Influence of Ingesting a Carbohydrate-Electrolyte Solution Before and During a 1-hr Running Performance Test

Ian Rollo and Clyde Williams

The aim of this study was to investigate the influence of ingesting a carbohydrate-electrolyte solution (CHO-E) on performance during a 1-hr treadmill run. Eight male endurance-trained runners (age 31 ± 8 yr, $M \pm SD$) completed three 1-hr performance runs separated by 1 wk. The study used a double-blind placebo (PLA) controlled design. On 2 occasions (P1, P2) runners consumed a placebo solution, 8 ml/kg body mass (BM), 30 min before and 2 ml/kg BM at 15-min intervals throughout the 1-hr run. On a separate occasion they consumed the same quantity of a 6.4% CHO-E solution (C). Total distances covered for P1, P2, and C trials were 13,685 ± 1,116 m, 13,715 ± 1,143 m, and 14,046 ± 1,104 m, respectively. Although there was no difference between the 2 PLA trials ($p > .05$), the distance covered during the C trial was significantly greater than in either PLA trial ($p < .05$). CHO ingestion resulted in a higher blood glucose concentration only at the onset of exercise ($p < .05$) compared with the PLA trials. Blood lactate, respiratory-exchange ratio, and CHO oxidation were similar in all 3 trials. In conclusion, ingestion of a 6.4% CHO-E solution before and during exercise was associated with improved running performance in runners compared with the ingestion of a color- and taste-matched placebo.

*Keywords*: time trial, speed, treadmill

The benefits of ingesting carbohydrate-electrolyte (CHO-E) solutions during prolonged cycling and running on endurance capacity have been established in well-controlled laboratory studies (for reviews see Coyle, 1992; Tsintzas & Williams, 1998). In contrast, there are relatively few studies on the benefits of ingesting carbohydrate during road races because of the difficulties of controlling variables that may influence the outcome of races, for example, the day-to-day differences in environmental conditions. Of the studies that created road races to examine the efficacy of ingesting carbohydrate on running performance, some (Tsintzas, Liu, Williams, Campbell, & Gaitanos, 1993) but not all (Burke, Wood, Pyne, Telford, & Saunders, 2005) reported a performance benefit. Therefore, it is not surprising

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that most studies on nutrition and performance have been designed to try to create
race conditions in well-controlled laboratory environments.

Most of the laboratory studies examined the influences of CHO ingestion on
everance capacity (>1 hr) rather than endurance performance, that is, time trials. This is because during shorter duration exercise (≤1 hr), endogenous stores of CHO
are unlikely to be limiting, so there is no clear rationale for providing additional
CHO. Nevertheless, some studies (Ball, Headley, Vanderburgh, & Smith, 1995;
Below, Mora-Rodriguez, Gonzalez-Alonso, & Coyle, 1995; Carter, Jeukendrup,
Mundel, & Jones, 2003; Neufer et al., 1987) but not all (Anantaraman, Carmines,
Gaesser, & Weltman, 1995; Desbrow, Anderson, Barrett, Rao, & Hargreaves, 2004;
Widrick et al., 1993) have shown a performance benefit of ingesting CHO during
short-duration high-intensity exercise such as time trials. However, all these studies
were conducted in cycling rather than running.

In comparison, relatively little information is available on CHO ingestion and
running performance at equivalent intensities and durations. For example, in one
laboratory study, runners completed a constant-pace 13-km treadmill run before
running 1.6 km as fast as possible while ingesting 6% and 8% CHO-E solutions
(Millard-Stafford, Rosskopf, Snow, & Hinson, 1997). The performance times for the
1.6-km run were significantly faster with ingestion of the CHO-E solutions than with
ingestion of placebo solutions. Although there are clear advantages of conducting
running studies in a well-controlled laboratory environment, treadmill running does
not normally allow runners to change their pace spontaneously. Treadmill speed
is usually changed manually by the runner or by the investigator at the request of
the runner. To overcome this limitation, we used a treadmill that allows runners to
change pace spontaneously without manually changing the treadmill speed. This
method allowed performance trials conducted under controlled laboratory condi-
tions to be more representative of “free running,” than those that use traditional
treadmill systems (Laursen, Francis, Abbiss, Newton, & Nosaka, 2007; Schabort,

Using this automated treadmill we developed a 1-hr running performance test
that required runners to complete the greatest possible distance in the set time (Rollo,
Williams, & Nevill, 2008). This performance test has a coefficient of variation (CV)
of 1.4%, which is smaller than those reported in earlier studies (Schabort et al.,
1998). Hopkins and Hewson (2001) previously reported that running tests require
a CV of 1.5% or less to detect small changes in running performance (Hopkins &
Hewson). Thus, the CV of 1.4% is sufficiently repeatable to be used as a measure of
endurance-running performance. Taking advantage of this advancement in treadmill
technology, we were well placed to extend the investigations on the performance
benefits of carbohydrate ingestion during running. To this end, the aim of the cur-
rent study was to investigate the influence of ingesting a 6.4% CHO-E solution on
the total distance completed during a 1-hr running performance test.

**Methods**

**Participants**

Eight endurance-trained male runners gave their written consent before participating
in this study approved by the Loughborough University Ethical Advisory Commit-
The runners’ physiological characteristics and running experience are reported in Table 1. The number of participants was determined using a nomogram based on the ratio limits of agreement (Nevill & Atkinson, 1997). All participants were experienced runners accustomed to training and competitions lasting at least 1 hr.

**Preliminary Tests**

After an overnight fast, runners reported to the laboratory and completed a 20-min test to determine the oxygen cost of treadmill running at submaximal speeds. Treadmill speed was increased every 4 min, heart rate (HR) was recorded at 15-s intervals using short-range telemetry (Polar Electro, Kempele, Finland), and expired air was collected in the last 60 s of each 4-min stage. Expired air was analyzed using the Douglas bag method (Williams, Nute, Broadbank, & Vinall, 1990). After adequate rest the VO\(_{2\text{peak}}\) and maximum HR of the runners were determined. The treadmill speed was kept constant, and from an initial gradient of 3%, the gradient was increased by 3% every 3 min until the runner achieved volitional fatigue (Taylor, Buskirk, & Henschel, 1955). Expired air and rating of perceived exertion (RPE; Borg, 1982) were collected at the end of each 3-min stage of the treadmill run.

All three main trials were carried out on a motorized treadmill (Runner MT2000, Bianchini and Draghetti, 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 (Minetti, Boldrini, Brusamolin, Zamparo, & McKee, 2003). The treadmill velocity increases or decreases as the runner moves to the front or 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 the treadmill console) the speed increases (0.8 m/s). If the runner stays in the middle of the treadmill (36–65 cm from the console) the speed remains constant. When the runner moves to the rear of the treadmill (>65 cm from the console) the speed decreases (1.1 m/s). Consequently, the runner will always be brought back to the center of the treadmill belt (Rollo et al., 2008).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Measure</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>31 ± 8</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.80 ± 0.07</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>74.9 ± 5.3</td>
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<tr>
<td>VO(_{2\text{peak}}) (L/min)</td>
<td>4.7 ± 0.4</td>
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<tr>
<td>VO(_{2\text{peak}}) (ml · kg(^{-1}) · min(^{-1}))</td>
<td>62.0 ± 4.7</td>
</tr>
<tr>
<td>Experience (years)</td>
<td>10 ± 5 (5–18)</td>
</tr>
<tr>
<td>Training frequency per week</td>
<td>4 ± 1 (3–5)</td>
</tr>
<tr>
<td>Miles/week</td>
<td>43 ± 17 (30–70)</td>
</tr>
</tbody>
</table>
**1-hr-Run Protocol.** Runners were fully habituated to the testing procedures before the study began. The study used a double-blind, placebo-controlled design. Runners were asked to refrain from heavy exercise and to consume their normal diet for 48 hr before each trial. No caffeine or alcohol was consumed during this period. Runners were asked to record their food intake in the 48 hr before the first trial and to replicate it before the next two trials. There were no significant differences between the three trials in the average daily energy intake or composition in terms of carbohydrate, protein, and fat consumed in the 48 hr before each trial.

Runners arrived at the laboratory after an overnight fast (12–15 hr) and sat at rest for 20 min before the collection of a 5-min resting expired-air sample. Runners then sat at rest for another 20 min before being allowed to empty their bladders, and then nude body mass 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% \( \dot{V}O_2 \text{peak} \). During the 5-min warm-up, expired air was collected between 4 and 5 min and then analyzed using the Douglas bag method. RPEs were taken after 3 min into the warm-up. On completion of the warm-up, runners were allowed 2 min to prepare for the run and empty their bladders again if required (on these occasions, urine was collected and the volume taken into account in body-mass-loss calculations). On completion of the 1-hr run, runners were towel-dried and body mass was recorded. Sweat rates were calculated by subtracting the runners’ postrun body mass from their body mass immediately before the run. The volume of fluid ingested during the run was recorded and accounted for in the calculation of body-mass loss.

All trials were performed in a laboratory (16 ± 1 °C, 58% relative humidity) containing the treadmill with a fan positioned 1 m in front of it to help cool the runner. Only the principal investigator was allowed in the laboratory to collect samples during the trials so that the runner was not distracted by the environment or extraneous activities. Runners were monitored throughout exercise via closed-circuit television by the principal investigator in an adjacent room. The treadmill display panel and the HR monitor were covered so that feedback to the runner was limited to a clock displaying the time remaining throughout the 1-hr run. Runners began the trial by standing at the front of the treadmill (1% gradient) and received 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 regarding distance covered, running speed, or HR until they had completed all three trials.

**Beverages.** The first trial, P1, was single-blind. All runners ingested the equivalent of 8 ml/kg BM of a color- and taste-matched placebo solution 30 min before the 1-hr run, and at 15-min intervals during the run they ingested the equivalent of 2 ml/kg BM, that is, at 15 min, 30 min, and 45 min. Each 2-ml/kg BM bolus of solution was served in two separate plastic volumetric syringes (Kendal Monoject). The solutions were weighed using an electronic balance (Mettler, Toledo AB54-s, Switzerland) to ensure that the correct volume was consumed 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. All syringes were empty after ingestion of the
solution during the run. The feeding schedule was designed to provide the runner with approximately 60 g/hr of CHO (quantities shown previously to improve performance). Ingestion of large volumes of fluid immediately before the run was avoided to minimize the risk of gastrointestinal (GI) discomfort’s affecting performance. The following two experimental trials adopted a double-blind random crossover design. Runners followed the described protocol, ingesting either a placebo (P2) or a commercially available 6.4% CHO-E solution (C; Lucozade Sport, Brentford, England). The placebo solutions were matched in formulation to the CHO-E solution except that they contained no CHO.

Fingertip blood samples (20 µl) were taken in duplicate at rest, immediately before the 1-hr run and at 15, 30, 45, and 60 min during the run. All blood samples were deproteinized, frozen, and later analyzed for the concentrations of glucose and lactate (Maughan, 1982). One-minute expired-air samples were collected using the Douglas bag method at approximately 15, 30, and 45 min into the 1-hr run. Runners’ stride lengths were determined by dividing the number of strides by the distance covered between 9 and 10 min, 19 and 20 min, 39 and 40 min, and 55 and 56 min.

**Psychological Scales.** The Feeling Scale (FS; Hardy & Rejeski, 1989) was used to assess the runners’ feelings regarding the affective dimension of pleasure–displeasure. The 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; Ekkekakis, Backhouse, Gray, & Lind, 2008). The perceived activation scale (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, Ali, Biddle, & Williams, 2007; Backhouse, Bishop, Biddle, & Williams, 2005; Hall, Ekkekakis, & Petruzzello, 2002). Both the FS and the FAS have the advantage of most other self-report scales of being easily administered during exercise. 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 at rest immediately before and at 15, 30, 45, and 60 min during the 1-hr run. Runners’ RPEs were collected using the Borg scale (Borg, 1982) during the warm-up and at 15, 30, and 45 min during the 1-hr run.

**Statistical Analysis**

All data were analyzed using SPSS (version 16.0). The mean differences in performance (total distance covered, running speed, stride length and frequency), psychological variables (RPE, FS, FAS, and GI), and trial order were detected using one-way within-measures analyses of variance (ANOVA) with Bonferroni pairwise comparison when significance was identified. Significant main effects for individual time points were further analyzed using paired t tests and the Bonferroni adjustment for the number of pairwise comparisons employed. Mean differences in self-selected running speed and comparisons over time (analyzed in 5-min blocks over the 1-hr run) were detected using a $3 \times 20$ (trial-by-time) within-measures ANOVA. All data are presented as $M \pm SD$, and a critical alpha level was set at $p \leq .05$ a priori.
Results

Performance

Total distances covered during the three trials were 13,685 ± 1,116 m, 13,715 ± 1,143 m, and 14,046 ± 1,104 m for the P1, P2, and C trials, respectively, $F(2, 14) = 12.1, p = .001$. The mean difference in distance covered between the P1 and P2 trials was 30.7 m ($p = 1.000$). The mean differences in distance covered between the C trial and placebo trials were 362 m (2.6%, $p = .027$) and 331 m (2.4%, $p = .011$) for the P1 and P2 trials, respectively.

Of the 8 runners who participated in the study, 7 increased the total distance covered during the 1-hr C trial. There was no trial-order effect between the three trials, $F(2, 14) = 3.0, p = .085$. If we were to interpret our results as a fixed distance, the mean distance run during the CHO trial (greatest distance), runners would have had to run for 93.6 s longer during the P1 trial and 86.4 s longer in the P2 trial to cover the same distance.

The mean running speeds for the three trials were P1 13.7 ± 1.1 km/hr, P2 13.7 ± 1.1 km/hr, and C 14.1 ± 1.1 km/hr, $F(2, 14) = 14.1, p = .0004$. The mean difference in running speed between the P1 trial and P2 trial was 0.03 km/hr ($p = 1.000$). Mean difference in self-selected running speed for the CHO trial was 0.39 km/hr faster than in the P1 trial ($p = .022$) and 0.36 km/hr faster than in the P2 trial ($p = .005$).

When 5-min blocks were analyzed, no significant difference in running speed was observed between P1 and P2 at any time point ($p > .05$). Self-selected running speed was significantly faster between 25 and 50 min in the C trial than in both the P1 and P2 trials ($p < .05$). Pacing strategy was similar between runners and consistent between trials. A significant effect of time on running speed was observed between 0–5 min, 45–50 min, and 55–60 min (Figure 1). There were no differences in stride frequency, 175 ± 12 strides/min, $F(2, 14) = 0.7, p = .528$, or stride length, 1.34 ± 0.20 m, $F(2, 14) = 0.4, p = 1.000$, between trials.

The treadmill performance test used in the current study has a CV of 1.4% (Rollo et al., 2008). Therefore, the overall improvements in running performance, after accounting for between-runs variability, were 1.2% and 1.0% for the C trial in comparison with the P1 trial and P2 trial, respectively. In real terms, we estimate that the participants ran approximately 164 m farther than in the P1 trial and approximately 137 m farther in the P2 trial. Thus, with respect to a fixed distance, improvements in time during the C trial would equate to 43.2 s in comparison with the P1 trial and a 36.0-s improvement in comparison with the P2 trial.

The 5-min warm-up speed was 11 ± 0.8 km/hr. VO$_2$ was 37 ± 4 ml · kg$^{-1}$ · min$^{-1}$, equivalent to 60% VO$_{2peak}$ for all trials. RPEs for the warm-ups were 9 ± 1 for Trials P1 and P2 and 10 ± 2 for the C trial.

Energy intake in the 48 hr before the trials was 2,676 ± 166 kcal/day, representing a daily intake of 426 ± 69 g of carbohydrate (5.5 g/kg BM), 86 ± 18 g of protein (1.2 g/kg BM), and 76 ± 25 of fat (1.0 g/kg BM). The mean volume of solution ingested 30 min before exercise was 600 ± 42 ml, providing 38 ± 3 g of CHO. The mean volume of fluid administered at 15-min intervals was 150 ± 11 ml. This provided a total of 450 ± 32 ml ingested during the 1-hr run, equating to 29 ± 2 g of CHO. The total quantity of CHO consumed during the CHO trial was 67 ± 5 g.
Figure 1 — Running speed (km/hr) over the 1-hr run with standard deviations shown at 5-min intervals for clarity. *Significant difference of carbohydrate-electrolyte solution (C) vs. placebo trials (P1 and P2; \( p < .05 \)). †Significant effect of time (\( p < .05 \)).
The relative exercise intensities during the three trials were 80% ± 6%, 79% ± 8%, and 80% ± 6% VO$_{\text{peak}}$ for Trials P1, P2, and C, respectively, $F(2, 14) = 0.2, p = .829$). No differences in HR values were observed between trials, P1 157 ± 13 beats/min, P2 158 ± 10 beats/min, and C 158 ± 8 beats/min, $F(2, 14) = 0.1, p = .882$. Calculated sweat rates were 1.4 ± 0.3 L/hr for P2 and 1.3 ± 0.4 L/hr for trials P1 and C. Mean weight loss over each 1-hr trial was 1 ± 0.3 kg, which represents less than 1% of mean body mass.

The RPE over the 1-hr run for both P trials was 15 ± 1 and was 14 ± 1 for the C trial; no differences were observed between trials, $F(2, 14) = 1.0, p = .378$. No difference was observed between trials for any of the psychological measures either at rest or during exercise, FAS P1 4.6 ± 0.6, P2 4.5 ± 0.6, and C 4.5 ± 0.7, $F(2, 14) = 0.3, p = .719$, and FS P1, 3.3 ± 0.5, P2 2.7, ± 0.8, and C 3.3 ± 0.5, $F(2, 14) = 0.4, p = .684$.

The mean values for GI discomfort were 1.9 ± .6, 1.2 ± .8, and 1.1 ± .7 for the P1, P2, and C trials, respectively, $F(2, 14) = 6.6, p = .010$. Mean differences between trials did not reach significance (P1 vs. P2, $p = .094$; P1 vs. C, $p = .073$; and P2 vs. C, $p = 1.00$). The measurements from the GI scale were strongly correlated with those from the visual analog scale ($r = .98$) and the FAS ($r = .98$). However, the measurements from the FS exhibited a weaker relationship with the visual analog scale ($r = .76$).

Mean blood glucose concentrations were 4.7 ± 0.6, 4.6 ± 0.6, and 5.3 ± 0.6 6 mmol/L for the P1, P2, and C trials, respectively, $F(2, 14) = 19.6, p < .001$ (Figure 2). No difference was observed between trials for blood lactate concentrations at any time point, $F(2, 14) = 2.5, p = .154$ (Figure 3).

The respiratory-exchange ratios averaged 0.93 ± 0.01, 0.90 ± 0.02, and 0.93 ± 0.01 for the P1, P2, and C trials, respectively, $F(2, 14) = 0.6, p = .579$. The rates of CHO oxidation, estimated from indirect calorimetry, were similar in each trial, P1 3.8 ± 0.4 g/min, P2 3.3 ± 0.4 g/min, and C 3.8 ± 0.2 g/min, $F(2, 14) = 3.5, p = .058$.

**Discussion**

The main finding of this study was that ingesting a 6.4% CHO-E solution significantly improved 1-hr running performance in comparison with ingesting a color- and taste-matched placebo. When asked to run as far as possible in 1 hr, 7 of 8 runners improved total distance covered when consuming the CHO-E solution. These results are consistent with those of other studies that show that CHO ingestion improves endurance capacity (Chryssanthopoulos, Hennessy, & Williams, 1994; Tsintzas, Williams, Singh, Wilson, & Burrin, 1995; Williams, Brewer, & Walker, 1992) and also improves endurance performance of endurance-trained runners during shorter, more intense exercise (Millard-Stafford et al., 1997).

To our knowledge, this is the first study to investigate the influence of CHO ingestion on 1-hr endurance-running performance, so it is difficult to make direct comparisons with other running studies of a similar duration. However, improvements in 1-hr exercise performance after ingestion of CHO have been shown in several cycling studies using time-trial protocols (Anantaraman et al., 1995; Ball et al., 1995; Below et al., 1995; Jeukendrup, Brouns, Wagemakers, & Saris, 1997; Mitchell et al., 1988).
Figure 2 — Mean blood glucose concentration (mmol/L) for each trial before and during each 1-hr run. *Significant difference between carbohydrate-electrolyte solution (C) and placebo trials (P1 and P2; $p < .05$). †Significant effect of time for Trial C.

Figure 3 — Mean blood lactate concentration (mmol/L) at rest and during each 1-hr running trial. †Significant effect of time ($p < .05$). Note. C = carbohydrate-electrolyte solution; P1 and P2 = placebo trials.
In the current study, the uncorrected overall improvements in distance covered of 2.6% and 2.4% after the ingestion of CHO are similar to the improvement observed previously in 1-hr cycle time-trial performance. Jeukendrup et al. (1997) reported that the time-trial performance of their cyclists was improved by 2.3% after the ingestion of a CHO-E solution in comparison with the ingestion of placebo. However, the 2.3% improvement in cycle time-trial performance is within the known variation of the cycle time-trial method (3.35%; Jeukendrup, Saris, Brouns, & Kester, 1996). In the current study we subtracted the known variation in the testing methodology, 1.4%, from the overall difference between the C and two PLA trials. Thus, we have confidence that the reported performance benefit of CHO-E solution ingestion was an effect of the intervention and not simply variation in the testing method. Another way of interpreting the results would be to consider that if the runners had been in a race, those in the PLA trial would have been approximately 150 m behind those in the C trial as they crossed the finish line.

Our findings are in agreement with those of Millard-Stafford et al. (1997), who, under controlled laboratory conditions, found that the ingestion of both a 6% and an 8% CHO-E solution improved 15-km running performance compared with the ingestion of water. Runners consumed 1 L of experimental solution 60 min before exercise, before ad libitum intake throughout the time trial. Unlike the current study, the performance benefit of CHO ingestion was only evident toward the end of the run. Self-selected running speed was approximately 5% faster over the final 1.5 km of the run during both CHO trials. Despite the similar duration, the current study differs from that of Millard-Stafford et al. in several aspects that may have influenced running performance. First, the 15-km run was performed in a warm environment (27 °C, 76% relative humidity). Exercising in a warm environment has been shown to cause a shift in substrate metabolism toward CHO oxidation and place a greater strain on the cardiovascular system as a result of the demands of thermoregulation (Burke, 2001). Thus, the benefits of providing CHO and fluid on performance may be magnified when exercising in a hot environment. This may explain, in part, why a large benefit was not observed in the current study, which was conducted in a thermoneutral environment.

Second, and key to performance testing, Millard-Stafford et al. (1997) used an intermittent running protocol with a manually controlled treadmill. The 15-km run was stopped on the completion of 7 km and 13.4 km for blood collections and ad libitum fluid intake. Because no warm-up was permitted, runners were instructed to perform at a “moderate” running speed for the first 5 min, before being asked to select speeds representing a “hard training pace.” After the last break (approximately 5 min) runners were then instructed to give an “all-out effort” to complete the final 1.5 km. Thus, the intermittent protocol may have prevented runners from following their “natural” or “optimal” pacing strategy toward the 15-km run. Millard-Stafford et al. observed no difference in running speed over the middle section of the run (7–13 km). In the current study, it is clear that improved performance is not a consequence of large differences in speed selection. Instead, the increase in distance covered with CHO ingestion is the result of runners’ selecting slightly faster speeds between 25 and 50 min (Figure 1). This observation is most likely a consequence of the automated treadmill’s being more responsive to spontaneous changes in self-selected running speed.
during the time trial. This phenomenon may be masked when treadmill running speed is controlled manually.

Relatively few studies have investigated the influence of CHO ingestion under real-life race conditions. It is interesting that the uncorrected performance benefit of the current study (2.6% and 2.4%) is similar to the performance improvement found with CHO ingestion during a 30-km road race (2.3%; Tsintzas et al., 1993). In that real-life study, runners performed thirty 1-km outdoor circuits, drinking either a 5% carbohydrate solution or water, immediately before and at 5-km intervals during the run. Unlike the current study, CHO ingestion did not appear to increase running speed. Instead, improved performance was attributed to runners’ being able to maintain their chosen running speed over the final 5 km of the run. In contrast to these earlier findings, Burke et al. (2005) found that providing approximately 1 g · kg⁻¹ · h⁻¹ CHO along with ad libitum water intake during a half-marathon had a negligible effect on race time in comparison with a placebo. Despite providing the CHO in the form of sports gels, the study failed to reduce the incidence of GI discomfort. In fact, ingesting sports gels induced some degree of GI discomfort in a small number of runners, which clearly impaired run performance. Drinking mineral water has been found to induce fewer symptoms of GI complaint than consuming a 6.8% CHO or CHO caffeinated drink during an 18-km run (van Nieuwenhoven, Brouns, & Kovacs, 2005). Despite not having a water-only trial, the ingestion of CHO in the current study appears to induce no greater risk of GI discomfort than the ingestion of placebo.

It has been suggested that taking physiological measures during time trials may interfere with the runners’ concentration (Jeukendrup et al., 1997) and therefore affect time-trial performance. In the current study all efforts were made to minimize interaction with the runner during the 1-hr run. Interaction was limited to the collection of expired air, delivery of drinks, and collection of finger-prick blood samples on three occasions during the run. In the current study, we are unable to determine whether run performance would have been further improved had no measurement interventions been included. However, the similarity between the two PLA trials suggests that interaction with the runners appeared to be consistent. With respect to disrupting running performance, CHO feedings have been shown to slow the time for a runner to pass through feeding zones during a half-marathon (Burke et al., 2005). Unpublished observations from our laboratory have shown that even drinking from easily accessible bottles causes a marked reduction in running speed on the automated treadmill. The reduction in speed is a consequence of the runners’ slowing to perform the action of tilting their head to drink. In the current study, we found that administering drinks in volumetric syringes allowed the runners to maintain running speed while drinking. In addition, providing the solutions in syringes ensured that the correct volume of fluid was consumed. The plastic syringe also reduced the risk of spillage, a common problem associated with providing drinks in cups.

The finding that CHO feedings improved 1-hr endurance-running performance in the current study is difficult to explain, because endogenous stores of CHO are unlikely to be limiting during exercise of 1 hr duration (Tsintzas, Williams, Boobis, & Greenhaff, 1995). Tsintzas, Williams, Boobis, and Greenhaff (1995) found that ingesting a 5.5% CHO solution immediately before and during a constant-pace 1-hr
treadmill run (70% VO2max) resulted in a decrease in muscle glycogen utilization in Type 1 fibers in comparison with ingesting water. Despite elevated blood glucose, total CHO-oxidation rates were similar between trials, and muscle glycogen was not limiting on completion of the 1-hr run. In the current study, any alteration in substrate metabolism with CHO ingestion is likely to have been masked by the intensity at which the run was performed—approximately 80% VO2peak (Coggan & Coyle, 1991). Consequently, in comparison with the study of Tsintzas, Williams, Boobis, and Greenhaff (1995) it is likely that CHO oxidation was elevated as a consequence of the increased demand on skeletal-muscle glycogen for energy provision (Arkinstall et al., 2004). The similarity in estimated substrate oxidation between trials in the current study is not surprising, because running speed and thus intensity were not significantly different over the three collection periods (p > .05). Preexercise feedings of CHO have been shown to cause hypoglycemia during exercise (Koivisto, Karonen, & Nikkila, 1981). The hypoglycemic response, however, has been shown to disappear within 10 min after exercise (Moseley, Lancaster, & Jeukendrup, 2003). Therefore, although the results do not show a pronounced hypoglycemic response to CHO ingestion in the current study, this occurrence could have been missed by the blood-collection times. If there was transient hypoglycemia in the current study during the first 10 min of exercise it did not appear to affect the selection of running speed. This finding is consistent with previous studies reporting that hypoglycemia during the first 10 min of exercise did not influence RPE or subsequent exercise performance (Moseley et al.).

In conclusion, the ingestion of a 6.4% CHO-E solution was associated with an increase in distance completed during 1 hr of treadmill running. There was no evidence that CHO ingestion provided any physiological or psychological advantage above that of ingesting a placebo solution, leaving the mechanisms responsible for improved performance unknown.

**References**


