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The effectiveness of a natural carbohydrate source (sun-dried raisins) versus sports jelly beans on prolonged cycling performance

Helena Rietschier
Louisiana State University and Agricultural and Mechanical College

THE EFFECTIVENESS OF A NATURAL CARBOHYDRATE SOURCE (SUN-DRIED RAISINS) VERSUS SPORTS JELLY BEANS ON PROLONGED CYCLING PERFORMANCE

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Helena Rietschier
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ABSTRACT

PURPOSE: This study was designed to examine the effects of sun-dried raisins versus sports jellybeans on endurance performance in trained cyclists/triathletes. METHODS: Ten healthy males (18-33 y) completed one water-only acclimatization (WAT) exercise trial and two randomized exercise trials. 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 sun-dried raisins (SDR) or Sports Jelly Beans™ (SJB) 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 (RER) during glycogen depletion period, RPE, 'flow' questionnaire responses, and sensory acceptance. RESULTS: There were no significant differences in endurance performance between any of the trials. Resting blood glucose levels were not significantly different between any of the trials and both CHO supplements were equally effective in maintaining blood glucose levels during the 120-min exercise bout compared to the WAT acclimatization trial (4.3 ± 0.3 mmol/L for WAT, 5.8 ± 0.4 mmol/L for SDR, and 5.4 ± 0.2 mmol/L for SJB). There were no significant differences in RPE or flow experiences between trials. Mean sensory acceptance scores were significantly higher for the SDR compared to the SJB (50.7 ± 1.7 for SDR and 44.3 ± 2.7 for SJB). CONCLUSIONS: Consuming SDR or SJB during 120 min of intense cycling result in similar time-trial performances and are equally effective in maintaining blood glucose levels during exercise.

CHAPTER 1 INTRODUCTION

The ability to maintain moderate- to high-intensity exercise lasting longer than 1 hour is largely dependent upon muscular energy stores and the cardiovascular system's capacity to deliver fuel and oxygen to the working muscles, the metabolic system's ability to convert that fuel into energy, and sufficient muscle and liver glycogen content [1]. Several studies have demonstrated that the ingestion of carbohydrate (CHO) in the form of a drink, during exercise bouts lasting 1 hour or longer, can promote endurance performance and maintain blood glucose levels compared to a placebo [2-5]. Today, the supplement market offers a wide variety of CHO supplements, including gels, bars, and most recently, sport jelly beans. These novel forms of CHO supplementation present athletes with more options for CHO supplements, and many times such supplements are more convenient than the traditional sports drink. However, low-cost, natural food products rich in CHO, such as sun-dried raisins, have been shown to enhance performance to a similar degree as sport gels.

To date, no study has compared the effects of raisins vs. sport jellybeans on exercise performance. The purpose of the present study was to assess differences in cycling performance when a) sun-dried raisins (SDR), b) sport jellybeans (SJB), or c) water-only (WAT) are used as a fuel source during prolonged exercise. Furthermore, the consumption of raisins during prolonged, high-intensity exercise may also maintain blood glucose levels for a longer period of time, potentially providing a fuel source later in exercise as glycogen stores become low. Therefore, we also examined differences in blood glucose responses and Rate of Perceived Exertion (RPE) values among trials. We also assessed which fuel source enhanced the subjects' ability to achieve the psychological state known as flow, which is associated with high levels of performance and a very enjoyable experience [6]. Lastly, we compared the palatability, acceptance, and preference of the two CHO supplements.

Specific Aims:

Primary Aim 1: Does the consumption of SDR promote time-trial performance to the same degree as SJB following a 120-min glycogen depletion period?

Secondary Aim 2: Which fuel source maintains euglycemia the longest during a 120-min glycogen depletion period?

Tertiary Aim 3: Which fuel source results in lower RPE ratings, higher "flow" scores, and greater sensory acceptance (palatability, tolerance, and preference)?

In order to address these aims, endurance-trained male and female cyclists/triathletes between the ages of 19-35 were recruited from Baton Rouge, LA (USA). All exercise trials entailed participants performing a 120-min constant-intensity cycling bout at a workload corresponding to 80% of lactate threshold [7], followed by a 10-km time trial. The independent variables were the fuel sources administered during exercise trials (WAT, SDR, SJB,). The dependent variables included time trial performance, power output during time trial, Respiratory Exchange Ratio (RER) and blood glucose during 120-min constant-intensity cycling bout, "flow" scores, RPE values, and sensory acceptance scores. The order in which the experimental trials were completed was counter-balanced so that ordering effects were controlled.

CHAPTER 2 REVIEW OF LITERATURE

ERGOGENIC EFFECTS OF CARBOHYDRATE

Fatigue experienced during prolonged exercise of moderate- to high-intensity in thermoneutral environments is often associated with either glycogen depletion in working muscles or hypoglycemia [8]. Therefore, it is common practice among both recreational and elite athletes to consume CHO supplements during such activities. Indeed, previous research has consistently demonstrated that CHO ingestion in the form of a sport drink, during exercise lasting ≥ 1 hour can enhance endurance performance and maintain blood glucose for a longer period of time compared with placebo [2, 5, 9, 10]. Coyle et al. (1986) concluded that CHO feeding via a sport drink during exercise at 70% $VO_{2\,MAX}$ prevented the drop in blood glucose that was observed with placebo [10]. Further, the CHO drink increased time to exhaustion by one hour. Similarly, Jeukendrup et al. (1997) examined the effects of CHO ingestion in the form a drink during exercise on a 1- hour time trial cycling performance and found that performance was improved by 2.3%, which is considered a significant improvement among elite cyclists [11]. Proposed mechanism(s) underlying the ergogenic effects of CHO ingestion during prolonged intense exercise include the maintenance of euglycemia and oxidation of blood glucose at high rates late in exercise, and a decreased rate of muscle glycogen utilization [8], although the 'sparing' of muscle glycogen by CHO feedings is controversial, as some studies suggest glycogen 'sparing' [12, 13] while others do not [3, 10].

Most of the studies investigating the effects of CHO supplements on endurance performance have utilized drinks as their form of supplement, and as a result of these studies, it is now generally accepted that CHO feedings in the form of such a supplement can improve endurance performance. Some studies have also examined CHO supplements in other forms, and these studies suggest that the form of CHO consumed does not influence its ergogenic potential.

For example, using a randomized, cross-over design, Lugo et al. (1993) investigated the performance and metabolic effects of consuming equal amounts of CHO (0.4 gm CHO/kg body weight) in solid form, liquid form, or both during 2 hours of cycling at 70% $VO_{2\,MAX}$ [14]. Following this exercise bout, subjects completed a

time trial. The liquid form of CHO supplement was a 7% CHO-electrolyte beverage (Fluid Replacement Energy Drink®, Ross Laboratories). The solid form was a commercially available sports bar (Sports Bar®, Ross Laboratories) providing 280 kcal of which 76, 18, and 6% of total energy was from CHO, protein, and fat, respectively. The combination treatment included half of the required CHO from the CHO-electrolyte beverage and half from the sports bar. While the caloric value of each treatment varied, the treatments were isoenergetic with respect to CHO (0.4 gm CHO/kg body weight). Glucose and insulin responses were similar among all CHO treatments. Time to complete the time-trial trial and total CHO oxidation were also similar among CHO trials, and results from a perceptual-sensory survey did not differ among CHO treatments.

In a different study examining the effects of CHO form from a food source on exercise performance, Murdoch et al. (1993) found that solid bananas and slurried bananas were equally effective in maintaining plasma glucose and enhancing endurance performance (time to exhaustion) [15]. Furthermore, in a 2004 review of the literature [2], Jeukendrup concluded that the form of CHO ingested during exercise (solid or liquid) does not affect the ergogenic potential of the CHO.

In recent years, novel forms of CHO supplements, such as gels and SJB, marketed to be more convenient, have become available and are popular among busy athletes and active people. Only one study has examined the effects of sports gels and SJB on exercise performance. In 2008, using a randomized study design, Campbell et al. [1] compared the effectiveness of three different forms of CHO supplements (sports drink, sports gel, SJB) with water only on the promotion of endurance cycling performance which was assessed by a 10-km time trial that was completed following an 80-minute constant-intensity cycling bout. Sixteen endurance-trained female and male cyclists/triathletes consumed one of three isocaloric CHO (0.6 g/kg/hr) supplement forms or water only for each experimental trial. Supplement forms included (a) sports drink (sucrose and glucose-fructose mix); (b) sports gel (maltodextrin and fructose); (c) SJB (sucrose and glucose); and (d) water only. Fluid intake was maintained throughout the test to ensure proper hydration and participants consumed the same amount of water for each test. At the conclusion of the study, the authors reported that compared water, all of the CHO supplement forms examined were equally effective in improving endurance performance and

maintaining blood glucose levels throughout the 80-minute constant intensity exercise bout. Though RPE increased significantly throughout the 80-min cycling bout and the 10-km time trial, no differences were observed between any of the treatments during the 80-min exercise bout. Interestingly, RPE values were higher during the 10-km time trial for SJB compared with sports drink.

FEEDING STRATEGIES AND OXIDATION OF INGESTED CARBOHYDRATE

Some studies have also investigated the optimal feeding schedule for CHO supplementation. It appears that the timing of CHO ingestion has very little impact on exogenous CHO oxidation rates [2]. In an early study by Krzentowski et al. (1984), participants walked at a 10% grade (45% $VO_{2\,MAX}$) for 4 hours. All participants ingested equivalent amounts of glucose (100 gm), but their schedule of intake was varied [16]. They either consumed the glucose after 15 or 120 minutes of walking. Rates of exogenous CHO oxidation followed an identical pattern from the time of CHO ingestion until 2 hours later. The amount of ingested CHO that was oxidized was similar during the 2 hours following ingestion (55 gm when CHO was ingested after 15 minutes and 54 gm when ingestion occurred at 120 minutes). In conclusion, this study indicates that the time in which CHO is consumed has no effect on rate of exogenous CHO oxidation.

Many times repetitive feeding schedules are employed because it has been shown that such a schedule accelerates the rate of gastric emptying, and thereby increases the delivery of CHO to the intestine [17, 18]. However, as pointed out by Jeukendrup & Jentjens (2000), gastric emptying is usually not a limiting factor in exogenous CHO oxidation [19]. Hence, it seems fair to conclude that the timing of CHO ingestion has a relatively small effect on exogenous CHO oxidation rates. Still, in a joint position statement by the American Dietetic Association (ADA), Dietitians of Canada (DC), and American College of Sports Medicine (ACSM), it is recommended that CHO intake begin shortly after initiation of exercise bout [20]; the ingestion of a bolus of a given amount of carbohydrate after 2 hr of exercise is not as effective as consuming the same amount at 15- to 20-minute intervals throughout the 2 hr of exercise [21].

The optimal amount of CHO consumption in order to obtain performance benefits has also been examined. Rehrer et al. (1992) compared the oxidation of different amounts of CHO ingested during 80 minutes

of cycling exercise at 70% $VO_{2\,MAX}$ [22]. Participants consumed a total of 58 gm or 220 gm glucose during 80 minutes of cycling. Measurements of the total amount of exogenous CHO oxidation revealed total oxidation was slightly higher with the larger CHO dose (42 gm vs. 32 gm during the 80 minutes of exercise). Although the amount of CHO consumed was increased almost four-fold with the 220 gm dosage, the total exogenous CHO oxidation rate was minimally affected. Pallikarakis (1986) also evaluated the oxidation of different amounts of CHO when ingested during 285 minutes of exercise at 45% $VO_{2\,MAX}$ and found that doubling the amount from 200 to 400 gm did increase exogenous CHO oxidation [23]. This rate of exogenous CHO oxidation, however, did not double and the percentage of the CHO consumed that was oxidized was actually slightly lower (59.5 and 56.8%, respectively). Thus, it has been suggested that there is a lower oxidation efficiency with larger dosages of CHO [24]. Due to the lower oxidation efficiency observed with larger doses of CHO, Jeukendrup has concluded that the oxidation of ingested CHO may be most favorable at ingestion rates near 1.0 to 1.2 g/min [2].

TYPE OF CARBOHYDRATE AND RATE OF CARBOHYDRATE OXIDATION

Carbohydrate supplements are often formulated with multiple transportable CHO with the main goal being to increase total CHO absorption and total CHO oxidation [19]. While SJB are widely used among athletes, consumption of SDR during exercise may improve endurance performance to the same, if not better, degree than SJB. Both of these energy sources are similar in CHO and energy content, although their sources of CHO vary slightly. While the primary sugars used in SJB are sucrose (glucose bonded to fructose) and glucose [1], the main sugars found in SDR are the monosaccharides fructose and glucose. Specifically, roughly half of the available CHO in SDR comes from fructose, while the remaining half comes from glucose [25].

Several studies have compared the oxidation rates of different types of ingested CHO with the oxidation rate of ingested glucose during exercise [24]. In a study by Wagenmakers et al. (1993), subjects ingested an 8% sucrose solution during 2 hours of cycling exercise at 65% $VO_{2\,MAX}$ [26]. During the 2 hours of cycling, a total of 145 g of sucrose was ingested, and it was estimated that 81 g was oxidized. The peak oxidation rate was 0.84 g/min, a rate similar to that observed after glucose ingestion in other studies. In a review of the literature,

Jeukendrup and Jentjens (2000) concluded that sucrose is oxidized at similar rates as glucose and that the efficacy of these two types of CHOs are similar [19].

The sugars present in SDR (fructose and glucose), on the other hand, have been found to be oxidized at different rates. Glucose is oxidized at relatively high rates (up to ~ 1g/min), while fructose is oxidized at a much slower rate during exercise. The lower rate of oxidation observed with fructose ingestion has been attributed to the fact that fructose must be converted into glucose in the liver prior to absorption [2]. Interestingly, fructose molecules from sucrose have been found to be more rapidly absorbed than equimolar amounts of the monosaccharide fructose [24]. As a result, the slower oxidation rate of fructose may be beneficial during longer endurance events.

In addition to differences in oxidation rates, glucose and fructose also utilize different transporters for intestinal absorption. Glucose is absorbed from the intestine by sodium-dependent glucose transporter 1 (SGLT1). It has been suggested that SGLT1 transporters can become "saturated" at glucose ingestion rates of 1.0-1.2 g/min. In contrast to glucose, fructose is absorbed from the intestine via sodium-independent GLUT-5 transporter [27]. Therefore, it likely that the ingestion of a combination of both glucose and fructose results in less competition for absorption compared with the consumption of isocaloric amounts of either type of CHO alone. As a result of the decreased competition, more CHO may reach the bloodstream to undergo oxidation. [27]. Further, drinks containing CHOs that use different transporters for absorption have been shown to have higher oxidation efficiency, meaning that smaller amounts of CHO remain in the gastrointestinal tract and thus, are less likely to cause gastrointestinal distress [2].

The glycemic index of SDR is also slightly lower than that of SJB. Specifically, SDR have a moderate glycemic index (GI) previously determined to be 64 [28], while SJBs tend to have a high GI. Although the GI of a food may be of little importance during exercise due the suppressed insulin response occurring during exercise, a food of moderate GI, such as SDRs can potentially enhance exercise performance by maintaining blood glucose levels for a longer period of time than foods having a higher GI such as SJB.

POTENTIAL ERGOGENIC EFFECTS OF RAISINS

Only one study has compared the effectiveness of SDR versus a commercially available CHO supplement (sports gel) in enhancing exercise performance [29]. In this crossover study, endurance trained cyclists (4 males, 4 females) consumed 1g CHO/kg body weight from either SDR or sports gel 45 minutes prior to a 45-minute constant-intensity cycling bout (70% $VO_{2\ MAX}$). Following this exercise bout, participants completed a 15-minute time trial. Blood samples were collected prior to, and immediately following the 45-minute constant-intensity cycling bout to determine insulin and fuel substrate concentrations (glucose, lactate, free fatty acids, triglycerides, and β-hydroxybutyrate). Few differences were found between the trials although there was a trend for higher concentrations of free-fatty acids in the raisin trial compared with the gel trial. No differences in the 15-minute time trial were detected, and the authors suggest that the duration of the 45- minute exercise bout utilized in this study may have been of insufficient length in order to detect differences in exercise performance. The authors propose that future studies should utilize a longer bout of exercise when comparing the ergogenic effects of SDR and sports gels.

ADDITIONAL BENEFITS OF RAISINS: PHYTOCHEMICALS

In addition to providing an excellent source of concentrated CHO and energy, SDR also offer overall health benefits by providing an excellent source of various plant compounds known as phytochemicals which have been shown to exert powerful antioxidant properties [30]. Antioxidants help neutralize harmful molecules known as reactive oxygen species (ROS) that are sometimes generated during aerobic metabolism when cytochromes of the electron transport chain "leak" electrons to oxygen, partially reducing it to form superoxide anion. Although not a strong oxidant, the superoxide anion can undergo spontaneous electron exchange reactions that generate hydroxyl radicals. Hydroxyl radicals are considered among the most reactive molecules in biological organisms [31].

The human body is equipped with an endogenous antioxidant defense system that functions to neutralize ROS. Some examples of endogenous antioxidants include: superoxide dismutase (SOD), glutathione peroxidase (GPx) and catalase [32]. We can also obtain antioxidants through dietary means. Vitamins A, C, and E are

examples of commonly consumed exogenous antioxidants. Non-nutrient plant compounds known as phytochemicals have also been shown to display potent antioxidant properties and are present in many foods, including SDR [33].

Sport jelly beans do provide a source of the antioxidant vitamin C (per ounce, 10% RDA), but this vitamin is present in isolation to the other vitamins and phytochemicals that occur naturally in fruits and vegetables. Unfortunately, many times isolated nutrients do not display the same health benefits as when these nutrients are consumed through natural foods where they exist in combination with other nutrients and phytochemicals that likely act synergistically [34].

Sufficient intake of a variety of antioxidants is important given that inadequate intake of such compounds can impair the body's ability to neutralize harmful ROS, resulting in oxidative damage to lipids, proteins, and DNA material [35]. Such damage has been implicated in the etiology of some forms of cancer, cardiovascular disease, and neurodegenerative diseases [36, 37].

EXERCISE-INDUCED OXIDATIVE DAMAGE AND EXERCISE PERFORMANCE

Although oxidative damage is frequently attributed to cigarette smoking and ultraviolet radiation, it can also be induced during exercise. The increase in oxygen consumption that occurs during intense physical activity leads to an increase in the formation of reactive oxygen species (ROS) (normally ~ 2-5% of total VO_2) [32]. In addition to their deleterious effects on health, excessive levels of ROS may contribute to the development of muscle fatigue [38]. Specifically, it appears that excessive ROS can damage muscle contractile proteins (myosin), and critical mitochondrial enzymes necessary for energy production (succinate dehydrogenase, cytochrome oxidase).

Reactive oxygen species may also interfere with the development of action potentials by damaging adenosine triphospatase (ATPase pumps) that are required for potassium influx back into skeletal muscle cells, thereby interfering with muscle contraction [39]. Due to their potential to impair exercise performance, much interest has arisen in the role of dietary antioxidants in attenuating the rise in ROS observed during strenuous

exercise. It has been suggested that by reducing oxidative damage during exercise, performance can be enhanced [40].

The total elimination of ROS, however, may actually be detrimental to exercise performance because a certain level of ROS is essential for optimal muscle contraction. The relationship between ROS and muscle contraction has been integrated in the optimal redox-tone model [38]. This model suggests that there is an intracellular redox state that is optimal for force generation and deviations from this optimum will result in the loss of force. Under basal conditions, the redox tone of muscle cells is more reduced than that of contracting muscle cells. A moderate increase in ROS during contraction is suggested to move the redox tone towards a more oxidized, and more favorable redox tone for muscle contraction. Thus, total depletion of ROS through excessive supplementation can potentially inhibit force production.

Reactive oxygen species may also play important roles in the adaptation of muscle cells to exercise training. In a 2008 study, Gomez-Cabrera et al. [41] found that moderate concentrations of ROS can serve as signals to promote the adaption of muscle cells to exercise through the modulation of gene expression. For example, this study found that vitamin C supplementation prevents the activation of two endogenous antioxidants (Mn-SOD and GPx) in skeletal muscle that normally occurs in response to exercise training. This study also found that vitamin C supplementation prevents the increase in mitochondrial content that occurs following endurance training.

Moderate concentrations of ROS are also necessary for normal force production. The depletion of ROS from unfatigued muscle through the use of the endogenous antioxidants SOD or catalase causes force to decline [38]. This is in agreement with the "optimal-redox-tone model" proposed by Reid in which there is an optimal level of ROS required for muscle contraction. Still, prolonged or high-intensity exercise has the potential to "overshoot" the optimal redox tone for muscle contraction, thereby depressing force production. In such situations, antioxidants can shift the redox state toward more optimal [38].

Lastly, moderate levels of ROS are beneficial for overall health as they play critical roles in lifesaving biological mechanisms. For example, when neutrophils and other phagocytic cells kill deadly microorganisms,

they greatly increase their oxygen consumption ("respiratory burst") which is quickly transformed into ROS that kill the invading bacteria. Further, through this burst of ROS, phagocytes also kill cancer cells. Thus, excessive levels of antioxidants can scavenge these important ROS and interfere with this protective mechanism [42].

COMMONLY CONSUMED ANTIOXIDANTS

Some vitamins, such as vitamins C and E, are well known for their antioxidant properties and are commonly consumed in supplemental form. In a 2006 study [35], professional soccer players were supplemented with 1,000 mg/d vitamin C and 800 mg/d α-tocopherol (most bioactive form of vitamin E). Following the 90-day supplemental period, two markers of oxidative damage (plasma thiobarbituric acid reactive substances (TBARS) and creatine kinase activity) were significantly lower in the supplemented group compared to the placebo group. While this finding suggests that such supplementation may reduce oxidative damage induced during heavy training, other studies have implicated that this level of supplementation may have detrimental effects on health. According to a meta-analysis published in the Annals of Internal Medicine (2005), any dosage of vitamin E greater than 400 IU/d may increase all-cause mortality [43]. This is alarming as the dosage of vitamin E implemented in the study by Zoppi et al. was 3 × greater (~ 1200 IU/d) than the level associated with all-cause mortality and had the study continued, the participants may have experienced health problems.

A possible explanation for the increase in all-cause mortality associated with vitamin E supplementation may be that when consumed in such high dosages, antioxidants can behave as pro-oxidants. For example, it has been shown that, in rats, the chronic administration of the antioxidant quercetin results in altered glutathione metabolism. It is well known that such alteration causes oxidative damage [33]. In addition, when an antioxidant neutralizes a reactive species, it becomes oxidized itself and may lead to oxidative damage [44].

QUERCETIN

While the antioxidant vitamins C and E have been well-researched over the years, another class of bioactive compounds, known as phytochemicals, are becoming of more interest in the scientific community due

to their health promoting properties. More specifically, these compounds have been found to have antioxidant, anti-inflammatory, and lipid-lowering actions [34]. The flavanoids are a class of naturally occurring phytochemicals, and are found abundantly in fruits, vegetables, grains, cocoa, tea, coffee, and red wine [45]. The consumption of flavanoid-rich food has been linked to reducing the risk of heart disease, cancer, and neurodegenerative disorders. These protective effects have been attributed to their powerful antioxidant properties [46].

Quercetin, one of the flavanoids identified in SDR (1.2 mg/oz) [47], has significantly stronger antioxidant properties than vitamin C [46]. Thus, much interest has arisen in the potential of quercetin to limit oxidative damage, but like other antioxidants, excessive intake of quercetin can actually impair exercise performance. Further, excessive intake of quercetin has been found to exert harmful effects. Choi et al. (2003) found that, in rats, chronic quercetin administration led to a decrease in glutathione (GSH) concentration [48]. Interestingly, another study discovered that if GSH is absent when quercetin acts to scavenge ROS, toxic byproducts are formed [44]. Furthermore, dysfunction in GSH metabolism has been linked to neurodegenerative diseases such as Alzheimer's disease, Huntington's disease, and Parkinson's disease [33].

Quercetin has also been examined for its potential to enhance exercise performance. MacRae & Mefferd (2006) found that 6 weeks of an antioxidant supplement combined with quercetin (600 mg/d) improved time trial performance [40]. This finding conflicts with a 2008 study by Quindry et al. [49] in which quercetin supplementation (1000 mg/d) failed to promote exercise performance. In this study, subjects supplemented with an antioxidant cocktail containing quercetin (1000 mg/d) 3 weeks prior to and during the 160-km Western States Endurance Run and race time was the primary outcome measure.

The dosages of quercetin administered to the participants of these studies were 10-20 times the amount that can be consumed through a typical vegetarian diet. Such high dosages have been suggested to potentially induce mutations and cytotoxicity when ingested over a long period of time [45]. Although the dosages implemented in the studies by MacRae et al. [40] & Quindry et al. [49] failed to show any adverse health effects

in the participants, the length of the supplementation period may not have been long enough for the negative side effects to manifest themselves.

The risks of such high dosages can be avoided by consuming antioxidants via whole foods where there is a balanced mixture of low levels of various phytochemicals and nutrients. There are several studies that have examined the effects of consumption of whole foods containing various antioxidants on markers of oxidative damage as well as on markers of chronic disease. In a study by Fraga et al. [36], researchers found that regular consumption of a flavanol-containing milk chocolate (FCMC) attenuated exercise-induced oxidative damage in young soccer players. In addition, the consumption of the FCMC had favorable effects on risk factors for cardiovascular disease as evidenced by decreases in blood pressure and LDL cholesterol levels following the 14-day FCMC dietary intervention.

The consumption of fresh fruits and vegetables has long been established as a way to increase consumption of dietary antioxidants although it is common practice to consume these health-promoting plant compounds via pills and capsules. Unfortunately, the beneficial compounds present in these supplements often exist in isolation to the other compounds found naturally in whole foods, and some studies suggest that optimal health benefits are achieved through the consumption of whole foods where these antioxidant compounds act synergistically [50].

Epidemiological studies have consistently demonstrated that the consumption of fruits and vegetables are strongly associated with reduced risk of chronic diseases [50] while pure compounds isolated from these foods have not shown the same benefits [34]. The isolated antioxidants either lose their bioactivity or do not behave in the same manner they do in whole foods [50]. For example, Vitamin C has been shown to act as an antioxidant, but when ingested at doses higher than 500 mg/d, this vitamin has been shown to be a pro-oxidant and cause increased DNA damage [34].

Both SJB and SDR provide a source of antioxidants. Specifically, SJB are fortified with vitamin C, while SDR contain a unique mixture of phytochemicals, including the flavanoids quercetin and kaempferol

[47]. These phytochemicals have been shown exert numerous health benefits including not only antioxidant activities, but also anticancer and antiviral activities.

Because of their antioxidant potential, SDR have been recently examined for their ability to reduce exercise-induced oxidative stress. In a study by Spiller et al. [51], SDR were shown to offer better protection from exercise-induced oxidative stress than an isocaloric glucose drink. In this cross-over study, nine healthy adult athletes (5 females and 4 males) completed a triathlon (1500 m swim, 40 km bicycle ride, and a 10 km run) twice, two weeks apart. Participants were divided into two groups and received either SDR or a glucose drink of same caloric value prior to the swim and halfway through the bicycle ride, and halfway through the run. During the second triathlon, the groups were reversed. Urine samples were collected prior to, and immediately following the completion of the triathlon. All females and 2 of the 4 males showed lower or no DNA damage following the triathlon in which SDR were consumed (as measured by urinary concentrations of 8-oxo-2'-deoxyguanosine; 8-oxo-2'-dG).

QUERCETIN AND MENTAL FOCUS

In addition to acting as an antioxidant, quercetin may have the potential to maintain an individual's ability to concentrate, pay attention, and act in a vigilantly following intense exercise [52]. In a 2007 study by Rocheleau et al. [52] forty trained, male cyclists were randomly assigned to either quercetin or placebo groups in a double-blind manner. Participants supplemented with either quercetin (1,000 mg/d) or placebo for 3 weeks prior to, and during a 3-day exercise period in which they cycled for 3h/day at ~ 57% of their maximal power output. To determine quercetin's ability to affect cognitive function, participants completed a sustained-attention, reaction-timed task prior to and after each exercise bout (10-minute Pyschomotor Vigilance Task, Walter Reed Army Institute of Research). Results indicated that all participants experienced a slowing of reaction time across the 3-days of intense exercise, and from pre-exercise to post-exercise across days, but the reaction time deficits observed from pre- to post-exercise were attenuated in those participants who received the quercetin treatment. Thus, it is possible that the quercetin-containing SDR may improve cognitive function compared with the SJB.

Flow is a psychological construct that represents those moments "when everything comes together for the performer," and has been associated with superior performance and is a valued experience for individuals engaging in physical activity [6]. Being able to achieve flow during sport and exercise can raise an experience to higher levels of both achievement and enjoyment [53]. The achievement of flow is not easy to attain, and its achievement involves a certain level of psychological skills, such as the ability to control attention. This is important as the previously mentioned study by Rocheleau et al. [52] found that quercetin has the potential to positively influence attention-requiring tasks. Therefore, the consumption of quercetin-containing SDR may promote the achievement of flow during intense exercise.

CONCLUSION AND SPECIFIC AIMS

Sun-dried raisins are a nutritious, convenient, typically palatable, and cost-effective source of concentrated CHO. They also provide an excellent source of phytochemicals, including quercetin. SJB are also a concentrated source of CHO, and are fortified with antioxidants like vitamin C, but they do not contain the natural mixture of antioxidants that are found in SDR. Furthermore, SJB cost about 3.5 times as much as SDR (per ounce: SJB ~$1.00, SDR ~ 0.29¢). Furthermore, previous research has demonstrated that low-cost, natural sources of CHO such as SDR are equally effective as the more expensive, commercial sports supplements (sports gels). To date, no study has assessed the differences in endurance performance following consumption of SDR vs. SJB. In addition, quercetin has recently been shown to positively influence cognitive function following exhaustive exercise. Therefore, the purpose of this study was to assess differences in time trial performance, metabolic responses (RER and blood glucose), mental state ("flow"), RPE, and sensory acceptance following consumption of a natural food (SDR) vs. a sports supplement (SJB). SJB were selected as the sports supplement as they are more similar in texture to SDRs than are sports gels. This study focused on three specific aims. First, this study compared the effectiveness of SDR and SJB in the promotion of endurance performance when fed during a 120-minute glycogen depletion period. Secondly, this study sought to compare metabolic responses to the two fuel sources. Lastly, this study examined which fuel source results in lower

ratings of perceive exertion (RPE) during a 120-minute glycogen depletion period, higher “flow” scores, and greater sensory acceptance (palatability, tolerance, and preference).

CHAPTER 3 MATERIALS AND METHODS

STUDY DESIGN

In this randomized, counter-balanced, crossover study, we examined the effects of the consumption of SDR versus SJB on endurance performance and blood glucose. We also examined differences in RPE, flow questionnaire responses, and sensory acceptance. To accomplish this, participants consumed one of two CHO (1.1g CHO/min.) supplement forms or water-only during a 120-min glycogen depletion period at 80% of their lactate threshold. Supplement forms included SDR (Sun Maid ®) and SJB (Jelly Belly ®). Following the glycogen depletion, participants completed a 10-km time trial. The order in which these treatments were implemented was counter-balanced so that ordering effects were controlled.

PARTICIPANTS

We recruited male and female endurance-trained cyclists/triathletes for this study through postings on online blogs of local cycling/triathlon club websites as well as via flyers posted at local bicycle shops. Participants were healthy as determined by health-history questionnaire and physical examination by a licensed physician. In addition, participants completed a Physical Activity Readiness Questionnaire (PAR-Q) and were informed of the experimental procedures (verbally and in writing). Participants completed an informed consent approved by the institutional review board of Louisiana State University. Upon providing informed consent, each participant was assigned a random identification number. Thereafter, all information regarding the participant was viewed by identification number in order to ensure confidentiality and privacy rights. Inclusion criteria included participants having a $VO_{2\,MAX}$ of 45 ml/kg/min or higher (males), 40 ml/kg/min or higher (females), being within 18-34 years of age, tobacco free, not pregnant, not taking oral contraceptives, and having no history of Diabetes Mellitus, Cardiovascular Disease, or peanut allergies. Participants also agreed to abstain from antioxidant supplements and ergogenic aids throughout the entirety of the study.

PEAK EXERCISE TESTING

Maximal Oxygen Consumption: Before the implementation of the experimental trials, participants reported to the Exercise Biochemistry laboratory for assessment of peak oxygen consumption ($VO_{2\,MAX}$). A metabolic cart

(Moxus) was used to measure oxygen consumption. An electronically braked CompuTrainer™ cycling training ergometer (Seattle, WA) was used concurrently with this cart and the cyclists own bicycle to control workload. Participants performed a 10-minute warm-up at a self-selected intensity not exceeding 100 watts (W). The warm-up was followed by a graded exercise test to determine $VO_{2\ MAX}$ 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 every 3 minutes until they reached 250 W. Thereafter, workload was increased by 25 W every minute until exhaustion. We defined exhaustion as the participant's inability to continue pedaling while seated. Heart rate (Polar, Kempele, Finland) and respiratory data were continuously. The VO_2 max test results were used for the calculation of the submaximal workloads for the lactate threshold test.

Lactate Threshold Test: For this test, participants cycled for 3 minute increments at 65, 70, 75, 80, 85, and 90% of their previously determined $VO_{2\ MAX}$. Upon arrival, participants received a finger stick in a non-dominant finger of their choice in order to obtain a resting blood lactate measure (Lactate Pro Analyzer, Quesnel, BC, Canada). Participants then cycled at 65% $VO_{2\ MAX}$ for 3 min. Finger sticks were conducted at the conclusion of each 3-min stage, and workload was increased to the next 5% increment. The test was concluded after cycling for 3 min at a workload representing 90% $VO_{2\ MAX}$ [7].

Calculation of Workload (Glycogen Depletion): The blood lactate results were plotted against workload. A power output (Watts) equivalent to 5% below that which elicited a blood lactate concentration of 4mmol/l was calculated for the 120-min constant-load cycling bout

[7]

EXPERIMENTAL PROTOCOL

For all exercise trials, participants reported to the Exercise Biochemistry laboratory following an overnight fast (10 hours) between the hours of 5:30am - 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 prior to each experimental trial and to consume the same diet for the 24-hours preceding each experimental trial. Prior to all experimental trials, participants' hydration status was assessed via urine specific

gravity (USG). Participants were required to have a USG below 1.029 in order to complete the trial [54].The first trial for all participants was a water-only acclimatization trial (WAT) which mimicked the experimental trials minus 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, in order 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 min cycling bout at a workload that was at 80% of their lactate threshold [7]. Once the workload was established, participants cycled at this intensity for two hours, and were given 250ml water in 20-minute intervals throughout this constant-load cycling bout. Participants then completed a 10-km time trial. For the experimental trials, one of two CHO (1.1g CHO/min.) supplement forms was randomly assigned. Supplement forms included (a) SDR (Sun Maid ®, 28 gm every 20 min), 90 kcal, 22 gm of CHO (glucose and fructose); (b) SJB (Jelly Belly sport beans ®, 26 gm every 20 min), 92.9 kcal, 22.3 gm CHO (sucrose and corn syrup (a mixture of glucose and fructose)). Carbohydrate intake was equally divided into 6 doses and was consumed in 20-minute intervals during the 120-min glycogen depletion period (Table 1). Water intake was kept constant for all experimental trials (250 ml every 20 min throughout glycogen depletion period).

Table 1. Comparison of the CHO and caloric content of the two CHO supplements.

SJB	SDR
Serving size: 26 grams (13 beans) Servings per trial: 6	Serving size: 28 grams Servings per trial: 6
CHO (gm): 22.3	CHO (gm): 22
Calories: 92.9	Calories: 90

MEASUREMENTS

Performance Measures: Exercise performance was assessed by the average power output and time to complete 10-km time trial.

Metabolic Responses: Capillary finger-prick blood samples were collected at rest and every 20 min during the 120-min glycogen depletion period, and were analyzed using an Accu-Chek Aviva glucose analyzer (Roche; Mannheim, Germany). During the last 5 min of each hour during the 120-min glycogen depletion period,

expired gases were collected and analyzed using the MOXUS metabolic cart with the last 3 min averaged to represent that sampling period [55]. From VCO_2 (volume of carbon dioxide production) and VO_2 (volume of oxygen consumption), total CHO and fat oxidation rates (g/min) were calculated using stoichiometric equations of Frayne (1983) with the assumption that protein oxidation during exercise was negligible [56].

Carbohydrate and Fat Oxidation Formulae:

CHO oxidation = 4.58 VCO2 - 3.23 VO2

Fat oxidation = 1.70 VO2 - 1.69 VCO2

Subjective Measures: Participants were asked to indicate the level of fatigue using Borg's Rating of Perceived Exertion (RPE) every 20 minutes throughout the 120-min glycogen depletion period. The flow state scale-2 (FFS-2) was administered to participants immediately following their experimental exercise trials[6]. Specific instructions were included at the top of the questionnaires. Sensory acceptance measures were evaluated immediately following 10-km time trial using a 9-point hedonic scale questionnaire [57].

DATA ANALYSIS

This study employed a within-participant repeated-measures design to compare the effect of two CHO supplements and water-only on time to complete a 10-km time trial, average power output during the time trial, blood glucose, RER, RPE, and flow questionnaire responses. Using SPSS, repeated measures analysis of variance (ANOVA) was performed with a post hoc analysis to determine significant differences. A dependent *t*-test was used to analyze the difference in sensory acceptance between the raisin and sports bean trials. An alpha level of $p \leq 0.05$ was considered statistically significant.

CHAPTER 4 RESULTS

DESCRIPTIVE CHARACTERISTICS OF PARTICIPANTS

Our initial intention was to recruit an even number of men and women to participate in this trial. After recruitment we successfully recruited 12 male and 3 female endurance-trained cyclists/triathletes for this study. Given the known differences in CHO metabolism observed between men and women during exhaustive exercise [58, 59], and the small number of women cyclists who volunteered for this trial, we chose to limit our analysis to men only. Accordingly, one male participant dropped out of the study prior to completing exercise trials due to scheduling conflicts. One male participant was unable to comply with the experimental protocol, and his data was excluded from the analysis. Demographic data for participants that completed the study are presented in Table 2.

Table 2. Participants' Physical Characteristics, M ± SEM

Variable	Males (*n* = 10)
Age (years)	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
$VO_{2\ max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	52.3 ± 1.3
Peak power output (W)	340.0 ± 13.0
Experimental workload (W)	179.0 ± 7.02

ENDURANCE PERFORMANCE

There were no significant differences in endurance performance between the two CHO supplements (Table 3).

Table 3. Time trial performance measures during the 10-km time trial, M ± SEM

Variable	WAT	SDR	SJB
Time (min)	17.3 ± 0.4	17.3 ± 0.4	17.3 ± 0.4
Power Output (W)	230.1 ± 12.7	229.3 ± 13.0	232.0 ± 13.6

METABOLIC RESPONSES

No significant differences were found among resting blood glucose levels for the three exercise trials. During the WAT acclimatization trial, glucose levels decreased significantly from resting values throughout the 120-minute cycling bout. Glucose levels were significantly higher for both CHO supplements than for WAT at the end of the 120 min cycling bout, with no differences between the CHO supplements ($p = 0.014$; Figure 1).

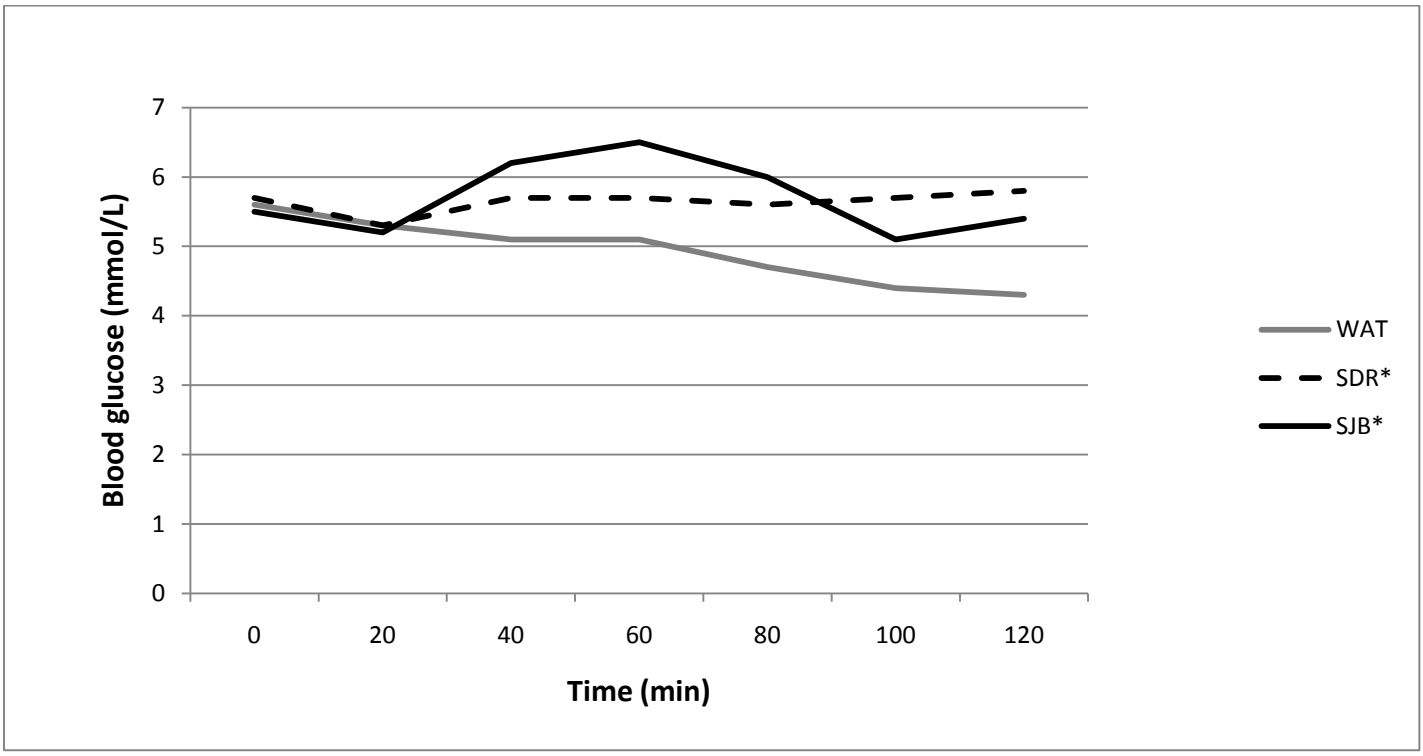

Figure 1. Blood glucose levels throughout 120-min glycogen depletion period. Water-only trials (WAT) n = 10; Raisin trials (SDR) n = 10; Sport jelly beans trials (SJB) n =10. Glucose levels were higher for both CHO supplements when compared to the WAT trial at the 120-min time point ($p = 0.014$).

Data for RER, substrate oxidation rates, and energy expenditure (EE) during the 120-min glycogen depletion period are shown in Table 4. Overall, RER was maintained at or above 0.84 for all experimental trials and we observed no significant differences in RER between any of the trials at hour 1. We did observe significantly higher RER for the CHO treatments compared to WAT during the second hour of the 2 hour ride with no differences observed between the CHO treatments. No significant differences in total CHO oxidation rates were observed at hour 1. The rate of total CHO oxidation was significantly higher at hour 2 during the CHO trials compared to WAT with no significant difference between the CHO treatments. Fat oxidation rates

were not significantly different between any of the trials at hour 1. The ingestion of CHO (SDR and SJB) resulted in significantly lower fat oxidation rates compared to the WAT trial during the second hour of the 2 hour ride with no significant differences between the CHO treatments. No significant differences in EE between any of the trials were found.

Table 4. RER, total CHO oxidation (CHOtot), total fat oxidation (FATtot), and energy expenditure (EE) during 120 min cycling exercise, M ± SEM. [abcde]Significant difference between WAT and CHO trials ([a]p=0.031); [b]WAT and SDR (p=0.010); [c]WAT and SJB (p=0.011); [d]WAT and SDR (p=0.022); [e]WAT and SJB (p=0.017).

	Time (min)	RER	CHOtot(g/min)	FATtot(g/min)	EE(kcal/min)
WAT	60	0.87 ± 0.01	2.04 ± 0.14	0.61 ± 0.04	13.63 ± 0.60
	120	0.84 ± 0.01	1.70 ± 0.11	0.81 ± 0.04	14.12 ± 0.50
SDR	60	0.88 ± 0.01	2.12 ± 0.08	0.55 ± 0.05	13.44 ± 0.50
	120	0.87 ± 0.01[a]	2.11 ± 0.10[b]	0.65 ± 0.06[d]	14.32 ± 0.47
SJB	60	0.89 ± 0.01	2.21 ± 0.13	0.55 ± 0.05	13.76 ± 0.41
	120	0.88 ± 0.01[a]	2.18 ± 0.11[c]	0.61 ± 0.06[e]	14.15 ± 0.36

SUBJECTIVE MEASURES

There were no differences in RPE between any of the treatments during the 120-min exercise bout (13.5 ± 0.3, 13.2 ± 0.2, 13.3 ± 0.2 for water-only, SDR, and SJB, 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 SDR versus SJB. One participant was unable to consume the SJB in their entirety during his trial due to gastrointestinal discomfort, and as a result, his data was excluded from our analyses. On the contrary, a different participant did not prefer the taste of SDR although he experienced no gastrointestinal issues during the raisin trial. Interestingly, the average of his responses to the Hedonics questionnaire was more than 2 standard deviations outside of the overall mean. Therefore, his responses were excluded from the analysis of the hedonics questionnaire.

CHAPTER 5 DISCUSSION

The purpose of this investigation was to compare the effectiveness of a natural source of CHO (i.e. SDR) and a manufactured CHO supplement purported to improve endurance performance in competitive cyclists/triathletes. Participants performed an exercise bout similar to what they would experience under racing conditions, with a moderately hard steady-state exercise bout, followed by a 10-kmTT. Therefore, this protocol is analogous to what an athlete would actually experience during a racing competition. This protocol has also been used in a number of other studies [1, 60, 61].

Sport jelly beans and SDR were ingested at a rate of 1.1g/min and isoenergetic with respect to both CHO and total calorie content. This amount of CHO intake was chosen as this is the dose that is generally recommended for endurance athletes and one that has been shown to provide the maximal rate at which ingested CHO can be oxidized[19]. These two CHO sources resulted in similar time-trial performances and were equally effective in maintaining blood glucose levels throughout the 120-minute glycogen depletion period compared with the water-only acclimatization trial. These results are consistent with previous studies that have examined the effects of different CHO supplement forms during prolonged cycling at moderate to high intensity. Campbell et al. (2008) showed in a study comparing a sports drink, SJB, and sports gel, when fed in isocaloric amounts, that each means of treatment was equally effective in maintaining blood glucose levels during prolonged intense cycling (80 min at 75% VO_{2PEAK}) and in improving endurance performance[1]. In this same study, blood glucose levels at the end of the 80-min glycogen depletion period were comparable to our results. Furthermore, in this same study, time to complete the 10-km TT and the average power output was also comparable to our participants' values.

The lack of significant difference in blood glucose levels at the conclusion of the 120-min 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. Moreover, higher total carbohydrate oxidation rates and lower total fat oxidation rates were observed during the 2nd hour of the CHO trials. This is in agreement with previous

studies [3, 62] and supports the hypothesis that CHO ingestion maintains euglycemia and high rates of CHO oxidation [63].

This study found no significant difference in RPE among the three trials, and this is in agreement with several other studies that failed to detect significant differences in RPE with CHO supplementation [1, 64]. Further, it has been suggested that the RPE scale may have poor reproducibility [65]. We also observed no differences in experiences of flow between the three trials. This is the first study to assess differences in flow experiences when ingesting different CHO supplement forms. We did observe a significant difference in overall preference between SDR and SJB. To date, no study has compared the sensory acceptance of SDRs and SJB, and this is the first study to report greater sensory acceptance of SDRs versus SJB.

The lack of significant difference in endurance performance observed between the CHO trials and the WAT trial was surprising. It is possible that the workload at which the participants were cycling at during the 120-min glycogen depletion period was not high enough to deplete glycogen stores to a level at which CHO supplementation would be beneficial. Another possibility is that the 10-km TT was not of sufficient length. Perhaps by having participants complete longer TT we would have observed significant performance improvements with the CHO supplements compared to the WAT trial.

STRENGTHS AND LIMITATIONS

This study had a few important strengths that are worth mentioning. First, in assessing exercise performance, many previous studies had participants exercise to exhaustion. While time-to-exhaustion is a frequent measure of performance, this measure has been shown to have poor reproducibility [66]. In contrast, the present study had participants complete a 10-km time trial as fast as possible. This protocol is more reproducible, and is also more akin to what an athlete would experience during competitive events. Furthermore, both CHO supplement forms provided equal amounts of CHO and calories. Each participant also underwent both treatments in balanced, randomized order. This allowed us to control for ordering effects.

Several limitations were identified over the course of this study. Participants were asked to complete 24 hour diet records before each trial. Unfortunately, not all participants complied with this record keeping.

Furthermore, some participants were unable to complete the experimental trials 5-7 days apart due to scheduling conflicts and injuries. Also, one participant competed in a half ironman after completing his water-only trial, and even after a 2 week recovery period, his time-trial performances during the CHO trials were markedly slower. The results of this study are also limited to exercise performed in thermo-neutral environments. Indeed, exercise in the heat has been shown to result in marked alterations in substrate utilization at rest and during exercise. Prolonged exercise in the heat leads to the distribution of blood to the skin in order to allow for evaporative cooling [67]. Consequently, blood flow to other organs such as the liver, kidney, inactive tissue and the gut will be reduced. This may impair the absorption of CHO (as well as other nutrients), and may eventually lead to a reduced oxidation of ingested CHO [19]. Lastly, this study took measurements of RER only during the end of each hour of the 2 hour glycogen depletion period, and this may have limited our ability to detect any potential differences in metabolism between the CHO trials.

FUTURE DIRECTIONS

Although this study provides evidence that SDR and SJB result in similar time-trial performances and are equally effective in maintaining blood glucose levels and high rates of CHO oxidation late in exercise, a few questions remain. For example, future research should measure RER more frequently during the glycogen depletion period in order to better detect any potential differences in metabolic responses between the two CHO sources. It may also be of interest to measure and compare exogenous CHO oxidation rates between the two CHO supplements.

CONCLUSIONS

It may be concluded from this study that SDR and a commercial sports supplement (i.e. SJB) fed in the amount of 1.1g/min during intense cycling elicit relatively similar performance and metabolic effects. Such findings suggest that natural foods such as raisins may be added to the list of CHO supplements available to athletes. In addition to being less expensive and less processed, SDR are convenient, portable, and contain a variety of naturally occurring nutrients that are not present in SJB. Some athletes may also prefer the taste of raisins to sport beans as evidenced by results from our Hedonics analyses. Lastly, SJB cost approximately 3.5

times as much as SDR (per ounce, SDR: 0.29¢; SJB: $1.00). Therefore, natural CHO-supplement forms such as SDR 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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APPENDIX A. FLOW-STATE 2 SCALE

Event Experience Scale (FSS-2)

Please answer the following questions in relation to your experience in the event or activity you have just completed. These questions relate to the thoughts and feelings you may have experienced while taking part. There are no right or wrong answers. Think about how you felt during the event/activity and answer the questions using the rating scale below. For each question circle the number that best matches your experience.

Rating scale

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1	2	3	4	5

PLEASE CIRCLE ANSWER

During the Event:

1. I was challenged, but I believed my skills would allow me to meet the challenge.				
1	2	3	4	5
2. I made the correct movements without thinking about trying to do so.				
1	2	3	4	5
3. I knew clearly what I wanted to do.				
1	2	3	4	5
4. It was really clear to me how my performance was going.				
1	2	3	4	5
5. My attention was focused entirely on what I was doing.				
1	2	3	4	5
6. I had a sense of control over what I was doing.				
1	2	3	4	5
7. I was not concerned with what others may have been thinking of me.				
1	2	3	4	5
8. Time seemed to alter (either slowed down or speeded up).				
1	2	3	4	5
9. I really enjoyed the experience.				
1	2	3	4	5
10. My abilities matched the high challenge of the situation.				
1	2	3	4	5
11. Things just seemed to be happening automatically.				
1	2	3	4	5
12. I had a strong sense of what I wanted to do.				
1	2	3	4	5
13. I was aware of how well I was performing.				
1	2	3	4	5
14. It was no effort to keep my mind on what was happening.				
1	2	3	4	5
15. I felt like I could control what I was doing.				
1	2	3	4	5
16. I was not concerned with how others may have been evaluating me.				
1	2	3	4	5
17. The way time passed seemed to be different from normal.				
1	2	3	4	5

CONTINUES OVER

Rating scale

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1	2	3	4	5

PLEASE CIRCLE ANSWER

During the Event:

18. I loved the feeling of the performance and want to capture it again.

1	2	3	4	5

19. I felt I was competent enough to meet the high demands of the situation.

1	2	3	4	5

20. I performed automatically, without thinking too much.

1	2	3	4	5

21. I knew what I wanted to achieve.

1	2	3	4	5

22. I had a good idea while I was performing about how well I was doing.

1	2	3	4	5

23. I had total concentration.

1	2	3	4	5

24. I had a feeling of total control.

1	2	3	4	5

25. I was not concerned with how I was presenting myself.

1	2	3	4	5

26. It felt like time went by quickly.

1	2	3	4	5

27. The experience left me feeling great.

1	2	3	4	5

28. The challenge and my skills were at an equally high level.

1	2	3	4	5

29. I did things spontaneously and automatically without having to think.

1	2	3	4	5

30. My goals were clearly defined.

1	2	3	4	5

31. I could tell by the way I was performing how well I was doing.

1	2	3	4	5

32. I was completely focused on the task at hand.

1	2	3	4	5

33. I felt in total control of my body.

1	2	3	4	5

34. I was not worried about what others may have been thinking of me.

1	2	3	4	5

35. I lost my normal awareness of time.

1	2	3	4	5

36. I found the experience extremely rewarding.

1	2	3	4	5

APPENDIX B. 9-POINT HEDONICS SCALE

Please evaluate this product and check the space that best reflects your feeling about the product.

1. How would you rate the **APPEARANCE** of this product?

Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

2. How would you rate the **COLOR** of this product?

Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

3. How would you rate the **OVERALL FLAVOR (taste and odor)** of this product?

Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

4. How would you rate the **SWEETNESS** of this product?

Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

5. Please rate the SWEETNESS of this product based on your preference

Not sweet enough	Just about right	Too sweet
[ ]	[ ]	[ ]

6. How would you rate the **SOURNESS** of this product?

Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

7. How would you rate the **TEXTURE/MOUTHFEEL** of this product?

Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

8. Please rate your **OVERALL LIKING** of this product?

Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely
[ ] 1	[ ] 2	[ ] 3	[ ] 4	[ ] 5	[ ] 6	[ ] 7	[ ] 8	[ ] 9

9. Is this product **ACCEPTABLE**? Yes [ ] No [ ]

10. Would you **BUY** this product if it were commercially available? Yes [ ] No [ ]

11. Would you **BUY** this product if it contains a health-promoting ingredient? Yes [ ] No [ ]

VITA

Helena Rietschier was born on Labor Day of 1983 in Baton Rouge, Louisiana. Waiting at home were two rowdy brothers and two sisters ready to play with their new baby doll. Life was never dull. Helena grew up surrounded by kids, living in a neighborhood considered safe enough for kids to ride bikes, skate, and play without a worry. There was a neighborhood swim team and most summers consisted of swim meets, pizza nights, and barbeques. Helena excelled in school from kindergarten to graduating from high school with honors. Following high school, she enrolled at Louisiana State University which had become a family tradition, with both parents and all older siblings being alumni. Helena began her college career with an interest in exercise and how it impacted health, majoring in kinesiology. Later in her undergraduate career, she became increasingly interested in the study of nutrition and psychology, and wanted to combine these two areas of study with her study of kinesiology. In 2008, graduating with *summa cum laude* honors from Louisiana State University, Helena earned a Bachelor of General Studies with minors in sports studies, nutritional sciences, and psychology. During her last semester as an undergraduate student, she was introduced to Dr. Laura Stewart of the LSU exercise physiology department at LSU whose research Helena found fascinating as it included aspects of both exercise and nutrition. Realizing her interest in this kind of research, Helena applied for the exercise physiology master's program at LSU. Under the guidance of Dr. Stewart, her major professor, Helena conducted her thesis project in the fall and spring of 2009-2010. Helena successfully defended her thesis in April of 2010 and will be awarded a Master of Science in kinesiology in the spring of 2010.

Helena's future plans include pursuing a career as a registered dietitian. She hopes to use her knowledge of kinesiology, nutrition, and psychology to help individuals achieve their goals for a healthier lifestyle.