Influence of Ingesting versus Mouth Rinsing a Carbohydrate Solution during a 1-h Run

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ABSTRACT

ROLLO, I., C. WILLIAMS, and M. NEVILL. Influence of Ingesting versus Mouth Rinsing a Carbohydrate Solution during a 1-h Run. Med. Sci. Sports Exerc., Vol. 43, No. 3, pp. 468–475, 2011. Purpose: To investigate the influence of ingesting versus mouth rinsing a carbohydrate–electrolyte solution on 1-h running performance. Methods: After a 14- to 15-h fast, 10 endurance-trained male runners (mean ± SD: VO2max = 65.0 ± 4.4 mL·kg−1·min−1) completed three 1-h performance runs separated by 1 wk. In random order, runners ingested either a 8-mL·kg−1 body mass of either a 6.4% carbohydrate–electrolyte solution (CHO) or a placebo solution (P) 30 min before or a 2-mL·kg−1 body mass at 15-min intervals throughout the 1-h run. On a separate occasion, runners mouth rinsed (R) a 6.4% CHO, i.e., without ingestion, at the same times as in the ingestion trials. Results: Total distances covered in the CHO, P, and R trials were 14,515 ± 756, 14,190 ± 800, and 14,283 ± 758 m, respectively. Runners covered 320 m more (90% confidence interval = 83–380 m, P = 0.019) in comparison with the R trial. There was no difference in distance covered between the R and P trials (P = 1.0). Conclusions: A greater distance was covered after the mouth rinse and ingestion of a 6.4% CHO during a 1-h performance run than when mouth rinsing the same solution or mouth rinsing followed by the ingestion of the same volume of a placebo solution. Key Words: TREADMILL, PERFORMANCE, TIME TRIAL, ENDURANCE

The benefits of carbohydrate (CHO) ingestion have been well established during exercise of prolonged duration. Most studies have reported that ingesting appropriate CHO solutions can improve endurance capacity, i.e., constant-pace exercise to volitional fatigue. During prolonged exercise, CHO ingestion exerts its effect by maintaining blood glucose concentrations, maintaining CHO oxidation, and, under certain circumstances, delaying the depletion of muscle glycogen (11,39). Recent studies have reported that CHO ingestion also has a positive effect on shorter (approximately 1 h) more intense (>75% VO2max) endurance performance and time trials. In these tests, participants are required to complete a preset amount of mechanical work (cycling) (22) or distance (cycling or running) (10,22) in as fast a time as possible or to complete as much work as possible in a specified time (33).

However, under these conditions, the rationale for providing exogenous CHO during exercise is unclear because it seems that blood glucose concentrations are well maintained and may even increase because of the increased output of hepatic glucose (34). Exogenous CHO has been reported to make a minimal contribution to CHO oxidation in the muscle in comparison with the oxidation of endogenous muscle glycogen during a short-duration exercise (25). Furthermore, the concentrations of muscle glycogen are unlikely to be limiting during endurance performance approximately 1 h in duration (25,34,35).

The absence of a clear metabolic advantage of providing additional substrate during laboratory time trials has led authors to speculate that any performance benefit from CHO ingestion may be a consequence of its effects on the central nervous system (CNS). The link between CHO ingestion and the CNS, specifically the brain, has been studied using functional magnetic resonance imaging (fMRI) (23,36). In a recent study, fMRI was used to examine the influence of oral exposure of glucose and maltodextrin on the brain. Chambers et al. (9) reported that both glucose and maltodextrin in the mouth activate regions in the brain associated with reward, such as the insula/frontal operculum, orbitofrontal cortex, and striatum. Speculatively, this “central effect” may explain reports from studies that have found that simply having CHO in the mouth has a positive effect on cycling time trial performance (8,9). Furthermore, these studies suggest that some of the benefits associated with CHO ingestion during endurance performance (22,30) may be due to the feed-forward mechanisms originating from the mouth. It is important to note, however, that not all studies have reported that CHO ingestion benefits time trial performance (12,25).

Intriguingly, a recent study reported that mouth rinsing a carbohydrate–electrolyte solution had a greater positive
effect on exercise performance than ingesting the same solution. Pottier et al. (28) reported that mouth rinsing a 6% carbohydrate–electrolyte solution (sucrose = 5.4 g 100 mL⁻¹, glucose = 0.46 g 100 mL⁻¹) improved cycling performance by 3.7% compared with ingesting the same solution (14 mL·kg⁻¹ body mass (BM)·h⁻¹) (28). The authors suggested that improved performance was due to CHO in the mouth acting on a centrally governed mechanism. However, these results are perplexing, given that the mouth was exposed to the same CHO solution in both the ingestion and rinse trials. The authors speculated that the ergogenic effect of having CHO in the mouth may be lost when ingesting a carbohydrate–electrolyte solution due to the short oral transit time.

We have recently reported that ingesting (30) or mouth rinsing (29) a carbohydrate–electrolyte solution improves 1-h running performance when compared with ingesting or mouth rinsing a placebo solution. However, as yet, we have not compared ingesting and mouth rinsing a carbohydrate–electrolyte solution on performance in the same group of runners. To this end, the purpose of the present study was to assess the relative effect of mouth rinsing and ingesting a carbohydrate–electrolyte solution on 1-h running performance.

METHODS

Participants

Ten male recreational runners gave their written consent before participating in this study approved by Loughborough University Ethical Advisory Committee. Their mean ± SD age, height, BM, and VO₂peak were 26 ± 6 yr, 1.81 ± 0.06 m, 74.2 ± 5.7 kg, and 65.0 ± 4.4 mL·kg⁻¹·min⁻¹, respectively. The number of participants was determined using a nomogram (3), i.e., to estimate the required sample size based on the relationship between the coefficient of variation of the test (1.4% [33]) and “worthwhile” changes in performance due to the intervention (3).

All the participants were experienced runners accustomed to training and/or competitions lasting at least 1 h in duration. Of the 10 runners, 6 regularly ingested CHO–E solutions or water during their training.

Treadmill

All main trials were carried out on a motorized treadmill (Runner MT2000; Bianchini and Draghetto, Cavezzo, Italy) that has an ultrasonic feedback-controlled radar modulator that spontaneously regulates treadmill belt velocity corresponding to the changing position of the runner on the treadmill belt. Thus, the treadmill velocity increases or decreases as the runner moves to the front or the back of the treadmill belt, respectively. Therefore, changes in velocity are achieved without the need for manual input or visual feedback from the runner. More specifically, when the runner moves to the front section of the treadmill (<36 cm from treadmill console), the speed increases (0.8 m·s⁻¹). If the runner stays in the middle of the treadmill (between 36 and 65 cm from treadmill console), the speed remains constant. When the runner moves to the rear of the treadmill (>65 cm from treadmill console), the speed decreases (1.1 m·s⁻¹). Consequently, the runner will always be brought back to the center of the treadmill belt (33).

1-h run protocol. A full description of the treadmill and methods has recently been published (33). A habituation trial was completed by all runners before the completion of three main 1-h running trials, in which runners either ingested a carbohydrate–electrolyte solution (CHO) or placebo solution (P) or mouth rinsed a carbohydrate–electrolyte solution without ingestion (R). The habituation involved the completion of the 1-h run; however, runners ingested water instead of consuming a carbohydrate–electrolyte containing beverage. Before testing, all participants were provided with the objectives of the studies in writing. They were informed that ingesting and mouth rinsing carbohydrate–electrolyte solutions have been shown to independently improve 1-h running performance. The study used a double-blind random crossover design for the ingestion trials. Runners were asked to refrain from heavy exercise and to consume a standardized diet 48 h before each trial, i.e., they recorded their food intake in the 48 h before the first trial and replicated it before the subsequent trials. There were no significant differences in the average daily energy intake (13.1 ± 1.6 MJ) or quantities of CHO (465 ± 97 g), protein (128 ± 20 g), or fat (99 ± 41 g) consumed in this 48-h period (dietary composition analyzed by CompEat Pro 5.8.0, Grantham, UK). All trials were separated by 7 d and conducted in the morning at the same time of day.

Each runner arrived at the laboratory after an overnight fast (14–15 h) and sat at rest for 20 min before the collection of a 5-min resting expired air sample. After a further 20 min at rest, the runner was allowed to empty his bladder, and then his nude BM was recorded. Before each trial, runners were fitted with an HR monitor (Polar Electro, Kempele, Finland) before completing a 5-min warm-up at a speed equivalent to 60% VO₂peak. During the 5-min warm-up, expired air was collected between 4 and 5 min and then analyzed using the Douglas bag method. RPE values were noted 3 min into the warm-up. On completion of the warm-up, the runners were allowed 2 min to prepare for the run and, if required, empty their bladder (on these occasions, urine was collected, and the volume was taken into account in the calculation of BM loss). On completion of the 1-h run, the runners were towel dried, and BM was recorded. Sweat rates were calculated by subtracting the runners’ postrun BM from their BM immediately before the run. The volume of fluid ingested during the run was recorded and accounted for in the BM loss calculation.

All trials were performed in a laboratory (20°C ± 1°C and 36% ± 6% relative humidity) in which only the principal investigator was allowed so that the runners were not distracted by the environment or extraneous activities. The treadmill display panel and the HR monitor were covered so that the only feedback received by the runner was from a clock displaying...
the time remaining of the 1-h run. Runners began the trial by standing at the front of the treadmill (1% gradient) and were then given the following instruction from the principal investigator: “this is a running performance test, run as far as you can in 60 min.” Runners received no feedback about their performance, i.e., distance covered, running speed, and HR until they had completed all three trials.

**Beverages.** The carbohydrate–electrolyte solution used in the present study was a commercially available 6.4% carbohydrate–electrolyte beverage (Lucozade Sport, Brentford, United Kingdom). The placebo solution was matched in formulation to the carbohydrate–electrolyte solution except that it did not contain CHO. Both the placebo and carbohydrate–electrolyte beverages contained artificial sweetener (aspartame). In the two ingestion trials, runners ingested the equivalent of 8 mL·kg⁻¹ BM of a carbohydrate–electrolyte solution or color- and -matched placebo solution 30 min before the 1-h run. Runners also ingested 25 mL immediately before the 1-h run and then the equivalent of 2 mL·kg⁻¹ BM at 15-min intervals during the run, i.e., at 15, 30, and 45 min. Each 2-mL·kg⁻¹ BM bolus of solution was served in two separate plastic volumetric syringes (Kendall Monoject, Mansfield, MA). In an attempt to ensure the same transient time in the mouth during the ingestion trials, runners were instructed to rinse the last mouthful of solution in the mouth for 5 s before ingestion. The solutions were weighed using an electronic balance (Mettler, Toledo AB54-s, Greifensee, Switzerland) to ensure the correct volume was ingested 30 min before exercise. A container with the solution was placed on the same electronic balance to ensure that the correct volume of solution was taken up into the plastic syringe. The feeding schedule was designed to provide the runner with approximately 60 g CHO·h⁻¹. The ingestion of large volumes of fluid immediately before the run was avoided to reduce the potential risk of gastrointestinal (GI) discomfort influencing performance.

The same carbohydrate–electrolyte solution used in the CHO trial was used for the mouth rinse trials (R). Each 25 mL of solution was delivered in a plastic volumetric syringe (Kendall monoject) at the following times: 30 min before, immediately before, and at 15-min intervals during the 1-h run. The solution was mouth rinsed for 5 s before being expectorated into a preweighed plastic container. The syringe and plastic container were weighed before and after each rinse using an electronic balance (Mettler, Toledo AB54-s) to determine the volume of rinsed solution and expectorate, respectively. The volume of expectorate was subtracted from the known volume of solution rinsed to determine whether any solution had been ingested or remained in the oral cavity.

**Blood and expired air collection.** Fingertip blood samples (300 μL) were taken at rest, immediately before the 1-h run, and at 15, 30, 45, and 60 min during the run. All blood samples were deproteinized with perchloric acid, frozen, and later analyzed for the concentrations of glucose and lactate concentrations (24). One-minute expired air samples were collected using the Douglas bag method at 15, 30, and 45 min into the 1-h run.

**Psychological scales.** The feeling scale (FS) (16) was used to assess the overall “feeling” of the runners, i.e., the affective dimension of pleasure–displeasure. This FS 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) (13). The perceived activation scale (FAS [37]) is a six-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 previous exercise studies (2). Both the FS and FAS have the advantage of most other self-report scales of being easily administered during exercise. GI discomfort was rated using a 12-point scale with anchors provided at 0 “neutral,” 4 “uncomfortable,” 8 “very uncomfortable,” and 12 “painful.” The FS, FAS, together with the GI scale were administered at rest, immediately before, and at 15, 30, 45, and 60 min during the 1-h run. Runners’ RPE values were assessed using the Borg Rating of Perceived Exertion Scale (7) during the warm-up and at 15, 30, and 45 min during the 1-h run.

**Statistical Analysis**

All data were analyzed using SPSS (version 16.0, Chicago, IL). The mean differences in performance (total distance covered and trial order) were detected using one-way within-measures ANOVA with Bonferroni pairwise comparison when significance was identified. The quantitative approach to the likelihood of the trial having a beneficial, trivial, or negative effect on running performance was further enriched by dividing the range of substantial values into more finely graded magnitudes. Using a spreadsheet by Hopkins (20), the P value was converted into 90% confidence intervals (CI) for, and inferences about, the true value of the effect statistic. It has been previously reported that distance runners and support professionals need to be concerned about changes in performance of between −0.5% and +1.0% (21). Thus, the set threshold value for the trial to have a beneficial or negative influence on performance was set at 1% of the mean distance covered during the three trials. Mean differences in self-selected running speed (analyzed in 5-min blocks during the 1-h run) and psychological scores were detected using a repeated-measures factorial ANOVA (trial × 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 used. All data are presented as mean ± SD, P ≤ 0.10, a priori (19).

**RESULTS**

The total distances covered in the CHO, P, and R trials were 14,515 ± 756, 14,190 ± 800, and 14,283 ± 758 m, respectively. There was no trial order effect between the three trials (F(2,18) = 0.8, P = 0.432). A threshold value of 143 m was set as the minimum distance that would result
in a meaningful difference in performance. The individual running performances are shown in Figure 1.

The mean difference in distance covered between the CHO and P trials was 320 m (90% CI of difference = 140–510 m; 2.2%, \( P = 0.01 \)). The mean difference in distance covered between the CHO and R trials was 230 m (90% CI of difference = 83–380 m; 1.6%, \( P = 0.019 \)). There was no difference in distance covered between the R and P trials (\( P = 1.0 \)). The chance that the true value of the effect has a beneficial, trivial, or negative influence on running performance is 94.8%, 5.1%, and 0.1%, respectively, for the CHO versus the P trial, 84.9%, 15%, and 0.1%, respectively, for the CHO versus the R trials, and 49.7%, 1.5%, and 48.7% for the R versus the P trials, respectively.

The mean running speeds for the three trials are shown in Figure 2. The mean physiological responses during the 1-h run are shown in Table 1. Blood glucose concentrations are shown in Figure 3. The mean psychological scores for FAS, FS, RPE, and GI discomfort values during the 1-h run are shown in Table 2.

The mean volume of fluid ingested 30 min before exercise was 594 ± 45 mL, which provided 39 ± 3 g of carbohydrate in the CHO trial. All runners successfully used the plastic syringes to ingest/rinse the drink provided during exercise. The 25 mL of solution ingested immediately before exercise provided 2 g of carbohydrate in the CHO trial. The mean volume of fluid ingested at 15-min intervals in the CHO and P trials was 148 ± 11 mL. This provided a total of 445 ± 34 mL during the 1-h run, supplying 29 ± 2 g of carbohydrate during the CHO trial. Thus, the total quantity of carbohydrate consumed during the CHO trial was 69 ± 5 g. There was no difference in the volume of solution rinsed
(25.9 ± 0.6 mL) and the volume of expectorate (25.9 ± 1.0 mL) during the R trial ($P = 0.649$).

The mean BM losses during the CHO and P trials were 0.8% and 0.9% of preexercise BM, whereas the BM loss was the R trial was 1.1%. Calculated sweat rates were 1.5 ± 0.3, 1.6 ± 0.2, and 1.5 ± 0.3 L·h$^{-1}$ for the CHO, P, and R trials, respectively. The 5-min warm-up speeds were 11.7 ± 0.4 km·h$^{-1}$, and the VO$_2$ was 39.6 ± 2.2 mL·kg$^{-1}$·min$^{-1}$, equivalent to 60% ± 5% VO$_{2peak}$ for all trials ($P > 0.10$).

**DISCUSSION**

The main finding of the present study was that ingesting a carbohydrate–electrolyte solution significantly improved 1-h running performance in comparison with mouth rinsing the same carbohydrate–electrolyte solution or ingesting the same volume of a placebo solution. The results of this study confirm previous observations that the ingestion of a 6.4% carbohydrate–electrolyte solution improved 1-h running performance in fasted runners (30).

Our findings are in agreement with studies that report the benefit of ingesting CHO solutions on self-selected running speeds during both laboratory-based treadmill tests and “real-life” road races. For example, in a controlled laboratory environment, the ingestion (1 L) of either a 6% or an 8% CHO solution 1 h before exercise improved self-selected running speed by approximately 5% during the final 1.6 km of a 15-km run, in comparison with the ingestion of water (27). Interestingly, the percentage improvement in the present study (2.2%) is similar to that reported during a real-life 30-km race (2.3%) (38). In this study, runners were asked to perform thirty 1-km outdoor circuits drinking either a 5% CHO solution or water, immediately before and at 5-km intervals during the run. However, instead of the self-selection of faster running speeds as observed in the present study (Fig. 2), improved running performance was attributed to runners being able to maintain their chosen running speed over the final 5 km of the run (38).

To our knowledge, the study of Pottier et al. (28) is the only one that has compared the influence of ingesting and mouth rinsing the same carbohydrate–electrolyte solution on endurance performance. In contrast to the results of the present study, they reported a 3.7% improvement in cycling time trial performance when their cyclists mouth rinsed a 6% carbohydrate–electrolyte solution (sucrose = 5.4 g·100 mL$^{-1}$, glucose = 0.46 g·100 mL$^{-1}$) compared with ingestion

![FIGURE 3—Mean blood glucose concentrations (mmol·L$^{-1}$). *Significant difference between the CHO trial and the P and R trials.](http://www.acsm-msse.org)
(14 mL·kg⁻¹·BM·h⁻¹) of the same solution. The authors suggest that improved performance was due to the CHO in the mouth acting on a centrally governed mechanism. However, it is important to note that the mouth (possible site of CHO receptor–modulating central pathways) would have been exposed to CHO in both mouth rinse and ingestion trials. To explain this discrepancy, the authors speculate that the ergogenic effect of CHO in the mouth may be lost because of the short oral transit time when ingesting carbohydrate–electrolyte solutions (28).

In the present study, the oral exposure to the carbohydrate–electrolyte solution was standardized between trials, i.e., each solution was held in the mouth for 5 s before either being expectorated or ingested. Thus, in contrast to Pottier et al. (28), our results revealed that combining mouth rinsing and ingesting a carbohydrate–electrolyte solution was 85% and 95% likely to benefit 1-h run performance compared with mouth rinsing alone or ingesting a placebo solution, respectively. In contrast to our previous study (29), mouth rinsing a carbohydrate–electrolyte solution did not improve 1-h running performance in comparison with the placebo trial. However, the clear difference between the present and previous study was that the placebo solution was ingested after the rinse, whereas previously, it had been expectorated. Thus, a possible explanation for the nonsignificant benefit of mouth rinsing a carbohydrate–electrolyte solution in comparison with placebo may be the ingestion of fluid per se having a positive effect on performance.

The ingestion of fluid during treadmill running has been reported to improve endurance capacity in comparison with a no fluid trial (14). A cycling study reported that the improved endurance capacity when fluid was ingested may be a consequence of a reduced HR, core temperature, and utilization of muscle glycogen compared with cycling without fluid ingestion (17). Other than the present study, a comparison of the influences of fluid intake and no fluid intake on 1-h running performance seems not to have been understood.

In the present study, the mouth rinse trial was equivalent to a “no-fluid” trial. The mean reduction in BM was 1.1%, which is similar to the findings of McConnell et al. (26), which reported a minimal effect of fluid ingestion on performance in a thermoneutral environment. In this study, cyclists completed 45 min of constant work followed immediately by a 15-min all-out effort to complete as much work as possible. The total work completed during the 15 min was similar with or without ingesting fluid, i.e., when water was ingested to prevent 50% and 100% of BM losses. Furthermore, there were no difference in HR, plasma volume, or body temperature between the fluid and no-fluid trials (26). Similarly, there were no differences in physiological responses between the mouth rinse and placebo trials in the present study. However, it is important to note that, although we were able to detect the improved performance in response to the ingestion of the carbohydrate–electrolyte solution, we did not detect any accompanying changes in oxygen uptake and HR values or blood lactate concentrations. The reason might be that our methods of monitoring physiological changes during exercise were not sufficiently sensitive to detect the consequences of small changes in running speed. Alternatively, the runners may have felt more relaxed after the mouth rinse and ingestion of the carbohydrate–electrolyte solutions, and so their general economy of effort was greater, resulting in a slightly faster running speed for the same oxygen uptake, HR, and blood lactate concentrations, but of course, this is merely speculation.

Ingesting (5,22,30) and mouth rinsing (8,9,28,29) CHO solutions can independently improve endurance performance. However, the potential performance benefit of mouth rinsing or ingesting carbohydrate–electrolyte solutions appears to be influenced by the CHO status of the participant before exercise. In a recent study, we found no benefit of carbohydrate–electrolyte ingestion on 1-h running performance when a preexercise meal was consumed 3 h before exercise (31). These findings are consistent with cycling studies that also

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**TABLE 2.** Mean psychological scores for FAS (F(2,18) = 7.1, P = 0.005), FS (F(2,18) = 4.7, P = 0.023), RPE (F(2,18) = 0.5, P = 0.498), and GI comfort (F(2,18) = 1.5, P = 0.246) during the CHO, P, and R trials.

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<th>Scale/Trial</th>
<th>Rest</th>
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<td>4.2 ± 1.0</td>
<td>4.6 ± 1.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.0 ± 0.9&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>P</td>
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<td>R</td>
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<td>3.4 ± 1.3</td>
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<td>R</td>
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<td>CHO</td>
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<td>10 ± 2</td>
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<td>17 ± 1&lt;sup&gt;c&lt;/sup&gt;</td>
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<sup>a</sup> Significant difference between the CHO and P trials.
<sup>b</sup> Significant difference between the CHO and R trials.
<sup>c</sup> Significant effect of time.
report that CHO supplementation has little ergogenic effect when endogenous glycogen stores are sufficient to maintain exercise intensity during the exercise (12). In contrast to the studies that have reported improvements in cycling time trial performance of fasted cyclists after mouth rinsing a carbohydrate solution (8,9), Beelen et al. (4) reported that there was no improvement in cycling performance when the cyclists were fed rather than fasted. In the present study, runners were required to undergo a prolonged fast (14–15 h) before exercise. Although many runners prefer to have a meal a few hours before exercise, it is not uncommon for runners to begin exercise after a prolonged fast, especially when competing in early morning races. Improvements in cycling time trial performance after the ingestion and mouth rinsing carbohydrate solutions have been reported more frequently than is the case for running studies. This may be largely the result of the different method used in running studies. In contrast to cycling studies where the cyclists can change their power output spontaneously simply by increasing their pedal frequency, in running studies, the runners usually have had to increase the treadmill speed by manually engaging with the treadmill control panel. This necessary interaction does not lend itself to measuring the spontaneous responses to ingesting carbohydrate or mouth rinsing carbohydrate solutions. In the present study, the treadmill used did not require a manual change of speed because the treadmill responded to the runners’ movement along the treadmill belt, i.e., it increased in speed with the runners increase in speed and slowed down when the runner slowed down (33). Therefore, we were able to capture the spontaneous self-selection of running speed during the nutritional interventions, and so this may explain the positive outcome of our recent studies in comparison with other running studies (40).

The mechanism responsible for improved performance in the carbohydrate–electrolyte trial is unlikely to be a consequence of the increased rate of exogenous CHO oxidation or elevated RER (Table 1) (25). Instead, reports from previous studies suggest that the increased rate of CHO oxidation is a consequence of the elevated running speed, i.e., exercise intensity during the CHO trial (1,25). The absence of a clear metabolic advantage of providing additional substrate during laboratory time trials has led authors to speculate that CHO ingestion may have a positive effect on the CNS. Several studies have used fMRI to investigate the central response to ingesting CHO solutions. Smeets et al. (36) reported that the ingestion of a glucose solution resulted in the activation of the hypothalamus, which was not observed with the ingestion of water, aspartame, or maltodextrin solution. The time course of activation corresponded with changes in blood glucose and insulin concentrations after CHO ingestion. Interestingly, the onset of activation began before the end of glucose ingestion, i.e., before the glucose entered the bloodstream (36). This phenomenon was investigated in detail by Chambers et al. (9), who reported that simply mouth rinsing both glucose and maltodextrin activated regions in the brain associated with reward (9). In addition, a recent study also provides evidence that CHO in the mouth can increase the excitability of the corticomotor pathways (15). Therefore, a “central effect” provides an appealing hypothesis to explain improved endurance performance when ingesting CHO–electrolyte solutions without any apparent peripheral metabolic changes (8,9,32). However, the results of the present study suggest that it is too early to recommend athletes mouth rinse and expectorate carbohydrate–electrolyte solutions as the performance benefit was only observed after mouth rinsing and ingestion. This phenomenon is worthy of further study particularly the determination of the relative contribution of a “central” and “peripheral” effect on performance when ingesting carbohydrate–electrolyte solutions during exercise. However, future research should aim to blind participants to the purpose of the investigation, which was a limitation of the present study.

In conclusion, mouth rinsing, followed by the ingestion of a carbohydrate–electrolyte solution, was associated with increased distance covered during a 1-h running performance test in comparison with mouth rinsing the same solution or mouth rinsing followed by the ingestion of a placebo solution.

This study did not receive funding from the National Institutes of Health, Wellcome Trust, Howard Hughes Medical Institute, or any other organization. This study was funded by Loughborough University. The results of this study do not constitute endorsement by the American College of Sports Medicine.

REFERENCES
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