Acute effects of chocolate milk and a commercial recovery beverage on postexercise recovery indices and endurance cycling performance

Kelly Pritchett, Philip Bishop, Robert Pritchett, Matt Green, and Charlie Katica

Abstract: To maximize training quality, athletes have sought nutritional supplements that optimize recovery. This study compared chocolate milk (CHOC) with a carbohydrate replacement beverage (CRB) as a recovery aid after intense exercise, regarding performance and muscle damage markers in trained cyclists. Ten regional-level cyclists and triathletes (maximal oxygen uptake 55.2 ± 7.2 $mL·kg^{-1}·min^{-1}$) completed a high-intensity intermittent exercise protocol, then 15–18 h later performed a performance trial at 85% of maximal oxygen uptake to exhaustion. Participants consumed 1.0 g $carbohydrate·kg^{-1}·h^{-1}$ of a randomly assigned isocaloric beverage (CHOC or CRB) after the first high-intensity intermittent exercise session. The same protocol was repeated 1 week later with the other beverage. A 1-way repeated measures analysis of variance revealed no significant difference (p = 0.91) between trials for time to exhaustion at 85% of maximal oxygen uptake (CHOC 13 ± 10.2 min, CRB 13.5 ± 8.9 min). The change in creatine kinase (CK) was significantly (p < 0.05) greater in the CRB trial than in the CHOC trial (increase CHOC 27.9 ± 134.8 $U·L^{-1}$, CRB 211.9 ± 192.5 $U·L^{-1}$), with differences not significant for CK levels before the second exercise session (CHOC 394.8 ± 166.1 $U·L^{-1}$, CRB 489.1 ± 264.4 $U·L^{-1}$) between the 2 trials. These findings indicate no difference between CHOC and this commercial beverage as potential recovery aids for cyclists between intense workouts.

Key words: sports nutrition, recovery, intermittent exercise, sports drinks, carbohydrate, creatine kinase.

Résumé : Les athlètes de haut niveau consomment des suppléments alimentaires pour optimiser la récupération afin de maximiser les effets de l'entraînement. Cette étude compare le lait au chocolat (CHOC) à une boisson de replacement d'hydrate de carbone (« CRB ») comme agent de récupération à la suite d'un effort intense de performance et comme aide à la réparation des lésions musculaires chez des cyclistes entraînés. Dix cyclistes et triathloniens (consommation d'oxygene maximale 55,2 ± 7,2 $mL·kg^{-1}·min^{-1}$) de niveau régional participent à une séance d'exercice intermittent de forte intensité puis, 15 à 18 h plus tard, à une épreuve de performance d'une intensité équivalent à 85 % du consommation d'oxygene maximale jusqu'à l'épuisement. Après la séance d'exercice intermittent, les participants consomment 1 $g·kg^{-1}·h^{-1}$ de sucre (CHO) contenu dans une boisson isoénergétique (CHOC ou CRB) distribuée aléatoirement. Le même protocole est reproduit la semaine suivante, mais en offrant l'autre boisson. L'analyse de variance à un facteur avec mesures répétées ne révèle aucune différence significative (p = 0,91) du temps réalisé aux deux épreuves de performance menées à 85 % du consommation d'oxygene maximale jusqu'à épuisement (CHOC 13 ± 10,2 min, CRB 13,5 ± 8,9 min). Au sujet de la créatine kinase (CK), les variations sont significativement plus importantes (p < 0,05) dans la condition CRB que dans la condition CHOC (CHOC, augmentation de 27,9 ± 134,8 $U·L^{-1}$ et CRB, augmentation de 211,9 ± 192,5 $U·L^{-1}$). On n'observe cependant aucune différence significative entre les 2 conditions en ce qui a trait aux niveaux de CK (CHOC, 394,8 ± 166,1 $U·L^{-1}$ et CRB 489,1 ± 264,4 $U·L^{-1}$) avant la seconde séance d'exercice. D'après ces observations, il n'y a pas de différences entre le lait au chocolat et la boisson commerciale pour favoriser la récupération chez des cyclistes entre deux séances intenses d'exercice.

Mots-clés : nutrition sportive, récupération, exercice intermittent, boissons pour sportifs, sucre, créatine kinase.

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Introduction

To maintain or improve the quality of sequential workouts, athletes have sought out nutritional practices including supplementation that maximize all aspects of recovery, including decreased muscle damage and muscle soreness and increased muscle glycogen resynthesis after exercise. Post-

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K. Pritchett.[1] Department of Health, Human Performance, and Nutrition, Central Washington University, Ellensburg, WA 98926, USA; Kinesiology Department, University of Alabama, Tuscaloosa, AL 35487, USA.
P. Bishop. Kinesiology Department, University of Alabama, Tuscaloosa, AL 35487, USA.
R. Pritchett and C. Katica. Department of Health, Human Performance, and Nutrition, Central Washington University, Ellensburg, WA 98926, USA.
M. Green. Department of Health, Physical Education, and Recreation, University of North Alabama, Florence, AL 35632, USA.

[1]Corresponding author (e-mail: KKerr@cwu.EDU).

exercise ingestion strategies have focused on timing, type of beverage, amount (volume, calories, carbohydrate (CHO), and protein (PRO) content), and frequency to determine the most effective way to speed glycogen recovery (Berardi et al. 2006). Recent research examining subsequent exercise performance and muscle damage suggests that a CHO-PRO, rather than a CHO-only, beverage ingested post exercise may favorably influence exercise recovery (Saunders et al. 2004; Skillen et al. 2008; Valentine et al. 2008). It is well known that athletes consuming a CHO-only beverage, rather than water or a placebo, have shown improvements in endurance performance (Coggan and Coyle 1991).

More recent research has looked at postexercise muscle damage with a CHO-PRO beverage. Thus, the addition of PRO to a CHO beverage would be practically important if it enhanced performance and recovery between exercise sessions with a short recovery period. One study examined creatine kinase (CK) levels post exercise after similar CHO-PRO beverage treatments. Saunders et al. (2004) found the addition of PRO to a CHO replacement beverage (CRB) resulted in a 40% longer time-to-exhaustion cycling trial and 83% lower CK levels 12–15 h after endurance cycling, compared with a CHO-only beverage. Similarly, Skillen et al. (2008) reported decreases in CK levels and fatigue after 2 weeks of supplementation with a 3.6% CHO + 1% amino acid solution. In contrast, a recent study found similar improvements in endurance performance between a CHO-PRO and a CHO-only beverage when matched for total kilocalories. Also, lower plasma CK levels were observed in the CHO-PRO, compared with the CHO-only, trial. The authors concluded that some of the reported improvements in exercise performance seen in the literature may be a result of the additional kilocalories from PRO (Valentine et al. 2008).

Results of studies comparing a CHO-PRO supplement with a CHO supplement (i.e., sports beverage) indicate improved performance with the CHO-PRO complex (Ivy et al. 2003; Saunders et al. 2004; Valentine et al. 2008; Williams et al. 2003), whereas others have observed no difference in performance (Berardi et al. 2006; Betts et al. 2005; Green et al. 2008). The differences among these findings could be due to an inconsistency in the caloric content of the beverages provided in the studies (Valentine et al. 2008). If absolute CHO content is held constant, adding PRO increases caloric content compared with the CHO-only beverage.

Based on its nutritional make-up, it has been suggested that chocolate milk (CHOC) could be an effective recovery aid that is readily available and relatively inexpensive (Karp et al. 2006; Thomas et al. 2009). Low-fat CHOC has a calorie content and CHO/PRO ratio similar to many CRB (e.g., Endurox R4 chocolate, PacificHealth Labratories, Woodbridge, N.J.). Karp et al. (2006) examined the efficacy of CHOC as a postexercise recovery aid between exercise sessions. Time to exhaustion improved significantly (~15 min) for the CHOC trial compared with the recovery beverage (Endurox) trial. However, not all sports have a recovery time of 4 h. Furthermore, this study only examined one aspect of recovery performance measures.

Consuming CHO within 30–60 min after exercise is critical for prompting optimal glycogen resynthesis (Karp et al. 2006). According to professional recommendations, consuming 50–75 g of CHO within 30–45 min after exercise, and 1.0–1.5 g CHO·kg body mass^{-1}·h^{-1} for the next few hours may be vital for optimizing glycogen resynthesis (Ivy et al. 2002; Jentjens and Jeukendrup 2003; Karp et al. 2006).

This study compared CHOC with a CRB as a recovery aid between consecutive high-intensity cycling bouts. Specifically, time to exhaustion at 85% peak oxygen consumption ($\dot{V}O_{2\ peak}$) and muscle damage indices (CK) were examined in trained cyclists. Based on the similarity of the 2 beverages (CHOC and CRB), it would have been difficult to justify an expected different response between the 2 drinks (Thomas et al. 2009). Therefore, the current study was designed to address the following hypotheses: (*i*) Because of similar CHO, PRO, and caloric content (CHOC vs. CRB), postexercise consumption of CHOC will be equally effective in attenuating muscle damage indices (CK) compared with a CRB (isocaloric) beverage; and (*ii*) CHOC will be equally effective in enhancing time to exhaustion in the second exercise session as a CRB taken between exercise sessions.

Materials and methods

Experimental approach to the problem

The relative effectiveness of postexercise recovery beverages (CHOC and CRB) in recovery from high-intensity intermittent exercise was examined in a repeated-measures crossover design. Recovery indices after high-intensity intermittent exercise were recovery of performance, reduction of muscle damage markers (CK), rating of perceived exertion (RPE), and subjective measures of muscle soreness. Regional-level cyclists and triathletes accustomed to high-intensity exercise were tested to improve the sensitivity and the external validity of the study. Well-trained participants were used in order to facilitate the detection of small differences because their performance was less likely to vary as a result of mood changes or learning. Participants performed the protocol on 2 occasions with at least 1 week in between. They were asked to discontinue all supplement use for at least 72 h prior to participating.

Subjects

Regional-level cyclists and triathletes (n = 10), defined by (*i*) a minimum of 2 years of involvement in endurance sports and (*ii*) a minimum of 6 training-hours per week, between the ages of 19 and 40 years were recruited to participate in this counterbalanced, crossover, repeated-measures study. Their mean (± SD) age, height, mass, body fat, maximal oxygen uptake ($\dot{V}O_{2\ max}$), and peak watts were 27.1 ± 7.9 years, 176.5 ± 3.6 cm, 72.1 ± 6.7 kg, 9.2 ± 3.5%, 55.2 ± 7.2 mL·kg^{-1}·min^{-1}, and 367.5 ± 38.7 W, respectively. The number of selected participants was based on an a priori power analysis. Based on data from Saunders et al. (2004) for both primary dependent measures with a power of 0.80, a minimal detectable difference could be detected in means of 350 for CK, 3 for muscle soreness, and 10 min for time to exhaustion, based on an estimated effect size of 1.0 SD units (SD between treatments: 200 for CK, 2 for muscle soreness, and 10 min for time to exhaustion), and a 2-tailed α-level of 0.05 power analysis indicated the need for 6 participants. Upon arrival, participants were fully informed of the purpose and associated risks, and written informed consent was obtained. Participants were not advised as to the nature or direction of the hypotheses. Age (years), height (cm), and mass (kg) were recorded, and body fat percentage was estimated using Lange skinfold calipers (Cambridge, M.D.) and a 3-site method (chest, abdomen, thigh) (Pollock et al. 1980). Participants completed a food frequency questionnaire at the beginning of the study and a 3-day food record during each trial (between consecutive trials) to control for any differences in dietary intake between the trials. Dietary records were analyzed for CHO, PRO, and fat composition using a computer software program (ESHA Food Processor, v. 8.0, Salem, Ore.).

All procedures were approved by the appropriate local Institutional Review Board. Each participant arrived at the laboratory after an 8-h overnight fast and having abstained from caffeine and alcohol for a minimum of 24 h. Participants were also instructed to refrain from exercise for 24 h prior to testing.

$\dot{V}O_{2\,max}$ and experimental design

Each participant performed an introductory testing and familiarization session and 2 separate trials (3 total sessions). $\dot{V}O_{2\,max}$ was determined during incremental exercise to volitional fatigue on a cycle ergometer (Excalibur sport 925900, Groningen, Netherlands). Seat height was set appropriately for each individual, with handlebars adjusted based on individual preference. Participants were required to maintain a cadence of 60 r·min^{-1} and were fitted with heart rate (HR) monitor transmitters (Polar, Stamford, Conn.) at the level of the sternum. Expired air was directed through a 1-way valve (Hans Rudolf, Kansas City, Mo.) and plastic tubing connected to a metabolic cart (Parvo Medics' TrueOne 2400, Sandy, Utah), which was calibrated prior to each test with a known gas composition. A 4-L precision syringe (Hans Rudolph) was used to calibrate the system for measurement of ventilation.

Testing was terminated when any of the following criteria were met: participant requested that the test be stopped for any reason, participant reached volitional exhaustion, participant displayed signs or symptoms that indicated the exercise test should be stopped (poor perfusion, pallor, etc.), participant could no longer maintain the required workload during testing, or testers felt for any reason it was unsafe for the participant to continue (ACSM 2009). Criteria for achievement of $\dot{V}O_{2\,max}$ were (*i*) RPE ≥ 19, (*ii*) respiratory-exchange ratio (RER) ≥ 1.1, (*iii*) plateau of oxygen consumption ($\dot{V}O_2$) with increased workload, and (*iv*) >85% of age-predicted maximum HR (Maud and Foster 2006). Two or more of these 4 criteria were met by all participants.

Each participant completed 2 counterbalanced exercise trials with at least 1 week between each trial. For each of the 2 trials, the first exercise bout consisted of a 50-min high-intensity intermittent cycling protocol. Afterward, subjects received either a CRB (Endurox R4 chocolate) or low-fat CHOC (Table 1). Participants returned to the laboratory 15–18 h after the first exercise bout, and completed a ride to exhaustion at 85% of $\dot{V}O_{2\,max}$ (Saunders et al. 2004). The same measurements were taken for each trial.

High-intensity intermittent protocol

Participants completed a 5 min cycling warm-up on the ergometer at 60% of $\dot{V}O_{2\,max}$ to allow the person to exercise at a constant "steady state," where physiological variables (HR and oxygen requirements) should remain stable. After completing the warm-up, participants completed 3 × 10-s "all-out" bicycle Wingate sprints interspersed with 50 s active recovery. The same procedures (5 min cycling at 60% of $\dot{V}O_{2\,max}$, followed by 3 × 10 s Wingate sprints) were each repeated for a total of 6 times (Pritchett et al. 2008). This exercise regimen simulates a typical high-intensity workout or a sporting competition in which recovery is important between exercise sessions.

Table 1. Mean ± SD daily dietary intake between treatments for each trial (n = 10).

Total energy and macronutrient content	Chocolate milk	Carbohydrate replacement beverage
Energy (kcals)	2488.0±557.9	2319.6±663.5
Carbohydrate (g)	305.4±56.1	292.1±76.9
Protein (g)	119.9±19.9	110.0±27.7
Fat (g)	90.5±35.8	73.1±37.2

Note: Values include macronutrients in the recovery beverages. No significant differences were observed between the trials.

Recovery period

Participants were given the recovery drinks (CHOC or CRB) immediately after the first exercise session, and again 2 h into the recovery period. The same total amount of CHO was given immediately after exercise and at 2-h post exercise (1.0 g CHO·kg^{-1}·h^{-1}) (Table 2). The beverages were isocaloric for both the trials (CRB and CHOC). The low-fat CHOC used in this study (Fred Meyer) consisted of sucrose (glucose plus fructose), lactose (glucose plus galactose), high-fructose corn syrup, and cocoa (Karp et al. 2006). The CRB used in this study (Endurox R4 chocolate) consisted of complex CHO (maltodextrin), glucose, whey PRO, crystalline fructose, L-arginine, DL-α tocopherol acetate, ciwujia, ascorbic acid, sodium chloride, citric acid, and L-glutamine. All drinks were poured into unmarked bottles. Subjects were allowed to drink water ad libitum during the full length of the recovery period, but no other food or drink was allowed. Subjects were instructed to replicate dietary intake for each trial.

Endurance performance trial

Participants returned to the laboratory after 15–18 h of recovery from the high-intensity intermittent cycling trial. Participants warmed up for 5 min on the cycle ergometer and then cycled at a workload predetermined to elicit approximately 85% of $\dot{V}O_{2\,max}$ until exhaustion (Saunders et al. 2004). Timing devices were hidden from participants' view to minimize bias. The participants were verbally encouraged to continue cycling as long as possible. RPE-Borg 6–20 (Borg 1982), and HR (Polar Electro Inc., Stamford, Conn.) were taken every minute. The trial was terminated when pedal cadence was slower than 60 r·min^{-1} or the participant could no longer continue. Time to exhaustion (minutes and seconds) was used to quantify performance in this trial.

Measurements

Blood samples for CK were obtained before the first exercise session (PRE) and before the second exercise session

Table 2. Comparisons (mean ± SD) of macronutrient content for recovery beverages.

Total energy and macronutrient content	Chocolate milk	Carbohydrate replacement beverage
Energy (kcals)	409.7±39.1	384.3±36.6
Carbohydrate (g)	72.1±6.9	72.1±6.9
Protein (g)	18.7±1.8	19.2±1.8
Fat (g)	5.2±0.5*	2.0±0.2
Volume (oz)	17.3±1.8	17.3±1.8

Note: Amount of beverage ingested immediately after exercise and 2 h into the recovery period. Based on body mass (1.0 $g \cdot kg^{-1}$).

*Significant difference ($p < 0.001$) between fat (grams) for each beverage.

(POST) for both trials. The PRE blood sample was collected before the first session to assess pre-exercise CK, and the POST was collected 15–18 h after the first exercise session to assess exercise-induced changes in CK. The samples consisted of 0.025 mL of blood obtained from the fingertip using a lancet (Becton Dickinson, Franklin Lakes, N.J.). Capillary blood samples were taken again before the second exercise session. To confirm an accurate calibration, CK controls were analyzed using low (112–176 $U \cdot L^{-1}$) and high (843–1095 $U \cdot L^{-1}$) concentrations of CK. Blood samples were analyzed for the average CK absorbance difference per minute at 340 nm using a spectrometer (Genesys 10 Series Thermo Spectronic, Rochester, N.Y.). Peak accumulation for CK levels has been indicated to occur anywhere between 12 and 24 h after exercise (Pagana and Pagana 2002). For the purpose of this study, CK levels were examined at 15–18 h after the first exercise session based on a study by Saunders et al. (2004). Muscle soreness was assessed using a 10-cm visual analog scale (Dannecker et al. 2003) with anchor points "no pain at all" at the left end and "unbearable pain" at the right end.

Statistical analysis

Basic descriptive characteristics were computed for the participants (Table 2). Mean values for RPE, pain, and HR were computed for each treatment. Data from the 2 trials were compared using a 2-factor (treatment × time) repeated-measures analysis of variance (ANOVA). A Tukey's post-hoc test was applied in the case of a significant ($p < 0.05$) F ratio to locate the differences with the ANOVA. A 1-way ANOVA for repeated measures was used to compare markers of muscle damage (CK), muscle soreness (visual analog pain scale), and performance between trials. Greenhouse–Geisser corrections were conducted for unequal variance data. All statistical analyses were performed using the Statistical Package for the Social Sciences for Windows software, v. 15.0 (SPSS Inc., Chicago, Ill.). All data were reported as means ± SD. Statistical significance was set at $\alpha < 0.05$.

Results

All subjects confirmed that they were not taking any nutritional supplements prior to beginning the study. There were no significant differences between the 2 beverages for calorie, CHO, and PRO content; however, there was a significant difference in fat content (grams) ($p < 0.001$) between the beverages (CHOC 5.2 ± 0.5 $U \cdot L^{-1}$, CRB 2.0 ± 0.2 $U \cdot L^{-1}$). The treatment beverages contained identical CHO levels, and similar levels of PRO and total kilocalories. This difference in the amount of fat between the 2 recovery beverages was not enough to significantly affect the difference in overall calorie content between the beverages.

Based on reported dietary intake, there were no significant differences in macronutrient intake (kilocalories, CHO, PRO, and fat) between the 2 trials (Table 1). Sleep patterns between the 2 trials were also monitored using the Stanford Sleepiness Questionnaire. There were no differences in sleep patterns between the 2 trials (CHOC 2.7 ± 0.8 $U \cdot L^{-1}$, CRB 2.5 ± 1.4 $U \cdot L^{-1}$) ($p = 0.7$). After the completion of the study, subjects were asked to provide subjective feedback about the beverages. Ten out of 10 participants preferred the taste and consistency of the CHOC.

Cycling time to exhaustion was examined in the performance trial. The average (±SD) power output determined to elicit 85% $\dot{V}O_{2\ max}$ was 319.6 ± 38.7 W. There was no significant difference ($p = 0.91$) between trials for cycling time to exhaustion (CHOC 13 ± 10.2 min, CRB 13.5 ± 8.9 min).

The results for CK levels are displayed in Fig. 1. There was no significant difference ($p = 0.29$) for the PRE CK level (CKpre) between the 2 trials (CHOC 366.8 ± 198.1 $U \cdot L^{-1}$, CRB 277 ± 168.4 $U \cdot L^{-1}$). A repeated-measures ANOVA revealed a significant ($p < 0.05$) interaction (treatment × time) for change in CKpre to the POST CK level (CKpost). A significantly higher ($p < 0.05$) increase in CK levels was observed for the CRB trial (increase CHOC 27.9 ± 134.8 $U \cdot L^{-1}$, CRB 211.9 ± 192.5 $U \cdot L^{-1}$); however, there was no significant difference ($p = 0.35$) for CKpost between the 2 trials (CHOC 394.8 ± 166.1 $U \cdot L^{-1}$, CRB 489.1 ± 264.4 $U \cdot L^{-1}$).

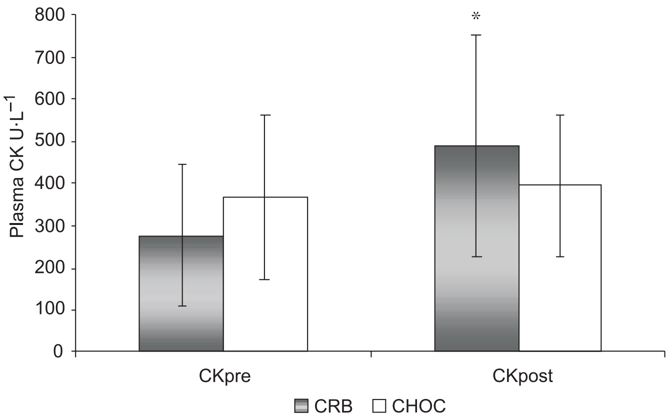
Muscle soreness using a visual analog scale (1–10) was examined immediately after the depletion trial (PRE) and prior to the time trial to exhaustion (POST) (Fig. 1). No interaction (treatment × time) for muscle soreness was observed. There were no significant differences for PRE muscle soreness (CHOC 5.6 ± 0.6, CRB 5.6 ± 0.7) ($p = 0.98$) and POST muscle soreness (CHOC 2.9 ± 0.8, CRB 3.7 ± 0.8) ($p = 0.48$) between the 2 trials. Subjective measures of muscle soreness decreased significantly ($p < 0.01$) from PRE to POST (decrease CHOC –2.7, CRB –1.9).

Discussion

The main objective of this study was to examine the acute effects of CHOC vs. a CRB beverage as a recovery aid between high-intensity exercise bouts, with respect to exercise performance and muscle damage indices, in regional-level cyclists and triathletes. Because it is well established that these recovery aids are effective, no comparison with control conditions was used. CHOC has been suggested to be an effective recovery aid because of its nutritional composition, and it is further appealing because it is relatively inexpensive and readily available (Karp et al. 2006). However, only 1 peer-reviewed study has examined its potential. This study incorporated a high-intensity intermittent cycling trial that was intended to simulate everyday sporting events.

The primary purpose of this study was to examine the effects of CRB vs. CHOC on indices of muscle damage, CK,

Fig. 1. PRE creatine kinase (CK) level (CKpre) and POST CK level (CKpost) for each trial. CHOC, chocolate milk; CRB, carbohydrate replacement beverage. *, Significantly greater increase than CHOC trial ($p < 0.05$).



and muscle soreness. A significant increase ($p < 0.05$) from CKpre (CHOC 366.8 ± 198.1 $U{\cdot}L^{-1}$, CRB 277 ± 168.4 $U{\cdot}L^{-1}$) to CKpost (CHOC 394.8 ± 166.1 $U{\cdot}L^{-1}$, CRB 489.1 ± 264.4 $U{\cdot}L^{-1}$) was observed in both trials. The change in CK from PRE to POST was significantly greater ($p < 0.05$) in the CRB trial compared with the CHOC trial (increase CHOC 27.9 ± 134.8 $U{\cdot}L^{-1}$, CRB 211.9 ± 192.5 $U{\cdot}L^{-1}$). The mean increase for CRB tended to be about 183 $U{\cdot}L^{-1}$ higher than for the CHOC, which may have practical significance. However, no differences were observed in CKpre or CKpost levels between the 2 treatments. This somewhat odd disparity in the findings is chiefly attributable to the magnitude of the mean differences. In other words, the analysis apparently was not sensitive enough to the initial difference between the 2 scores, but when expressed as a change score, relative to the error variance, a difference was detected. Because we have no clear explanation for the differences in initial CK, the difference in the change score should be interpreted with caution. To our knowledge, no studies have compared the effects of 2 similar beverages with isocaloric amounts of CHO and PRO on indices of muscle damage. Most of the literature has examined the effects of a CHO-PRO vs. a CHO-only beverage. Some of these studies failed to control for large differences in calorie content between the beverages (Ivy et al. 2003; Saunders et al. 2004), which may have influenced outcomes.

Recent studies have examined isocaloric beverages (CHO-PRO vs. CHO-only) in an attempt to control for the additional PRO kilocalories. Romano-Ely et al. (2006) examined the effects of a CHO-PRO-antioxidant (A) vs. a CHO-only beverage on biochemical markers of muscle damage, and found significantly lower ($p < 0.05$) CK levels with the CHO-PRO-A beverage. It should be noted that the recovery beverages were ingested both during and after exercise. Also, CK levels were examined at 24-h post exercise, perhaps missing the peak increase in CK that occurs within the 12–24-h period post exercise (Pagana and Pagana 2002).

In addition to blood parameters of muscle damage, muscle soreness was examined after the high-intensity, intermittent cycling trial and prior to the time trial to exhaustion, to increase the internal validity of the study. It has been suggested in the literature that multiple measures of recovery enhance the design of studies examining recovery (Romano-Ely et al. 2006). Subjective measures of muscle soreness using a visual analog scale indicated that muscle soreness levels were decreased after 15–18 h of recovery, with both beverages equally effective in attenuating muscle soreness.

Another primary purpose was to investigate differences in performance 15–18 h after a high-intensity, intermittent cycling trial when CHOC or CRB was consumed post exercise. Cycling time to exhaustion at a workload eliciting 85% of $\dot{V}O_{2\,max}$ was not significantly different between trials (CHOC 13 ± 10.2 min, CRB 13.5 ± 8.9 min). It has been suggested that differences in performance between a CHO-PRO and a CHO-only beverage (Ivy et al. 2003; Saunders et al. 2004; Williams et al. 2003) could be attributed to the differences in calorie content between the beverages (Romano-Ely et al. 2006). Recent studies have reported improvements in subsequent muscle function (Skillen et al. 2008; Valentine et al. 2008) and cycling performance (Thomas et al. 2009; Valentine et al. 2008) and decreased fatigue (Skillen et al. 2008) with a CHO-PRO beverage compared with a CHO-only beverage when the beverages were matched for calorie content. Our findings support other studies that have found no difference in time to exhaustion when comparing 2 recovery beverages (Green et al. 2008; Millard-Stafford et al. 2005; Romano-Ely et al. 2006).

In comparison with our findings, 2 studies (Karp et al. 2006; Thomas et al. 2009) found cycling time to exhaustion at 70% of $\dot{V}O_{2\,peak}$ to be 49% and 51% longer with CHOC vs. CRB, respectively. However, the recovery time between the glycogen depletion trial and the performance trial was 4 h. The authors speculated that recovery time may have limited the complete digestion of Endurox, composed of complex CHO (maltodextrin) (Karp et al. 2006). CHOC, composed of monosaccharides and disaccharides, was allowed enough time for complete digestion, and the increased fat content may have increased circulating free fatty acids and delayed glycogen depletion. The recovery period used in the current study was 15–18 h in duration to allow for complete digestion of both recovery beverages. Also, Karp's study used 70% of $\dot{V}O_{2\,peak}$, whereas this study incorporated a higher percentage of $\dot{V}O_{2\,peak}$. The protocol for the performance trial was chosen based on the notion that there is greater reliance on muscle glycogen as greater intensities are utilized (Williams et al. 2003; Saunders et al. 2004). Consequently, it is arguable that a higher-intensity protocol creates a more favorable paradigm in which the effectiveness of a recovery beverage might be evaluated. The differences in recovery periods, depletion trial, and time trial protocol of the Karp study and the present study make direct comparison of these results difficult.

After completion of the study, participants were asked to provide feedback regarding the recovery beverages. All participants preferred the taste and consistency of the CHOC. Participants felt that the CRB had to be shaken frequently to keep the beverage mixed well. Three participants complained of gastrointestinal distress (bloating and gas) with the CRB; however, none complained of gastrointestinal distress with the CHOC.

Conclusion

The administration of 2 recovery beverages matched for CHO and PRO content resulted in similar findings. Plasma CK levels and subjective measures of muscle soreness were similar at 15–18 h post exercise for CHOC and CRB. However, there was a significantly ($p < 0.05$) higher increase in CK levels from PRE to POST in the CRB trial compared with the CHOC trial. Cycling time to exhaustion at 85% of $\dot{V}O_{2\ max}$ was not significantly different between trials. These findings further support the effectiveness of CHOC as a potential recovery aid for cyclists between intense workouts.

Practical applications

CHOC as a postexercise recovery aid appears to be as effective as another carbohydrate replacement beverage. Because the CHO/PRO ratio of CHOC is similar to other recovery beverages, it may be as useful in attenuating muscle damage post workout. Furthermore, CHOC serves as a more convenient, cheaper, premixed, and, based on current observations, more palatable recovery beverage option for many athletes.

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