Carbohydrate mouth rinsing in the fed state does not enhance time trial performance

Milou Beelen¹, Jort Berghuis¹, Ben Bonaparte¹, Sam B. Ballak¹, Asker E. Jeukendrup², and Luc J.C. van Loon¹

¹ Department of Human Movement Sciences, Nutrition and Toxicology Research Institute Maastricht (NUTRIM), Maastricht University, Maastricht, the Netherlands.

² School of Sport and Exercise Sciences, University of Birmingham, Birmingham, United Kingdom.

Address for correspondence:
M. Beelen
Dept. of Human Movement Sciences
Maastricht University
PO Box 616
6200 MD Maastricht
The Netherlands
Tel: +31 43 3881390
Fax: +31 43 3670972
E-mail: Milou.Beelen@BW.unimaas.nl

Running title: carbohydrate mouth rinsing and performance
Abstract

It has been reported previously that mouth rinsing with a carbohydrate containing solution can improve cycling performance. The purpose of the present 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. **Methods:** Fourteen male, endurance trained athletes were selected to perform 2 exercise tests in the morning after consuming a standardized breakfast. Subjects performed a ~1 h time trial on a cycle ergometer, while rinsing their mouth with either a 6.4% maltodextrin solution (CHO) or water (PLA) after every 12.5% of the set amount of work. Borg’s rate 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. **Results:** 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=0.57). In accordance, average power output (265±5 vs 266±5 W, P=0.58), heart rate (169±2 vs 168±2 bpm, P=0.43) and RPE (16.4±0.3 vs 16.7±0.3 W, P=0.26) did not differ between treatments. Furthermore, after dividing the trial into eights, no differences in power output, heart rate or perceived exertion were observed over time between treatments. **Conclusion:** Carbohydrate mouth rinsing does not improve time trial performance when exercise is performed in a practical, postprandial setting.

**Key words:** exercise, cycling, mouth wash, maltodextrin
Introduction

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 et al., 1986; Foskett et al., 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., 1999; Neufer et al., 1987; Tsintzas & Williams, 1998). Moreover, several studies have shown that carbohydrate intake during exercise spares endogenous muscle glycogen stores (Stellingwerff et al., 2007; Tsintzas & Williams, 1998; van Loon et al., 1999; Yaspelkis et al., 1993).

Several studies report that carbohydrate ingestion can also improve performance during more intense exercise of short duration, i.e. exercise lasting less than 45-60 min (Anantaraman et al., 1995; Ball et al., 1995; Below et al., 1995; Carter et al., 2003; el-Sayed et al., 1997; Jeukendrup et al., 1997; Jeukendrup, 2004; Neufer et al., 1987). However, there is no apparent metabolic explanation for this observation, as endogenous carbohydrate stores should not limit exercise performance during short exercise tasks (Jeukendrup et al., 1997; McConell et al., 2000). To examine exogenous and endogenous glucose kinetics during high intensity cycling exercise, Carter et al. (2004b) tested 6 endurance athletes for 1 h at 75% W\text{max} 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 following 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 and/or gastrointestinal tract.

To test this hypothesis, Carter et al. (2004a) investigated the impact of a carbohydrate mouth rinse solution on 1 h 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 and/or exogenous carbohydrate oxidation on performance. Subjects were reported to cycle faster following a mouth rinse with a 6.4% maltodextrin solution at every 12.5% of the trial completed, when compared to a placebo rinse (59.6±1.5 and 61.4±1.6 min in the maltodextrin and placebo treatment, respectively, P<0.05). 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 et al. (2007) failed to confirm the proposed ergogenic benefits of carbohydrate mouth rinsing during a 1 h performance run. Although there is no obvious explanation for the apparent discrepancy between findings, it might be attributed to the fact that Whitham & McKinney applied high-intensity running as opposed to cycling exercise.

In the study by Carter et al (2004a) subjects 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 h 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 those conditions where liver glycogen stores might be compromised. We hypothesize that the proposed ergogenic properties of a carbohydrate mouth rinse will not be evident when exercise is performed in a more practical, postprandial setting. Therefore, the present study investigates the impact of a carbohydrate mouth rinse on time trial performance in endurance-trained cyclists, with exercise being performed 2 h after a standardized breakfast.
Methods

Subjects

Fourteen male, endurance trained cyclists participated in this study (age: 24±1 y, bodyweight: 72.6±2.4 kg, height: 1.85±0.02 m, body mass index: 21.1±0.4 kg·m⁻², \( W_{\text{max}}: 5.4±0.1 \text{ W·kg BM}^{-1} \)). All selected subjects were competitive cyclists who exercised at least twice a week, and more than 100 km per week. Subjects were fully informed on the nature and possible risks of the experimental procedures, before their written informed 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 4 visits to the laboratory, which was maintained at 21.6±0.1 ºC 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 subjects’ maximum workload capacity (\( W_{\text{max}} \)). Visits 2, 3 and 4 involved a simulated time trial, where a set amount of work had to be performed within the shortest possible timeframe. Visit 2 was included as a familiarization session. Visit 3 and 4 represented the experimental trials, during which the subjects were given either a 6.4% maltodextrin solution (CHO) or water (PLA) to rinse around their mouth at pre-determined intervals. The experimental trials were performed in a double blind, counterbalanced order, and with each visit separated by at least 7 days.
Diet and activity prior to the experiments

All subjects received a standardized dinner and snacks for the evening prior to each experimental day (75.6±4.5 kJ·kg\(^{-1}\), consisting of 41±1 energy percent (En%) carbohydrate, 19±1 En% protein, and 40±1 En% fat). Subjects were provided with measured amounts of all food products and were instructed to take all meals and snacks at pre-determined time intervals the day prior to testing. Subjects were instructed to maintain dietary records during the 2 days prior to visits 2, 3 and 4 and to keep a training diary during the entire test period. Two days prior to their visits, subjects were permitted to exercise at a relative low intensity (heart rate below 150 bpm) for a maximum of 2 h. One day prior to each visit, subjects refrained from exhaustive physical labour and sports activities.

Maximal workload capacity

Subjects performed an incremental exercise test to exhaustion to determine their maximal workload capacity (W\(_{\text{max}}\)). After a 5 min warm-up at 100 W, workload was set at 150 W and increased with 50 W every 2.5 min until exhaustion (Kuipers et al., 1985). Workload (W), cadence (rpm) and heart rate (Polar, Finland) were recorded at every interval. The appropriate seat position, handle bar height and orientation were determined and replicated in each subsequent visit.

Time trials

Subjects reported to the laboratory at 8.30 a.m. following an overnight fast. They received a standardized breakfast at 08.45 a.m. (39.5±0.8 kJ·kg\(^{-1}\), providing 67±2 energy
percent (En%) carbohydrate, 13±1 En% protein and 20±2 En% fat). The breakfast provided the subjects with a total amount of carbohydrates of 2.36±0.04 g·kg⁻¹. Following breakfast, subjects were not allowed to eat or drink, except for water, until the start of the time trials at 11.00 a.m. Prior to testing, subjects were weighed, fitted with a heart rate monitor and familiarized with the Borg’s scale of perceived exertion (Borg, 1982). After a 10 min warm-up at 40% $W_{\text{max}}$, subjects were instructed to perform a set amount of work (1053±48 kJ) in the shortest time possible. Total work to be performed was calculated according to the equation by Jeukendrup et al. (1996), where:

$$\text{Total amount of work} = 0.75 \cdot W_{\text{max}} \cdot 3600$$

Where $W_{\text{max}}$ is the maximal workload capacity determined at visit 1 and 3600 is the duration in seconds (equivalent to 1 h). The ergometer was set in the linear mode so that 75% $W_{\text{max}}$ was obtained when the subjects cycled at their preferred cadence (96±2 rpm), which was determined during visit 1. The ergometer was connected to a computer, which calculated and displayed the total amount of work performed. The only information subjects 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 the subject to provide cooling and air circulation during the trials. At the start and every 12.5% of the time trial completed, subjects received 25 mL of the test drink to rinse around their mouth. The rate 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 subject and the investigators, except for Borg scale recording and mouth rinse administration. No
encouragement was given to the subject and they were kept unaware of performance related information, such as exercise time, heart rate and cycling cadence.

*Mouth rinse protocol*

Each subject 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. Subjects rinsed the fluid around the mouth for 5 s and then spat it into a bowl held by an investigator. Subjects 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, subjects were asked whether they could distinguish between the different rinse solutions. Maltodextrin is a partially hydrolyzed starch that, when dissolved in water, is colourless and non sweet. Maltodextrin was obtained from AVEBE (Veendam, The Netherlands). Beverage administration was randomized via a random-number generator (SPSS v12.0.1), and coding of beverages was performed by a non-affiliated researcher to ensure double blinding.

*Statistical analyses*

All data are expressed as mean and standard error of the mean (mean±SEM). A 2-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-ratio’s, Scheffe’s post-hoc tests were applied to locate the differences. For non-time dependent variables, a paired Students’ t-test was used to compare differences in
treatment effect. Statistical significance was set at P<0.05. 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±1.14 min and 67.52±1.00 min in the CHO and PLA treatment, respectively (Figure 1, P=0.57). The average power output was 265±5 W and 266±5 W in CHO and PLA, respectively, with no differences between trials (P=0.58). The individual differences in power output between trials are shown in Figure 2. The average power output for every 12.5% of the time trial completed is presented in Figure 3, no treatment over time interaction was observed between the CHO and PLA treatments (P=0.44).

Heart rate, RPE and body mass

Average heart rate, rate of perceived exertion (RPE) and body mass loss in the CHO and PLA trial are listed in Table 1. Heart rate increased rapidly following the onset of exercise, reaching maximal values during the latter stages of the time trial (180±3 and 178±3 bpm in CHO and PLA, respectively; P=0.31). RPE values increased throughout the time trials, reaching 18.9±0.3 and 19.1±0.3 in the CHO and PLA treatment, respectively (P=0.50). No treatment over time interactions were observed for heart rate (P=0.97) and RPE (P=0.34) between treatments. Body mass loss averaged 1.45±0.1 and 1.51±0.1 kg for CHO and PLA respectively, with no differences between treatments (P=0.52).
Mouth rinse

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

The present study shows that carbohydrate mouth rinsing does not affect performance, power output, rate of perceived exertion, and heart rate during a high intensity cycling time trial performed 2 h after a standardized breakfast.

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

In the present study, we investigated 14 highly trained athletes during 2 high-intensity time trials, while receiving either a 6.4% carbohydrate (CHO) or placebo (PLA) mouth rinse solution at every 12.5% of the trial completed. All time trials were started at 11.00 am, 2 h after consuming a standardized breakfast. Our data show no improvement in exercise performance between the CHO and PLA mouth rinse treatment (Figure 1). Performance time, workload, heart rate and RPE were similar between trials at all timepoints (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).
To determine the proposed practical relevance of carbohydrate mouth rinsing during exercise, we assessed time trial performance 2 h after consuming a carbohydrate-rich breakfast, as opposed to testing in a fasted condition. Carter et al. (Carter et al., 2004a) 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 centres in the brain via carbohydrate receptors in the oral cavity. One might expect that stimulation of these centres would result in lower rates of perceived exertion (RPE) in the CHO vs 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. Both peak RPE values as well as the 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 centres in the brain. Although evidence on the existence of glucose receptors in the mouth remains to be established (Carter et al., 2004a), it could be speculated that from an evolutionary perspective such receptors would be of great importance under conditions where liver and/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 present study, as we provided subjects with a standardized carbohydrate-rich breakfast 2 h prior to exercise.

In general, coaches, recreational and elite athletes generally translate scientific research for application in their own sports practice, especially when ergogenic benefits are
reported. As a consequence, the proposed ergogenic benefit of having a small amount of carbohydrate in the mouth has received much media attention. However, the present study provides evidence to show 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 present 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.
References


Acknowledgements

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Figure legends

**Figure 1.** Mean performance time in the PLA and CHO treatments. Values are expressed as means±SEM. Data was analyzed with a paired Students’ t-test (P=0.57).

**Figure 2.** Individual and mean percentage change in power output from PLA in the CHO treatment. [■] indicates mean power output and [■] indicates those subjects that correctly differentiated the CHO from the PLA beverage.

**Figure 3.** Mean power output during every 12.5% of the time-trial in the PLA and CHO treatments. Values are means±SEM. Data were analyzed with ANOVA repeated measures (treatment x time). Treatment effect, P=0.76; time effect, P=0.01; interaction of treatment and time, P=0.44.
Table 1. Heart rate, power output, RPE and weight loss

<table>
<thead>
<tr>
<th></th>
<th>CHO (bpm)</th>
<th>PLA (bpm)</th>
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<tbody>
<tr>
<td>Heart rate (bpm)</td>
<td>169±2</td>
<td>168±2</td>
</tr>
<tr>
<td>Average power (W)</td>
<td>265±5</td>
<td>266±5</td>
</tr>
<tr>
<td>RPE (Borg scale)</td>
<td>16.4±0.3</td>
<td>16.7±0.3</td>
</tr>
<tr>
<td>Body mass loss (kg)</td>
<td>1.45±0.1</td>
<td>1.51±0.1</td>
</tr>
</tbody>
</table>

Values are expressed as means ± SEM.
Figure 1

PLA

CHO

60  62  64  66  68  70

Time (min)

159x127mm (150 x 150 DPI)
Figure 2

159x127mm (150 x 150 DPI)
Figure 3
159x127mm (150 x 150 DPI)