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CARBOHYDRATE-ELECTROLYTE INGESTION HAS NO EFFECT ON HIGH INTENSITY RUNNING PERFORMANCE OR BLOOD METABOLITES

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ABSTRACT

CARBOHYDRATE-ELECTROLYTE INGESTION HAS NO EFFECT ON HIGH INTENSITY RUNNING PERFORMANCE OR BLOOD METABOLITES. **Robinson, E.M., L.B. Graham, J. Moncada, B. Jensen, M. Jones AND S.A. Headley. JEPonline. 2002;5(1):49-55.** This study was designed to explore the effect of a carbohydrate-electrolyte solution (CE) on time to exhaustion in treadmill running. After a 12-hr fast, competitive male runners (mean±SD; age 24.10±4.31 years; body mass 74.27±19.51 kg; VO₂peak 65.51±7.19 ml/kg/min) from western Massachusetts (n=10) performed two run to exhaustion protocols, each a week apart, at 100% VO₂peak. Sixty minutes prior to the run, subjects ingested either a CE or a placebo (PL) beverage. Variables of glucose, lactate, ammonia, respiratory exchange ratio (RER), and The Borg Category-Ratio Scale Rate of Perceived Exertion (RPE) were examined with a repeated measures 2x3 analysis of variance (ANOVA), computed separately for each variable. The interaction effect was not significant (p>0.05) for any variable. The main effects for time were significant (p<0.05) for lactate, RER, and RPE. Lactate, RER, and RPE scores were higher at the end of the run as compared to the baseline and post warm-up time periods. No differences were found for glucose and ammonia. A repeated measures t-test was employed to compare the time to exhaustion scores. Time to exhaustion was not significantly (p>0.05) longer during the CE trial. In conclusion, time to exhaustion at 100% VO₂peak was not improved with the consumption of a CE beverage prior to the run.

Key Words: Exhaustion, Glucose, Lactate, Ammonia, RER, RPE.

INTRODUCTION

Fatigue can be slowed by many extraneous variables, such as the ingestion of carbohydrate supplementation. One of the most commonly known causes of fatigue is the reduced availability of carbohydrate for oxidation. Researchers (1, 3, 4) have examined the effects of carbohydrate supplementation on endurance exercise lasting over 90 min. Thus, fatigue primarily occurs in the latter stages of prolonged endurance exercise when substrate

concentrations are not readily available to fuel the muscle tissue. Recently, the possibility of enhancing anaerobic performance through carbohydrate supplementation during exercise has been proposed (5,6-9).

The relative availability of glucose in the blood and glycogen in the working muscles is the limiting factor when determining the endurance capacity for high intensity endurance exercise (10,11). For the endurance athlete, one of the parameters that contribute to success in competition and a high volume of training is the availability of carbohydrate as an energy substrate. After an overnight fast, liver glycogen levels become low or depleted, which compromised the body's ability to regulate blood glucose (10). The decline in glucose levels in a fasted state contributes to the early onset of fatigue during endurance exercise. Ingesting carbohydrate during prolonged, high intensity exercise can enhance performance by increasing plasma glucose levels, thus reducing the early onset of fatigue in the athlete (4).

During the past decade most of the researchers in the area of carbohydrate supplementation have focused on endurance events greater than 90 min. However, there is a great need to effectively study the metabolic parameters that exist during short duration high-intensity exercise, and establish whether carbohydrate ingestion provides an ergogenic effect, similar to or different from endurance exercise.

We hypothesized that during an exhaustive run of high-intensity, the sprint capacity of male runners would be enhanced under the influence of carbohydrate supplementation compared to without supplementation.

METHODS

Subjects

The subjects in this study consisted of 10 competitive male runners. The subjects were between 18 and 36 years of age, ran a minimum of 25 mi/week, had a $\text{VO}_{2\text{peak}}$ of at least 55 mL/kg/min, and were recruited from various running clubs within Western Massachusetts. Subjects were required to adhere to the guidelines set in the testing procedures.

Testing Procedures

Body weight (kg) and height (cm) were measured with a Detecto™ scale. Heart rate was measured with a Polar™ Vantage XL Heart Rate Monitor (Model # 45900, Stamford, CT). Ratings of perceived exertion (RPE) were measured with the Borg 15-point category-ratio scale (14).

Respiratory values of oxygen consumed (VO_2) and carbon dioxide expired (VCO_2) were measured from expired air using a SensorMedics metabolic cart (2900 System, Yorba Linda, CA). Plasma glucose levels were measured using enzymatic spectrophotometry as described by Sigma Diagnostics (assay number G-5767). The blood lactate levels were measured using the YSI Lactate Analyzer (Model 1500-L, Yellow Springs, OH). Plasma ammonia levels were measured using enzymatic spectrophotometry as described by Sigma Diagnostics (assay number 171-UV). Time to exhaustion was measured according to the protocol of Robinson, Graham, and Headley (21), and was measured from the time the subjects removed their hands from the handrails to start the run, until they put them back on the handrails to end the run.

Procedures

Subjects were required to participate on three test days. Prior to testing, subjects were given an informed consent document to complete, as well as a medical history questionnaire and a medication and drug summary. Subjects were also asked to record a detailed training journal, and a diet journal, for the day prior to each of the testing sessions. The subjects were asked to maintain similar dietary and training regimes prior to each trial. Diet analyses were calculated for total calories, grams and percent of carbohydrate, protein, and fat with Mosby's NutriTrac Nutritional Software.

The first test day consisted of a peak oxygen consumption test ($\text{VO}_{2\text{peak}}$) (19) to assess the aerobic capacity of the subject via indirect calorimetry. The $\text{VO}_{2\text{peak}}$ test was utilized to establish 100% $\text{VO}_{2\text{peak}}$ for the running trials. The $\text{VO}_{2\text{peak}}$ test commenced at 0% grade with a running speed of 4.0 mi/hr for 1 min, increased to 5 mi/hr from 1-2 min, and thereafter speed was increased each min to 9 mi/hr at 6 min. The percent grade was then increased 1%/min to $\text{VO}_{2\text{peak}}$, which was defined as the highest VO_2 value measured during the test. The peak value was associated with a respiratory exchange ratio greater than 1.0, peak heart rate comparable to an age-predicted maximum, and a plateau in VO_2 with a change in workload (16). The second and third test days were identical counter-balanced, double blind trials using 500 mL of lemon-lime carbohydrate-electrolyte supplement (Gatorade, 6% solution, CE) or a placebo (Gatorade, PL) beverage. Both beverages were formulated and donated by the Gatorade Company (Gatorade, Barrington, IL). The beverage was consumed at refrigerator temperature and according to the guidelines established by the American College of Sports Medicine (ACSM) (2): 500 ml, 1 hr before exercise.

Prior to the trials, each subject performed two practice runs on the treadmill to familiarize themselves with the running protocol. Each subject warmed-up at 75% $\text{VO}_{2\text{peak}}$ for 15 min. After the warm-up, a 5 min rest was taken. After the rest, each subject ran at 100% $\text{VO}_{2\text{peak}}$ until exhaustion, with each trial 1 week apart. Subjects were not allowed to wear a wristwatch during the trials. The metabolic cart was calibrated prior to each session.

Plasma glucose (15), blood lactate (16), plasma ammonia (17), and RER (13) were measured during each trial at baseline before the warm-up, after the 15-min warm-up, and after exhaustion was reached. Blood was drawn via venipuncture and analyzed in duplicate. Ratings of perceived exertion (RPE) were measured with the Borg 15-point category-ratio scale (14) during each trial after the 15-min warm-up, and after exhaustion.

Statistical Analysis

The results obtained for the dependent variable time to exhaustion were analyzed using a repeated measures t-test. A 2x3 (beverage x time) repeated measures analysis of variance (ANOVA) was computed for each dependent variable of glucose, lactate, ammonia, and RER. A 2x2 (beverage x time) repeated measures ANOVA was computed for RPE at the time periods of after the 15-min warm-up, and after exhaustion. Statistical significance was accepted at $p < 0.05$, and all analyses were performed using the Statistical Package for Social Sciences (20).

RESULTS

The subjects of this study were competitive male runners between 18 and 36 years old from Western Massachusetts. Descriptive statistics for the subjects and for the physiological data are presented in Table 1 and Table 2, respectively. To more efficiently describe the results of the study, two subsections are presented: (a) the time to exhaustion variable analysis; and (b) the analyses for the physiological variables.

Table 1: Descriptive characteristics of the subjects.

Age (yr)	$\text{VO}_{2\text{peak}}$ (mL/kg/min)	Weight (Kg)
4.10±4.31	65.51±7.19	74.27±19.51

Time to Exhaustion

The mean time to exhaustion running score with a CE beverage condition and the mean time to exhaustion running score with a PL beverage condition were not significantly different, $t=1.24$, Table t (9)=±2.26, $p > 0.05$. The mean time to exhaustion scores are presented in Figure 1.

Physiological Variables

Data for all physiological variables are presented in Table 2. For blood glucose and ammonia, no significant beverage x time interactions, beverage main effects, or time main effects were found. For each of lactate, RER and RPE, a significant main effect for time was found. Mean lactate, RER and RPE values at the 15-min time period were not significantly ($p>0.05$) different from the baseline time period.

However, values at the end of the trial were significantly ($p<0.05$) higher than an average of the means at baseline and 15-min time periods.

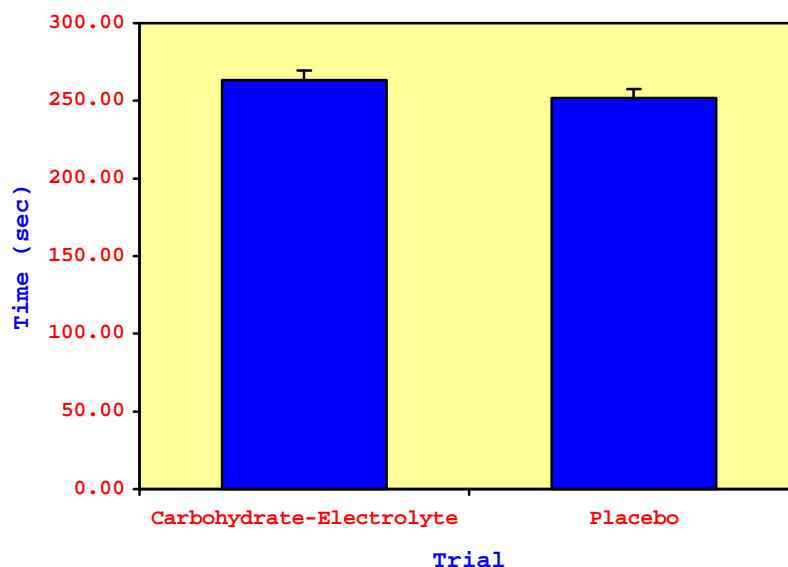


Figure 1. Times to exhaustion (s) for the CE and PL trials.

Table 2. Physiological data for male runners after a run to exhaustion during the CHO and PL trials.

<i>Variable</i>	<i>Baseline</i>	<i>15-min</i>	<i>Exhaustion</i>
<i>Glucose (CE)</i>	89.40±6.64	90.30±5.85	88.60±4.33
<i>Glucose (PL)</i>	87.70±3.06	83.30±.64	96.20±8.36
<i>Lactate (CE)</i>	1.16±0.21	1.37±0.26	7.53±0.42
<i>Lactate (PL)</i>	1.11±0.14	1.54±0.26	7.39±0.48
<i>Ammonia (CE)</i>	113.00±15.25	150.90±17.98	175.10±17.26
<i>Ammonia (PL)</i>	182.60±25.22	177.00±17.96	183.30±21.75
<i>RER (CE)</i>	0.90±0.04	0.98±0.04	1.17±0.04
<i>RER (PL)</i>	0.90±0.03	0.92±0.02	1.15±0.04
<i>RPE (CE)</i>		3.40±0.73	9.30±0.26
<i>RPE (PL)</i>		2.70±0.65	9.10±0.38

CE=Carbohydrate-Electrolyte; PL= Placebo; Glucose (mg/100 mL); Lactate (mmol/L); Ammonia (μ mol/L)

DISCUSSION

The research was designed to determine whether or not supplementation with a carbohydrate-electrolyte beverage prior to high intensity running would increase the time to exhaustion in competitive male runners. The variables that were examined included time to exhaustion, plasma glucose, blood lactate, plasma ammonia, respiratory exchange ratio (RER), and rating of perceived exertion (RPE).

The major finding of this investigation was that high intensity running was not improved subsequent to a carbohydrate-electrolyte supplementation regimen. Secondary physiological findings were also observed which clarified the intense nature of the protocol. Lactate, RER, and RPE scores were higher at the end of the run to exhaustion as compared to the baseline and post warm-up time periods. Glucose and ammonia, however, did not change over the three test trials.

The running protocol utilized in this study was the Robinson Protocol (21). Robinson et al. (21) examined the test re-test coefficient of stability to test the consistency of the times for the run to exhaustion protocol. The reliability estimate in the study was 0.993 using 5 subjects. Hence, the fact there was no difference between the two run tests to exhaustion was probably not due to a measurement error

This study is one of the first investigations where the effects of ingesting carbohydrate on maximal running capacity was assessed together with measurement of glucose, lactate, ammonia, RER, and RPE. The effects of CE supplementation on high intensity and sub-maximal runs has been examined by other researchers; however, Robinson et al. and Pizza et al. (21,9) were the only researchers to examine running to exhaustion at peak capacity. Pizza et al. (9) reported that high intensity short duration running was enhanced following a carbohydrate loading protocol. Pizza et al. (9) did not use a beverage supplementation protocol; rather, the study involved a multiple day dietary manipulation of either a high carbohydrate diet or a mixed diet. Tsintzas et al. (22) reported that during a run to exhaustion, running time was longer in the carbohydrate-supplemented trial than in the PL. Ball et al. (5) reported that sprint performance following 50 min of cycling was improved with the supplementation of a carbohydrate-electrolyte beverage. Jarvis (8) examined cyclists to determine if the intermittent feeding of a carbohydrate-electrolyte supplement would improve the sprint performance of female cyclists during two 50-min high-intensity (80% $\text{VO}_{2\text{max}}$) cycling bouts, one with the ingestion of a 7% carbohydrate-electrolyte supplement, and the other with a “Crystal Light” PL. In agreement with the results of this study, Jarvis (8) found that carbohydrate-electrolyte ingestion did not significantly increase the sprint performance of female cyclists after 50 min of high-intensity cycling. However, these researchers did not examine an all out high intensity exercise bout to exhaustion, where exhaustion was determined individually.

Subjects in the current research study were competitive male runners who were cognizant of the ergogenic effect of carbohydrate supplementation on running performance. The evidence of similar glucose values between trials and among time periods suggests that the high intensity nature of the activity did not allow enough time for an interaction between the beverage and time periods. Although glucose is the primary fuel for short term, high intensity exercise, and the depletion of glycogen has been demonstrated to be related to the onset of fatigue (4), the time involved in the run to exhaustion protocol was not long enough to elicit a depletion of the glucose and glycogen stores within the blood, muscles, and the liver. Glycogen depletion or hypoglycemia was not responsible for the onset of fatigue, and thus fatigue had to be reached by another mechanism.

Williams (2) stated that fatigue is the incapacity to pursue exercising at a desired level of intensity, and can be either of central or peripheral origin. Fatigue is linked to both the intensity and the duration of the exercise, and is therefore associated with a decrease in phosphocreatine (PC) levels, muscle glycogen levels, blood glucose levels, and a decrease in blood volume (7). Some other mechanisms that are associated with fatigue include the accumulation of lactate, the accumulation of ammonia, decreased pH, increased inorganic phosphates, loss of muscle potassium, and an increase in brain serotonin.

The subjects in this study ran to volitional exhaustion, and thus reached fatigue by some mechanism other than glycogen depletion. Although many phenomena take place during the process of fatigue, the probable cause of fatigue during this research study of high intensity exercise was the disruption of cellular metabolism (7). Although a depletion of PC may be related to the incapacity to sustain a high force production in extremely high intense exercise, the cellular disruption may have been attributable to a greater dependence on glycolytic ATP turnover and an associated metabolic acidosis.

The subjects in this study had lactate levels ranging from baseline levels of 1.0 to greater than 8.0 mmol/L at exhaustion. Lactate levels greater than 6.0 mmol/L may be high enough to contribute to fatigue (16, 2). High lactate levels coincide with increased proton accumulation, which in turn can potentially inhibit the enzyme phosphofructokinase (PFK) within the muscle, and thus slow glycolysis. This increased acidity also inactivates some of the key enzymes involved in energy transfer and further inhibits muscle contractility (23, 16).

Similar to the accumulation of lactate, increasing levels of ammonia have also been associated with fatigue (23,24). The subjects in this study had high plasma ammonia levels (greater than 180 μ mol/L). Roeykens et al. (24) reported high ammonia levels at the end of a graded maximal exercise test, and also postulated that the rise in ammonia was possibly associated with fatigue. Carbohydrate-electrolyte supplementation did not have an effect on ammonia levels; however, ammonia may still have been a contributing factor in fatigue at this intensity of exercise.

One of the possible causes of fatigue can be explained via the central fatigue hypothesis (7). The central fatigue hypothesis suggests that increased brain serotonin can cause deterioration in exercise performance. Low plasma branch chain amino acids (BCAA) (leucine, isoleucine and valine) allow the small amino acid tryptophan to effectively cross the blood-brain barrier and thus be converted to serotonin. High levels of serotonin have been shown to decrease anxiety, create a perception of relaxation, and thus when related to exercise performance, may decrease time to fatigue (7). Relative to the perception of general fatigue, the RPE scores were not different between the trials; thus the perception of work was not different when consuming either a CE beverage or a PL.

In conclusion, all-out running time to exhaustion is not increased when competitive male runners are supplemented with a carbohydrate-electrolyte beverage. Thus, runners who engage in high intensity, short-duration running do not benefit from a carbohydrate-electrolyte supplementation regimen prior to racing. Additionally, ammonia levels do not decrease when consuming a carbohydrate-electrolyte beverage prior to racing.

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