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The Influence of Carbohydrate Mouth Rinse on Self-Selected Speeds During a 30-min Treadmill Run

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The purpose of this study was to examine the influences of a carbohydrate (CHO) mouth rinse on self-selected running speeds during a 30-min treadmill run. Ten endurance-trained men performed 2 trials, each involving a 10-min warm-up at 60% VO_{2max} followed by a 30-min run. The run was performed on an automated treadmill that allowed the spontaneous selection of speeds without manual input. Participants were asked to run at speeds that equated to a rating of perceived exertion of 15, mouth rinsing with either a 6% CHO or taste-matched placebo (PLA) solution. In addition to recording self-selected speeds and total distance covered the authors assessed the runners' subjective feelings. The total distance covered was greater during the CHO than during the PLA trial ($p < .05$). Faster speeds selected during the first 5 min of exercise corresponded with enhanced feelings of pleasure when mouth rinsing with the CHO solution. Mouth rinsing with a CHO solution increased total distance covered during a self-selected 30-min run in comparison with mouth rinsing with a color- and taste-matched placebo.

Keywords: running, RPE, performance

Prolonged exercise depletes stores of muscle glycogen (Bergstrom & Hultman, 1967). Ingesting appropriate carbohydrate (CHO) solutions before and during exercise has been shown to delay fatigue (Bergstrom, Hermansen, Hultman, & Saltin, 1967; Coggan & Coyle, 1987; Tsintzas, Williams, Boobis, & Greenhaff, 1996) and improve exercise performance (Anantaraman, Carmines, Gaesser, & Weltman, 1995; Jeukendrup, Brouns, Wagenmakers, & Saris, 1997). The quantity of CHO required to benefit exercise performance has been shown to be approximately 40–60 g/hr (Ball, Headley, Vanderburgh, & Smith, 1995; Carter, Jeukendrup, Mundel, & Jones, 2003; Coyle, 1992; el-Sayed, Balmer, & Rattu, 1997; Jeukendrup et al.; Millard-Stafford, Rosskopf, Snow, & Hinson, 1997). Ingesting CHO throughout prolonged exercise contributes to glucose metabolism in the muscle (Coyle). In some cases this leads to a more gradual degradation of endogenous glycogen stores throughout exercise (Tsintzas et al., 1996), but in others there is an improvement in endurance capacity without evidence of glycogen

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sparing (Coyle, Coggan, Hemmert, & Ivy, 1986). The reasons for these differences might be associated with the type of exercise, for example, cycling versus running, but this might be too simplistic an idea and so further research is required (Tsintzas & Williams, 1998).

During exercise in which endogenous glycogen stores are unlikely to limit performance, there does not appear to be a clear rationale for supplying additional CHO. McConell, Canny, Daddo, Nance, and Snow (2000) found that only a small percentage (26%) of total CHO consumed actually enters the peripheral circulation during high-intensity endurance exercise. In addition, ingesting glucose had no effect on CHO oxidation, muscle metabolism, or performance during exercise to fatigue at approximately 80% peak oxygen uptake (McConell et al.). Nevertheless, there are studies that have shown that ingesting a CHO solution during relatively short-duration exercise tests improves performance without apparently influencing muscle metabolism (Anantaraman et al., 1995; Powers et al., 1990). For example, Jeukendrup et al. (1997) found that performance during a 1-hr time trial was improved when their cyclists ingested a CHO–electrolyte solution. Subsequent investigations using the same exercise protocol found that infusing glucose (60 g/hr) had no influence on performance (Carter, Jeukendrup, Mann, & Jones, 2004), but simply mouth rinsing with a CHO solution without ingestion led to significant improvement in performance. The results of these and other studies have led to the suggestion that ingesting CHO solution and even simply tasting a CHO solution might exert a positive influence on the brain and central nervous system (Carter, Jeukendrup, & Jones, 2004).

The concept that CHO might exert a central effect is of interest because it is consistent with findings that runners "feel better" and report lower ratings of perceived exertion (RPEs) while ingesting a CHO solution during prolonged running (Backhouse, Ali, Biddle, & Williams, 2007; Backhouse, Bishop, Biddle, & Williams, 2005). If there is central recognition of CHO, it is reasonable to ask whether this alters the runners' perception of exercise and, if so, whether this translates into faster self-selected running speeds. The performance benefits of simply "tasting," however—that is, mouth rinsing with a CHO solution—observed in a cycling study have not been confirmed during treadmill running. Whitham and McKinney (2007) found no difference in total distance covered or RPE when runners mouth rinsed with either a 6% CHO or a placebo solution at 6-min intervals throughout a 45-min time trial. One of the limitations of studies that use treadmill running to assess nutritional interventions on time-trial performance is that the treadmill speed is adjusted manually either by the runner or by the investigator. This approach does not allow runners to change their speed spontaneously according to how they "feel" (Laursen, Francis, Abbiss, Newton, & Nosaka, 2007; Whitham & McKinney). In contrast, power output during cycling can be quickly changed simply by changing pedal cadence. Thus, cycling might be a more sensitive way of reflecting how the cyclists feel during time trials after nutritional interventions. This difference in exercise mode might explain why the improvement in time-trial performance during cycling, as a result of mouth rinsing with a CHO solution, was not confirmed during treadmill running (Carter, Jeukendrup, & Jones, 2004; Whitham & McKinney).

To overcome this limitation we used an automated treadmill system that allows free and spontaneous changes in running speed without manual input. This automated system is more sensitive to the selection and alteration in running speed throughout exercise than are traditional treadmills (Whitham & McKinney, 2007). Therefore it should allow runners to change their speed according to how they feel. Although administering the RPE scale (Borg, 1982) provides information on the intensity of the perceived exertion, it does not help describe how the runners feel during exercise (Hardy & Rejeski, 1989). Administering both a Feeling Scale (FS) and an RPE scale, it is possible to measure not only "what" (RPE) but "how" (FS) a person feels (Hardy & Rejeski). In addition, whether runners' feelings are "good or bad" (pleasure–displeasure) or they feel energized (i.e., an activated state) during exercise is also relevant because it is likely that might influence their performance (Acevedo, Gill, Goldfarb, & Boyer, 1996). The perceived-activation scale (Felt Arousal Scale [FAS]; Svebak & Murgatroyd, 1985) has been shown to be a valid measure of participants' perception of their own bodily arousal or activation during exercise (Backhouse et al., 2007).

To this end, the aim of the current study was to investigate the influence of mouth rinsing with a CHO solution and taste-matched placebo solution on self-selected treadmill running speeds. In addition, we wanted to determine whether runners felt any better while mouth rinsing with the CHO solution during the 30-min run and so explore possible links with their choice of running speeds. To help runners select the same range of treadmill speeds, they were asked to select a pace that represented a rating of 15 (*hard*) on the Borg RPE scale (Borg, 1982).

Methods

Participants

Ten endurance-trained recreational runners (age 23 ± 4 years, body mass 75 ± 7 kg, height 181 ± 7 cm, VO_{2max} 62 ± 3 ml · kg^{-1} · min^{-1}; $M \pm SD$) gave their written consent before participating in this study approved by the Loughborough University Ethical Advisory Committee. The number of participants was determined using a nomogram based on the ratio limits of agreement (Nevill & Atkinson, 1997). Participants regularly ran for 30–60 min, 3–5 days a week. Hence, the duration of the run in the current study was within their normal training program.

Experimental Design

Determination of maximal oxygen uptake and familiarization with the automated treadmill were completed during the first visit to the laboratory (Taylor, Buskirk, & Henschel, 1955). The second visit involved runners' becoming fully habituated with the demands of the experimental protocol. Experimental trials on Visits 3 and 4 were separated by 7 days, using a randomized, double-blinded crossover design.

Treadmill

All tests were carried out on a motorized treadmill (Runner MT2000, Bianchini and Draghetti, Cavezzo, Italy). The treadmill used in this study had an ultrasonic feedback-controlled radar modulator that spontaneously regulated treadmill belt speed corresponding with the changing position of the runner on the treadmill belt (Minetti, Boldrini, Brusamolin, Zamparo, & McKee, 2003). The treadmill speed increased or decreased as the runner moved to the front or the back of the treadmill belt, respectively. Changes in speed were therefore achieved without the need for manual input or visual feedback to the participant. More specifically, when the runner moved to the front section of the treadmill (<36 cm from treadmill console) the speed increased (0.8 m/s). If the runner remained in the middle (36–65 cm from treadmill console) of the treadmill, speed remained constant. When the runner moved to the rear of the treadmill (>65 cm from treadmill console) the speed decreased (1.1 m/s). Consequently the runner was always brought back to the center of the treadmill belt. Running speeds were logged by computer at 15-s intervals for the duration of the run.

In the 48 hr before the main trials runners were asked to consume and record their habitual diet similar to that which they adopted before preparing for a race. Runners were also asked not to consume caffeine or alcohol during this period. The same diet was repeated before each trial. On the morning of each trial runners reported to the laboratory after an overnight fast and sat quietly in a comfortable environment (20 °C, 55% relative humidity) for 30 min. After 25 min at rest, a 5-min expired-air sample was collected and analyzed using the Douglas bag method (Tsintzas, Williams, Singh, Wilson, & Burrin, 1995). Thereafter, participants emptied their bladder before their body mass was recorded.

All tests were conducted in a laboratory maintained at 19 ± 1 °C, relative humidity 62% ± 8%, containing only the treadmill and fan positioned 1 m in front of the runner with constant air speed to provide cooling throughout the run. Human interaction was limited to the collection of expired-air samples, ratings on subjective scales, and the delivery of solutions. Runners were monitored throughout exercise via closed-circuit television by an investigator in an adjacent room. The treadmill display panel was covered during each trial so that runners were only able to see a clock displaying the time remaining during each phase of the run. All trials involved 40 min of treadmill running using a 1% treadmill gradient to simulate the energetic cost of outdoor running (Jones & Doust, 1996).

The tests comprised a 2-min walk at 4 km/hr followed by a 10-min warm-up run at a speed equivalent to 60% VO_{2max}. Immediately after the 10-min warm-up run the runners began the 30-min trial. The runners were asked to select a speed that they perceived to be equivalent to a "hard pace" RPE of 15 for the 30-min run and were free to adjust the speed using the automated treadmill system. On completing the 30-min run, the runners walked for another 2 min at 4 km/hr before towel drying and having their body mass recorded. Runners received no feedback about the distance covered over the 30-min run until the completion of the study.

Expired Air, Heart Rate, and Ambient Conditions

Expired air was collected and analyzed using the Douglas bag method; substrate oxidation was subsequently determined by indirect calorimetry (Frayn, 1983). Heart rate was monitored and recorded at 5-s intervals using short-range telemetry (Polar Electro, Kempele, Finland). Dry- and wet-bulb temperatures were measured using a whirling hygrometer (Brannan Thermometers Ltd., UK).

Solution and Rinse Protocol

During the two main trials participants rinsed around the oral cavity either a 6.0-g/100-ml CHO solution or a taste-matched placebo (PLA) for 5 s before expectorating it into a preweighed plastic bag. Plastic bags were reweighed using an electronic balance (Mettler, Toledo AB54-s, Switzerland) to help determine whether any of the solution had been ingested. Each mouth-rinse solution (20 ± 1 °C) was administered immediately after collection of resting expired air, immediately before the warm-up, and at 3 min, 6 min, and 9.5 min during the warm-up run. During the 30-min run the mouth rinse was administered at 5-min intervals. Each 25-ml bolus of solution was served in a plastic syringe (Kendal monoject). This was done 10 times, equating to 250 ml of solution rinsed and expectorated over the duration of the trial.

Subjective Scales

The FS (Hardy & Rejeski, 1989) was used to assess the feelings of the runners, that is, the affective dimension of pleasure–displeasure. This FS scale is an 11-point single-item bipolar rating scale that ranges from –5 to + 5. Anchors are provided at the 0 point (*neutral*) and at all odd integers, ranging from *very good* (+5) to *very bad* (–5; Ekkekakis, Backhouse, Gray, & Lind, 2008). The FAS (Svebak & Murgatroyd, 1985) is a 6-point, single-item measure of perceived activation–arousal (energized). The scale ranges from 1 to 6, with anchors at 1 (*low arousal*) and 6 (*high arousal*), and has been used in prior exercise studies (Backhouse et al., 2007, 2005; Hall, Ekkekakis, & Petruzzello, 2002). Both the FS and FAS have the advantage of most other self-report scales of being easily administered during exercise. Gastrointestinal (GI) comfort was rated using a 12-point scale with anchors provided at 0 *neutral,* 4 *uncomfortable,* 8 *very uncomfortable,* and 12 *painful*. The FS, FAS, and GI scales were administered on participants' arrival at the laboratory, 25 min into the rest period, immediately before and at 3 min, 6 min, and 9.30 min into the 10-min warm-up run. During the 30-min run the scales were presented to the runners every 5 min, that is, before the delivery of the solutions. The runners also completed the FS, FAS, and GI scales on completing the 30-min run and at the end of the 2-min cool-down walk.

Statistical Analysis

All data were analyzed using SPSS (version 13.0). A Shapiro–Wilk test was used to normally distribute the data. The mean differences in self-selected running speed and comparisons over time (analyzed in 5-min blocks over the 30-min run) were detected using a two-factor (Trial × Time) repeated-measures analysis of variance (ANOVA), with repeated measures on both factors used to analyze for main effects and interaction of the two factors. Significant interaction between the trial and time factors in the ANOVA was explored using the Holm–Bonferroni stepwise method. For comparisons between single normally distributed data, paired Student's *t* tests and Pearson's correlation coefficient were used to examine differences between trials. Psychological and GI scales were analyzed using a two-factor ANOVA with repeated measures on two factors (experimental condition and sampling time). Significant main effects for individual time points were further analyzed using paired *t* tests, and the Bonferroni adjustment for the number of pairwise comparisons was employed. All data are presented as *M* ± *SD*. Alpha significance level was set at .05.

Results

Mean energy intake over the 48 hr before exercise was 10.3 ± 3.2 MJ/day. The mean masses of CHO, fat, and protein consumed during the 48-hr record period were 5.1 ± 1.7, 1.1 ± 0.6, and 1.3 ± 0.4 g · kg BM^{-1} · day^{-1}, respectively. No trial-order effect was discovered in any variables reported.

Physiological Response

There was no difference between trials in heart-rate response to exercise: mean heart rate during the 10-min warm-up was 130 ± 6 beats/min for both CHO and PLA trials. Heart rates analyzed at 15-s intervals in 5-min blocks revealed a significant increase during the 30-min run ($p < .05$). There were no differences, however, between CHO and PLA trials (CHO 162 ± 7 beats/min vs. PLA 161 ± 7 beats/min, $p > .05$). The mean losses of body mass as sweat were 0.9 ± 0.4 kg and 0.8 ± 0.2 kg for the PLA and CHO trials, respectively ($p > .05$).

Subjective Response

Rating of perceived activation (FAS) increased from rest (CHO 2.2 ± 1.0, PLA 2.7 ± 0.7) to the start of exercise ($p < .05$). No difference was observed over the 30-min run, and there were no differences between trials (CHO 3.8 ± 0.2 vs. PLA 3.6 ± 0.1, Figure 1). There were no differences in ratings of pleasure–displeasure (FS) at rest (CHO 1.1 ± 1.0 vs. PLA 1.0 ± 1.2). FS was elevated, however, at the start of the 30-min run in participants rinsing with the CHO solution (PLA 1.3 ± 1.2 vs. CHO 2.2 ± 0.6, $p < .05$; Figure 2), but there were no differences between trials during the remainder of the 30-min run (CHO 1.9 ± 0.2 vs. PLA 1.6 ± 0.1, $p > .05$). Although there were no differences in GI discomfort at rest (CHO 0.8 ± 1.1 vs. PLA 0.7 ± 1.1), it did increase over the 30-min run, but with no differences between trials (CHO 1.6 ± 0.8 vs. PLA 1.5 ± 0.6; Figure 3).

Self-Selected Running Speed

Pacing strategy during the 30-min run can be seen in Table 1. The self-selected running speed for PLA was 12.9 ± 1.3 km/hr vs. 13.2 ± 1.1 km/hr for the CHO trial ($p > .05$; Figure 4). Analyzed at 15-s intervals in 5-min blocks, self-selected speed was faster in the first 5 min of the 30-min run participants rinsing with the CHO solution ($p < .05$). Consequently, runners covered a significantly greater distance during the first 5 min of the 30-min run (CHO 1,039 m vs. PLA 1,016 m). The total distance covered was 6,469 ± 515 m during the PLA trial and 6,584 ± 520 m during the CHO trial. Thus, during the CHO trial the distance run was 115 m farther—1.7% of the total distance—than in the PLA trial ($p < .05$). Post-trial interviews with the runners revealed that only 2 of the 10 runners were able to correctly identify the solution they had rinsed with during the tests.

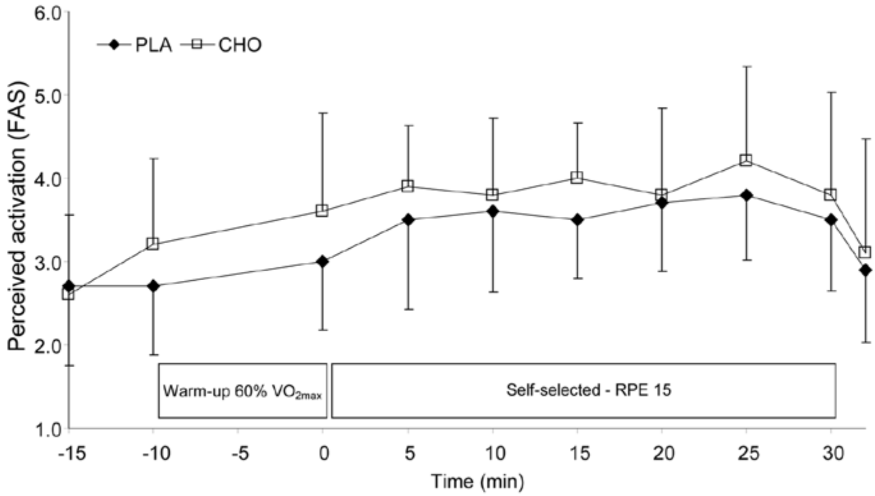

Figure 1 — Perceived activation (Felt Arousal Scale [FAS]; *M* ± *SD*) during the carbohydrate (CHO) and placebo (PLA) trials. –10 to 0 = warm-up at 60% VO_{2max}. 1 = *low activation,* 6 = *high activation*.

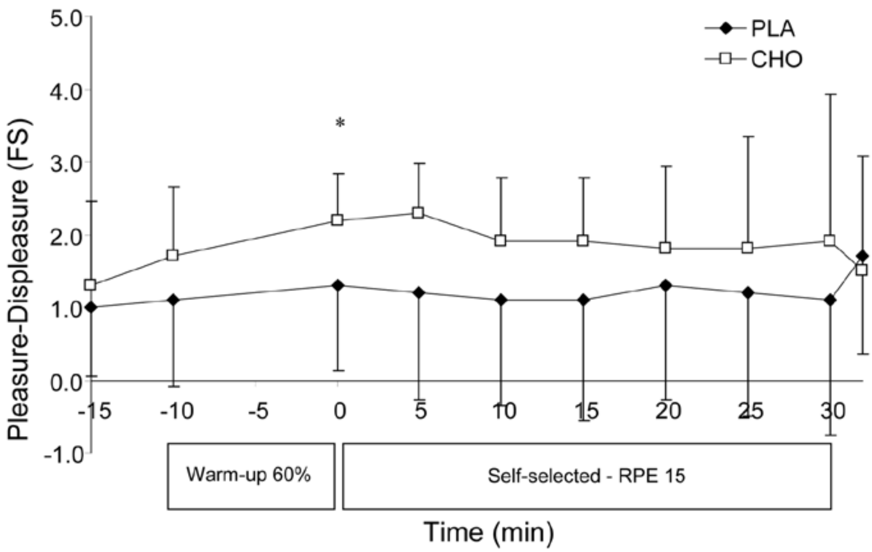

Figure 2 — Pleasure–displeasure (Feeling Scale [FS]; *M* ± *SD*) during the carbohydrate (CHO) and placebo (PLA) trials. –10 to 0 = 10-min warm-up at 60% VO_{2max}. The pleasure–displeasure scale ranges from +5, *very good,* to –5, *very bad*. *$p < .05$.

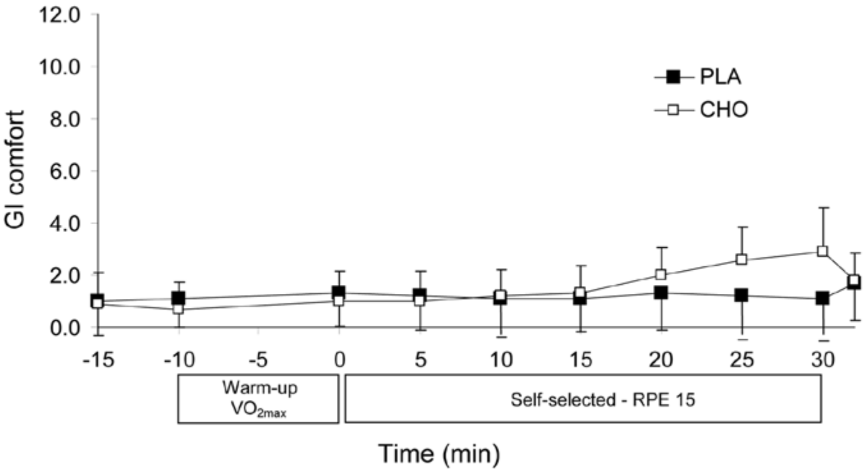

Figure 3 — Gastrointestinal (GI) comfort during the carbohydrate (CHO) and placebo (PLA) trials. –10 to 0 = 10-min warm-up at 60% VO_{2max}. 0 = *neutral,* 4 = *uncomfortable,* 8 = *very uncomfortable,* 12 = *painful*.

Metabolism

No difference was observed in resting oxygen uptake (VO_2) between the two trials (PLA = 0.30 ± 0.04 L/min, CHO = 0.31 ± 0.06 L/min) or respiratory-exchange ratio (PLA = 0.89 ± 0.12, CHO = 0.87 ± 0.04). During the 10-min warm up, VO_2 and respiratory-exchange ratio (PLA = 2.5 ± 0.2 L/min, 0.92 ± 0.06, CHO = 2.5 ± 0.2 L/min, 0.91 ± 0.04) were not different between the CHO and PLA trials. The quantity of solution expectorated was equal to or greater than the quantity rinsed (PLA 252.5 ± 2.4 ml vs. CHO 251.5 ± 1.7 ml, $p > .05$).

There was no difference in estimated CHO oxidation rate during the resting period before exercise (CHO 0.19 ± 0.05 g/min vs. PLA 0.22 ± 0.05 g/min) or during the 10-min warm-up (CHO 2.5 ± 0.2 g/min PLA 2.5 ± 0.2 g/min). Estimated fat metabolism did not differ at rest (CHO 0.06 ± 0.07 g/min, PLA 0.07 ± 0.02 g/min) or during the 10-min warm-up (CHO 0.31 ± 0.23 g/min, PLA 0.43 ± 0.23 g/min). Estimated energy expenditure (kcal · kg body mass^{-1} · km^{-1}) over the duration of the 30-min run was significantly greater in participants who rinsed with the CHO solution (CHO 493 ± 54 kcal vs. PLA 485 ± 55 kcal, $p < .05$).

Discussion

The aim of this study was to determine whether mouth rinsing with a CHO solution influences the self-selection of running speeds, as well as possible links between the choice of speeds and how the runners "felt" at the time. The results of the study showed that mouth rinsing with a 6% CHO solution significantly increased the self-selected speed during the first 5 min of the 30-min run. The

Table 1 Mean Performance Variables for the Carbohydrate and Placebo Trials

		30-min Performance Test					
	Group	0–5	5–10	10–15	15–20	20–25	25–30
Running speed (km/hr), $M \pm SD$	carbohydrate	12.5 ± 0.9*†	12.9 ± 0.9*	13.1 ± 1.0	13.2 ± 1.2*	13.6 ± 1.3*	13.9 ± 1.5*
	placebo	12.1 ± 1.1*	12.6 ± 1.0*	12.8 ± 1.1	13.0 ± 1.3	13.4 ± 1.4*	13.7 ± 1.6*
Distance covered (m)	carbohydrate	1,039*†	1,075*	1,091	1,101*	1,124*	1,152*
	placebo	1,016*	1,052*	1,069	1,085*	1,102*	1,124*

*Significant difference ($p < .05$) in running speed over time. †Significant difference between treatments.

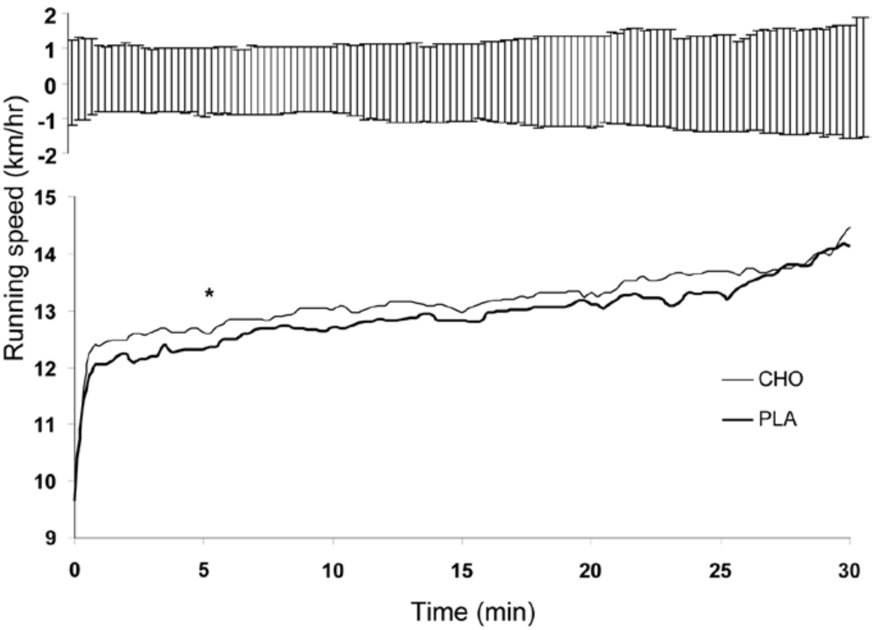

Figure 4 — Mean running speed for the carbohydrate (CHO) and placebo (PLA) trials during the 30-min performance test. For clarity, *SD* is shown on a separate ordinate. Mean running speed for PLA = 12.9 ± 1.3 km/hr vs. 13.2 ± 1.1 km/hr for CHO. *Significant difference in speed analyzed in 5-min blocks ($p < .05$).

selection of an initial faster speed resulted in a greater distance covered over the first 5 min and contributed to a significant difference in total distance covered in 30 min.

Rather than complete a set distance in the fastest time possible, we asked the runners to select a speed that equated to a "hard" pace—15 on the Borg scale (Borg, 1982)—for a 30-min run. Using an automated treadmill the runners were able to spontaneously adjust their speed with no manual input, thus providing a unique insight into how a CHO mouth rinse influenced self-selected running speed. We acknowledge, however, that runners' interpretation of an RPE of 15 (*hard*) would undoubtedly be influenced by the run duration. Therefore, we informed runners of the specific run time, 30 min, and provided them with the time remaining during the run.

The results of the current study provide some support for the findings of Carter, Jeukendrup, and Jones (2004), who reported that mouth rinsing with a 6.4% maltodextrin solution improved 1-hr cycle time-trial performance. In their study, the cyclists were able to maintain a higher power output for the first 75% of the time trial while mouth rinsing with the CHO solution. In addition, they completed the time trial while recording the same RPE as in the placebo trial, even though they were exercising at a higher power output. Similarly, in the current study we found that despite being asked to run at the same perceived exertion, runners selected faster running speeds when mouth rinsing with the CHO solution. In contrast to Carter, Jeukendrup, and Jones, however, this difference only reached statistical significance over the first 5 min of exercise (Table 1). After 5 min the effect of the CHO mouth rinse appeared to diminish with time (Figure 4).

In contrast to the results of the current study, Whitham and McKinney (2007) recently reported that mouth rinsing with a CHO solution had no effect on 45-min running performance on a traditional treadmill. Runners completed a warm-up run at 65% of VO_{2max} before being asked to run as far as possible in 45 min. Runners mouth rinsed with either a 6% maltodextrin or a placebo solution before and during the time trial. No difference in running speed or perceived exertion was reported at any time point during the trials. It is unclear why the findings of the current study differ from those of this recent study. Direct comparisons are difficult, because the current study was not a time trial per se. Whitham and McKinney used a traditional treadmill that required manual changes in speed, whereas in the current study the automated treadmill changed speed as the runners increased or decreased their pace. Studies in which runners change the treadmill speeds manually might not have the same degree of sensitivity to nutritional interventions as is the case when using an automated treadmill (Whitham & McKinney). Thus, manually changing the speed might not be sufficient to detect any subtle effects that CHO mouth rinse might have on the runners (Laursen et al., 2007; Whitham & McKinney). Furthermore, in the mouth-rinse study that used a manually controlled treadmill, speeds were recorded at 5-min intervals (Whitham & McKinney). In the current study treadmill speeds were recording every 15 s, which provided a better description of the runners' responses to the mouth-rinse solutions. Alternatively, as seen in the current study, the major effect of mouth rinsing with CHO is observed at the beginning of exercise and, as previously mentioned, diminished with time. Thus, as the exercise duration increases, the likelihood of reporting a significant difference in distance run will decrease. Although this does not support the results reported for cycling by Carter, Jeukendrup, and Jones (2004), it might explain why Whitham and McKinney found that mouth rinsing with a CHO solution had no effect on the distance covered during 45 min of treadmill running.

Possible placebo effects might have large influences when one is investigating small changes in exercise performance (Clark, Hopkins, Hawley, & Burke, 2000). Despite its' being colorless and nonsweet, Carter, Jeukendrup, and Jones (2004) reported that 4 of their 9 participants were able to identify the CHO mouth-rinse solution. Whitham and McKinney (2007) resolved this potential problem by adding bitter lemon juice to their maltodextrin and placebo solutions, resulting in only 1 of the 7 runners identifying the CHO solution. In the current study only 2 of the 10 runners were able to distinguish between an orange-flavored 6% glucose solution and a color-, viscosity-, and tasted-matched placebo. Although the CHO solution differed from maltodextrin used in previous mouth-rinse studies (Carter, Jeukendrup, & Jones; Whitham & McKinney), the solutions were suitably indistinguishable without the addition of any potentially undesirable masking agents.

All runners increased their running speed during the final 15 min of the 30-min run. This finding is consistent with both laboratory (Palmer, Borghouts, Noakes, & Hawley, 1999; Rauch, St. Clair Gibson, Lambert, & Noakes, 2005; Weltan, Bosch, Dennis, & Noakes, 1998a, 1998b) and field (Billat, Slawinski, Danel, & Koralsztein, 2001; Sandals, Wood, Draper, & James, 2006) studies that observed an increase in speed over the final stages of exercise. The observed increase in speed toward the end of the 30-min run was unexpected, however, because the runners were asked to maintain the same perceived exertion for the duration of the run. The increases in speed were not accompanied with improved perceived activation or pleasure–displeasure that might be expected when nearing the completion of a run. Therefore it would be of interest to determine how the selection of speed and psychological response might change when the duration of the run is blinded. In this case, no increases of speed would be expected because the runners would not know when they were nearing completion of the exercise. Nevertheless, in the current study, blinding runners to the exercise duration would have prevented them from repeating their perceived effort on the exercise task. This is supported by our findings that the pattern of energy expenditure during the 30-min run did not change greatly between trials or runners (Figure 4; Foster et al., 2003). The amplitude of positive changes in running speed were greater, however, when mouth rinsing with the CHO solution—0.3 km/hr faster over the 30 min (Figure 5).

How runners select a speed for a given duration or distance remains an unanswered question. It has been suggested that during exercise athletes use a monitoring process that allows them to complete a prescribed distance before exhausting their available sources of energy or fuel (Foster et al., 2003). The subjective evaluations of one's condition, that is, "how you feel," has been described as interoception (Craig, 2002). During exercise interoception might be involved in, for example, the selection of running speeds. Interoception functions through the lamina I spinothalamocortical system and acts as a homeostatic afferent pathway that conveys signals from small-diameter primary afferents representing the physiological status of all tissues of the body. These feelings have not only a sensory but also an affective motivational aspect (Craig). In the current study, administering both the FS and the FAS scale enabled a more complete description and examination of the subjective experience after mouth rinsing with a CHO solution. Ingesting CHO has been reported to elevate perceived activation during the final 30 min of 120-min intermittent running exercise (Backhouse et al., 2007) and also to attenuate the decline in pleasure–displeasure during a 120-min bout of cycling (Backhouse et al., 2005). To our knowledge, no findings relating to these scales have been reported for shorter duration exercise. In the current study, there was a trend for runners to experience higher perceived activation while mouth rinsing with the CHO solution, but it failed to reach statistical significance. The observation of an enhanced feeling of pleasure at the onset of the 30-min run when rinsing with the CHO solution corresponded to the significant increase in speed over the first 5 min. These findings, taken together with those of Backhouse et al. (2005, 2007), suggest that the ingestion or recognition of CHO in the mouth might induce a "feel good" effect.

We speculate that the brain or lamina I spinothalamocortical system might be monitoring the physiological integrity of muscle or whole-body CHO stores. Recognition of CHO in the mouth might relay signals of an incoming energy source to the brain. This "promise" of additional CHO might generate an altered response toward exercise, for example, the selection of faster running speeds in the first 5 min of the run, as in the current study. Subsequently, when the brain receives

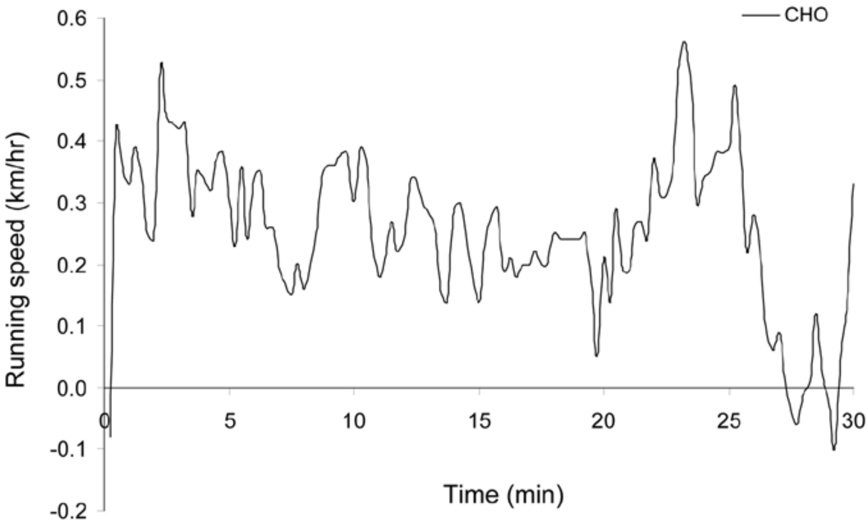

Figure 5 — Mean difference in running speed between the cholesterol (CHO) and placebo trials during the 30-min performance test. Mean running speed for placebo = 12.9 ± 1.3 km/hr vs. 13.2 ± 1.1 km/hr for CHO ($p > .05$).

feedback that no energy source has arrived, exercise behavior might be adjusted accordingly (Figure 4). Similarly, the promise of additional CHO might induce an altered psychological response toward exercise, for example, runners' experiencing enhanced feelings of pleasure at the onset of exercise. When the brain receives feedback that no energy source has arrived, mood state is adjusted accordingly (Figure 2). This might explain why no significant differences in perceived activation or pleasure–displeasure were observed during exercise in the current study but have been reported with CHO ingestion during prolonged exercise wherein the promise of CHO delivery was met—the CHO solution was ingested (Backhouse et al., 2007, 2005).

In summary, mouth rinsing with a 6% CHO solution significantly altered the initial self-selected speed during the first 5 min of a 30-min run at a set RPE. The increase in speed corresponded with runners' experiencing elevated feelings of pleasure at the onset of the exercise task. The precise mechanisms responsible for the link between the positive feelings induced by mouth rinsing with CHO and the selection of faster running speeds remain to be determined.

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