

The effect of carbohydrate mouth rinse on a 30-minute arm cranking performance

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Running title: Carbohydrate mouth rinse and arm cranking performance

Abstract: The aim was to examine the effect of carbohydrate mouth rinse on 30-minute arm cranking performance. Twelve healthy, active males (age 21.6, SD = 3.1 years; mass 76.2, SD = 12.2 kg) volunteered in a single-blind, randomised crossover design. Firstly they completed an incremental exercise test to exhaustion ($\text{VO}_{2\text{max}}$ test) on an arm crank (50W for 2 minutes, increasing by 10W every minute). During visit 2 and 3 they arm cranked for maximal distance over 30 minutes at a resistance equivalent to 50% of their peak power, mouth rinsing for 5 seconds with either 25ml of a tasteless 6.4% maltodextrin solution (CHO) or 25ml of water (placebo) every 6 minutes. A letter cancellation test was performed pre and post exercise to measure cognitive function. The result showed that cognitive function was not significantly different between trials ($P = 0.874$). There was no significant difference in distance arm cranked between trials ($P = 0.164$) even though 9 out of 12 participants had improved performance on the CHO trial. In conclusion, further research is needed to determine the ergogenic effect of CHO mouth rinsing on upper body exercise performance.

Keywords: Arm crank; carbohydrate mouth rinse; cognitive function; upper body exercise

Introduction

There is a lot of evidence illustrating that ingesting carbohydrate (CHO) improves performance and delays the onset of fatigue in endurance exercise (Coyle *et al.*, 1986; Rollo and Williams, 2011; Snyder, 2011; Tsintzas *et al.*, 1996). This is thought to be due to an increase of glucose availability and slower rate of endogenous glycogen break down. This will prevent glycogen stores from getting depleted, which would lead to fatigue (Coyle *et al.*, 1986; Karelis *et al.*, 2010; Tsintzas and Williams, 1998). There is also research suggesting that CHO ingestion helps maintain skill performance (Ali and Williams, 2009; Bottoms *et al.*, 2006; Bottoms *et al.*, 2012; Phillips, 2012; Vergauwen *et al.*, 1998) and improve cognitive function (Bottoms *et al.*, 2006; Collardeau *et al.*, 2001; Welsh *et al.*, 2002) when fuel is not such a limiting factor in performance.

Different methodological factors have been shown to influence the effect that CHO mouth rinse has on performance, such as the duration of the solution being in the mouth (Pottier *et al.*, 2010; Sinclair *et al.*, 2014), nutritional status (Beelen *et al.*, 2009; Carter *et al.*, 2004; Fares and Kayser, 2011; Lane *et al.*, 2013) and the type of exercise being undertaken (Beaven *et al.*, 2013; Bortolotti *et al.*, 2013; Chong *et al.*, 2011; Dorling and Earnest, 2013). Not all studies using CHO mouth rinse have reported significant improvements in performance (Beelen *et al.*, 2009), however the majority of these studies did observe improvements in performance just not with statistical significance. More importantly, no study to date has reported a decrease in performance (Rollo and Williams, 2011).

It has consistently been shown that CHO mouth rinse improves exercise lasting around one hour (Carter *et al.*, 2004; Pottier *et al.*, 2010; Rollo *et al.*, 2008; Sinclair *et al.*, 2014). This is thought to be due to receptors in the oral cavity (yet to be discovered) positively influencing the anterior cingulate cortex and ventral striatum as well as other brain regions (Haase *et al.*, 2009), leading to higher feelings of pleasure and a lower perceived exertion (Rollo *et al.*, 2011; Snyder, 2011). The physiological response that occurs during upper and lower body exercise in terms of differences in oxygen cost (Smith *et al.*, 2006) and maximal oxygen uptake (VO_{2max}) (Lusina *et al.*, 2008) has been clearly established. It has also been shown that blood lactate accumulates at lower intensities during upper body exercise compared to lower body exercise (Sawka, 1986), resulting in greater perceived exertion. This body of evidence suggests that CHO mouth rinse may influence upper and lower body exercise performance in a different manner through the moderation of perceived exertion as regulated by the central nervous system. To date the effect of CHO mouth rinse on upper body exercise has not yet been established.

As well as improving exercise performance, a limited number of recent studies have started to explore the effect of CHO mouth rinse on cognitive function. CHO mouth rinse resulted in shortened reaction times on incongruent trials on the Stroop task (Sanders *et al.*, 2012); this task requires participants to name a colour word that may (congruent) or may not (incongruent) be presented in the same colour ink as the name of the word. This task is performed at speed and assesses attention, processing speed and the incongruent trials assess participants' ability to inhibit their automatic response (e.g. stopping themselves from saying the word "blue", when shown the word "red", which has been presented in blue ink). Others have identified that brain areas including the primary taste cortex and regions involved in visual perception are associated with CHO mouth rinse (Turner *et al.*, 2014). In the present study, because the Stroop takes some time to administer, we administered a letter cancellation task to assess cognitive

performance. Like the Stroop, letter cancellation is a visually presented task that uses attention and requires speeded performance.

The positive effect of CHO mouth rinse on lower body exercise (lasting ~1h) has already been established, however, for athletes that predominately use their upper body the benefits are not yet known. The aim for this study was therefore to examine the effect of CHO mouth rinse on a 30-minute arm cranking performance, looking at both physiological and cognitive variables. The hypothesis was that CHO mouth rinse would improve arm crank performance and have a positive effect on cognitive function.

Materials and Methods

Participants

Twelve healthy, active males (age 21.6 years, SD = 3.1 years; height 1.75 m, SD = 7.1 m; mass 76.2 kg, SD = 12.2 kg; VO_{2max} 32.7 ml/min/kg, SD = 6.8 ml/min/kg; HR_{max} 164.6, SD = 21.6 $beat \cdot min^{-1}$) participated in this study. Participants were not specifically upper body trained and free from musculoskeletal pathology at the time of data collection. All participants also provided written informed consent. University Ethics Committee approval for the study's experimental procedures was obtained and followed the principles outlined in the Declaration of Helsinki.

Procedure

A single-blind, randomised crossover design was used in this study. The participants were required to attend the laboratory on 3 different occasions, separated by a week, where all the testing took place under similar conditions (room temperature 19.7°C, SD = 0.7°C; Humidity 35%, SD = 3.3%). On their first visit they performed an incremental exercise test to exhaustion (VO_{2max} test) on an arm crank ergometer (Monark, Ergonomic 891E) to determine their peak oxygen consumption (VO_{2peak}), maximal heart rate (HR_{max}) and to get an indication of their peak power. The incremental test was used to determine the relative resistance that was applied in the following two experimental trials, which was set at 50% of the peak power reached by the participant in the VO_{2max} test. During the two experimental trials the participants had to arm crank for maximal distance over 30 minutes while rinsing their mouths for 5 seconds, every 6 minutes, with either 25 ml of a tasteless 6.4% maltodextrin (MyProtein) solution (CHO) or 25 ml of water (placebo). **Pilot testing confirmed that participants were unable to identify which solution was which.** The participants were asked to refrain from alcohol, caffeine and strenuous exercise 24 hours prior to each visit. They were also asked to consume a similar diet on the day of testing and not to consume any food for at least 2 hours prior to each visit.

Visit 1

During the first visit the participants had to complete a VO_{2max} test. The participants' height, mass and age were recorded and they were fitted with a heart rate monitor (Polar FT1). Blood pressure was measured (Omrom M7) to make sure that the participants were fit to perform a VO_{2max} test.

The VO_{2max} test was carried out on the arm crank and gas analysis was recorded throughout (Cosmed Quark b² metabolic analyse-gas analysis) to determine VO_{2peak} . The participants' arm cranked at 50 Watts (W) for 2 minutes followed by an increase of 10 W every minute, with the crank rate set at 70 $rev \cdot min^{-1}$, until exhaustion (Smith *et al.*, 2001). Heart rate and gas analysis were recorded throughout and peak minute power was determined by the power maintained throughout the last minute of the test. Blood lactate sample was taken, using LactatePro

(Arkray), pre and post the VO_{2max} test. The first session also gave the participants a chance to familiarise themselves with the equipment used in the two experimental trials.

Visits 2 & 3

During both experimental trials the aim was to arm crank for maximal distance during 30 minutes. On arrival, body mass, blood pressure (BP), and blood lactate (BL) were recorded and a letter cancellation task was performed (Edmonds *et al.*, 2013). The task required participants to cross off as many of the letter 'U' as they could from a matrix of letters in 30 seconds. This test has been shown to be a valid and reliable measure of visual attention (cognitive function) (Edmonds and Burford, 2009; Edmonds *et al.*, 2013; Edmonds and Jeffes, 2009). The participants were fitted with a heart rate monitor (Polar FT1) and their resting heart rate was recorded. After performing a 3 minute warm-up on the arm crank the participants started their 30 minute trial, where they arm cranked at a self-paced cadence with a resistance equivalent to 50% of their peak power achieved in their VO_{2max} test. Immediately before the trial began the participant rinsed their mouth with either 25ml of a tasteless 6.4% maltodextrin solution (CHO) or a placebo (water) for 5 seconds. During the trial the mouth rinsing procedure was repeated every 6 minutes and heart rate ($\text{beat}\cdot\text{min}^{-1}$), cadence ($\text{rev}\cdot\text{min}^{-1}$) and perceived exertion (RPE) of arms (RPE_{arms}) and overall ($\text{RPE}_{\text{overall}}$), using the 6- to 20-point Borg scale (Borg, 1982), were recorded. At 30 minutes the last values were collected, BP and blood lactate were re-taken and another letter cancellation task was performed. The participants' body mass was also re-measured to determine whole body sweat loss.

Statistical analyses

Descriptive statistics of means \pm standard deviation were obtained for each condition. To compare total distance covered using the two solutions during the 30 min protocol a paired t-test was conducted. To examine the effect of mouth rinse on pacing, HR and RPE, a 5 x 2 (time x trial) repeated measures ANOVA was also conducted. Main effects were further explored using post-hoc pairwise comparisons and significant interactions were examined via simple main effects. Statistical significance was accepted at the $p \leq 0.05$ level. Effect sizes were calculated using partial Eta^2 (η^2). All statistical procedures were conducted using SPSS v20.0 (SPSS Inc., Chicago, IL, USA).

Results

Distance

Nine out of 12 participants arm cranked further during the CHO trial compared to the PLA trial. The mean distance travelled in the CHO trial was therefore greater (12.3, SD = 1.4 km) compared to the PLA trial (11.9, SD = 1.5 km), although this difference was not statistically significant ($t_{(11)} = -1.46$; $P = 0.164$).

Figure 1 near here

Cadence

There was a main effect of time for cadence ($F_{(4,40)} = 92.415$; $P < 0.01$, $p\eta^2 = 0.902$; Figure 2), with post hoc demonstrating an increase of cadence in both trials at minute 30 compared to all other times ($P = 0.03$). CHO mouth rinsing had no effect on cadence as there was no main effect for trial ($F_{(1,10)} = 2.11$; $P = 0.177$, $p\eta^2 = 0.174$) and no significant interaction between trial and time ($F_{(4,40)} = 1.605$; $P = 0.192$, $p\eta^2 = 0.138$).

Figure 2 near here

Physiological Measures

Table 1. Mean \pm SD physiological variables during the 30 minutes exercise for both trials.

	RPE_{arms} (Borg Scale)	RPE_{overall} (Borg Scale)	HR (beat.min- 1)	Sweat loss (l)
CHO	15 \pm 3	13 \pm 4	144 \pm 25	0.3 \pm 0.1
PLA	14 \pm 3	13 \pm 4	139 \pm 25	0.3 \pm 0.2

There was a main effect for time in heart rate (HR) ($F_{(5,50)} = 122.40$; $P < 0.01$, $p\eta^2 = 0.924$) as the post hoc demonstrated an increase in HR during the first 12 minutes, followed by a plateau between minutes 12 to 24, and ending with a further increase in HR during the last 6 minutes in both trials. As can be seen from Table 1, HR was similar during the two trials with no main effect for trial ($F_{(1,10)} = 2.96$; $P = 0.116$, $p\eta^2 = 0.229$) or a significant interaction between trial and time ($F_{(5,50)} = 1.118$; $P = 0.363$, $p\eta^2 = 0.101$).

There was a main effect for time for both RPE_{arms} ($F_{(4,44)} = 45.24$, $P < 0.01$, $p\eta^2 = 0.804$) and RPE_{overall} ($F_{(4,44)} = 67.34$; $p < 0.01$, $p\eta^2 = 0.860$) with both increasing as time increased. RPE_{arms} and RPE_{overall} were similar for both trials with no effect of CHO mouth rinsing ($F_{(1,11)} = 1.907$; $P = 0.195$, $p\eta^2 = 0.148$ and ($F_{(1,11)} = 0.844$; $p > 0.378$, $p\eta^2 = 0.071$, respectively). RPE_{arms} reached 18 ± 2 at the cessation of exercise during both trials, whereas RPE_{overall} reached 17 ± 3 during both trials.

There was a main effect of time ($F_{(1,9)} = 57.23$; $p < 0.01$, $p\eta^2 = 0.864$), with blood lactate increasing from rest (1.9, SD = 1.0 and 1.7 SD = 0.8 mmol.l⁻¹ for CHO and PLA, respectively) to post exercise in both trials (6.9 SD = 2.8 and 7.9 SD = 3.5 mmol.l⁻¹, respectively). There

was however no main effect of trial ($F_{(1,9)} = 1.124$; $p = 0.317$, $\eta^2 = 0.111$) or interaction between time and trial ($F_{(1,9)} = 3.65$; $p = 0.088$, $\eta^2 = 0.288$). There was no significant difference in sweat loss (determined from body mass change during the exercise) between the two trials ($T_{(11)} = -2.55$; $p = 0.80$).

Letter cancellation task

As shown in Figure 3, the mean score for the cancellation task was higher post exercise in both the CHO trial (pre-CHO 32.5, SD = 5.6, post-CHO 34.2, SD = 5.0) and the PLA trial (pre-PLA 33.4, SD = 4.7, post-PLA 35.5, SD = 3.8), therefore there was a main effect of time ($F_{(1,11)} = 15.97$; $P = 0.002$, $\eta^2 = 0.592$). There was no significant difference in letter cancellation task score between the trials ($F_{(1,11)} = 0.522$; $P = 0.485$, $\eta^2 = 0.045$).

Figure 3 near here

Discussion

The aim of this study was to examine the effect of CHO mouth rinse on 30-minute arm cranking performance. This represents one of the first examinations of the influence of CHO mouth rinsing on arm cranking performance. There was no significant effect of carbohydrate mouth rinsing on arm cranking performance. This differs to the majority of the research which has been conducted on the lower body (Carter *et al.*, 2004; Chambers *et al.*, 2009; Fares and Kayser, 2011; Lane *et al.*, 2013; Pottier *et al.*, 2010; Rollo *et al.*, 2008).

Looking at the individual results, 9 out of 12 participants improved performance with the other 3 having no change. The improvement in performance equated to 2.7% increase in distance, which if the participants were trained would be a substantial improvement in performance. The increase is similar to previous findings as most studies have reported an improvement of between 1.5 - 3.7% when rinsing with a CHO solution (Carter *et al.*, 2004; Chambers *et al.*, 2009; Fares and Kayser, 2011; Lane *et al.*, 2013; Pottier *et al.*, 2010; Rollo *et al.*, 2008). Due to the untrained nature of the participants there would be greater natural variation in their existing performance level, therefore the result should be viewed with caution. We must also note that the improvement in upper body exercise in the CHO trial was not significantly greater compared to the placebo trial. The lack of statistical significance in this study compared to previous lower body studies (Carter *et al.*, 2004; Chambers *et al.*, 2009; Fares and Kayser, 2011; Lane *et al.*, 2013; Pottier *et al.*, 2010; Rollo *et al.*, 2008) may be due to the differences in perceived exertion that can occur between upper and lower body exercise. Ratings of perceived exertion have been shown to be greater during exercise tasks using smaller muscle groups compared to larger groups (Gamberale, 1972), suggesting a greater fatigue during upper body exercise. In addition, Pandolf *et al.* (1984) found one of the greatest contributors to RPE during arm exercise was systolic and diastolic blood pressures. This differed to the main contributors for RPE during lower body exercise which was blood lactate and ventilatory equivalent of oxygen (Pandolf *et al.*, 1984). Potentially the increase in motivation resulting from stimulation of the central cortex from CHO mouth rinsing is sufficient to overcome the increase in RPE from lactate and ventilatory equivalence but not sufficient to overcome increases in blood pressure. In addition, exercise performance for durations of less than 30 minutes have generally found no improvement in performance with CHO ingestion (Jeukendrup *et al.*, 2008; Palmer *et al.*, 1998). Jeukendrup *et al.* (2013) that this is because of the greater sensations of fatigue and discomfort associated with higher exercise intensities overriding the beneficial effects of the CHO. Since upper body exercise produces greater sensations of fatigue than lower body, this argument could also account for the lack of significance in the present study. Finally, muscle mass is smaller for the upper body and maybe

an improvement in motivation results in smaller changes in performance which are less detectable. As previously mentioned 9 out of 12 participants had an improvement in performance. It may be the case that differences in performance were due to some participants having a greater muscle mass. Future work might seek to correlate arm volume with changes in performance or alternatively treat arm volume as a moderator in order to isolate the contribution that this variable plays in the CHO-performance relationship. Further research is needed to understand the mechanisms of CHO mouth rinsing and thus the differences in response between upper and lower body exercise.

CHO mouth rinse affected scores achieved in the letter cancellation task in a similar manner to PLA, with scores higher post exercise after both trials, and no significant difference between the two trials. These results suggest that CHO mouth rinse did not have an effect on cognitive function. Previous studies have shown an improvement in cognitive function post exercise when ingesting a CHO solution, changes thought to be resulting from a reduction in mental load, enabling increased ability to focus (Bottoms *et al.*, 2006; Collardeau *et al.*, 2001). It has been suggested that glucose levels could alter brain activity which would influence cognition (Patterson and Gray, 2007; Welsh *et al.*, 2002). The results from the current study suggest that just rinsing the mouth with CHO may not be enough to affect cognitive function. However, a recent study found that drinking just 25mls water improved performance on the letter cancellation task compared to no intervention (Gardner *et al.*, 2014) thus, it is possible that swilling CHO and PLA both improved performance relative to no intervention and this could be explicitly tested in future work.

Future research needs to build on this study to further determine the effect of CHO mouth rinse on upper body exercise performance. A higher intensity exercise bout may be applied as the intensity in the current study was lower than in most research conducted on lower body exercise. It is proposed that a higher concentration of CHO solution or longer duration should be applied to see if that moderates the effect of CHO on upper body exercise. Cognitive response should be further examined using sports specific visual search tasks.

Conclusion

In conclusion, the current investigation adds to the literature by examining the influence of CHO mouth rinsing on arm cranking performance. The results of this study indicate that CHO mouth rinsing does not improve arm cranking performance in a trial lasting 30 minutes. The analysis provided throughout the course of this paper with particular reference to the role that perception of effort plays in moderating the CHO mouth rinse-performance interaction suggests a nuanced relationship exists which must be further elucidated before any practical recommendations can be forwarded.

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