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Sun-Dried Raisins are a Cost-Effective Alternative to Sports Jelly Beans in Prolonged Cycling

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Abstract

The purpose of this study was to examine the effects of a natural carbohydrate (CHO) source in the form of sun-dried raisins (SDRs) vs. Sports Jelly Beans™ (SJBs) on endurance performance in trained cyclists and triathletes. Ten healthy men (18–33 years) completed 1 water-only acclimatization exercise trial and 2 randomized exercise trials administered in a crossover fashion. Each trial consisted of a 120-minute constant-intensity glycogen depletion period followed by a 10-km time trial (TT). During each experimental trial, participants consumed isocaloric amounts of SDRs or SJBs in 20-minute intervals. Measurements included time to complete 10-km TT, power output during 10-km TT, blood glucose levels and respiratory exchange ratio during glycogen depletion period, rate of perceived exertion (RPE), 'flow' questionnaire responses, and a hedonic (i.e., pleasantness) sensory acceptance test. There were no significant differences in endurance performance for TT time (SDRs vs. SJBs, 17.3 ± 0.4 vs. 17.3 ± 0.4 seconds) or power (229.3 ± 13.0 vs. 232.0 ± 13.6 W), resting blood glucose levels (5.8 ± 04 mmol·L^{-1} for SDRs and 5.4 ± 0.2 mmol·L^{-1} for SJBs), RPE, or flow experiences between SDR and SJB trials. However, the mean sensory acceptance scores were significantly higher for the SDRs compared to the SJBs (50.7 ± 1.7 vs. 44.3 ± 2.7). Consuming SDRs or SJBs during 120 minutes of intense cycling results in similar subsequent TT performances and are equally effective in maintaining blood glucose levels during exercise. Therefore, SDRs are a natural, pleasant, cost-effective CHO alternative to commercial SJBs that can be used during moderate- to high-intensity endurance exercise.

Introduction

The ability to maintain moderate- to high-intensity exercise lasting longer than 1 hour is largely dependent upon the capacity of the cardiovascular system to deliver metabolic substrates to working muscles and the presence of sufficient muscle and liver glycogen to maintain physical work capacity ([3]). Investigations show that carbohydrate (CHO) supplementation before and during an exercise bout quickly increases CHO availability for oxidation ([6,33]) and effectively increases plasma glucose concentrations during muscle glycogen depletion ([4,6]). Additionally, several studies have demonstrated that the ingestion

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of a liquid CHO source during exercise bouts lasting 1 hour or longer improves endurance performance through the maintenance of blood glucose levels ([12,13,18,19]). For example, research indicates that CHO muscle glycogen stores are the primary source of fuel during the first 1 hour of strenuous aerobic exercise. As exercise continues past 1 hour, glycogen stores are depleted, resulting in a larger reliance on blood glucose in conjunction with muscle glycogen. Although the ingestion of CHO does not appear to spare muscle glycogen, it does provide for an increase in CHO oxidation during the latter part of prolonged exercise, effectively limiting hypoglycemia and increasing time to fatigue ([5]). Carbohydrate supplementation also aids in recovery from strenuous exercise by decreasing the reliance on fatty acid oxidation for adenosine triphosphate (ATP) generation to reestablish resting physiological homeostasis after a strenuous exercise bout ([9]).

A large body of evidence supports CHO supplement induced metabolic alterations allowing for quicker recovery time and greater performance with strenuous aerobic exercise. As a result, the dietary supplement industry offers a wide variety of processed CHO supplements, including gels, bars, and more recently, sports jelly beans (SJBs). Given that professional, collegiate, and recreational sporting events are supplement centered and heavily marketed to, athletes at all levels may be left with the impression that “specially designed” supplements are essential for optimal performance. Yet, these products are often expensive and cheaper, natural foods that may provide a healthier alternative are often overlooked. For example, Earnest et al. ([11]) have shown that honey powder is as effective as more traditional CHO administration schema during cycling time-trial (TT) performance ([11]). There are low-cost, natural food products rich in CHO, such as sun-dried raisins (SDRs) that have the potential to improve performance to a similar degree. Sun-dried raisins are nutritious, convenient, typically palatable, and are a cost-effective source of concentrated CHO ([1]).

Only 1 study has compared the effectiveness of SDRs vs. a commercially available CHO supplement (sports gel) in enhancing exercise performance ([22]). In this crossover study, endurance-trained cyclists (4 men, 4 women) consumed 1 g $CHO \cdot kg^{-1}$ body weight from either SDRs or sports gel 45 minutes before a 45-minute constant-intensity cycling bout (70% O_2max) followed by a 15-minute TT. Few differences were found between the trials, although there was a trend for higher concentrations of free-fatty acids in the SDR trial compared with in the gel trial ([22]).

Although it is essential to demonstrate that a particular natural food or supplement is effective in optimizing endurance performance at the physiological level, it is necessary to understand whether the supplement may influence the athlete from both sensory and psychological standpoints. Hedonics is the subjective pleasure associated with food intake ([2]). Specifically, this measure evaluates the perceived appearance, color, flavor (taste and odor), texture, and overall liking of the food. A positive food hedonic score is related to food consumption with foods of higher hedonic value being consumed more frequently ([10]). If athletes do not deem a food to be pleasurable when consumed, it is likely that they may not consume it in the amounts and when it is needed during training and competition. Flow is a psychological construct that represents moments, “when everything comes together for the performer.” Flow has been associated with superior performance and is a valued experience for individuals engaging in physical activity ([16]). The ability to achieve flow, which involves an ability to control attention during exercise, can raise the experience to higher levels of both achievement and enjoyment ([16]).

Given that SJBs are about 3.5 times more expensive than SDRs (per ounce: SJBs ~$1.00, SDR ~ 0.29¢), an investigation into the effectiveness of SDRs may provide athletes with a lower cost, natural alternative CHO source during exercise. The purpose of this study was to evaluate differences in TT performance, metabolic responses (respiratory exchange ratio [RER] and blood glucose), mental state (“flow”), rate of perceived exertion (RPE), and hedonics after consumption of a natural food, SDRs, vs. a sports supplement, SJBs. We hypothesized that SDRs would be preferred by the athlete and equally effective in improving endurance performance from both metabolic and mental state perspectives.

Methods

Experimental Approach to the Problem

This was a study designed to examine whether SDRs would be an effective substitute for SJBs in well-trained, college-aged men during a prolonged high-intensity cycling activity in a controlled indoor environment. Informed consent was received from all riders, and the study was approved by the Institutional Review Board of Louisiana State University and performed in accordance with the tenets described in the Declaration of Helsinki.

Initially, an assessment of maximal oxygen consumption (O_2max) and onset of blood lactate (OBLA) was used to help determine subject eligibility for the study and target workload during the trials. To test the ability of SDRs vs. SJBs to aid in exercise performance in cyclists, it was necessary to complete a glycogen depletion session, which involved the 2-hour constant-load ride just below the OBLA. This preexhaustion period has been used successfully in another study using CHO-supplement trials ([31]). The first trial for each subject was an acclimation trial where the athlete was able to make any adjustments to the workload and became familiar with the protocol. The second and third trials involved the same 2-hour glycogen depletion period followed by a 10-km TT. Athletes ingested 1 of 2 CHO (1.1 g CHO$\cdot$min^{-1}) supplement forms (SDRs or SJBs) in a randomly assigned order. The influence of the SDRs and SJBs on the final 10-km TT performance was the main outcome variable. Blood glucose, a measure of substrate use, and measures of perceived exertion and the “pleasantness” of the SDRs and SJBs were secondary outcome measures.

Subjects

Healthy, male endurance-trained cyclists and triathletes ($N = 10$) completed all sessions. Participant characteristics are presented in Table 1. Participants completed a health-history questionnaire and received approval to participate from a physician. Criteria to be eligible for the study included being 18–34 years of age, having a O_2max of 45 ml$\cdot$kg$^{-1}\cdot$min^{-1} or higher, being tobacco free, and having no history of diabetes or cardiovascular disease. Participants were also asked to follow their normal dietary and training regimens and agreed to abstain from antioxidant supplements and ergogenic aids throughout the entirety of the study.

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Procedures

Maximal Oxygen Consumption—Maximal oxygen consumption was measured using the MOXUS metabolic cart (AEI Technologies, Naperville, IL, USA), and participants used their own bicycle mounted on CompuTrainer™ cycling training ergometer (Seattle, WA, USA). Each participant initiated the testing trial by a 10-minute warm-up at a self-selected intensity not exceeding 100 W. The warm-up was followed by a graded exercise test in which the baseline workload was set at 150 W. After cycling at this workload for 5 minutes, there was an increase of 50 W·min^{-1} until they reached 250 W. Thereafter, workload was increased by 25 W·min^{-1} until exhaustion.

Onset of Blood Lactate—Upon arrival, participants received a finger stick in a nondominant finger of their choice to obtain a resting blood lactate measure (Lactate Pro Analyzer, Quesnel, BC, Canada). Participants then cycled on a CompuTrainer™ cycling training ergometer (Seattle, WA, USA) at 65% O_2max for 3 minutes. The workload was increased every 3 minutes to 65, 70, 75, 80, 85, and 90% of their previously determined O_2max. Finger sticks were performed in the last few seconds of each 3-minute stage. The test was concluded after cycling for 3 minutes at a workload representing 90% O_2max ([27]). Blood lactate results were plotted against workload and a power output (watts) equivalent to 5% below that which elicited a blood lactate concentration of 4 mmol·L^{-1} was calculated for initial testing in the 120-minutes constant-load cycling acclimation session ([27]).

Experimental Protocol—Participants reported to the Exercise Biochemistry laboratory at Louisiana State after an overnight fast (10 hours) between 5:30 am and 10:30 am. Participants were asked to abstain from alcohol, caffeine, and strenuous exercise for the previous 24 hours. They were also asked to complete a 24-hour diet record before each experimental trial and to consume the same diet for the 24 hours preceding each experimental trial. Before all experimental trials, participants' hydration status was assessed via urine specific gravity (USG). Participants were required to have a USG < 1.02 to participate ([26]). All subjects were not taking any medications at the time of their trials.

The first trial for all participants was a water-only acclimatization trial, which mimicked the experimental trials without the CHO supplements. This trial allowed the participants to become familiar with the exercise protocol and schedule of water intake that was to be implemented during the experimental trials. This trial also allowed for workload adjustments, if necessary, to ensure that participants would be able to complete the 2-hour constant-load cycling bout. At minimum, participants were required to perform the 120-minute cycling bout at a workload that was at least 80% of their OBLA ([27]). Once the workload was established, participants cycled at this intensity for 2 hours, and were given 250 mL water in 20-minute intervals throughout the constant-load cycling bout. Participants then completed a 10-km TT.

The experimental trials were matched, balanced and crossover in design. For the experimental trials, CHO intake was equally divided into 6 doses and was consumed in 20-minute intervals during the 120-minute glycogen depletion period (Figure 1). Specifically, 1 of 2 CHO (1.1 g CHO·min^{-1}) supplement forms was assigned for the first CHO trial and included either (a) SDRs (Sun Maid®, 28 g every 20 minutes), 90 kcal, 22 g of CHO (glucose and fructose) or (b) SJBs (Jelly Belly sport beans®, 26 g every 20 minutes), 92.9 kcal, 22.3 g CHO (sucrose and corn syrup [glucose and fructose]) (Table 2). The other CHO source was consumed during the second CHO trial.

Performance Measures and Metabolic Responses—Exercise performance was assessed by the average power output and time to complete a 10-km TT. Capillary finger-prick blood samples were collected at rest and every 20 minutes during the 120-minute glycogen depletion period, and were analyzed using an Accu-Chek Aviva glucose analyzer (Roche; Mannheim, Germany). During the last 5 minutes of each hour during the 120-minute glycogen depletion period, expired gases were collected and analyzed using the MOXUS metabolic cart with the last 3-minute averaged to represent that sampling period ([30]). Total CHO and fat oxidation rates ($g \cdot min^{-1}$), using VCO_2 and O_2, were calculated using the stoichiometric equations of Frayn ([14]) with the assumption that protein oxidation during exercise was negligible. The formulas used were CHO oxidation = $4.58\ VCO_2 - 3.23\ O_2$ and fat oxidation = $1.70\ O_2 - 1.69\ VCO_2$ ([14]). Figure 1 provides an outline of all measures obtained during the experimental trials.

Self-Report Measures—Participants were asked to indicate level of fatigue using Borg's RPE scale every 20 minutes throughout the 120-minute glycogen depletion period. The flow state scale-2 was administered to participants immediately after their experimental exercise trials ([15]). Sensory acceptance measures were evaluated immediately after the 10-km TT using a 9-point hedonic scale questionnaire ([28]). The hedonic scale measures a person's response in terms of pleasantness.

Statistical Analyses

This study employed a within-participant repeated-measures design to compare the effect of 2 CHO supplements and water-only on time to complete a 10-km TT, average power output during the TT, blood glucose, RER, RPE, and flow and hedonics questionnaire responses. SPSS (Chicago, IL, USA) and SAS (Cary, NC, USA) were used to analyze the data. Repeated-measures analysis of variance was performed with post hoc analyses to determine significant differences. A dependent *t*-test was used to analyze the difference in food hedonics between the SDR and SBJ trials. An alpha level of $p \leq 0.05$ was considered statistically significant. Interclass correlations*R*s) were >0.96 for metabolic, blood lactate, and glucose measures.

Results

Performance and Metabolic Outcomes

There were no significant differences in time to completion or average power output during the 10-km TT between the 2 CHO supplements (Table 3). No significant differences in resting blood glucose levels were found for the 3 exercise trials (Figure 2). Data for RER, substrate oxidation rates, and energy expenditure (EE) during the 120-minute glycogen depletion period are shown in Table 4. Overall, RER was maintained at or above 0.84 for all experimental trials, and there were no significant differences in RER, total CHO, or fat oxidation rates or EE between any of the trials.

Subjective Measures

There were no differences in RPE between any of the treatments during the 120-minute exercise bout (13.2 ± 0.2, 13.3 ± 0.2 SDRs, and SJBs, respectively). There were also no significant differences in flow experiences between any of the treatments. Hedonic scores for the SDR trial were significantly higher than for the SJB trial (50.7 ± 1.7 and 44.3 ± 2.7, respectively; $p = 0.004$), indicating greater preference for SDRs vs. SJBs.

Discussion

The primary findings from this study show that SDR offer similar benefit to a commercial sports supplement (i.e., SJBs) product when fed to participants in the amount of 1.1 $g \cdot min^{-1}$ during intense cycling. The findings of this study further show that SDRs are more acceptable as indicated by a questionnaire measuring the hedonic sensation of the SDR treatment. In brief, a hedonic score assesses the amount of pleasure derived from a treatment condition. As such, these findings support our hypothesis that natural foods, such as raisins, may be added to the list of CHO supplements available to athletes.

Both SJBs and SDRs are similar in CHO and energy content, although the CHO sources vary slightly. Although the primary sugars found in SJBs are sucrose and glucose ([3]), the main sugars found in SDRs are the monosaccharides fructose and glucose in roughly a 1:1 ratio ([23]) (Table 1). In this study, SBJs and SDRs were ingested at a rate of 1.1 $g \cdot min^{-1}$, the recommended dose for endurance athletes shown to provide maximal CHO oxidation in response to ingestion ([17]) and were isoenergetic with respect to both CHO and total caloric content. Both SBJ and SDR CHO sources resulted in similar TT performances and were equally effective in maintaining blood glucose levels throughout the 120-minute glycogen depletion period. These results are consistent with those of previous studies that have examined the effects of different CHO-supplement forms during prolonged cycling at moderate to high intensity ([24,25]). For example, Campbell et al. ([3]) showed in a study comparing a sports drink, SJBs, and sports gel, that, when fed in isocaloric amounts, each means of treatment was equally effective in maintaining blood glucose levels during prolonged intense cycling (80 minutes at 75% O_2peak) and in improving endurance performance ([3]). In this same study, blood glucose levels at the end of the 80-minute glycogen depletion period, time to complete the 10-km TT, and the average power output were all comparable to our results in the present study.

The lack of a significant difference in blood glucose levels at the conclusion of the 120-minute glycogen depletion period between the SDR and SJB trials indicates that both CHO-supplement forms are equally effective in maintaining blood glucose concentrations. Consequently, both sources act as an effective fuel source in the later stages of prolonged exercise. This is in agreement with results of previous studies ([17,18]) and supports the hypothesis that CHO ingestion maintains euglycemia and high rates of CHO oxidation ([19]).

Furthermore, we found no significant differences in RPE among SBJ and SDR trials, in agreement with several other studies that failed to detect significant differences in RPE with CHO supplementation ([3,32]). We also observed no differences in experiences of flow between the trials, a novel finding because this is the first study to assess differences in flow experiences when ingesting different CHO-supplement forms. The hedonics results indicated a preference for SDRs when compared to SJBs. To date, no study has compared the hedonics of SDRs and SJBs, and this is the first study to report greater sensory acceptance of SDRs vs. SJBs.

This study had a few important strengths that are worth mentioning. First, in assessing exercise performance depending on CHO supplementation, previous studies required participants to exercise to exhaustion ([6]). Although time to exhaustion is a frequent measure of performance, it has been shown to have poor reproducibility ([20]). In contrast, this study had participants complete a 10-km TT as fast as possible. This protocol has also been used in a number of other studies ([3,7,27]), is more reproducible, and is also more akin to what an athlete would experience during competitive events.

Several limitations were identified over the course of this study. First, the testing environment limits the translation of our results to exercise performed in thermoneutral environments. For example, exercise in the heat has been shown to result in marked alterations in substrate use at rest and during exercise and may affect tissue-specific CHO use. Indeed, prolonged exercise in the heat leads to redistribution of blood to the skin to allow for evaporative cooling. Consequently, blood flow to other organs such as the liver, kidney, inactive tissue, and the gut are reduced ([21]), impairing the absorption and oxidation of CHO within these limited tissues ([19]), but allowing increased CHO availability for use within other tissues where blood flow is increased, such as contracting skeletal muscle. Second, although our current study found no differences in CHO oxidation between either SDRs or SBJs, RER measurements were only obtained at the end of each hour during the 120-minute glycogen depletion period, limiting our ability to detect any potential differences in metabolism between the CHO trials at other time points. Even though we based the number of subjects required for this project on another similar study ([22]), it is important to note that the small number of subjects may have limited our ability to observe differences. Furthermore, additional supplementation for a longer duration before the onset of exercise or during the exercise trials with SBJs or SDRs may have affected the variables measured in this study. In conclusion, the results of this study show that SDRs offer no better, but more importantly, no worse an effect for athletes during exhaustive tasks resembling a competition. Moreover, given the results of our hedonic analysis, the results of this trial suggest that athletes participating endurance activities may better accept SDRs as a means of maintaining CHO intake during training and competition. Though it is conceivable that any food substance can become “boring,” or mundane, SDRs provide an acceptable, natural, and low-cost alternative to traditional commercial CHO supplements.

Practical Applications

The results of this study suggest that raisins should be included as a cost-effective natural source of CHO during intense cycling. When provided in equal amounts throughout a 2-hour cycling bout followed by a 10-km TT on a Computrainer, SDRs were just as effective as SJBs with respect to TT performance. Also, SDRs were able to maintain blood glucose levels just as effectively as SJBs, and athletes enjoyed the SDRs more than the SJBs. We feel this is an important point of application, where emerging reports suggest that CHO mouth rinses provide an ergogenic benefit on par with ingestible CHO ([8,29]). Because no mechanism of action for this intuitively unlikely response has been identified, recent theories suggest CHO may affect the central nervous system, therein also influencing the activation of brain areas linked to motivation and reward ([8]). Because our trial is one of the first to incorporate a measure of pleasure sensation, future research efforts examining nutrition supplementation may also wish to consider adding these types of assessments to their testing battery.

In addition to being less expensive and a more natural alternative, SDRs are convenient, portable and contain a variety of naturally occurring nutrients that are not present in SJBs. Therefore, natural CHO-supplement forms such as SDRs are effective nutritional aids that present athletes with more options to combat the problems of supplement digestibility and acceptability that may be encountered during endurance training and competition.

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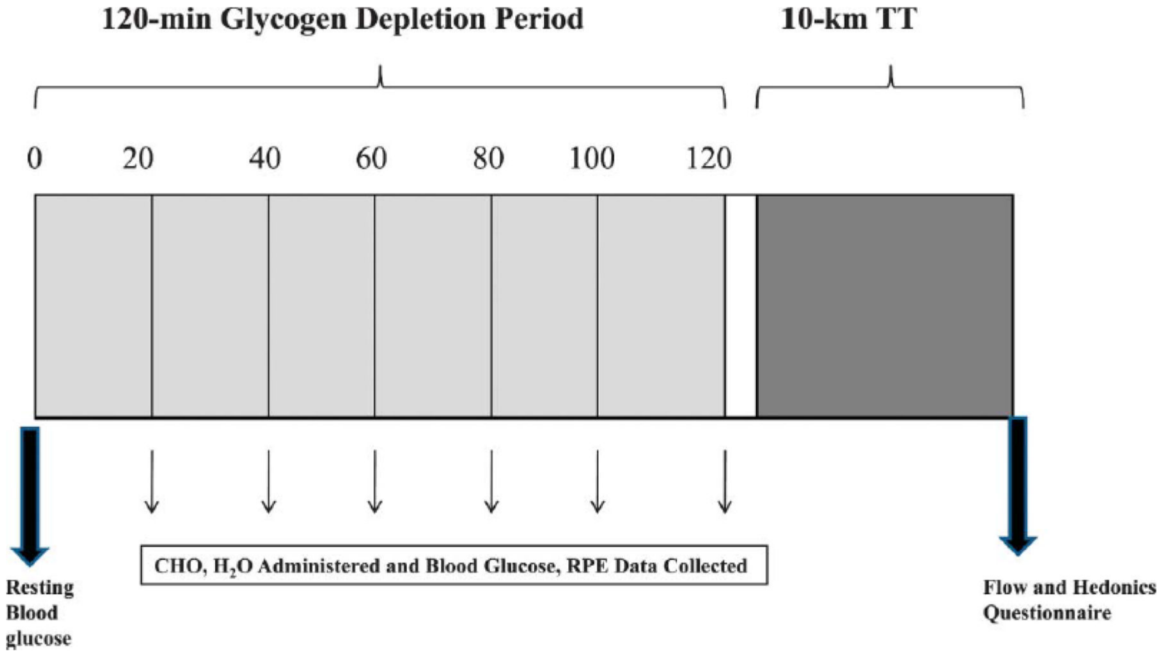

Figure 1.
Experimental trial diagram. TT = time trial, CHO = carbohydrate, RPE = rate of perceived exertion.

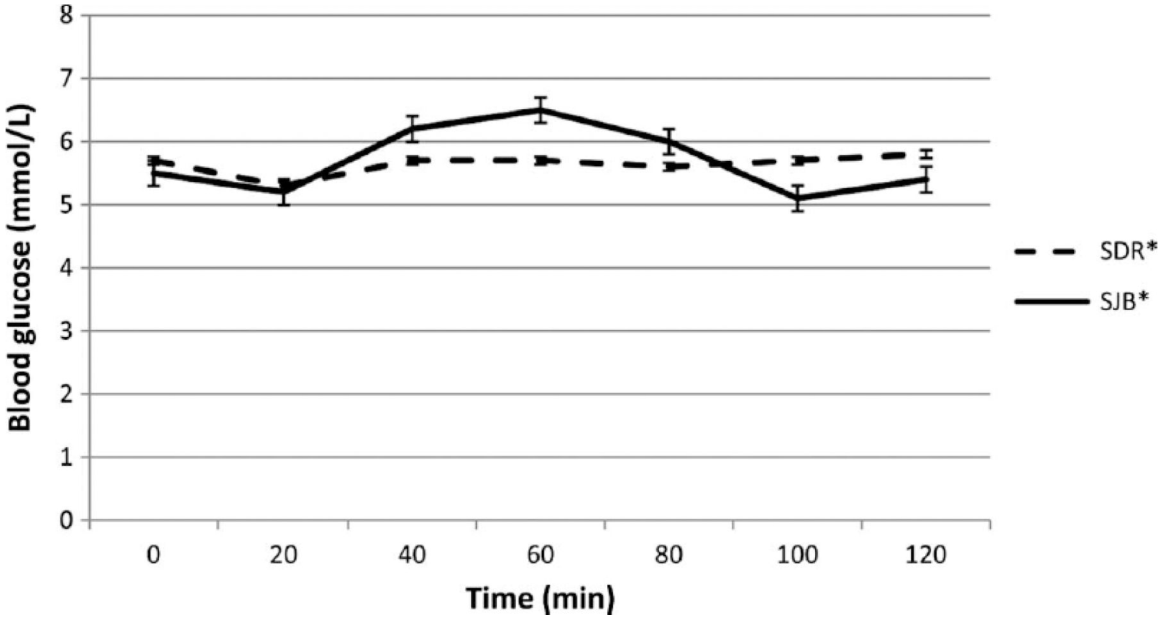

Figure 2.
Blood glucose concentrations throughout the 120-minute glycogen depletion period. Sun-dried raisin (SDR) trials n = 10; sport jelly bean (SJB) trials n = 10. SDR = dotted line, SJBs = solid line.

TABLE 1.

Anthropometric measurements.*†

Variable	Men (*n* = 10)
Age (y)	24.4 ± 1.7
Height (cm)	176.6 ± 2.3
Weight (kg)	78.0 ± 2.4
BMI ($kg \cdot m^{-2}$)	25.0 ± 0.7
$\dot{V}O_2max \left(ml \cdot kg^{-1} \cdot min^{-1}\right)$	52.3 ± 1.3
Peak power output (W)	340.0 ± 13.0
Experimental workload (W)	179.0 ± 7.02

*BMI = body mass index.

†Values are mean ± *SEM.*

TABLE 2.

Nutritional information for SJBs and SDRs.*

Variable	SJBs	SDRs
Serving size (g)	26	28
Servings per trial	6	6
Carbohydrate content (g)	22.3	33
Calories	92.9	90.9

*SJBs = sports jelly beans; SDRs = sun-dried raisins.

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TABLE 3.

Time-trial performance measures during the 10-km time trial.[*†]

Variable	SDRs	SJBs
Time (min)	17.3 ± 0.4	17.3 ± 0.4
Power output (W)	229.3 ± 13.0	232.0 ± 13.6

[*] SJBs = sports jelly beans; SDRs = sun-dried raisins.

[†] Values are mean ± *SEM*.

TABLE 4.

Respiratory exchange ratio, CHOtot, FATtot, and EE during 120-minute cycling exercise.[*†]

	Time (min)	RER	CHOtot (g·min $^{-1}$)	FATtot (g·min $^{-1}$)	EE (kcal·min $^{-1}$)
SDRs	60	0.88 ± 0.01	2.12 ± 0.08	0.55 ± 0.05	13.44 ± 0.50
	120	0.87 ± 0.01	2.11 ±0.10	0.65 ± 0.06	14.32 ± 0.47
SJBs	60	0.89 ± 0.01	2.21 ± 0.13	0.55 ± 0.05	13.76 ± 0.41
	120	0.88 ± 0.01	2.18 ± 0.11	0.61 ± 0.06	14.15 ± 0.36

[*]RER = respiratory exchange ratio; CHOtot = total carbohydrate oxidation; FATtot = total fat oxidation; EE = energy expenditure; SJBs = sports jelly beans; SDRs = sun dried raisins.

[†]Values are mean ± *SEM*.