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Metabolic and Performance Effects of Raisins Versus Sports Gel as Pre-Exercise Feedings in Cyclists

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Abstract. Kern, M., C.J. Heslin, and R.S. Rezende. Metabolic and performance effects of raisins versus sports gel as pre-exercise feeding in cyclists. *J. Strength Cond. Res. 21(4):1204–1207. 2007.*—Research suggests that pre-exercise sources of dietary carbohydrate with varying glycemic indexes may differentially affect metabolism and endurance. This study was designed to examine potential differences in metabolism and cycling performance after consumption of moderate glycemic raisins vs. a high glycemic commercial sports gel. Eight endurance-trained male ($n = 4$) and female ($n = 4$) cyclists 30 ± 5 years of age completed 2 trials in random order. Subjects were fed 1 g carbohydrate per kilogram body weight from either raisins or sports gel 45 minutes prior to exercise on a cycle ergometer at 70% $\dot{V}O_2$max. After 45 minutes of submaximal exercise, subjects completed a 15-minute performance trial. Blood was collected prior to the exercise bout, as well as after the 45th minute of exercise, to determine serum concentrations of glucose, insulin, lactate, free fatty acids (FFAs), triglycerides, and β-hydroxybutyrate. Performance was not different ($p > 0.05$) between the raisin (189.5 ± 69.9 kJ) and gel (188.0 ± 64.8 kJ) trials. Prior to exercise, serum concentrations of glucose and other fuel substrates did not differ between trials; however, insulin was higher ($p < 0.05$) for the gel (110.0 ± 70.4 $\mu U \cdot ml^{-1}$) vs. raisin trial (61.4 ± 37.4 $\mu U \cdot ml^{-1}$). After 45 minutes of exercise, insulin decreased to 14.2 ± 6.2 $\mu U \cdot ml^{-1}$ and 13.3 ± 18.9 $\mu U \cdot ml^{-1}$ for gel and raisin trials, respectively. The FFA concentration increased (+0.2 ± 0.1 $mmol \cdot L^{-1}$) significantly ($p < 0.05$) during the raisin trial. Overall, minor differences in metabolism and no difference in performance were detected between the trials. Raisins appear to be a cost-effective source of carbohydrate for pre-exercise feeding in comparison to sports gel for short-term exercise bouts.

Key Words. ergogenic, endurance, cycling, glycemic index, carbohydrate

Introduction

Dietary carbohydrate has been demonstrated to enhance endurance performance when fed either before (11) or during (8) exercise. As reviewed by Burke et al. (1), researchers have suggested that pre-exercise carbohydrate feedings may prove most beneficial if the carbohydrate source has a relatively low glycemic index (GI). Glycemic index is a measure of the effect that a food has on the glycemic response over time (7). It is typically measured by comparing the 2-hour blood glucose response to 50 g of carbohydrate from a test food vs. 50 g of carbohydrate from a standard food (either glucose or white bread).

Although not all studies agree, likely because of differences in timing of feeding, quantity of carbohydrate, or GIs of test foods, some research suggests that consumption of a lower GI food prior to exercise is more effective in enhancing performance than consumption of higher GI foods (2, 15). Improvements in performance may be because of reduced feeding-induced hyperglycemia resulting in a lower insulin response, which may prevent subsequent exercise-induced "reactive hypoglycemia" as well as lower pre-exercise blood lactate and free fatty acid (FFA) concentrations. However, several studies have detected no difference in performance for pre-exercise feedings of lower vs. higher GI foods (4, 5, 12, 15, 16). Some research also suggests that lower GI feedings promote higher blood glucose concentrations later in exercise compared with higher GI feedings, which has been associated with significant improvements in some (15) but not all (9) studies.

Raisins are a nutritious, widely available, typically palatable, and potentially cost-effective source of dietary carbohydrate with a GI previously determined to be 64 (7). Sports gels are carbohydrate-based, semisolid, commercial sports supplements marketed as a convenient exogenous energy source. Research has previously demonstrated that low-cost, natural foods rich in carbohydrate fed prior to exercise can influence performance similarly to a more expensive, commercial sports supplement (10).

The objective of this study was to assess differences in metabolism and cycling performance after consumption of a lower (raisins) vs. a higher (commercial sports gel) GI food. We hypothesized that feeding a lower GI food 45 minutes prior to initiation of exercise would favorably alter metabolism and exercise performance.

Methods

Experimental Approach to the Problem

This study was designed to determine the metabolic and performance differences of a commercial sports gel vs. raisins, which are similar in total carbohydrate and moisture contents but different in GIs, when fed prior to exercise. To accomplish this, we fed isoenergetic amounts of the foods 45 minutes prior to the subjects completing a constant intensity 45-minute exercise bout followed by a 15-minute performance ride using a randomized, balanced, cross-over design. The independent variables were sports gel and raisin consumption, and the dependent variables were pre-exercise and postexercise serum concentrations of glucose, insulin, lactate, FFAs, β-hydroxybutyrate (BHB), and triglycerides (TGs) as well as exercise performance. Assessing the effects of these feedings on the selected metabolic dependent variables allowed us to examine how metabolism might be altered by these feedings. An understanding of the metabolic changes caused by different pre-exercise feedings can provide practitioners with insight into effective feeding strategies. Although performance assessment is often considered subjective, we included it to potentially demonstrate direct influences of the feedings on this dependent variable.

TABLE 1. Physical characteristics of subjects.

Variable	Men (n = 4)	Women (n = 4)
Age (y)	30.2 ± 2.3	29.2 ± 5.8
Weight (kg)	75.5 ± 5.8	56.22 ± 5.2
$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})	64.1 ± 3.4	47.5 ± 10.6

Subjects

Twelve in-season endurance-trained cyclists (including triathletes and duathletes) were recruited to participate and asked to maintain training levels throughout the study. Inclusionary criteria consisted of being within 18–40 years of age, cycling at least 150 miles per week, having no metabolic disorders, no cigarette smoking, and not being pregnant. Eight male (n = 4) and female (n = 4) subjects aged 30 ± 5 years completed the entire protocol. Four subjects withdrew for reasons unrelated to the study. Table 1 presents the physical characteristics of the subjects who completed all testing. Prior to initiating the study, all subjects were required to complete a health risk screening questionnaire and sign a written consent. The protocol was approved by the San Diego State University Institutional Review Board.

Procedures

Maximal Testing. Prior to beginning the feeding trials, subjects reported to the laboratory for assessment of peak oxygen uptake ($\dot{V}O_2max$) and to establish a workload to elicit 70% of $\dot{V}O_2max$ using a ramped exercise test. The baseline workload was set at 200 W for men and 100 W for women, and incremental increases of 25 W every 2 minutes occurred until exhaustion. Expired gasses were analyzed with a metabolic cart (ParvoMedics Truemax 2400, Sandy, UT). This visit also served as familiarization with the exercise protocol. All exercise tests were performed on an electronically braked cycle ergometer (Lode, The Netherlands).

Glycemic Index Determination. Five subjects completed testing to determine the GIs of the test foods. To accomplish this, subjects reported to the laboratory following an overnight (12-hour) fast. Glycemic indexes of servings of raisins and sports gel providing 50 g of available carbohydrate were assessed relative to 50 g of available carbohydrate from white bread according to the methods of Wolever et al. (17). The control and the test foods were assessed in random order. All test meals were consumed within 10 minutes. Capillary finger-prick blood samples were collected in a 250-μl heparinized Natelsen capillary tube during fasting and at 15, 30, 45, 60, 90, and 120 minutes after consumption of each meal. Collected blood was centrifuged at 4–8° C for 10 minutes at 1,200g. Aliquoted serum was frozen and stored at −70° C for subsequent batch analysis of glucose concentrations. Serum glucose was assessed enzymatically with a kit from Sigma Diagnostics (St. Louis, MO). The areas under the glycemic-response curves of the raisins and sports gel were expressed relative to the response to bread.

Feeding and Performance Protocols. Subjects reported to the laboratory in a (12-hour) fasted state having abstained from alcohol, tobacco, caffeine, and strenuous exercise for the previous 24 hours to complete 2 randomly ordered exercise trials. Subjects were instructed to continue their normal diet habits during the days separating trials. Subjects consumed raisins (California, red) prior to exercise on 1 occasion and a commercial sports gel (Clif Shot, vanilla, Berkeley, CA) prior to the other. Trials were separated by at least 7 days. One gram of carbohydrate per kilogram body weight from either raisins or sports gel was fed, and subjects rested in a seated position for 45 minutes. Blood was collected from an antecubital vein at the end of the resting period in tubes containing clot activator and gel separator for serum as well as tubes containing ethylenediaminetetraacetic acid (EDTA) for whole blood. After the resting period, subjects warmed up on a cycle ergometer for 3 minutes at 100 W then cycled for 45 minutes at 70% of $\dot{V}O_2max$. At that time, a second blood sample was collected and subjects began a 15-minute performance trial with the cycle ergometer set in "linear" mode to determine total accumulated work. Subjects were blinded from knowledge of work output but were kept informed of the time remaining to completion throughout the test. To minimize thermal stress, the temperature in the laboratory was kept at 21 ± 1° C, and the subjects were cooled with an electric fan during exercise.

Measurements. Blood for serum was allowed to clot at room temperature and then centrifuged at 1200g for 10 minutes at 4–8° C. Serum was stored at −70° C for future analysis. Serum glucose, TGs, and BHB were assessed using colorimetric kits from Sigma Diagnostics. Serum FFA concentrations were determined using a kit from Wako Bio Products (Richmond, VA). Whole blood lactate was analyzed using a YSI Sport 1500 analyzer (Yellow Springs, OH). Insulin was assessed by radioimmunoassay (DPC, Inc., Los Angeles, CA).

All postexercise values were corrected for blood/plasma volume shifts using hemoglobin and hematocrit measures according to the method of Dill and Costill (3). Hemoglobin was analyzed by the cyanmethemoglobin technique with a kit from Sigma Diagnostic, and hematocrit was determined using microcapillary tube centrifugation. All assays were completed in duplicate.

Statistical Analyses

Statistical analyses were conducted using the Statistical Program for the Social Sciences computer software package. Data are presented as mean ± *SD*. A paired-comparisons t-test was used to analyze the difference in performance between the trials. Repeated measures analysis of variance (2 trials × 2 timepoints) tests were used to analyze differences in biochemical variables. Paired comparisons t-tests were used as post hoc tests where necessary. An alpha level of $p \leq 0.05$ was considered statistically significant.

RESULTS

The GIs for raisins and sports gels were 88 ± 13 and 117 ± 15, respectively (p = 0.060). Biochemical data for the exercise trials are presented in Table 2. Serum glucose concentrations decreased significantly ($p < 0.05$, main effect) with exercise, although responses were similar between trials. Blood lactate concentrations increased ($p < 0.05$, main effect) with exercise but did not differ between trials. Serum TG concentrations were similar between trials and unaltered by exercise ($p > 0.05$). The FFA concentrations were nearly identical between trials at the onset of exercise. A main effect of exercise for increased ($p < 0.05$) serum concentrations was detected; however, a significant difference ($p < 0.05$) from onset to the 45th minute of exercise was detected within the raisin trial only. Furthermore, a trend (p = 0.088) for higher end concentrations of FFAs in the raisin trial compared with the gel trial was apparent. Serum BHB concentrations increased ($p < 0.05$, main effect) with exercise and were

TABLE 2. Comparison of insulin and fuel substrate concentrations before and after 45 minutes of exercise following feedings of raisins versus sports gel 45 minutes prior to cycling (n = 8).*

Variable	Raisins		Sports gel	
	Pre-exercise	Postexercise	Pre-exercise	Postexercise
Insulin ($\mu U \cdot ml^{-1}$)†	61.4 ± 37.4^{a}	13.3 ± 18.9^{b}	110 ± 70.4^{c}	14.2 ± 6.2^{b}
Glucose ($mmol \cdot L^{-1}$)†	7.15 ± 1.80	6.19 ± 1.57	6.87 ± 1.29	5.73 ± 0.94
Lactate ($mmol \cdot L^{-1}$)†	1.79 ± 0.32	2.32 ± 1.15	1.39 ± 0.29	2.49 ± 1.51
Free fatty acids ($mmol \cdot L^{-1}$)†	0.29 ± 0.08^{a}	0.49 ± 0.15^{b}	0.26 ± 0.09^{a}	0.36 ± 0.16^{ab}
Triglycerides ($mmol \cdot L^{-1}$)	0.95 ± 0.35	1.02 ± 0.41	0.85 ± 0.34	0.86 ± 0.37
β-hydroxybutyrate ($mmol \cdot L^{-1}$)†	0.07 ± 0.02	0.08 ± 0.04	0.06 ± 0.02	0.08 ± 0.02

* Data are presented as mean ± *SD*. Significant differences ($p < 0.05$) within a variable are denoted by differing superscript letters.

† Significant ($p < 0.05$) main effect of exercise detected.

similar before and after exercise between the trials. No difference ($p > 0.05$) in power output during the performance trial was detected between the raisin (189.5 ± 69.8 kJ) and gel (187.9 ± 64.8 kJ) trials. Responses for metabolic and performance measures were similar between genders.

DISCUSSION

Raisins and sports gel tend to produce different glycemic responses during rest. When expressed using pure glucose as the standard, the GI values obtained for raisins and sports gel can be converted to 62 for raisins, which is very similar to the value (64) reported by Jenkins et al. (7), and 88 for the sports gel. Although the foods studied tended to affect blood glucose responses differently during GI testing, we detected few differences in exercise metabolism when raisins and the sports gel were provided as pre-exercise feedings. It was hypothesized that because of their lower GI, raisins would elicit a more favorable metabolic effect that could translate to enhanced performance in comparison with sports gel. Although FFA concentrations were higher after 45 minutes of exercise for the raisin trial, no difference in the 15-minute performance rides were detected. The overall similar responses may suggest that although raisins tend to have a lower GI than the sports gel, the difference is not sufficient to elicit a significantly different impact on most pre-exercise and postexercise metabolic responses or relatively short performance bouts.

Researchers that have observed major differences in metabolic responses in the past have generally fed foods with a very low GI (i.e., less than 40) in comparison with foods with a much higher GI (2, 15, 16). Raisins have a relatively moderate GI, which may not be sufficiently low to produce major metabolic shifts in comparison with some higher GI foods. Wee et al. (16) detected metabolic differences during exercise after feeding a very low GI food (lentils) vs. a high GI meal that produced a 7-fold greater area under the curve over a 2-hour period following consumption. Interestingly, those researchers detected no effects on time to exhaustion. Conversely, DeMarco et al. (2) fed a carbohydrate-rich meal with a GI of 69 as their selection of a high GI food and detected poorer performance than during a trial in which a low GI meal (36) was consumed. Because major changes in metabolism have been detected after feeding particularly low GI foods, it is possible that the GI of raisins may be too high to expect significant enhanced metabolism and performance in comparison with the sports gel when consumed at the amounts fed here and for the duration of exercise completed in this study.

The lack of pre-exercise and postexercise differences in serum glucose and whole blood lactate concentration responses between the trials of this study was surprising. Higher serum glucose concentrations were expected after 45 minutes of exercise during the raisin trial, because lower GI foods fed prior to exercise tend to elicit a lower insulin response, which can eliminate the significant exercise-induced drop in serum glucose concentrations following high GI pre-exercise feedings (16). In some cases, consuming carbohydrate prior to exercise has been shown to raise blood glucose levels during the event, allowing the muscles to reduce utilization of their limited glycogen stores (6). This sparing of glycogen is believed to be the primary mechanism for enhanced performance when carbohydrates are consumed prior to exercise. Foods with a lower GI typically elicit a more sustained blood glucose response with lower peak glucose concentration. Some researchers have reported that blood glucose levels are higher at the start of exercise and during the bout with consumption of low GI foods prior to exercise in comparison to foods with high GIs (2, 4, 12, 15, 16). Because subjects did not experience rebound hypoglycemic soon after initiation of exercise as may have been expected following consumption of the higher GI food (sports gel), our expectation of observing a difference in performance after just 1 hour of exercise was diminished.

Consumption of the lower GI raisins was also expected to result in lower blood lactate levels at the end of the submaximal exercise bout, suggesting a lower rate of carbohydrate oxidation. This effect has been reported by some investigators (13, 15), who have indicated that lactate levels were significantly higher during exercise with the high GI feeding. Others have failed to detect differences in lactate concentrations with feedings of foods varying in GI, however (4, 16). Furthermore, increased carbohydrate utilization during exercise following consumption of higher GI foods is not always accompanied by higher lactate concentrations (4). The results of the present study suggest that differences in blood glucose and lactate concentrations did not occur after 45 minutes of exercise with a 45-minute pre-exercise feeding protocol of 1 gram per kilogram of a moderate vs. a high GI carbohydrate-rich food.

Researchers have consistently concluded that serum concentrations of FFAs are lower during exercise following consumption of high GI foods prior to the exercise bout (4, 5, 12, 15, 16). This is likely because of an inhibition of lipolysis by insulin as well as an increase in utilization of carbohydrate for energy. The higher GI feedings in these studies also produced elevated insulin concentrations along with the reduced FFA concentrations.

Decreased carbohydrate oxidation has also been demonstrated to accompany the higher FFA concentrations that occur with lower GI feedings (4, 16). Pre-exercise insulin concentrations were higher following the consumption of the higher GI sports gels vs. the raisins in this study, which were accompanied by suppressed FFA concentrations after 45 minutes of exercise. As stated, however, this did not translate to improved short-term endurance exercise performance.

Our research is not the first to fail to detect differences in performance with feeding lower GI food compared with higher GI foods before exercise (4, 5, 12, 14, 16). Those studies that have detected performance enhancement with lower GI feedings have typically reported robust shifts in metabolism that may explain the improvements in endurance (2, 14). With the exception of elevated FFAs in the raisin trial, little difference in metabolism after 45 minutes of exercise was apparent in the current study. Sparks et al. (12) concluded from their research that muscle glycogen may have been relatively high at the beginning of their subjects' performance trials following both the low GI and high GI feedings, which would limit the likelihood of detecting an effect of the feedings on performance. This may have been the case as well in the current study because our exercise bout was relatively short in duration and muscle glycogen was not purposely depleted prior to exercise. However, Febbraio et al. (4) used a longer exercise protocol in their study and also failed to observe any effects of GI on performance after feeding 1 g carbohydrate per kilogram 30 minutes before 2.5 hours of exercise.

PRACTICAL APPLICATIONS

It may be concluded from this study that, despite their differences in GI, raisins and a commercial sports gel fed in the amount of 1 g of carbohydrate per kilogram of body weight 45 minutes prior to cycling elicit relatively similar metabolic effects after 45 minutes of exercise and an equal work output during a subsequent 15-minute performance trial. The similarity of responses suggests that it may be valuable for athletes, coaches, and trainers to consider the type of carbohydrate-rich food to consume prior to short-term endurance exercise. Raisins are less expensive than sports gels and are a source of naturally occurring nutrients; therefore, they offer an advantage to those desiring a "food first" approach to nourishment. When recommending specific foods to athletes, conditioning coaches should consider the preferences of the individual and the presence of any known allergy. Furthermore, the moderate differences in metabolism detected between the raisins and sports gel suggest that future research should determine if raisins can improve performance relative to a gel when fed prior to a longer bout of exercise. Additionally, because some research has suggested that protein incorporation along with carbohydrate for postexercise feedings may be useful during recovery (18), the potential benefits of a raisin and nut based trail mix should be studied.

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