration. Consequently, the authors suggested that carbohydrate ingestion during high-intensity exercise of short duration might exert its ergogenic effect by acting through the central nervous system, possibly mediated by glucose receptors in the mouth or gastrointestinal tract.

To test this hypothesis, Carter, Jeukendrup, and Jones (2004) investigated the impact of a carbohydrate mouth-rinse solution on 1-hr time-trial performance. The use of a mouth-rinse treatment, in which a carbohydrate solution is spat out without swallowing, was chosen to remove any influence of the gut or exogenous carbohydrate oxidation on performance. Participants were reported to cycle faster after a mouth rinse with a 6.4% maltodextrin solution at every 12.5% of the trial completed compared with a placebo rinse (59.6 ± 1.5 and 61.4 ± 1.6 min in the maltodextrin and placebo treatments, respectively, p < .05). The authors concluded that carbohydrate mouth rinsing improves time-trial performance and that the mechanism responsible might be an increase in central drive or motivation mediated by glucose receptors in the mouth. More recently, Whitham and McKinney (2007) failed to confirm the proposed ergogenic benefits of carbohydrate mouth rinsing during a 1-hr performance run. Although there is no obvious explanation for the apparent discrepancy between findings, it might be because Whitham and McKinney applied high-intensity running as opposed to cycling exercise.

In the study by Carter, Jeukendrup, and Jones (2004), participants were tested while performing demanding time trials in a fasted state. It remains to be established whether their findings are reproducible in a more practical situation, in which athletes generally consume a carbohydrate-rich meal ~2 hr before competition. From an evolutionary viewpoint, it can be speculated that the potential stimulating effect of glucose in the mouth might be of considerable impact under conditions when liver glycogen stores might be compromised. We hypothesized that the proposed ergogenic properties of a carbohydrate mouth rinse would not be evident when exercise was performed in a more practical, postprandial setting.
Therefore, the current study investigated the impact of a carbohydrate mouth rinse on time-trial performance in endurance-trained cyclists, with exercise being performed 2 hr after a standardized breakfast.

Methods

Participants

Fourteen male endurance-trained cyclists participated in this study (age 24 ± 1 year, body weight 72.6 ± 2.4 kg, height 1.85 ± 0.02 m, body-mass index 21.1 ± 0.4 kg/m², $W_{\text{max}}$ 5.4 ± 0.1 W/kg body mass). All were competitive cyclists who exercised at least twice a week and for more than 100 km/week. Participants were fully informed on the nature and possible risks of the experimental procedures before their written consent was obtained. The study was approved by the Medical Ethical Committee of the Academic Hospital Maastricht, The Netherlands.

Study Design

The protocol consisted of four visits to the laboratory, which was maintained at 21.6 ± 0.1 °C with a relative humidity of 46% ± 1%. All exercise tests were carried out on an electronically braked cycle ergometer (Lode Excalibur, Groningen, The Netherlands). Visit 1 involved an incremental exercise test to exhaustion to determine participants’ maximum workload capacity ($W_{\text{max}}$). Visits 2, 3, and 4 involved a simulated time trial in which a set amount of work had to be performed within the shortest possible time frame. Visit 2 was a familiarization session. Visits 3 and 4 were the experimental trials, during which the participants were given either a 6.4% maltodextrin solution (CHO) or water (PLA) to rinse around the mouth at predetermined intervals. The experimental trials were performed in a double-blind, counterbalanced order separated by at least 7 days.

Diet and Activity Before the Experiments

All participants received a standardized dinner and snacks for the evening before each experimental day (75.6 ± 4.5 kJ/kg, consisting of 41 ± 1 energy percent [En%] carbohydrate, 19 ± 1 En% protein, and 40 ± 1 En% fat). They were provided with measured amounts of all food products and instructed to take all meals and snacks at predetermined times the day before testing. Participants were instructed to maintain dietary records during the 2 days before Visits 2, 3, and 4 and to keep a training diary during the entire test period. Two days before their visits, participants were permitted to exercise at a relatively low intensity (heart rate below 150 beats/min) for a maximum of 2 hr. The day before each visit, they refrained from exhaustive physical labor and sport activities.

Maximal Workload Capacity

Participants performed an incremental exercise test to exhaustion so that we could determine their $W_{\text{max}}$. After a 5-min warm-up at 100 W, workload was set at 150 W and increased by 50 W every 2.5 min until exhaustion (Kuipers, Verstappen,
Keizer, Geurten, & van Kranenburg, 1985). Workload (W), cadence (rpm), and heart rate (Polar, Finland) were recorded at every interval. The appropriate seat position, handlebar height, and orientation were determined and replicated for each subsequent visit.

Time Trials

Participants reported to the laboratory at 8:30 a.m. after an overnight fast. They received a standardized breakfast at 8:45 a.m. (39.5 ± 0.8 kJ/kg, providing 67 ± 2 En% carbohydrate, 13 ± 1 En% protein, and 20 ± 2 En% fat). The breakfast provided 2.36 ± 0.04 g/kg of carbohydrates. After breakfast, participants were not allowed to eat or drink, except for water, until the start of the time trials at 11:00 a.m. Before testing, participants were weighed, fitted with a heart-rate monitor, and familiarized with the Borg scale of perceived exertion (Borg, 1982). After a 10-min warm-up at 40% $W_{\text{max}}$, they were instructed to perform a set amount of work (1,053 ± 48 kJ) in the shortest time possible. Total work to be performed was calculated according to the equation of Jeukendrup, Saris, Brouns, and Kester (1996):

$$\text{Total amount of work} = 0.75 \times W_{\text{max}} \times 3,600$$

where $W_{\text{max}}$ is the maximal workload capacity determined at Visit 1 and 3,600 is the duration in seconds (equivalent to 1 hr). The ergometer was set in linear mode so that 75% $W_{\text{max}}$ was obtained when the participants cycled at their preferred cadence (96 ± 2 rpm), which had been determined during Visit 1. The ergometer was connected to a computer that calculated and displayed the total amount of work performed. The only information participants received was the absolute amount of work performed and the percentage of work performed relative to the set amount of work. This information was displayed on a computer screen in front of the ergometer. A fan was placed 1 m behind each participant to provide cooling and air circulation during the trials. At the start and every 12.5% of the time trial completed, participants received 25 ml of the test drink to rinse around the mouth. The rating of perceived exertion (RPE) was recorded at the start and every 25% of the time trial completed, and heart rate (Polar, Finland) was recorded continuously throughout the test. During each time trial, no interaction occurred between the participant and the investigators except for Borg-scale recording and mouth-rinse administration. No encouragement was given to the participants, and they were kept unaware of performance-related information such as exercise time, heart rate, and cycling cadence.

Mouth-Rinse Protocol

Each participant was given a 25-ml bolus of either a 6.4% maltodextrin solution (CHO) or water (PLA) at the start and after every 12.5% of the time trial completed. Participants rinsed the fluid around the mouth for 5 s and then spat it into a bowl held by an investigator. They were informed that in both trials a CHO drink containing an identical amount of CHO, but from different sources, was given. At the end of the fourth visit, they were asked whether they could distinguish between the different rinse solutions. Maltodextrin is a partially hydrolyzed starch that,
when dissolved in water, is colorless and nonsweet. It was obtained from AVEBE (Veendam, The Netherlands). Beverage administration was randomized via a random-number generator (SPSS v. 12.0.1), and beverages were coded by a non-affiliated researcher to ensure double blinding.

Statistical Analyses

All data are expressed as $M \pm SEM$. A two-factor repeated-measures analysis of variance (ANOVA) with time and treatment as factors was used to compare differences between treatments over time. In case of significant $F$ ratios, Scheffé’s post hoc tests were applied to locate the differences. For non-time-dependent variables, a paired Student’s $t$ test was used to compare differences in treatment effect. Statistical significance was set at $p < .05$. All calculations were performed using SPSS package, version 15.0 (SPSS Inc., USA).

Results

Performance Time and Power Output

Performance time did not differ between trials and averaged $68.14 \pm 1.14$ min and $67.52 \pm 1.00$ min in the CHO and PLA treatments, respectively (Figure 1; $p = .57$). The average power outputs were $265 \pm 5$ W and $266 \pm 5$ W in CHO and PLA, respectively, with no differences between trials ($p = .58$). The individual differences in power output between trials are shown in Figure 2. The average power outputs for every 12.5% of the time trial completed are presented in Figure 3. No treatment-by-time interaction was observed between the CHO and PLA treatments ($p = .44$).

![Figure 1](image-url) — Performance time in the placebo and carbohydrate treatments. Values are expressed as $M \pm SEM$. Data were analyzed with a paired Students’ $t$ test ($p = .57$).
Average heart rate, RPE, and body-mass loss in the CHO and PLA trials are listed in Table 1. Heart rate increased rapidly after the onset of exercise, reaching maximal values during the latter stages of the time trial (180 ± 3 and 178 ± 3 beats/min in CHO and PLA, respectively; \( p = .31 \)). RPE values increased throughout the time trials, reaching 18.9 ± 0.3 and 19.1 ± 0.3 in the CHO and PLA treatments, respectively (\( p = .50 \)). No treatment-by-time interactions were observed for heart
rate \((p = .97)\) or RPE \((p = .34)\) between treatments. Body-mass loss averaged 1.45 \(\pm 0.1\) and 1.51 \(\pm 0.1\) kg for CHO and PLA, respectively, with no differences between treatments \((p = .52)\).

**Mouth Rinse**

Nine of the 14 participants could not distinguish a difference in taste between the solutions. One participant tasted a difference but could not distinguish CHO from PLA. Four participants correctly differentiated between the CHO and PLA solutions. Of these 4 participants, 2 performed the time trial faster with the CHO mouth rinse (Figure 2).

**Discussion**

The current study shows that carbohydrate mouth rinsing does not affect performance, power output, RPE, or heart rate during a high-intensity cycling time trial performed 2 hr after a standardized breakfast.

Two previous studies investigated the effect of carbohydrate mouth rinsing on performance during high-intensity exercise of relatively short duration (<1 hr). Carter, Jeukendrup, and Jones (2004) reported enhanced cycling time-trial performance when a CHO solution was rinsed around the mouth during exercise. However, Whitham and McKinney (2007) failed to confirm these findings when applied in a running exercise protocol. In both studies participants performed the time trials in a fasted state, which is not representative of a practical situation, in which athletes generally consume a carbohydrate-rich meal ~2 hr before competition.

In the current study, we investigated 14 highly trained athletes during two high-intensity time trials who were provided either a 6.4% CHO or a PLA mouth-rinse solution at every 12.5% of the trial completed. All time trials were started at 11:00 a.m., 2 hr the participants had consumed a standardized breakfast. Our data show no improvement in exercise performance between the CHO and PLA mouth-rinse treatments (Figure 1). Performance time, workload, heart rate, and RPE were similar between trials at all time points (Table 1, Figures 1 and 3). In fact, the performance times in our time trials showed a coefficient of variation of 3.45%, similar to previous reports on the validity of time trials as a means to assess exercise performance in a laboratory setting (Jeukendrup et al., 1996).

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<th>Carbohydrate</th>
<th>Placebo</th>
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<tr>
<td>Heart rate (beats/min)</td>
<td>169 (\pm 2)</td>
<td>168 (\pm 2)</td>
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<tr>
<td>Power output (W)</td>
<td>265 (\pm 5)</td>
<td>266 (\pm 5)</td>
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<td>Rating of perceived exertion (Borg scale)</td>
<td>16.4 (\pm 0.3)</td>
<td>16.7 (\pm 0.3)</td>
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<td>Body-mass loss (kg)</td>
<td>1.45 (\pm 0.1)</td>
<td>1.51 (\pm 0.1)</td>
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To determine the proposed practical relevance of carbohydrate mouth rinsing during exercise, we assessed time-trial performance 2 hr after consumption of a carbohydrate-rich breakfast, as opposed to testing in a fasted condition. Carter, Jeukendrup, and Jones (2004) speculated that the mechanism by which carbohydrate mouth rinsing exerts its ergogenic effects on exercise performance might be mediated by the stimulation of pleasure and reward centers in the brain via carbohydrate receptors in the oral cavity. One might expect that stimulation of these centers would result in lower RPE in the CHO than the PLA experiment. However, in line with previous reports by Carter et al., we observed no differences in RPE between the CHO and PLA mouth-rinse time trials. Peak RPE values and changes in RPE over time did not differ between experiments. Therefore, our observations on RPE do not seem to support the hypothesis that carbohydrate mouth rinsing during exercise stimulates pleasure and reward centers in the brain. Although evidence of the existence of glucose receptors in the mouth remains to be established (Carter, Jeukendrup, & Jones), it could be speculated that from an evolutionary perspective such receptors would be very important under conditions when liver or muscle glycogen stores are largely reduced. However, when liver glycogen stores are readily available to sustain intense exercise of short duration, the relevance of this mechanism is questionable. The latter might explain the absence of any ergogenic benefits of carbohydrate mouth rinsing in the current study, because we provided participants with a standardized carbohydrate-rich breakfast 2 hr before exercise.

In general, coaches and recreational and elite athletes generally translate scientific research for application in their own sports practice, especially when ergogenic benefits are reported. Consequently, the proposed ergogenic benefit of having a small amount of carbohydrate in the mouth has received much media attention. However, the current study provides evidence that a carbohydrate mouth rinse does not improve exercise performance when applied in a practical, fed condition. Nonetheless, the proposed presence of carbohydrate receptors in the mouth and their potential role in affecting mood and performance during exercise conditions when endogenous glycogen reserves are compromised warrants further research.

In conclusion, the current study shows that carbohydrate mouth rinsing during high-intensity exercise of short duration does not improve performance capacity when exercise is performed in a postprandial state.

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References


