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Effects of Chocolate Milk Ingestion During Recovery on Lactate Clearance, Creatine Kinase, Muscle Soreness and Endurance Performance in Male Runners

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ABSTRACT

Recovery following exercise is essential for any athlete. This study was conducted to determine the effects of post-exercise beverages on exercise biomarkers and endurance levels. Eleven university runners performed three sessions of incremental exercise test until volitional exhaustion, followed by 2 hours of intervention recovery receiving cross-randomised mineral water (MW), carbohydrate solution (CS) or chocolate milk (CM) before performing an endurance test 24 hours later. Blood lactate was measured immediately after the test and every 30 minutes. Creatine kinase and muscle soreness were determined after 24 hours before 2.4 km run test. Results show CM had significantly lower creatine kinase levels than MW after 24 hours. CM recorded better muscle soreness ratings and lactate removal rates than MW and CS. However, there was no difference in endurance performance between treatments. In conclusion, this study proved that CM can be an effective post-exercise beverage for faster recovery.

Keywords: Chocolate milk, carbohydrate, recovery, exercise biomarker, runner.

INTRODUCTION

Optimal nutritional consumption is well known to improve recovery and adaptation between training sessions (Heaton et al., 2017). Many athletes and coaches recognise the benefits of taking proper diets and nutrient intake to speed up the recovery process and enhance the performance of athletes (Amawi et al., 2024). A few factors that must be considered are the types of nutrients, the accurate amounts of nutrients, and the timing of nutrients consumed (Bourdas, Souglis, Zacharakis, Geladas, & Travlos, 2021). For athletes, the intake of post-exercise nutrients is essential to restore glycogen stores and protein synthesis so the body is ready for the next exercise session (Poole, Wilborn, Taylor, & Kerksick, 2010).

A study by Pritchett and Pritchett (2012) found that chocolate milk has optimal nutrients and is suitable for endurance athletes' recovery beverages**.** The four-to-one carbohydrate and protein ratio in chocolate milk helps prolong the ability to perform multiple bouts of strenuous endurance exercises (Pritchett & Pritchett, 2012). Fitriani, Setiarini, Ahmad, Purwaningtyas, and Fitria (2023) showed a similar result. Plus, it has a high glycemic index, is easily accessible, and is much cheaper than other sports beverages (Saunders, 2011).

According to Gilson et al. (2010), getting chocolate milk after a high-intensity exercise could also help athletes boost recovery and improve endurance performance in their next bouts of exercise, even in the limited recovery period, compared to when they drink other sports beverages. The development of post-exercise muscle soreness and muscle damage following high-intensity eccentric exercise is common in many athletes. At this point, food and diet can be critical aspects of those recoveries.

Post-exercise ingestion of chocolate milk has been shown to augment recovery following high-intensity aerobic exercise (Saunders, 2011). A study by Berardi, Noreen, and Lemon (2008) reported that chocolate milk enhances subsequent post-exercise recovery and performance better than certain carbohydrate beverages. However, another study on the effectiveness of chocolate milk showed no improvement in the recovery indices, as Pritchett, Bishop, Pritchett, Green, and Katica (2009) proved. Thus, the effectiveness of chocolate milk as a recovery beverage remains to be seen (Mitchell, 2013). Further study of the efficacy of chocolate milk incorporating specific exercise biomarkers, such as creatine kinase and lactate levels, should be conducted to understand the recovery effects of the beverage.

MATERIALS AND METHODS

Participants

Eleven competitive male runners aged 23 ± 2 years voluntarily participated in this study. They had consistent training volumes for at least two months and trained for endurance exercises for a minimum of 5.5 hours per week. All participants were free from taking potentially ergogenic supplements one month before the study and declared themselves healthy and fit for the study as declared in the informed consent form approved by the research ethics committee of University Technology MARA (Ref: 600-IRMI (5/1/6). The participants also completed the PAR-Q form (ACSM, 2013) to confirm the absence of any risk factors associated with this study, such as being free from lactose intolerance. Before experiment days, all participants completed a 3-day food record to keep track of the meals and the number of calories consumed. Participants' physical characteristics, such as weight and height, were measured according to standard protocols.

Post-exercise beverages

Three post-exercise beverages were used: mineral water (MW), carbohydrate solution (CS) and chocolate milk (CM). A single brand of commercial energy drinks containing 11 g/100g (28 g/serving) carbohydrates and sports gels 65 g/100g (20 g/serving) were used as CS. A single commercial chocolate milk powder containing 21 g/35g serving carbohydrates, 3.3 g/35g serving fats and 7 g/35g serving protein was used as the CM beverage. The administration of CS and CM was adjusted to provide a dose of 1.5 g/kg body weight/hour of macronutrients for each beverage. In order to make CS and CM isocaloric and provide the target dose amount per serving, the beverages' servings were adjusted by adding some water. For example, a 60-kg subject was given CS containing 45 g/serving carbohydrates by mixing one can of the energy drink with one sachet of the sports gels and a similar amount (45 g) of chocolate milk powder for CM dissolved in 240 ml of water for each serving. Thus, two servings of either CS or CM in an hour provide 90 grams of energy-yielding nutrients to the 60-kg subject to meet the dose requirement. Additional water was allowed for subjects to relieve thirst and be comfortable. The volume of beverages ingested by participants was 240 mL per intake.

Protocol

This experimental research utilised a crossover design in which eleven male runners performed three treatments of incremental exercise tests (Bruce, 1971) until volitional exhaustion before receiving either MW, CS, or CM beverages on separate days. Each subject received a serving of 240 ml of beverage immediately after burnout, followed by 30-minute intervals. The recovery period lasted two hours, meaning every subject received four servings of each beverage. Each treatment was separated by a washout period of a week to avoid carryover effects. Following the incremental exercise test, lactate was measured immediately after exercise burnout and at every 30-minute interval afterwards for 2 hours. Creatine kinase (CK) level, muscle soreness rating, and 2.4 km run time were determined 24 hours later, and the latter was determined after the CK and muscle soreness protocols were performed (Figure 1).

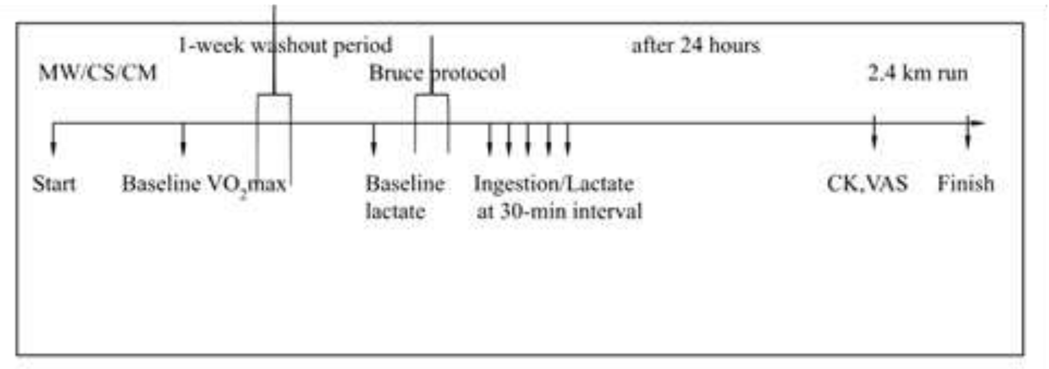

Figure 1 Experimental and intervention protocol.

The Bruce protocol and 2.4-km run were performed on the COSMED Treadmill (T150, Germany). Program 4 of the Bruce protocol, which consists of seven stages with three minutes for each stage, was used for the incremental exercise test. A baseline VO2 max was determined a week before the experimental intervention. A metabolic cart cardiopulmonary (COSMED, Quark CPET, Italy) was used to measure and monitor participants' VO2 max. A heart rate transmitter (Polar RS 100, Finland) was used to monitor heart rate during rest and exercise by attaching the electrode to the participants' chests using strappers. Blood pressure was monitored using an automatic blood pressure monitor (Omron HEM-7121, Japan). All measurements were conducted according to standard protocols and manufacturers' instructions.

The visual analogue scale (VAS), developed by Huskisson (1974), was used to determine muscle pain or soreness. VAS was rated based on the Pritchett et al. (2009) scale using a 100 cm horizontal line with anchors. Participants marked the rating of "How sore are your legs?" on a 10-point analogue scale: 0 = "no soreness", 1 to 3 = "mild pain", 4 to 6 = "moderate pain", 7 to 9 = "severe pain" and 10 = "the worst pain you can imagine" following active movement which was walking across the laboratory. The muscle soreness rating was measured twice, before (baseline) and 24 hours after the incremental exercise. Rating of Perceived Exertion (RPE) was determined using a Borg 10-Category Ration (CR10) RPE scale to assess the exercise intensity. This scale reflects signals sent from the body, thus allowing participants to provide the perception of the intensity of exertion (Morishita, Tsubaki, Takabayashi, & Fu, 2018).

Blood lactate and CK were measured using a lactate analyser (Accutrend, Germany) and a dry biochemical analyser (Reflotron® Plus, Germany). Blood was obtained from a finger prick placed on lactate and CK test strips before being analysed in the respective analysers. Lactate clearance was determined using the equation of lactate clearance = (lactate initial − lactate delayed) / lactate initial × 100 (expressed as a percentage). A computer software program, Nutritionist Pro™ Diet Analysis, was used to analyse participants' food intake and dietary records.

Data analysis

Data were analysed using Statistical Package for Social Science (SPSS) software version 27 (IBM Corp., 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp.. Unless stated otherwise, descriptive analysis variables were expressed in mean and standard deviation (SD). One-way multivariate analysis of variance (MANOVA) was used to compare the effects of three types of post-exercise ingestions (MW, CS, and CM) on outcome measures (lactate level, CK level, VAS, and 2.4 km run time). Tukey's HSD post-hoc test was used to determine which groups differ. Statistical significance was set at 0.05 with a 95% confidence interval in all analyses.

RESULTS AND DISCUSSION

The demographic data of the participants are summarized in Table 1. The participants were aged between 20 and 25 years, with an average age of 22.6 ± 1.7 years. Their heights ranged from 1.59 to 1.76 meters, with a mean height of 1.68 ± 5.32 meters. Participants' weights varied between 54 and 72 kg, averaging 62.4 ± 6.5 kg. The weekly training hours ranged from 5.5 to 8.0 hours, yielding a mean of 6.91 ± 0.94 hours. The baseline VO2 max values varied from 48.07 to 57.06 ml.kg^-1.min^-1, with a mean of 51.56 ± 2.99. The energy intake of the participants in the first, second, and third weeks of the experiment was consistent across all groups. Specifically, the energy intake for the runners was 1857 ± 141 kcal/day for the Milk with Water (MW), 1888 ± 143 kcal/day for the Carbohydrate Solution (CS), and 1935 ± 144 kcal/day for the Chocolate Milk (CM) (Table 2).

Table 1 Physical characteristics and training profiles of participants.

	Mean	Standard Deviation	Range
Age (years)	22.6	1.7	20 – 25
Height (m)	1.68	0.05	1.59 – 1.76
Weight (kg)	62.4	6.5	54 – 72
Training hours per week	6.9	0.9	5.5 – 8.0
VO2max (ml/kg/min)	51.6	3.0	48.1 – 57.1

Table 2 Energy intake, creatine kinase level, muscle soreness and 2.4-km trial performance of participants.

	MW	CS	CM	*P* value
Self-reported energy intake (kcal/day)	1857±141	1888±143	1935±144	0.4442*
Blood CK (IU/L)	199±40	162±49	117±17$^{\#,\wedge}$	0.0000* $^{\#}$0.0000 $^{\wedge}$0.0231
Muscle soreness (VAS score)	2.82±0.87	2.18±0.6	0.82±0.41$^{\#,\wedge}$	0.0000* $^{\#}$0.0000 $^{\wedge}$0.0000
2.4-km trial (s)	730±69	715±76	701±70	0.6442*

*One-way ANOVA, #MW vs CM, ^CS vs CM

Figure 2 illustrates the baseline and post-exercise recovery blood lactate levels across different interventions. All three intervention beverages had nearly identical resting (baseline) blood lactate levels. After incremental exercise, blood lactate levels peaked immediately (0 minutes) and subsequently decreased over the following 120 minutes. Notably, in the CM treatment, lactate levels dropped significantly in the first 30 minutes before gradually diminishing over the next 90 minutes. In contrast, the MW and CS treatments showed a steady decline in lactate levels throughout the same recovery period. By the end of the 2-hour recovery period, the lactate levels for all treatments had nearly returned to baseline.

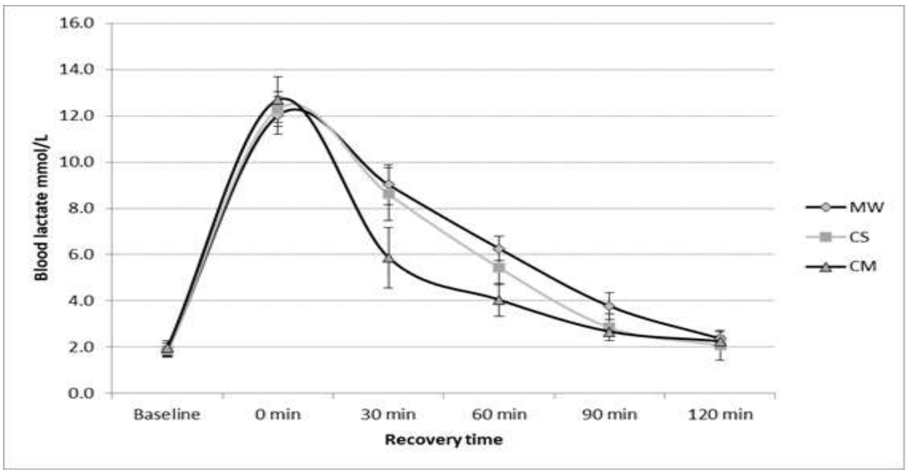

Figure 2 Blood lactate levels during 2 hours recovery at 30-min intervals following incremental exercise test. * MW vs CM (p=0.000); ^ CS vs CM (p=0.000); 1# MW vs CS (p=0.020); 2# MW vs CS (p=0.001).

Figure 3 compares lactate clearance between treatments over 30-minute intervals. After incremental exercise and fluid ingestion, the CM group demonstrated the highest rate of lactate clearance, significantly surpassing both MW and CS. Lactate clearance was approximately 54% after 30 minutes for CM, compared to 24.6% for MW and 29.6% for CS. This trend continued at 60 minutes, with CM showing 68.1% clearance, while MW and CS recorded 47.7% and 55.5%, respectively. After 90 minutes, CM remained significantly higher than MW at 79% compared to 68.5%, while being similar to CS at 76.7%. The lactate clearance for all treatments was comparable after 120 minutes.

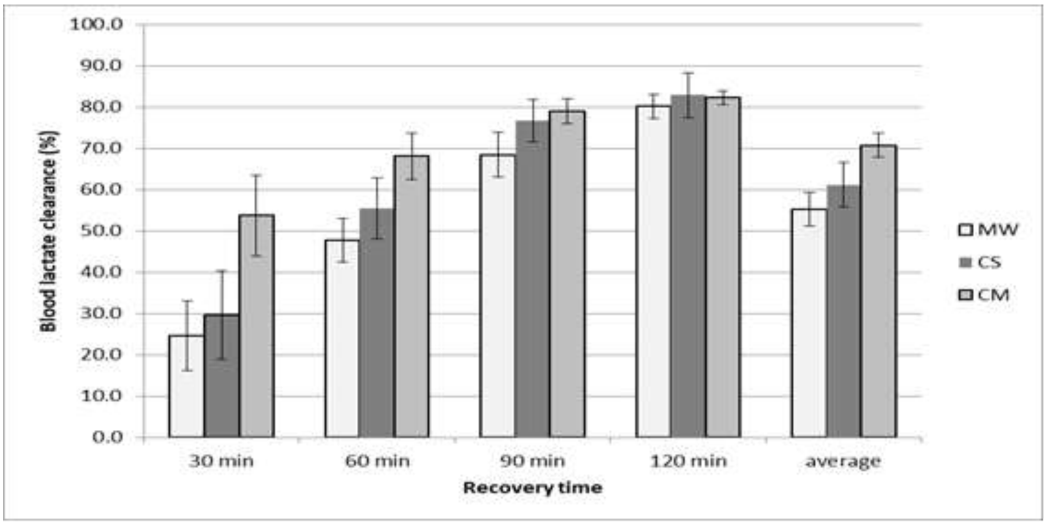

Figure 3 Blood lactate clearance during 2 hours recovery at 30-min intervals following incremental exercise test. * MW vs CM (p=0.000); ^ CS vs CM (p=0.000); 1# MW vs CS (p=0.017); 2# MW vs CS (p=0.001); 3# MW vs CS (p=0.008).

Ingestion of CM had a notable impact on blood creatine kinase (CK) levels, with CK levels for participants receiving CM being significantly lower than those for MW and CS (Table 2). Specifically, CM recorded 117 ± 17 IU/L, which was significantly lower than MW (199 ± 40 IU/L; p = 0.0000) and CS (162 ± 49 IU/L; p = 0.0231). Additionally, CM consumption resulted in reduced muscle soreness, with runners experiencing better Visual Analog Scale (VAS) scores compared to those receiving MW and CS. The VAS score for CM was 0.82 ± 0.41, significantly lower than MW (2.82 ± 0.87; p = 0.0000) and CS (2.18 ± 0.6; p = 0.0000). Performance in a 2.4 km time trial was similar across treatments, with times recorded at 730 ± 69 seconds for MW, 715 ± 76 seconds for CS, and 701 ± 70 seconds for CM trials.

The participants in this study shared similar demographic characteristics, being in comparable age brackets, with equivalent weekly training hours and VO2 max, indicating similar fitness levels. The energy intake was also consistent, suggesting that dietary differences did not influence trial outcomes. The key finding of this study is that ingesting chocolate milk during recovery significantly enhances blood lactate removal and reduces creatine kinase levels, a marker for muscle damage and soreness, following high-intensity endurance exercise. However, chocolate milk did not lead to significant improvements in performance during the 2.4 km time trial when compared to isocaloric carbohydrate solutions and control beverages.

Due to the high-intensity nature of exercise, skeletal muscles may endure mechanical and biochemical stresses, resulting in elevated muscle damage biomarkers, increased muscle soreness, and impaired muscle function, which in turn can negatively influence athletic performance (Bessa et al., 2016). Low-fat chocolate milk provides a carbohydrate-to-protein ratio of 4:1 (similar to many commercial recovery drinks) and offers fluids and electrolytes to assist in recovery post-exercise. Consuming chocolate milk at a rate of 1.0-1.5 g/kg of body weight/h immediately after exercise and again two hours later is deemed optimal for recovery and may reduce indicators of muscle damage (Pritchett & Pritchett, 2012). In our study, the chocolate milk used had a carbohydrate-to-protein ratio of 3:1, with additional calories from fats matching the caloric content of carbohydrate energy drinks. The role of fats in enhancing fat oxidation during recovery from exhaustive exercise is believed to be negligible. Although high carbohydrate ingestion elevates glucose and insulin levels during recovery, carbohydrate oxidation and pyruvate dehydrogenase activation are reduced during exhaustion.

This supports the hypothesis that glycogen resynthesis holds high metabolic priority. During the initial hours of recovery, plasma fatty acids, very low-density lipoprotein triglycerides, and intramuscular acetylcarnitine stores are likely important energy sources for aerobic metabolism (Kimber, Heigenhauser, Spriet, & Dyck, 2003).

Numerous studies have examined the potential effects of chocolate milk on recovery indices. Many of these studies have concluded that chocolate milk consumption during recovery may reduce post-exercise muscle damage and soreness while improving performance compared to carbohydrate beverages. However, some studies have shown no significant difference between chocolate milk and carbohydrate beverages (Pritchett et al., 2009; Molaeikhaletabadi et al., 2022).

In this study, a significant difference was found in the reduction of creatine kinase levels between chocolate milk and carbohydrate beverages. The lower creatine kinase levels observed among participants who consumed chocolate milk align with several studies (Luden, Saunders, & Todd, 2007; Gilson et al., 2010) that reported lower creatine kinase levels in swimmers and runners after consuming chocolate milk following endurance exercise. Similarly, a study conducted by Birinci et al. (2023) indicated that chocolate milk could reduce blood creatine kinase levels among soccer training athletes.

The reduction in creatine kinase levels among participants who consumed chocolate milk was lower than that observed in those who consumed carbohydrate beverages and mineral water, suggesting that chocolate milk may be more effective in minimizing muscle damage after high-intensity endurance exercise. Tanabe, Fujii, and Suzuki (2021) proposed that post-exercise nutritional supplements are theorized to lessen secondary or delayed onset damage rather than reduce the initial mechanical damage from exercise. It is possible that chocolate milk increases protein concentrations outside the cell, potentially enhancing the recovery rate (Kloby Nielsen, Tandrup Lambert, & Jeppesen, 2020). These findings suggest that the availability of amino acids, particularly essential amino acids, may help reduce muscle damage and promote muscle recovery (Gwin, Church, Wolfe, Ferrando, & Pasiakos, 2020).

Plasma or serum creatine kinase is often used as a biomarker for muscle damage. However, some studies have indicated that creatine kinase levels may correlate poorly with direct measures of muscle damage or function (Gilson et al., 2010). Therefore, relying solely on creatine kinase levels as an indicator of muscle damage should be discouraged (Pasiakos, Lieberman, & McLellan, 2014). Consequently, since muscle recovery cannot be conclusively determined from creatine kinase data alone, this study also examined ratings of muscle soreness.

Chocolate milk positively influenced ratings of muscle soreness following heavy endurance exercise when compared to carbohydrate beverages and a placebo, with the VAS (Visual Analog Scale) scores for chocolate milk ingestion indicating better outcomes. The VAS has high reliability and validity for assessing acute pain (Bijur, Silver, & Gallagher, 2001). This finding suggests a potential enhancement of muscle recovery with chocolate milk, which is nutritionally rich in protein. This observation aligns with previous studies (Greer, Price, & Jones, 2014; Molaeikhaletabadi et al., 2022) that found protein in recovery beverages can alleviate changes in muscle soreness after heavy endurance exercise. Betts and Stevenson (2011) noted that a mix of carbohydrates and protein might have a positive effect on functionally relevant biomarkers of muscular impairment, positing that protein acts as an ergogenic aid in this context. Additionally, there is evidence that adding protein to recovery beverages helps replenish the free amino acid pool, decreasing indirect muscle damage indicators during endurance exercise (Saunders, Kane, & Todd, 2004). However, Alghannam, Gonzalez, and Betts (2018) asserted that repeated exercise capacity following short-term recovery could be optimized when carbohydrates are ingested at ≥ 1.2 g/kg body mass per hour to maximize muscle glycogen replenishment. Adding protein to carbohydrates during post-exercise recovery may be beneficial when carbohydrate intake is suboptimal (≤ 0.8 g/kg body mass per hour) for effectively restoring muscle glycogen and ensuring repeated exercise capacity.

Understanding blood lactate clearance during recovery following heavy endurance exercise is essential for grasping exercise metabolism. Blood lactate concentration is sensitive to the metabolic state of tissues, indicating the onset and disposal of lactate in the circulation in response to exercise (Emhoff & Messonnier, 2023). Our study demonstrated that chocolate milk ingestion after endurance exercise improved lactate clearance and reduced lactate levels more effectively than placebo and carbohydrate beverages. These findings are consistent with previous research indicating that chocolate milk significantly lowers serum lactate during the recovery period following exhaustive exercise compared to a placebo (Amiri, Ghiasvand, Kaviani, Forbes, & Salehi-Abargouei, 2019). Another study by Potter and Fuller (2015) also found that chocolate milk had a positive effect on lactate clearance from the bloodstream compared to water. The protein content in chocolate milk, along with the amino acids it contains, likely contributes to these effects.

CONCLUSIONS

In conclusion, consuming 1.5 g/kg/hour of chocolate milk during a 2-hour recovery period helped reduce creatine kinase level, which is a biomarker for muscle damage and soreness. It also improved the rate of lactate removal after high-intensity aerobic exercise. However, there was no significant improvement in participants' performance in a 2.4 km time trial when comparing chocolate milk to isocaloric carbohydrates and control beverages.

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