Acute modulation in dietary behavior following glycogen depletion and post-exercise supplementation in trained cyclists

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Acute modulation in dietary behavior following glycogen depletion and post-exercise supplementation in trained cyclists

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Abstract

We investigated the influence of immediate post-exercise dietary supplementation on the subsequent food consumption pattern and endurance exercise performance in physically trained individuals. On two occasions, trained male cyclists performed a glycogen-depleting exercise bout followed by a 2-hour nutritional supplementation period, 28 hours of free-living recovery, and a subsequent 40-km cycling time trial. During the 2-hour post-exercise supplementation, subjects consumed equal volumes of reduced-fat chocolate milk (CM) or a sports beverage (SB) in a single-blind, randomized design. Thereafter, cyclists maintained a food log during the free-living recovery period. Dietary and exercise performance parameters were compared between the treatment beverage visits. No differences in total caloric and macronutrient intakes over the course of free-living recovery were detected between the CM and SB trials. However, a significant interaction (treatment × time) was detected for caloric and macronutrient intakes during the early phase of free-living recovery, such that significantly larger proportions were consumed shortly following SB as compared with CM. No difference was observed in completion time of the 40-km cycling time trial (CM: 66.9 ± 4.1 vs SB: 66.9 ± 3.7 min). Hence, cyclists achieved similar levels of recovery during the prolonged, free-living period despite the different acute, post-exercise nutrient intake rates. We suggest that given adequate time, the athletes appear to unconsciously modify their food consumption in response to varied post-exercise supplementation such that subsequent day exercise performance is equivalent.

Key words: carbohydrate, chocolate milk, recovery, food intake, endurance performance
Introduction

Muscle glycogen is the predominant skeletal muscle fuel source utilized during prolonged, intensive exercise, and glycogen depletion is recognized as a potential limiting factor to this type of performance (Costill et al. 1981). The depletion of muscle glycogen is not only associated with the eventual cessation of exercise but is also suggested to be related to the perception of fatigue (Ivy 1998). Therefore, replenishment of muscle glycogen following exhaustive exercise is paramount for optimizing subsequent physical performances. In order to maximize the rate and level at which depleted muscle glycogen is restored, it is recommended that athletes consume high-carbohydrate (CHO) meals or CHO-loaded drinks immediately following intensive physical work training in preparation for the next exercise bout (Costill et al. 1981); delaying CHO intake for even as little as two hours post-exercise curtails the maximal restoration rate of muscle glycogen (Ivy et al. 1988). This particularly holds true when the recovery time between two exercise bouts is limited (e.g., < 4 hours).

More recently, adding protein (PRO) to CHO loads has shown to enhance recovery from high-intensity endurance workouts as compared to CHO alone (Ivy et al. 2003; Williams et al. 2003). The phenomenon is ascribed to the insulinotropic properties of PRO and amino acids, which facilitates glucose transportation into muscle cells and increases glycogen resynthesis when the post-exercise CHO ingestion rate is suboptimal (Zawadzki et al. 1992; Ivy 1998; Van Hall et al. 2000; van Loon et al. 2000; Wojcik et al. 2001). With respect to the post-exercise supplementation recommendations already alluded to, chocolate milk (CM) has been proposed as an effective recovery drink (Saunders 2011). Specifically, previous studies have focused on the efficacy of CM on improving athletes’ performance in multiple daily exercise bouts (Karp et al. 2006; Thomas et al. 2009; Ferguson-Stegall et al. 2011; Lunn et al. 2012). The rationale for the
use of CM following exercise is that it supplies a relatively large amount of CHO in small serving volume, provides adequate water replacement, and contains the suggested optimal ratio of CHO and PRO (4:1) that is similar to supplemental feedings previously shown to be effective (Ivy et al. 2002; Williams et al. 2003; Saunders et al. 2004). However, most of research into post-exercise nutrition strategies has used shortened (2–8 hours), activity-restrictive recovery periods and restricted subjects' dietary intake. While this research design isolates the impact of specific macronutrients on muscle glycogen synthesis rate and subsequent exercise performance, this method fails to consider the athlete's potential ability to select and modify dietary intake in addition to the ingestion of different recovery beverages. In other words, when the recovery period diet is unrestricted (i.e., total calories or macronutrient composition are not controlled), it is not well understood how differing post-exercise supplementation beverages influence the quantity and timing of macronutrient consumption over the following 24 hours. Given that the majority of athletes train once a day, additional data upon the consequences of dietary manipulation providing more typical extended recovery periods appear warranted.

In general, human eating behavior does not respond quickly to the energy expenditure of an exercise bout (King et al. 1997). Several studies have reported no effect of exercise on dietary intake immediately and up to 24 hours following exercise regardless of the mode and intensity (Imbeault et al. 1997; King et al. 2010; Balaguera-Cortes et al. 2011; Gonzalez et al. 2013). Conversely, fewer studies have shown that participants consume more calories during the initial meal following exercise (Pomerleau et al. 2004; Martins et al. 2007). The discrepancy in previous study findings may be partly explained by the conditioning status of the subjects studied. Compared to sedentary people, habitual exercisers tend to change their food choices to compensate for the “excess” resulting from caloric manipulation, suggesting that physically
active individuals are able to adjust dietary intake to maintain energy balance (Long et al. 2002). While exercise-induced caloric deficits can potentially compromise future performance, manipulating nutrient content of the diet may have the ability to rectify the negative energy balance (King et al. 1996). However, it remains unclear whether or not the benefits of single to 2 doses of post-exercise supplements are still apparent when diet is self-selected and unrestricted during a longer recovery period in trained athletes.

Due to limited information on the relation among intense exercise, dietary supplementation, and athletes’ dietary behavior, the present study was primarily focused on the potential modification of short-term energy and macronutrient intakes following exhaustive exercise and specific post-exercise refueling treatments in physically trained cyclists. Secondary to this, an additional purpose was to determine the relation between the post-exercise refueling treatments and exercise performance subsequent to an extended recovery. Hence, we hypothesized that athletes would alter their short-term caloric and macronutrient intakes following the post-exercise refueling treatments so as to maintain similar daily energy balance. Secondarily, we hypothesized that given a sufficiently long recovery period and the ability to alter their own diet, exercise performance would be similar following the post-exercise refueling treatments.

**Materials and methods**

**Subjects.** Twelve male cyclists (n = 12) were recruited to participate in this study. Subjects were regularly trained (moderate- to high-intensity cycling, 9.7 ± 3.4 hours per week) and actively competed intra- and/or extramural cycling races based on the self-report. Other selection criteria included healthy non-smokers and maximal oxygen consumption (VO2max) above 55 ml·kg⁻¹·min⁻¹ in the incremental cycling test (Karp et al. 2006) to confirm their training
status. Subjects’ characteristics were present in Table 1. Due to the nature of the study, individuals with lactose intolerance and milk/chocolate allergies were excluded from participation. Prior to subject recruitment all protocols and procedures used in this study conformed to the Declaration of Helsinki and were approved by the Institutional Review Board of Indiana University. All volunteers provided written informed consent after written and verbal explanations of the procedures and risks were presented.

Experimental design. Cyclists were required to complete two treatment sessions, each separated by 2 weeks. Aerobic capacity (\(\dot{V}O_{2\text{max}}\)) and maximal power output (\(P_{\text{max}}\)) were preliminarily determined using an incremental exercise protocol on a mechanically braked cycle ergometer (Ergomedic 874E, Monark Exercise AB, Langley, WA, USA). Subjects carried out a glycogen depletion trial, supplementation and recovery periods, and a 40-km cycling time trial for each supplemental beverage ingested. The supplemental beverages were randomly assigned in a crossover design such that each subject served as his own control. All subjects were required to refrain from physical activity for 24 hours prior to each testing session. Total body water was estimated using bioelectrical impedance analysis (BIA-101S, RJL Systems, Clinton Township, MI, USA) before each exercise bout. The glycogen depletion and time trial exercise bouts were separated by 30 hours of passive recovery. During the initial 2 hours of the recovery period, subjects were provided with either reduced-fat CM (The Kroger Co., Cincinnati, OH, USA) or sports beverage (SB; Gatorade Thirst Quencher, The Gatorade Co., Chicago, IL, USA). The composition of CM and SB was listed in Table 2. The selections for the supplement drinks and the administration pattern were adopted from previous studies from our lab and others, showing that compared with SB, post-exercise CM ingestion improved muscle recovery (Ferguson-Stegall et al. 2011; Lunn et al. 2012) and subsequent exercise performance (Karp et al. 2006;
Thomas et al. 2009; Ferguson-Stegall et al. 2011, Lunn et al. 2012) with a shorter recovery period. The drinks were prepared by outside personnel so investigators were blind to the treatment allocation. Subjects were instructed to eat *ad libitum* and record their daily diets during the 28-hour post-depletion/supplementation, free-living recovery period. The research protocol of each testing day for the two treatments is shown in Figure 1.

**Glycogen depletion trial.** The procedure for this test has been previously described (Kuipers et al. 1987; Van Hall et al. 2000). Subjects visited the lab at 8 AM following an 8–10 hour overnight fast. To deplete muscle glycogen, alternating bouts of 2-minute exercise at 90% $P_{\text{max}}$ and 2-minute recovery at 50% $P_{\text{max}}$ were repeated until the subject could no longer maintain the pedal cadence set in the $\dot{VO}_{2}\text{max}$ test. Then, the intensity of the exercise phase was decreased by 10%, and the subject continued to work until he failed to ride at the required RPM. The pattern of 10% decrement in the exercise intensity and alternating bouts of cycling were continued to proceed until the subject was unable to sustain his required cadence for a minute while cycling at the 60% $P_{\text{max}}$ and 50% $P_{\text{max}}$ bouts. At that moment, the trial was stopped. Water consumption was unrestricted and recorded during the trial.

**Supplementation and recovery period.** While resting in the laboratory, cyclists were required to begin drinking the supplemental beverages immediately following the glycogen-depleting exercise and again two hours later. The volume of CM ingested corresponded to 1.0 g of CHO·kg$^{-1}$ body weight for each dose (Ivy 1998; van Loon et al. 2000; Jentjens and Jeukendrup 2003; Ivy 2004). Subjects received an isovolumic SB (0.4 g of CHO·kg$^{-1}$ per dose) in the alternate session. Except for *ad libitum* water, no other food or beverage was allowed within the 2-hour supplementation period. Upon consuming the second treatment dose, subjects were released from the laboratory with instructions to: 1) adopt their normal living routine for the rest
of recovery period prior to the cycling time trial the following day; and 2) maintain a detailed
food log.

*Forty-kilometer cycling time trial.* Cyclists reported to the laboratory following 30-hour
recovery from the end of the glycogen depletion exercise bout. After a 5-minute warm-up on a
computer-interfaced bike trainer (Velotron, RacerMate Inc., Seattle, WA, USA), subjects were
asked to cycle a simulated distance of 40-km as fast as possible. The reliability and validity of
simulated time trials using Velotron have been previously reported, in terms of performance,
physiological measurements, and pacing strategy (Abbiss et al. 2009; Noreen et al. 2010; Stone
et al. 2011; Thomas et al. 2012). Elapsed time and heart rate (Polar T61-CODED, Polar Electro,
Lake Success, NY, USA) were continuously recorded during the time trial. Rating of perceived
exertion (RPE) was recorded every 5 minutes. Subjects were permitted to drink water *ad libitum*
during the time trial, and the amount of water consumed was recorded.

*Dietary analysis.* For the three days prior to the glycogen depletion trials, subjects were
instructed to record their intake of all CHO-containing foods. Subjects received instruction on
using the American Diabetes Association’s Dietary Exchange List System that classifies foods
by macronutrient content (Wheeler et al. 2008). Upon completion of the glycogen depletion
exercise trial, subjects were given a food diary to record all food and beverage consumed until
the 40-km time trial the following day. The food diary was analyzed by a registered dietitian
using the United States Department of Agriculture’s (USDA) National Nutrient database
accessed through ChooseMyPlate.gov (DepartmentofAgriculture 2011).

*Statistical analysis.* Comparisons of the results between the treatments were made using
paired Student’s t-tests except for the free-living dietary data. Two-way ANOVA with repeated
measures was performed to examine the main effects and interaction of treatment and time on
the free-living dietary intake. If significant interaction was detected, the paired t-test was used for the simple contrast of the treatments in each time point, with the Bonferroni correction for the familywise error. Statistical analyses were accomplished using statistical software (SAS 9.3, SAS Institute Inc., Cary, NC, USA). Statistical significance was set at $p < 0.05$. Data are presented as mean ± S.D. unless otherwise specified.

Results

The average amount of CHO consumed in the three days prior to the CM and SB trials were $5.9 ± 3.1 \text{ g·kg}^{-1} \cdot \text{day}^{-1}$ and $6.1 ± 3.5 \text{ g·kg}^{-1} \cdot \text{day}^{-1}$, respectively ($p > 0.05$). Thus, though we do not have the direct data on muscle glycogen content, we posit that the muscle glycogen available for each trial is similar based on the near-identical levels of CHO intake. Body mass ($71.2 ± 2.2$ vs $71.1 ± 2.2$ kg) and total body water ($38.3 ± 1.4$ vs $37.8 ± 1.2$ kg) measured upon arrival to the laboratory were not different between the CM and SB visits. In regard to the total time (CM: $105.0 ± 34.3$ min, SB: $99.3 ± 28.1$ min) and total amount of work (CM: $1353 ± 546$ kJ, SB: $1263 ± 463$ kJ) completed during the glycogen-depleting exercise bouts, CM and SB trials did not differ. During the 2 hours of post-exercise supplementation, subjects ingested equal volumes of CM and SB, but CM provided greater energy and macronutrient content per serving compared to SB (Table 2).

Dietary intake

The total amount of calories and macronutrients consumed over the entire free-living recovery period (28 hours) did not differ after ingesting CM or SB (Table 3). Due to the absence of dietary activity recorded during bedtime, the intake data before and after sleep were grouped and pooled for the first 12 hours and last 12 hours of the free-living diet. The caloric and macronutrient intakes during the two periods were also similar between the CM and SB trials.
Further examination of the dietary records, however, revealed that eating behavior during the initial 12 hours of the free-living recovery period was different between the supplementation beverages (treatment × time interaction; \( p < 0.05 \)). Specifically, cyclists consumed a relatively larger portion of food in the early phase of recovery following SB compared with CM supplementation (Figure 2A) and then gradually reduced their intake to the late night (Figure 2B). Subjects exhibited similar dietary intake rate and pattern in the 12 hours prior to the cycling time trial (i.e., last 12 hours of the free-living recovery, Figures 3A and 3B). Further, despite the greater energy and macronutrient content of CM, the total amounts of energy and macronutrients consumed during the period between the glycogen-depleting and time trial exercise bouts, including the 2-hour supplementation period, were not different between the CM and SB visits (Table 4).

**Exercise performance**

For the 40-km time trial, performance time following ingestion of CM and SB was identical (66.9 ± 4.1 min and 66.9 ± 3.7 min, respectively) as was average power output (248 ± 40 W and 248 ± 38 W, respectively). Moreover, no differences were observed between the treatments in other variables such as heart rate and average RPE measured over the course of the time trial (data not shown). Additionally, the amount of water ingested during the time trial was not different between the CM and SB visits.

**Discussion**

The primary finding of the present study is that the timing of the free-living diet, in terms of the caloric and macronutrient intakes, is modified according to the composition of the post-exercise supplement drink content ingested immediately after a bout of glycogen depleting exercise. Following CM ingestion, which appears to have served as a type of meal substitution,
cyclists’ dietary intake over the subsequent 6 hours accumulated at a slower rate (see Figure 2A) and then rapidly increased, likely to reflect the regular dinnertime (see Figure 2B). By contrast, it appears that cyclists were less satiated after SB, and thus, motivated to consume a relatively larger portion of their total food in the early free-living period (i.e., first 6 hours) and then less later in the evening. In effect, subjects were able to modify their caloric and macronutrient intake patterns following post-exercise beverage ingestion, intriguingly, in such a way that the total amount of calories consumed over the free-living recovery was similar between CM and SB. Furthermore, perhaps due to this unconscious ability to regulate their diet, and combined with a long recovery period, there was no exercise performance benefit to drinking the supplement following intensive exercise.

It has been found that consuming single preloads of varied-calorie/macronutrient composition does not affect subsequent spontaneous feeding behavior over the following two (Rolls et al. 1989) to 24 hours (Degraaf et al. 1992). On the contrary, other research indicates that energy intake (EI) is altered after eating meals that vary in CHO, fat (Goldberg et al. 1998) or PRO (Weigle et al. 2005). These studies, however, used dietary manipulation over a longer duration (≥1 day), making it difficult to compare with findings of the present study. The incomparable findings between the studies could be attributed not only to the different duration of dietary manipulation but other methodological considerations (i.e., an exercise protocol). It has been suggested that an EI pattern different from normal following dietary manipulation may not occur in an acute setting without completion of additional physical activity (Bray et al. 2008).

Our data implicate the combined influences of an intensive exercise bout and the beverage supplement on changing subsequent dietary behavior. Numerous studies have
demonstrated that intense exercise does not have a short-term effect on subsequent food intake (Imbeault et al. 1997; King et al. 1997; King et al. 2010; Balaguera-Cortes et al. 2011; Gonzalez et al. 2013). Yet, these studies did not include a supplementation period immediately following the exercise bout. Therefore, in conjunction with previous findings, our results indicate that completion of exhaustive exercise and the content of a supplementation beverage interact to alter the dietary behavior of trained cyclists over the following 12 hours.

An individual’s training state may also play a critical role in the ability to manipulate EI following intensive exercise. Physically active individuals are more inclined to regulate their diet to maintain energy balance compared with non-exercisers (Barr and Costill 1992; Long et al. 2002; Rumbold et al. 2015), which may contribute to the disparity between the current findings and those already mentioned above. The long-term effect of exercise on free-living dietary intake appear inconsistent between regular exercisers (Barr and Costill 1992) and non-regular exercisers (Stubbs et al. 2002). Therefore, in addition to the findings of Barr and Costill (1992), who showed that collegiate swimmers modified their EI in correspondence with training volume over the course of the training season, we believe that athletes also are capable of acutely modulating their diet in response to the energy expended during an exercise bout and insufficient EI resulting from the post-exercise supplement.

The exact mechanism(s) for how conditioning status increases the ability to regulate subsequent energy and macronutrient intake following exercise remains to be established. The modification of eating pattern observed in the current study could be via effects of long-term exercise on hormones regulating appetite (Gomez-Merino et al. 2002; Foster-Schubert et al. 2005; Jones et al. 2009) although their direct impacts on the subsequent EI is unclear (Hopkins et al. 2011). Of note, dietary intake in the present study was altered only within the 12 hours
following supplementation, but the total amount of food and its macronutrient composition measured over the entire 30-hour recovery period did not differ between the treatments. The time over which the diet is examined may also explain why some studies have found unaltered diet selection when the EI was assessed on a daily basis (Degraaf et al. 1992; Stubbs et al. 1993; Shetty et al. 1994; King and Blundell 1995; King et al. 1997; Snitker et al. 1997).

Another possible mechanism whereby exhaustive exercise and post-exercise supplementation might affect dietary behavior could be the interplay between muscle glycogen stores and blood glucose concentrations. Ratings of hunger and satiety and meal initiation have been observed to be synchronized with the circulating glucose level of blood (Melanson et al. 1999b). Furthermore, the association between meal initiation and decline in blood glucose tends to be more tightly linked after glycogen storage is depleted and partially restored, whereas depleting glycogen alone causes slow elevation of hunger feeling and delays in the onset of feeding (Melanson et al. 1999a). Studies using functional magnetic resonance imaging has also shown that perturbations to the blood glucose level lead to activation of brain regions associated with the drive to eat and preference of high-calorie diet under hypoglycemia (Page et al. 2011). Our findings are supportive of observations from those previous studies: in our glycogen-depleted subjects who received SB (low CHO content), circulating blood glucose likely remained at a low level, and thus, activation of certain brain regions manifested as increased EI in the immediate hours following the supplementation period.

The other major finding from this study is that CM consumption immediately following fatiguing exercise did not improve cycling performance the following day in comparison with a commercial SB. Although post-exercise CM ingestion has been shown to facilitate muscle recovery (Ferguson-Stegall et al. 2011; Lunn et al. 2012) and improve subsequent exercise
performance after limited recovery periods (Karp et al. 2006; Thomas et al. 2009; Ferguson-Stegall et al. 2011; Lunn et al. 2012), the lack of performance benefits attributable to CM here is contrary to these findings. As an example, Thomas et al. (2009) reported that subjects had better endurance capacity and cycled 43% longer 4 hours later following CM ingestion compared to SB. Different duration of recovery periods presumably explain the inconsistency between study findings.

Prior work has suggested that the timing of CHO intake might be less of a determinant in replenishing muscle glycogen stores compared to the total CHO intake when athletes were given 24 hours of recovery. Following glycogen depletion Burke et al. (1996) provided subjects an identical amount of CHO with different feeding frequencies, either large volume (2.5 g CHO·kg\(^{-1}\)) fed a few times or a small portion (0.6 g CHO·kg\(^{-1}\)) ingested frequently over 24 hours. The authors failed to find differences in muscle glycogen stores even though blood glucose and insulin responses were greater when consuming the large-volume diet. Similarly, Parkin et al. (1997) reported that a 2-hour delayed ingestion of CHO resulted in no effect on muscle glycogen content at 8 hours and 24 hours following a bout of strenuous exercise when subjects consumed multiple diets containing high CHO (2.5 g CHO·kg\(^{-1}\)) over a 24-hour recovery period. For optimal replenishment of muscle glycogen, the authors proposed that sufficient CHO should be ingested within the initial 6 hours if athletes fail to consume CHO immediately after fatiguing exercise (Parkin et al. 1997). Nonetheless, the lowest limit of the CHO intake necessary to restore muscle glycogen to pre-exercise levels was not determined. It should be noted that their subjects ingested 7.5 g CHO·kg\(^{-1}\) within 6 hours post-exercise, which is higher than the amounts observed in the present study (CM: 4.2 g CHO·kg\(^{-1}\), SB: 3.7 g CHO·kg\(^{-1}\)).
When the findings of Burke et al. (1996) and Parkin et al. (1997) are both considered, it seems reasonable, then, that muscle glycogen stores were replenished to a high level given that subjects in the present study obtained sufficient amounts of CHO from their self-selected diets even without commensurate CHO during the immediate 2-hour post-exercise recovery period. Instead of free-living diets, the studies mentioned above (Burke et al. 1996; Parkin et al. 1997) used standardized meals and the amounts of subjects’ total CHO intake were high (~700–900 g CHO·day⁻¹). By choosing food freely and eating *ad libitum* following the 2-hour supplementation period, subjects in our study also achieved the recommended daily CHO intake (Costill et al. 1981) with CM and SB (see Table 3). Hence, the results of the present study suggest that athletes are able to partake enough CHO from their daily dietary choices such that immediate post-exercise feeding regimes are less important for exercise performances following prolonged recovery periods.

**Conclusion**

The findings of the present study demonstrate that athletes can modify eating behavior based upon the energy expended during exercise and the post-exercise supplementation beverage but with no change to total daily food intake as a whole. Furthermore, cyclists appear able to consume sufficient CHO from daily diets to replenish depleted muscle glycogen stores, such that post-exercise ingestion of CM offers no exercise performance benefit in trained cyclists compared with SB when there is a sufficiently long recovery period. Taken together, we propose that trained athletes are able to quickly respond to the glycogen depletion and the energy deficit from a fatiguing exercise bout and subsequent refueling supplement, which in turn leads to the similar exercise performance on the next day.

**Acknowledgement**
The study was designed by JMS; data were collected and analyzed by HW, JLS and EJD; data interpretation and manuscript preparation were undertaken by HW, JLS, JMS, and AKL. All authors approved the final version of the paper.

**Disclosure Statement**

The authors declare that there are no conflicts of interests.

**References**


PMID:21222130.


<table>
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<tr>
<th>Subject</th>
<th>Age (year)</th>
<th>Mass (kg)</th>
<th>Height (cm)</th>
<th>$\dot{V}O_{2\text{max}}$ (ml·kg$^{-1}$·min$^{-1}$)</th>
<th>$P_{\text{max}}$ (W)</th>
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*Note.* $\dot{V}O_{2\text{max}}$: maximal oxygen consumption relative to body mass; $P_{\text{max}}$: maximal power output obtained in the incremental cycling test.
Table 2. Nutritional Content of Post-Exercise Supplement Drinks

<table>
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<tr>
<th>Drink</th>
<th>Chocolate Milk</th>
<th>Sports Beverage</th>
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<tr>
<td>Volume (ml)</td>
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<td>1020 ± 122</td>
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<tr>
<td>Energy (kcal)</td>
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<tr>
<td>Carbohydrate (g)</td>
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<td>Fat (g)</td>
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<tr>
<td>Protein (g)</td>
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<td>0 ± 0*</td>
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<tr>
<td>Sodium (mg)</td>
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<tr>
<td>Potassium (mg)</td>
<td>1794 ± 215</td>
<td>128 ± 15*</td>
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*Note. Values are mean ± S.D. *significantly different from chocolate milk, p < 0.05.
### Table 3. Composition of Subjects' Diets during the 28-hr Free-Living Recovery Period

<table>
<thead>
<tr>
<th>Drink</th>
<th>Chocolate Milk</th>
<th>Sports Beverage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28h</td>
<td>First 12h</td>
</tr>
<tr>
<td>Energy (kcal)</td>
<td>4482 ± 720</td>
<td>3185 ± 943</td>
</tr>
<tr>
<td>(kcal·kg(^{−1}))</td>
<td>63.6 ± 9.9</td>
<td>45.5 ± 11.3</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>561 ± 106</td>
<td>392 ± 129</td>
</tr>
<tr>
<td>(g·kg(^{−1}))</td>
<td>8.0 ± 1.7</td>
<td>5.6 ± 1.7</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>167 ± 34</td>
<td>122 ± 38</td>
</tr>
<tr>
<td>(g·kg(^{−1}))</td>
<td>2.4 ± 0.4</td>
<td>1.7 ± 0.5</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>184 ± 58</td>
<td>129 ± 50</td>
</tr>
<tr>
<td>(g·kg(^{−1}))</td>
<td>2.6 ± 0.8</td>
<td>1.8 ± 0.6</td>
</tr>
</tbody>
</table>

*Note. 28h: the total amount consumed during the free-living recovery after the post-exercise supplementation; First 12h: the amount consumed during the first 12 hours into the free-living recovery; Last 12h: the amount consumed during the last 12 hours of the free-living recovery; no data in between due to bedtime. Values are mean ± S.D.*
Table 4. Composition of Subjects' Total Dietary Intake (Supplement Drinks + Free-Living Diets)

<table>
<thead>
<tr>
<th>Drink</th>
<th>Chocolate Milk</th>
<th>Sports Beverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
<td>5246 ± 746</td>
<td>4998 ± 972</td>
</tr>
<tr>
<td>(kcal·kg(^{-1}))</td>
<td>74.4 ± 9.7</td>
<td>71.3 ± 14.5</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>701 ± 105</td>
<td>651 ± 108</td>
</tr>
<tr>
<td>(g·kg(^{-1}))</td>
<td>10.0 ± 1.7</td>
<td>9.3 ± 1.7</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>176 ± 34</td>
<td>178 ± 59</td>
</tr>
<tr>
<td>(g·kg(^{-1}))</td>
<td>2.5 ± 0.3</td>
<td>2.5 ± 0.7</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>222 ± 60</td>
<td>205 ± 73</td>
</tr>
<tr>
<td>(g·kg(^{-1}))</td>
<td>3.1 ± 0.7</td>
<td>2.9 ± 1.0</td>
</tr>
</tbody>
</table>

*Note.* Values are mean ± S.D.
Figure captions

Fig. 1. Schematic diagram of the treatment protocol.

Fig. 2. Dietary intake relative to the total amount consumed during the first 12 hours of free-living recovery after the post-exercise supplementation; →, chocolate milk trial; ←, sports beverage trial. (A) Dietary data are accumulated every 2 hours following the end of post-exercise supplementation (0h). (B) Dietary data are separated by every 2 hours following the end of post-exercise supplementation (0h). *significant difference between the treatments at the time point, p < 0.05. Error bars indicate S.E.M. No data between 12h and 16h due to bedtime.

Fig. 3. Dietary intake relative to the total amount consumed during the last 12 hours of free-living recovery prior to the 40-km time trial; →, chocolate milk trial; ←, sports beverage trial. (A) Dietary data are accumulated every 2 hours prior to the 40-km time trial (28h). (B) Dietary data are separated by every 2 hours prior to the 40-km time trial (28h). No differences between the treatments were observed. Error bars indicate S.E.M. No data between 12h and 16h due to bedtime.