Carbohydrate-Electrolyte Feedings and 1h Time Trial Cycling Performance

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The effects of a commercial sports drink on performance in high-intensity cycling was investigated. Nine well-trained subjects were asked to complete a set amount of work as fast as possible (time trial) following 24 h of dietary (subjects were provided with food, energy 57.4 ± 2.4 kcal/kg and carbohydrate 9.1 ± 0.4 g/kg) and exercise control. During exercise, subjects were provided with 14 mL/kg of either 6% carbohydrate-electrolyte (CHO-E) solution or carbohydrate-free placebo (P). Results showed that subjects’ performances did not greatly improve (time, 62:34 ± 6:44 min:sec (CHO-E) vs. 62:40 ± 5:35 min:sec (P); average power output, 283.0 ± 25.0 W (CHO-E) vs. 282.9 ± 29.3 W (P), P > 0.05) while consuming the sports drink. It was concluded that CHO-E consumption throughout a 1-h time trial, following a pre-exercise dietary regimen designed to optimize glucose availability, did not improve time or power output to a greater degree than P in well-trained cyclists.

Key Words: carbohydrate-electrolyte supplementation, sports drinks, high intensity exercise, drinking

It is widely documented that the ingestion of a carbohydrate-electrolyte beverage (CHO-E) during prolonged endurance exercise ( ≥ 2 h, ~70% VO_{2max}) benefits performance, even in trained subjects, by delaying fatigue, improving substrate availability and oxidation rates, and/or improving performance times (for a review, see reference 7). The influence (if any) of dietary variables on high intensity cycling performance of approximately 1 h duration is, however, more difficult to clarify.

Two studies have investigated the effects of altering pre-exercise carbohydrate alone on cycling performance of approximately 1 h (11, 18). Both demonstrated that an intake above reasonable levels (carbohydrate ≥ 6 g · kg body weight · d) produced neither significant effects on performance or hypoglycemia (blood glucose levels ≤ 3.5 mmol/L). Both studies indicate that if sports drinks are to provide any performance benefit it is unlikely to come from factors that influence substrate availability. Unfortunately, neither study investigated the effect of providing a CHO-E beverage throughout the exercise trials.
The influence of CHO-E consumption during cycling performances of approximately 1 h has been investigated (1-3, 6, 8-10, 13, 15, 16). Considering the aforementioned results of Hawley et al. (1997) and Paul et al. (2003), it is surprising that the majority of these studies (1-3, 8-10, 13, 16) but not all (6, 15) demonstrate that CHO-E beverages taken during the event have a positive effect on performance.

The potential mechanism(s) by which this performance improvement might occur has also been examined. The availability of blood glucose (1, 15), neuromuscular (16), and placebo (6) effects have all been examined in the literature. The focus of the present study, however, is on performance and therefore will only be able to elucidate if, and not how, CHO-E beverages affect high intensity cycling performance.

The CHO-E beverage studies all note the importance of pre-trial dietary control and have taken some precautions to standardize it. The dietary preparation for these studies, however, ranged from subjects either “self-selecting” their meals in the preceding 24 h using nonspecific dietary consumption guidelines (e.g. subjects instructed to consume a “high-carbohydrate” diet) (13) to subjects fasting > 6 h pre-trial (15). In effect, this could result in subjects that 1) have considerably different pre-trial muscle glycogen concentrations both within and between subjects, and 2) have not consumed food for up to 12 h in the case of a morning trial. Both factors limit the confidence with which we can interpret the effectiveness of consuming carbohydrate-containing beverages during high-intensity cycling.

The aim of the present study was therefore to strictly apply the guidelines suggested for optimal pre-exercise nutrition and determine if a commercial sports drink consumed throughout a cycling time trial of approximately 60 min improves performance.

The dietary manipulation was intended to supply a high-carbohydrate diet for the 24 h prior to each trial, a high-carbohydrate/low-dietary fiber/low-fat snack 2 h pre-exercise and adequate fluid intake over 24 h to optimize body carbohydrate stores and to avoid any effects of hypohydration. This was done to minimize any changes in performance that could be attributed to subject dietary preparation.

Results from this type of study should also make it easier to educate cyclists on the appropriateness of consuming commercial sports drinks for cycling events lasting approximately 60 min as the dietary preparation is more in keeping with suggested pre-exercise behaviors (4).

A time trial protocol was chosen for its low coefficient of variation and its use in previous research primarily investigating performance (12, 13). In the present study, however, we have standardized the dietary variables, and investigated whether there is a performance-enhancing effect from a commercially available sports drinks when athletes present to the laboratory in an optimal nutritional and physiological racing state.

**Methods**

Nine well-trained male subjects (cyclists and triathletes) volunteered for this double-blind crossover study approved by both the Deakin University and Griffith University ethics committees. Subject details (mean ± standard deviation) were
age 30.0 ± 7.3 y, body mass 75.2 ± 6.6 kg, VO$_{2peak}$ 65.1 ± 5.9 mL/kg/min, and W$_{max}$ 386 ± 21 W. A number of the subjects ($n = 6$) had taken part in a previous (3 to 4 wk prior) reliability investigation (unpublished) during which subjects undertook 2 incremental tests to exhaustion on a electromagnetically braked cycle ergometer (Schoberer Rad Messtechnik, Jülich/Königskamp, Germany) which quantified subjects peak oxygen consumption (VO$_{2peak}$), maximum heart rate (HR$_{max}$), and maximal work load (W$_{max}$). The remaining subjects were asked to perform an incremental test prior to commencing the study. The incremental test began at 100 W and increased by 50 W every 5 min until exhaustion. Similar to Jeukendrup et al. (13), W$_{max}$ was calculated using the following equation:

$$W_{max} = W_{out} + (t/300) \times 50$$

where $W_{out}$ is the last completed stage and $t$ is the time in the final stage. For all exercise bouts (incremental maximal tests, familiarizations, and time trials), Sport-tester® (Polar, Kemele, Finland) heart rate monitors were used.

**Procedure**

**Pre-Trial Control**

Subjects were provided with all foods and fluids to be consumed for the 24 h prior to the testing sessions (energy ≈ 55 kcal/kg body weight and carbohydrate ≈ 9 g/kg body weight). Subjects were also provided with a “race breakfast” (carbohydrate ≈ 2 g/kg body weight) for the morning of the trial. The diet was designed to match the pre-exercise nutritional intake suggested to athletes to prime muscle fuel stores (4). Subjects were provided with a checklist to complete as they ate their provisions including a section to note any variations from the items provided. If subjects consumed more or less food than the amount provided for the initial experimental trial, this was noted in their food record, and the same type and amount of food was then consumed in the preceding 24 h of the 2nd experimental trial. Subjects were asked to refrain from consuming caffeine or alcohol-containing foods or fluids for the 24 h prior to each trial. Subjects were required to consume the “race breakfast” (juice, fruit bread, jam, and a sports bar in various quantities) approximately 2 h prior to the commencement of the exercise trial. The aim of the breakfast was to “top-up” liver glycogen stores while avoiding gastrointestinal upsets (4). Subjects were permitted to partake in light training on the day prior to the trial; however, this activity was to be completed before midday.

**Exercise Trial**

The need for familiarization was based on time trial experience and the number of instances subjects had ridden in our laboratory. When necessary, subjects completed familiarization trials on the cycle ergometer prior to the exercise tests. The exercise trial consisted of a simulated time trial in which the ergometer was set in the isokinetic mode (constant cadence, variable power output). Cadence was based on individual preference (range 90 to 95 rpm) and was the same for both trials. After a warm-up, subjects were asked to perform a certain amount of work
(equal to about 60 min of cycling) as fast as possible. The time taken to complete
the set amount of work was the performance measure. This type of testing has been
reported to generate highly reproducible results (13, 14). The total amount of work
was calculated as 14 kJ/kg body weight (body weight measured at initial time trial).
This figure was chosen as previous research has shown well-trained cyclists take
≈ 25 min to complete a similar 7 kJ/kg time trial (5).

Subjects were informed that an intensity of approximately 75% \( W_{\text{max}} \) was
recommended for optimal 1 h cycling performance. Subjects were only able to
observe their power output, heart rate, and time elapsed for the 1st 10% of the
trial. Following this “pacing period” the only information subjects received was the
percentage of work completed. In the final 10% of each time trial a countdown of
the number of kilojoules remaining and verbal encouragement were provided. A fan
was placed in front of the subjects to provide some cooling during the time trials.
A single fingertip blood sample was taken at the completion of each trial (2 min
post-exercise). The sample was immediately transferred to an Advantage™ (Roche
Diagnostics) blood glucose monitor for quantification of the subject’s blood glucose
level via the reaction of the glucose dehydrogenase enzyme on the test strip.

Similarly to Jeukendrup’s study (13), subjects performed 2 time trial tests
that were undertaken at the same time of the day to avoid any circadian variance.
The trials were conducted in environmentally stable conditions (temperature
22 °C, relative humidity 45 to 55%).

**Beverages**

Subjects received a different drink on each trial. Trials were separated by at least
4 d. The drinks consumed were 1) 6% carbohydrate-electrolyte (CHO-E) solution
(Gatorade®, Quaker Oats) and 2) artificially sweetened (aspartame) and flavored
placebo (P). The drinks were developed to be indistinguishable, made with the
same flavorings and electrolyte concentrations. The drinks were provided in a
double-blind, random order with 5 subjects receiving the placebo drink and the
remaining 4 sports drink solution in their 1st trial.

During the warm-up for each trial (self-paced at a intensity below 100 W)
the subjects consumed an 8 mL/kg bolus of the test beverage. They then ingested
3 further amounts of 2 mL/kg each between 20 to 30%, 50 to 60%, and 70 to
80% of the total amount of work. This fluid regimen was chosen to promote rapid
gastric emptying (19). The drinks were placed in bidons that were left resting on
the ergometer frame requiring subjects to reach down to collect the fluid, as is
common in race conditions.

On completion of both trials subjects were asked to complete a questionnaire
detailing their experiences during the study. Food consumption data was analyzed
by a qualified sports dietitian using Foodworks™ version 3.01 (Xyris Software,
Brisbane), dietary analysis software.

**Statistics**

The presence of any order effect and the effect of drinks on performance were
tested via paired \( t \)-tests. All results are expressed as mean ± standard deviation.
Statistical significance was set at \( P < 0.05 \).
Results

Dietary Intake

Table 1 details the subjects’ 24-h pre-trial dietary intake. The data was calculated following a review of dietary checklists and clarification with each subject of foods consumed. The “race breakfast” provided 8.8 ± 0.6 kcal/kg and 1.8 ± 0.2 g/kg of energy and carbohydrate, respectively. Unfortunately, 1 subject inadvertently consumed 3 cups of coffee exactly 24 h prior to his 1st trial. The subject was a regular coffee drinker and was told to repeat this intake for the 2nd trial. On review of the subject questionnaires it became apparent that the time trial drinks were indistinguishable. Three subjects correctly identified the trial during which they thought they received the sports drink, but only one indicated any degree of certainty.

Performance

No test order effect was seen. On average, the subjects rode 0.2% faster drinking the CHO-E drink compared with the placebo solution (Table 2). Figure 1 illustrates the individual changes in time trial performance. This level of performance improvement was not statistically significant ($P = 0.85$). Five of the nine subjects rode faster while receiving the sports drink. No statistically significant differences were seen in average power (Table 2). Likewise, no changes were observed in heart rate (average CHO-E 165.6 ± 10.4 vs. P 167 ± 11 bpm), rate of perceived exertion (average CHO-E 15.4 ± 1.7 vs. P 15.4 ± 1.7) or post-exercise blood glucose level (CHO-E 5.39 ± 0.8 mmol/L vs. P 4.78 ± 0.8 mmol/L) between the 2 drinks.

Table 1  Average Dietary Intake Data of Day –1

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<table>
<thead>
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<tbody>
<tr>
<td>Total energy (kcal)</td>
<td>4316 ± 370</td>
</tr>
<tr>
<td>Energy/kg (kcal/kg)</td>
<td>57.4 ± 2.4</td>
</tr>
<tr>
<td>Total carbohydrate (g)</td>
<td>682 ± 57</td>
</tr>
<tr>
<td>Carbohydrate/kg (g/kg)</td>
<td>9.1 ± 0.4</td>
</tr>
<tr>
<td>Total fluid (mL)*</td>
<td>4037 ± 760</td>
</tr>
</tbody>
</table>

Note. Values are averages ± standard deviation. *Excluding fluid in food.

Table 2  Average Time and Power Output of Time Trials

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time (min:s)</th>
<th>Power (watts)</th>
</tr>
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<tbody>
<tr>
<td>CHO-E</td>
<td>62:34 ± 6:44</td>
<td>283.0 ± 25.0</td>
</tr>
<tr>
<td>Placebo</td>
<td>62:40 ± 5:35</td>
<td>282.9 ± 29.3</td>
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Note. Values are averages ± standard deviation.
Discussion

Our main finding was that with adequate pre-exercise carbohydrate, average performance did not differ when a commercially available sports drink was ingested during a 1-h cycling time trial. Although we found an average performance improvement (0.2% increase in power output), the magnitude of this improvement was not statistically significant.

Five of the subjects rode faster following ingestion of the CHO-E beverage during the time trial. There was no difference in the ranked time trial times, aerobic capacity (as determined by VO$_{2\text{peak}}$), or post-exercise blood glucose levels of these athletes compared to those who rode faster while receiving the P.

Improvements in performance following the consumption of sports drinks during cycling tasks lasting approximately 1 h have been demonstrated (1-3, 8-10, 13, 16). In the most “real life” of these, Jeukendrup and colleagues (13) conducted a performance-based study that demonstrated a significant improvement in performance of 2.3%. The difference in significance between this result and the present data might be attributed to the larger number of subjects ($n = 19$) in the Jeukendrup et al. study (13). Below and co-authors (3) demonstrated a 6.3% improvement in performance when their subjects were asked to complete a set amount of work as fast as possible after 50 min of intense cycling (85% VO$_{2\text{max}}$). In another trial in which subjects were asked to cycle as far as possible in 1 h, el-Sayed et al. (8) demonstrated that their trained subjects could cycle further following the ingestion of a carbohydrate-containing beverage (i.e. 41.5 km vs. 41 km). The potential limitation with all of these studies, however, is the lack of strict dietary control. In our investigation, subjects were provided with adequate carbohydrate pre-trial in an attempt to elucidate if further ingestion of carbohydrate during the event improved performance. One could suggest that the magnitude of improvements seen in previous studies could in part be the result of the more “laboratory”-based protocols that have athletes fast pre-trial.
We identified only 2 studies where the researchers provided subjects with pre-prepared food for the 24 h prior to a 1 h cycling time trial to ensure pre-exercise dietary standardization (15, 16). Both studies involved a “time-to-fatigue” performance test (i.e. protocols with higher coefficients of variation) and neither demonstrated a statistically significant improvement in performance despite increased average times [13% (16) and 2.2%(15)] to fatigue when ingesting carbohydrate. In both studies, however, subjects were required to provide routine gas exchange and blood sampling, factors that a number of authors have suggested might influence the “true” performance of the subjects (13, 17).

The underlying mechanism by which sports drinks could be of benefit to exercise conducted over approximately 1 h (i.e. 80 to 85% VO$_{2\text{max}}$) is presently under investigation. The findings of Anantaraman and co-workers suggested that feeding carbohydrate during exercise showed no benefit over immediate pre-exercise carbohydrate consumption (1). Furthermore, McConnell and co-workers (15) suggested that any difference in performance was unlikely to arise from a metabolic advantage that the carbohydrate might provide. They found that of 84 g of carbohydrate ingested only 28 g appeared in the peripheral circulation during trials when providing sports drink before and during testing. Likewise, we observed no post-exercise blood glucose level differences, suggesting that glucose availability was not significantly altered by the consumption of the CHO-E beverage throughout the time trials.

In a recent investigation, Nikolopoulos and colleagues (16) demonstrated changes in muscle fiber electrical activity during 1 h trials when ingesting carbohydrate compared with placebo. This provides further evidence that consuming carbohydrate beverages during high-intensity exercise has effects outside those relating to substrate availability that could assist in improving performance. However, any physiological changes induced by the consumption of a CHO-E beverage during exercise in the present study were not sufficient to affect performance.

Our results could be explained by the normal variation seen in human performance as the coefficient of variation in tests of this nature is ≈ 3% (13). This study involved a maximum of 2 familiarization trials on the laboratory bicycle by subjects. A limitation of any study involving time trial cycling is the unfamiliarity of cyclists with the laboratory bicycle equipment. It has been suggested that up to 6 bouts of time trial cycling might be required before reliable results can be obtained (J. Hawley, personal communication).

In conclusion, this study was designed to examine the effect of commercial sports drinks on performance when an athlete complies with the guidelines suggested for optimal pre-exercise nutrition (i.e. high dietary carbohydrate intake and a carbohydrate meal 2 to 4 h prior to exercise). Under such conditions, CHO-E ingestion had no effect on 1-h cycling performance.

Acknowledgements

The authors would like to acknowledge the assistance of Mark Osborne and Shaun D’Auria from the Queensland Academy of Sport, Greg Cox and Louise Burke from the Australian Institute of Sport, and Beverley Gallagher and Judy Bauer from the Wesley Hospital for their technical assistance. Likewise thanks to Deakin University and Nestle Australia for their financial support.
References


