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Simon Devenney

Kieran Collins

Marcus Shortall

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3 authors:

Simon Devenney
Technological University Dublin - Tallaght Campus

Kieran Collins
Technological University Dublin - Tallaght Campus

Marcus Shortall
Technological University Dublin - Tallaght Campus

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ORIGINAL ARTICLE

Effects of various concentrations of carbohydrate mouth rinse on cycling performance in a fed state

SIMON DEVENNEY, KIERAN COLLINS, & MARCUS SHORTALL

Department of Science, Centre for Exercise and Metabolic Science, Institute of Technology Tallaght, Dublin, Ireland

Abstract
The objective of this study was to identify the effects of mouth rinsing with a 6% and 16% carbohydrate solution (CHO) on time trial performance when compared to a 0% control (PLA) when in a fed state. Twelve recreationally active males underwent three trials by which they had to complete a set workload (600 ± 65 W) in a fed state. Throughout each trial, participants rinsed their mouths with a 25 ml bolus of a 0% PLA, 6% or 16% CHO (maltodextrin) for every 12.5% of work completed. Rating of perceived exertion (RPE) and heart rate were recorded every 12.5% of total work. Performance times and power output improved significantly when using the 6% and 16% CHO versus the PLA trial (6% versus PLA, $p = .002$ and 16% versus PLA, $p = .001$). When comparing the performance times of the 6% to 16% CHO, no significance was observed ($p = .244$). There was no significant difference between heart rate levels or RPE values across the three trials. In conclusion, mouth rinsing with a 6% or 16% CHO solution has a positive effect on a cycling time trial performance undertaken in a fed state.

Keywords: *Maltodextrin; 16% CHO solution; 6% CHO solution; exercise; power output; time trial performance*

Introduction

The ingestion of carbohydrates and their beneficial effects on exercise performance in both prolonged bouts of exercise (>2 h) and also in high-intensity exercise (>75% VO_2max) have been previously documented (Coyle, Coggan, Hemmert, & Ivy, 1986; Foskett, Williams, Boobis, & Tsintzas, 2008). Carbohydrate ingestion can have a positive impact during exercise as it plays an important role in reducing the rate of liver glycogen depletion and slows the rate by which fatty acids are utilised as a fuel source (Hargreaves, Hawley, & Jeukendrup, 2004; Jeukendrup et al., 1999; Jeukendrup, Rollo, & Carter, 2013; Stellingwerff et al., 2007; Tsintzas and Williams, 1998; van Loon, Jeukendrup, Saris, & Wagenmakers, 1999).

It has been reported that mouth rinsing with a carbohydrate solution (CHO) works best during the later stages of a 1 h cycling time trial, as there is a reduction in power (Carter, Jeukendrup, & Jones, 2004). Carter et al. (2004) investigated the effects of rinsing a participant's mouth with a CHO (6.4% maltodextrin) compared to a 0% placebo (PLA) during a 1 h time trial. Each solution was rinsed around the mouth every 12.5% of the trial completed and then expelled in order to prevent swallowing the solution. Results reported that the use of 6.4% CHO solution meant a 2.9% improvement in average time to completion when compared to the PLA results. Carter et al. (2004) hypothesised that mouth rinsing with a CHO solution can improve time trial performance through the activation of oral receptors that can trigger the reward pathways of the brain and body.

The majority of studies that investigate the effects of CHO mouth rinsing on performance have focused on cycling performance, there have been studies which have investigated the effects of CHO mouth rinsing on other endurance sports (Dorling & Earnest, 2013; Kasper et al., 2016; Rollo, Cole, Miller, & Williams, 2010; Rollo, Williams, Gant, & Nute, 2008). Rollo et al. (2008) investigated the effects of CHO rinsing of running performance after an overnight fast, using similar administering and expelling techniques used in previous studies, giving a 25 ml bolus at predetermined stages in

Correspondence: Simon Devenney, Department of Science, Centre for Exercise and Metabolic Science, Institute of Technology Tallaght, Tallaght, Dublin, Ireland. E-mail: simon.devenney@ittd.ie

both the warm-up and time trial. The overall study results showed that CHO rinsing has a positive effect on running performance, with running speeds quicker in the first 5 min of the 30 min trial in the CHO group when compared with the PLA group. It was also indicated that the CHO group covered more distance in the first 5 min of the trial while also having a 1.7% increase in total distance covered when compared with the PLA group. Recent work by Kasper et al. (2016) investigated the effects of CHO rinsing and caffeine on high-intensity interval running capacity in a carbohydrate-restricted state. After completing a glycogen depletion test 24 h prior to the exercise session, participants completed a 45 min steady-state run (65% VO_2max) followed by a high intensity interval running (HIT) protocol consisting of 1 min at 80% followed by a minute at 60% until the onset of fatigue. The study showed that the use of CHO rinse and caffeine ingestion increased the exercise capacity of individuals during HIT when compared with a PLA and a standalone CHO rinse.

The majority of CHO rinse studies have investigated concentrations of 6% or 6.4%, with more recent studies looking at a higher concentration (Lane, Bird, Burke, & Hawley, 2012). A 1.8% improvement in time trial performance was noted when a 10% CHO solution was rinsed for 10 s with participants monitored in a fed state, with 3% improvements shown in a fasted state (Lane et al., 2012). These findings compare favourably to the previous research findings of the 6% and 6.4% studies, showing an improvement in performance linked to activation of oral receptors. Not all the studies which have investigated CHO rinsing have discovered positive findings. Beelen et al. (2009) showed no enhancement in performance when mouth rinsing a CHO solution (6.4% maltodextrin) while in a fed state, while there was also no difference when comparing the CHO solutions to the PLA solution. The results showed no significant difference in performance times in the CHO or PLA group, while also stating no difference was seen in the heart rate or power output.

It has been well documented to date that mouth rinsing of a 6% or 6.4% CHO solution can have a positive effect in relation to performance in a fasted state; however, the effect of this concentration in a fed state is unclear. The aim of the current study is to develop the foundations set by Beelen et al. (2009) and Lane et al. (2012) by investigating the effects of rinsing with the traditional CHO rinse solution (6%) and a higher concentration (in this situation a 16% CHO) have on exercise performance when compared with a 0% solution while participants are in a fed state. By using a 6% and 16% solution, the current study is able to compare two solutions which can replicate two commercially available sports drinks and determine their benefits and also to determine if there is a concentration dependence with regards to exercise performance and one could hypothesise that by comparing one concentration to another, performance improvement could be further enhanced with the use of a higher concentration of CHO due to a greater saturation of oral receptors.

Methods

Recruitment: Twelve recreationally active males volunteered to participate in this study (age 22 ± 7 years, body weight 69 ± 9 kg, height 1.75 ± 0.07 m, body-mass index 22 ± 1.7 kg/m^2, W_{max} 260 ± 28 W, VO_2max, 51 ± 3 ml kg^{-1} min^{-1}), all of whom had engaged in cycling activities (3–5 days a week/5–8 h per week). All participants were informed verbally and in written form of the study design and the physiological demands they would be placed under. Each individual completed a medical questionnaire and consent form prior to testing. The study was approved by the local research ethics committee.

Overall study design: The protocol consisted of four visits to the laboratory with all tests carried out on a cycle ergometer (Wattbike Pro, British Cycling Wattbike, Nottingham, England). Visit 1 involved a RAMP test to determine each participant's maximum aerobic power or work capacity (W_{max}). In the remaining three visits, individuals completed a set amount of work, which was individualised and calculated based on their maximum work capacity, in the shortest timeframe possible. In a randomised, repeated measures and double blinded study, participants rinsed a 6% or 16% CHO solution or 0% PLA around the mouth at predetermined intervals.

Activity and diet before experiments: Participants were asked to keep a two-day training diary prior to each test visit, while they were allowed to undertake low-intensity exercise (heart rate below 150 beats/min) for up to 2 h. Along with the training diary, a two-day dietary diary was recorded in order to prevent the disruption of the results. Participants were also asked to refrain from consuming alcohol and caffeine in the 24 h prior to each visit. The dietary diaries were a tool used to ensure participants consumed the same diet on the 2nd, 3rd and 4th visit. Participants consumed a meal 2–3 h before testing (49 ± 2% carbohydrates, 18 ± 1% protein and 33 ± 2% fat) which was recommended by the authors.

Maximum workload capacity protocol: The maximum aerobic capacity test is a modified protocol which was based on the protocol performed by

Beelen et al. (2009). Each participant performed an all-out incremental exercise test which was used to determine their W_{max}. Each participant underwent a 5 min warm-up at 100 W. On completion of the warm-up, the workload was set at 150 W and increased by 25 W every 2.5 min until the onset of exhaustion instead of the 50 W increase (Pottier, Bouckaert, Gilis, Roels, & Derave, 2010). The increased workload of each stage throughout this protocol was influenced by an increase in cadence. Heart rate (Polar RS200, Polar Electro, Finland), rating of perceived exertion (RPE) and cadence were recorded on the completion of each interval. W_{max} of each individual was calculated using the following formula: $W_{out} + (t/150) \times 25$, where W_{out} is the watts of the last complete stage and t is the time spent in the final unfinished stage (Kuipers, Keizer, Brouns, & Saris, 1987).

Time-trial protocol: Prior to the commencement of the test protocol, each participant was weighed and baseline blood lactate levels were recorded and individuals were fitted with a heart rate monitor (Polar RS200, Polar Electro, Finland) which was linked with the Wattbike. Participants endured a 5 min warm-up at approximately 40% of W_{max}, during which they were familiarised with the BORG scale of perceived exertion (RPE) (Borg, 1982, 1990). Following completion of the warm-up, participants were asked to complete a set amount of work in the quickest time possible. The total amount of work to be completed was calculated using a modified version of Jeukendrup, Saris, Brouns, and Kester (1996) equation:

$$\text{Total amount of work in Joules} = 0.65 \times W_{max} \times 3,600.$$

The equation by Jeukendrup et al. (1996) calculated 75% of the participants W_{max} for endurance trained athletes, although due to recreational nature of the participants in the study and with evidence from previously unpublished work, the authors sought to modify the equation to 65%. The time trial protocol employed is designed to standardise workload so that each subject takes approximately 1 h to complete the work. The Wattbike was kept at a uniform resistance (resistance of 4) throughout the time trial performance for each participant in order to maintain a similar intensity for each participant. Participants were only able to view the total amount of work they had performed, with heart rate, time and cadence values blocked from view and clocks removed to prevent participants knowing the time. No encouragement was offered throughout the test and the only interaction was when solutions were given for rinsing at 12.5% completed intervals, or to record HR, cadence and RPE at every 12.5% of completion. Laboratory conditions were held constant (ambient temperature 18–21°C) throughout each trial, with participants cooled using an electric fan.

Mouth rinse protocol: Over the three time trial visits, participants would use a 0% (PLA), 6% or 16% CHO solution (maltodextrin, due to lack of colour and taste). Each sample was a 25 ml bolus which was weighed before and after mouth rinsing, which was to ensure none of the sample was ingested. A bolus was provided to the participant after the warm-up and every 12.5% of completion in the trial. The solution was rinsed around the mouth for 5 s before being expelled into a pre-weighed container. Solutions were made by an external researcher who was not affiliated to the study, to ensure the trial remained a double-blind study.

Statistical analysis: All collected data were analysed using SPSS (Version 22.0, Chicago, IL). The variables were compared using a one-way repeated measure ANOVA, which was done to examine the effects across the three time trial performances and their corresponding solutions (0% PLA, CHO 6% and CHO 16%). Overall time of completion, average power output, cadence and speed were compared between each trial. Heart rate and RPE were compared at each individual stage across all three tests and were analysed using two-way repeated measures ANOVA. All data are represented using mean ± standard deviation with significance set at $p < .05$.

Results

Performance time and power output: In relation to time trial performance, both CHO solutions were significantly faster in comparison with the PLA trial, as performance times for the 6% CHO versus the PLA trial were 58.8 ± 7.0 min versus 62.3 ± 7.6 min ($p = .002$) while performance times for the 16% CHO trial versus the PLA trial were 57.9 ± 7.6 ($p = .001$). The individual differences in time to completion across all trials are shown in Figure 1(c).

A significant difference was also observed in average power output and average speed across the three trials. When comparing the 6% trial versus PLA and 16% trial versus PLA, power outputs were 174 ± 20 W versus 163 ± 23 W ($p = .002$) and 177 ± 23 W ($p = .001$), respectively. However similar to performance time, no significance was reported in power output when comparing the 6% trial to the 16% trial ($p = .291$). A non significant difference was observed in the average speed maintained when comparing the 6% and 16% trial ($p = .273$),

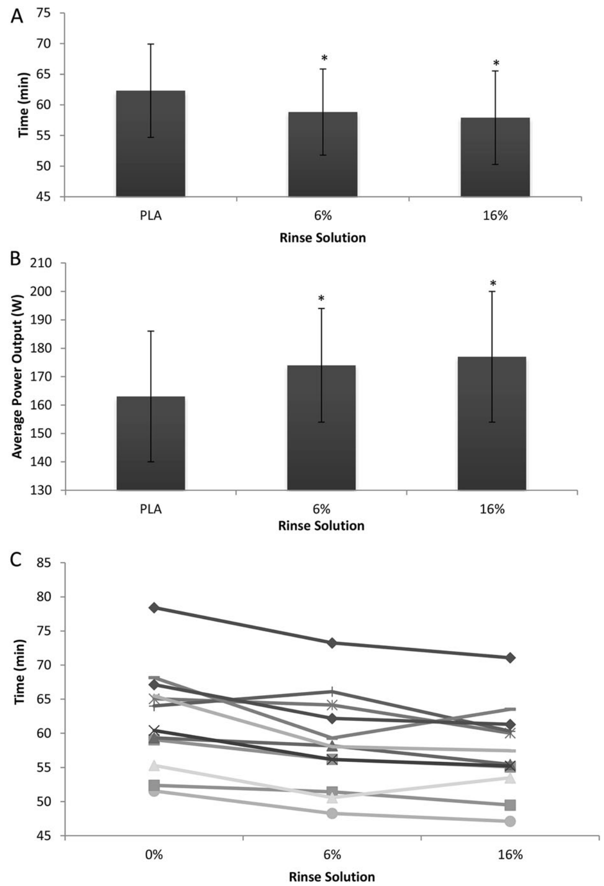

Figure 1. Performance times (A), average power output (B) and individual performance times (C) in the placebo and carbohydrate trials with values expressed as Mean ±SD. (A)* statistical difference $p<0.05$; (B)*statistical $p<0.05$.

significance was seen when either CHO trial, 6% or 16%, was compared with the PLA trial (34.8 ± 1.6 km h^{-1} versus 34.1 ± 1.7 km h^{-1}, $p = .002$, and 35.1 ± 1.8 km h^{-1}, $p = .001$). Power output and speed were typically observed to be higher in the first 10 min and final 15 min across in both carbohydrate trials in comparison to the PLA trial.

Heart rate and RPE: Values for heart rate and RPE were seen to increase steadily with the onset of exercise across the three trials. Average heart rate values of the PLA, 6% and 16% trials were 148 ± 18, 153 ± 20 and 153 ± 15 bpm, respectively, with maximal values for the PLA, 6% and 16% trials reaching 168 ± 18, 171 ± 19 and 174 ± 14 bpm, respectively. There were no differences in heart rate responses across the three trials ($p > .005$). Similar to heart rate, RPE values steadily increased throughout the three trials, with average values of 14.3 ± 1.07, 14.2 ± 1.7 and 13.8 ± 1.5, for the PLA, 6% and 16% trial, respectively. Maximum RPE values were recorded at 16.3 ± 1.5, 17.4 ± 1.7 and 17.3 ± 1.9, for the PLA, 6% and 16% trial, respectively. A non significant difference was reported in RPE values across the three trials ($p > .005$).

Rinse solution detection: From the 12 participants in the study, 4 were able to distinguish a difference in the mouth rinsing solutions used across the three time trials, reporting a difference in feel or viscosity of the solutions. Out of the four who reported a difference, three performed better in the 16% trial when compared with both the 6% and PLA trial, while the fourth performed better in the 6% trial when compared with both the 16% and PLA trial. The other nine participants could not distinguish any difference across the three solutions.

Discussion

The aim of the current study was to investigate the effects mouth rinsing with a 6% and 16% CHO have on exercise performance in comparison to a 0% solution while participants are in a fed state. The current study shows that when compared to a PLA, the use of carbohydrate mouth rinse can lead to improvements in performance times, average power outputs and average speed during a time trial performed in a fed state. Early studies have investigated the effects of carbohydrate mouth rinsing on performance during high-intensity exercise. Carter et al. (2004) reported improvements of 2.9% in cycling time trial performance with use of a maltodextrin mouth rinse, while improvements of 3.7% were reported when a mono and disaccharide sports rinse was substituted instead of the maltodextrin mouth rinse (Pottier et al., 2010). However, studies by Whitham and McKinney (2007) and Beelen et al. (2009) did not support these findings, reporting no difference in performance times when comparing a carbohydrate mouth rinse to a PLA. The studies by Carter et al. (2004), Pottier et al. (2010) and Whitham and McKinney (2007) all investigated the performance benefits of carbohydrate mouth rinsing within a fasted state, while the study by Beelen et al. (2009) looked at the benefits in a fed state. The current study took the same premise as the study by Beelen et al. (2009), with 12 participants performing three separate time trials while in a fed state, where they were provided with a 6% CHO, 16% CHO or PLA mouth rinse solution at every 12.5% of the trial completed. The use of nutritional diaries and same day/time testing enabled the monitoring of each participants fed status. The results show improvements in time to completion in both CHO trials in comparison with the PLA trial, with significant improvements in time of completion in both CHO time trials. This improvement in time of completion is associated with each participant's ability to sustain both greater power output and higher speed during the 6% and 16% trial. Both heart rate responses and session RPE were similar across the three trials. By testing the participants of the current study in a fed state as opposed to a fasted state, the practical relevance of carbohydrate mouth rinsing can be determined.

It is believed that the CHO mouth rinse stimulates the reward regions of the brain via oral receptors due to the caloric content of the CHO (Chambers, Bridge, & Jones, 2009; Turner, Byblow, Stinear, & Gant, 2014). One would think that this stimulation of the reward pathways would lead to lower RPE levels observed in the CHO trials compared to the PLA. However, similar to previous reports no differences were observed in RPE between either CHO trial and the PLA trial. The concentration and rinse duration may also have an impact on the effectiveness of the CHO rinse. The vast majority of the current research has use of a 6% or 6.4% CHO rinse solution for 5 s duration (Beaven, Maulder, Pooley, Kilduff, & Cook, 2013; Carter et al. 2004; Dorling & Earnest, 2013; Pottier et al., 2010; Rollo et al., 2008, 2010), while improvements in time trial performance have been noted with a greater solution concentration and longer rinse duration in both fed and fasted states (Lane et al., 2012). A greater concentrated solution consisting of 16% maltodextrin was compared to the traditional 6% solution and PLA in the current study. As previously stated both CHO rinse solutions improved cycling performance in comparison to a PLA (improvements of 5.6% and 7.1% observed), although no significant difference was observed when comparing both CHO trials to each other. Using a higher concentration of mouth rinse may enhance the saturation of the oral receptors leading to a greater stimulation of the reward pathways reported by Chambers et al. (2009) and Turner et al. (2014), although further investigation on the mechanism is required.

Conclusion

The applications of carbohydrate rinsing have grown since the first study by Carter et al. (2004), with the current literature investigating the effects in sports ranging from cycling (Beelen et al., 2009; Fares & Kayser, 2011; Lane et al., 2012; Pottier et al., 2010) to running (Rollo et al., 2008, 2010; Rollo & Williams, 2011; Whitham & McKinney, 2007), with more recent studies investigating the effects on field sport simulation and strength work (Dorling & Earnest, 2013; Jensen, Stellingwerff, & Klimstra, 2015; Painelli et al., 2011). With the ergogenic benefits well documented, the data can translate from the scientific field to the practical setting for athletes and coaches alike, as the current study along with other findings suggest that CHO rinsing at regular intervals may benefit those athletes reporting gastrointestinal problems. In conclusion, the present study shows that the use of carbohydrate mouth rinsing during high-intensity exercise can lead to an improvement in exercise capacity during a simulated time trial when exercise is carried out in a fed state.

Disclosure statement

No potential conflict of interest was reported by the authors.

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