Reviews Press

Research

Chocolate milk improves post-exercise recovery, in tennis players

Curtis Wadey*, Ian Perkins and Julia Potter

Department of Physical Education, University of Chichester, College Lane Chichester, West Sussex, PO19 6PE, UK

***Corresponding authors**
Curtis Wadey, BA (Hons)
Department of Physical Education
University of Chichester, College Lane Chichester, West Sussex
PO19 6PE, UK
Tel. +44 (0) 7724859570
E-mail: cwadey1@hotmail.co.uk

***Received:** May 31st, 2018*
***Accepted:** July 3rd, 2018*
***Published:** July 5th, 2018*

Citation
Wadey C, Perkins I, Potter J. Chocolate milk improves post-exercise recovery, in tennis players. *Rev Press*. 2018; 2(1): 77-83. doi: 10.28964/Rev-Press-2-111

Abstract

Background: Chocolate milk (CM) may have ergogenic effects as a short-term recovery aid, the aim of this study was to test CM's efficacy as a recovery aid.
Methods: Eight male tennis players (Mean ± SD: age, 19.2±1.0 years; mass, 72.0±10.1Kg; VO_{2Max}, 47.6±3.7ml.kg^{-1}.min^{-1}) participated in a randomised cross-over design, separated by seven days. Participants completed performance tests including repeated sprints, a tennis skills test and exercise to exhaustion. After which, 400ml of CM or water was consumed and blood glucose levels were measured post-drink consumption. A further 400ml of CM or water was consumed 2 hours post exercise cessation. Following a 24-hour recovery period, participants repeated the performance tests following an identical protocol. Physiological and psychophysiological measures of response were collected during the protocol such as, blood glucose, lactate, pulse rate and ratings of perceived exertion.
Results: After 24-hour recovery no significant differences were observed in the consecutive bout for repeated sprints and tennis skills between the water and CM condition. There was a significant difference in time to exhaustion between water (466±201 seconds) and CM (660±125 seconds) in the consecutive bout (p=.002). Despite working for longer in the CM condition there was no significant change in physiological or psychophysiological response (blood glucose, lactate, RPE and HR). Blood glucose levels were significantly elevated post CM consumption ($p \leq 0.001$) and a three-day muscle soreness diary reported no significant difference in DOMS (p=0.065).
Conclusion: This indicated CM had ergogenic effects upon tennis performance over a consecutive day, which is potentially beneficial in a tournament setting.

Key Words: Carbohydrates; Proteins; Hydration; Muscle Soreness; Insulinotropic.

Introduction

Tennis players perform an extremely fatiguing sport for consecutive days, during a tournament. The ability to recover from one match to the next is important because athletes with reduced glycogen stores and exercise-induced muscle damage (EIMD) are known to suffer with a decline performance. [1] Recent research on the effect of consecutive match play, states players alter their technique and shot selection in order to mitigate their fatigued state. [2]

While there is a body of research in recovery and nutrition in sport, there is surprisingly little within tennis. [3] However, recently there has been a growing trend using CM as a recovery aid. [4-6] Chocolate milk's efficacy in assisting recovery has been reported within soccer [7], climbing [5] and Judo [8]. A recovery strategy should involve the restoration of metabolic reserves (such as glycogen) and hydration. [9-11] Chocolate milk (CM) contains up to 90% water and has a 4:1 carbohydrate to protein ratio. This is known to aid three key areas of recovery, glycogen synthesis, protein synthesis and rehydration.

In tournaments athletes need a rapid recovery of glycogen to facilitate optimal performance in consecutive bouts. This relies on the consumption of glucose, which is heavily featured in CM (10 grams per 100ml). The carbohydrates in CM consist of natural bovine sugars glucose, galactose, lactose and commercially added sugars such as glucose-fructose syrup, increasing the glycaemic index and insulinotropic effects of the drink. This in concert with the increase in insulin levels and sensitivity post-exercise may promote a larger anabolic environment. [12]

Insulin increases the translocation of GLUT-4 to the cell surface, increasing the uptake of glucose into the muscle cell, stimulating glycogen synthase and glycogenesis. [12] The fact that the carbohydrates are found alongside protein in CM increases the insulinotropic effect of the milk (up to 88%). [13] However, when carbohydrates are administered at optimal rates ($1.2g•kg^{-1}•h^{-1}$) protein has been reported to add no significant effect. [12] This may be due to relativity low levels of insulin achieving a threshold, whereby maximal translocation of GLUT-4 has already been achieved.

Milk contains 80% casein and 20% whey proteins. Whey rapidly digests and causes a large and transient rises in amino acids (such as leucine), this means amino acids are readily available in the blood shortly after consumption, initiating a faster recovery process. [14] Casein is digested over a longer period of time and causes a lasting elevation of amino acids. [15] This will promote both a quick and long lasting rise in amino acids stimulating protein synthesis, suppressing proteolysis and increasing an insulin response.

The impact of carbohydrate and protein (CHO + Pro) drinks on performance after exhaustive exercise has been explored in cyclists. Saunders and colleagues reported an increased cycling performance by up to 40% when drinking a CHO + Pro beverage over a carbohydrate drink. What makes this feat more impressive was the no significant difference between blood lactate and VO_2 consumption between conditions.[16] Rustad, *et al*, also reported increased performance with CHO+Pro compared with a CHO condition (27.5%) in lab based efficacy studies. [17]

In sport-specific research, CM has been found to increase endurance within rock climbing. Time to exhaustion increased by 20% beyond baseline conditions compared to a control drink (water) and reduced EIMD after a 24-hour recovery period. [5] In weight-graded sports CM has been found to significantly increase performance in a specific judo fitness test and significantly reduce EIMD without impeding on intentional weight loss. [8] In a soccer study CM was found to reduce perceptual levels of muscle soreness and significantly reduce creatine kinase levels. However, there was no difference in performance tests compared to an isocaloric placebo. [7] This indicated CM could increase performance and reduce EIMD; possibly due to the enhanced glycogen synthesis, protein synthesis and suppressed proteolysis post-exercise, but this has not been directly measured.

Whilst the majority of research has focused on recovery of metabolic reserves and EIMD, hydration is another consideration because tennis players are known to have sweat rates of more than 2.5 $L·h^{-1}$ and not be able to drink more than 1.2 $L·h^{-1}$, resulting in dehydration. [18] Full-fat and semi-skimmed milk have been reported as the second most hydrating beverages; significantly better than a range of drinks including water and second only to clinical oral rehydration solutions. [19]

The evidence suggests that CM could have the potential to support tennis player's short-term recovery, by increasing hydration, gluconeogenesis and protein synthesis. Moreover, CM is relatively cheap, has a good taste and is easily transported making it practically simple and easy to administer.

The aim of the current study was to investigate CM's efficacy as a short-term (overnight) recovery aid, in tennis performance. It was hypothesised that CM will have a positive effect on performance (repeated sprints, tennis skills and time to exhaustion) within a consecutive bout. Moreover, improvements in subsequent exercise performance would not be at the cost of increased physiological or psychophysiological response. Finally it was hypothesised that CM consumption may result in decreased perceptions of EIMD following the subsequent exercise bout.

Materials and Methods

Participants

Eight male trained tennis players were sampled to participate (age, 19.2±1.0 years; height, 181.1±7.3 cm; mass, 72.0±10.1 kg; BMI, 21.8±2.1 $kg/metres^2$; predicted $VO_{2\,max}$, 47.6±3.7 $ml.kg^{-1}.min^{-1}$; years of experience, 10.3±4.0). Participants regularly competed in league three of the British Universities and Colleges Sport. All players had tournament and league experience at both club and county events. Written informed consent was obtained from all participants and the University of Chichester's ethics board approved the study. The appearance and taste of CM did not facilitate a double-blind design, as there is no placebo available.

Procedures

The venue for the data collection was an indoor tennis centre; this site was chosen in order to reduce environmental variables. The playing surface was a medium-fast hard court (Plexicushion); it was not an International Tennis Federation approved playing surface. The mean temperature across all testing was 10.5±1.5°C with relative humidity at 77.7±9.7% (Zeal H4 Whirling Hygrometer, Zeal Ltd.). Seven days prior to testing preliminary measures were assessed, VO_2 max was estimated by a multistage fitness test. [20 21] Immediately prior to testing, motivation was recorded (1-5 Likert) before each testing session, to monitor whether participants were equally invested in all sessions. Participants consistently indicated that they were positively motivated and remained stable for all testing sessions: There was no significant interaction for bout and drink ($F_{(1,7)}$ =1.75, p=.22, ES = 0.20), nor significant main effect for bout ($F_{(1,7)}$ =0.20, p=.66, ES = 0.28) or drink ($F_{(1,7)}$ =2.33, p=.17, ES = 0.25).

This trial was a repeated measure, randomised cross-over design. Each bout of testing was at the same time of day for each participant, across two consecutive weekends. To outline the protocol testing involved a warm up; a basic skills test of the player's groundstroke and service accuracy, an intermittent exercise protocol to volitional exhaustion. The aim of the protocol to exhaustion was to induce a situation from which physiological recovery was required. The protocol was repeated following a 24-hour recovery period, having been administered CM or water as a control drink. A 24-hour recovery period was considered suitable, as it is similar to what an elite player would receive in a masters 1000 competition, adding ecological validity to the study design. [22]

Warm up

The participant had a standardised warm up before every session, consisting of a five-minute jog (target pulse rate of 120-150 beats-per-minute), 20 ground stokes against the ball machine, 10 serves and 15 bouts of the modified version of the tennis-specific sprint test with 10 seconds recovery between bouts. [23 24] A digital stopwatch with a lapping function (IPad Air 2, Apple™, USA) recorded the participants and times were logged.

The Modified Loughborough Tennis Skills Test (MLTST)

Following a three-minute rest period, the MLTST was used to set a baseline of player skill. A ball machine (Tennis Tower 'Professional Player' ™) was used to create reliable feeds (variance tested at 93.3% once first five feeds were removed) to the participant; accuracy, velocity and frequency were carefully controlled. The ball machine placed the new pressurised (Head Team ™) balls two metres from the baseline and one a metre from the singles tramline on both sides of the court alternatively. For increased accuracy of feeds, the researcher oscillated the ball machine manually. This test had a ball delivery frequency of 15 balls a minute and adequate recovery to ensure fatigue does not reduce performance. [24 25]

In order to ascertain accuracy of ball placement the participants undertook a 'target practice' test, this was achieved by modifying the Loughborough Tennis Skills test. [25] The two most significant adaptations to the test were a more simplified scoring system (described below) and that the results were recorded live by a skilled researcher, using a frequency table for time efficiency. On the opposite side of the court there were two targets ('A'&'B') each target was 2.1m^2 and situated in each corner of the baseline. The participant was instructed to hit to target 'A' for 20 balls, then a further 20 balls at target 'B'. If the participant was successful in hitting the targets they received three points. Participants also received an additional point if they hit the ball in, within the rear court. The second section of the LTST is a service test. This required two further targets ('C'&'D'), the dimension of the targets were 4.0m x 0.6m and location was placed at the deepest point of the service box. Participants served a total of 20 balls at match pace into the target areas, 10 from the deuce and a further 10 from the advantage side. Participants received 3 points for every target they hit ('C' or 'D'). Any let serve hit was repeated and the result was not recorded.

The Modified Loughborough Intermittent Tennis Test (MLITT)

The LITT is a sensitive design that can be used to test dietary aids. [23] The protocol followed four minutes of maximal match pace hitting with a 40 second rest interval. This cycle would repeat until volitional fatigue. The ball machine again placed the balls two metres from the baseline and one a metre from the singles tramline on both sides of the court alternatively. In pilot studies the standard 30 balls per minute delivery rate was too frequent; therefore, under the advice of two independent tennis coaches the ball delivery rate was reduced to 21 balls per minute in order to match the participants. [26] This value was chosen because the machine ejected the next ball, as the participant's ball reached the opposite baseline, which mirrors a match pace rally increasing the protocol's ecological validity. Moreover, by reducing the ball frequency it fatigued the participants over a longer which, helped to establish the efficacy of CM as a recovery aid.

One minute prior to the test participant's blood lactate, blood glucose (YSI 2300, Analytical Technologies, Farnborough, Hants, UK), ratings of perceived exertion (RPE) and pulse rate (ANA WIZ Ltd, FPX50DL, Surbiton, Surrey, UK) were recorded. [27] During the test the participants rallied against the ball machine for four minutes after which they would receive 40 seconds rest and then they would repeat until volitional exhaustion. The protocol would stop after volitional exhaustion or if they failed to reach two shots in succession. Upon competition of the MLITT pulse rate and RPE were recorded immediately, and blood lactate and glucose were measured with a fingertip blood sample five minutes post exercise cessation.

The CM (400ml Yazoo ™; containing CHO, 40g; Pro 12.8g; Fat, 6g; Salt, 0.4g) or water (400ml) was administered 15 minutes after protocol cessation, one minute and ten minutes after the drink blood glucose was measured (TRUEyou, Nipro Diagnostics, Fareham, Hants, UK). A further drink (400ml Yazoo or 400ml water) was taken two hours post exercise completion with participant's next meal.

A blind trial was not attempted, as a suitable placebo could not be sourced. Previous studies have used control drinks that were not iso-caloric or iso-electrolyte, and as in this study acted as fluid replacement drinks only. [5 28]

Participants were asked to complete detailed food diaries during the first testing period and repeat this calorific intake for the second condition. The participants confirmed to not having alcohol or any additional caffeine for 24 hours prior to and during the trial. Participants also completed Exercise Induced Muscle Damage questionnaires on both days of testing and one day post. Completion of these questionnaires required manual palpation of eight tennis specific muscle areas (Posterior shoulder; Gluteus maximus; Triceps brachii; Iliopsoas; Gastrocnemius; Tibialis anterior; Hamstring group and Quadricep group at rest on a soreness (likert) scale 1-10.

Blood Sampling and Analyses

A fingertip blood sample pre-and post-trial was taken while the participant was at rest using a single used lancet and lancet was used with a capillary collection device (Microvette, CB300). Blood lactate and glucose pre and post was measured within two minutes of the sample being drawn (YSI 2300, Analytical Technologies, Farnborough, Hants, UK). Blood glucose levels post drink were analysed instantly, by a portable glucose monitor (TRUEyou, Nipro Diagnostics, Fareham, Hants, UK).

Statistical analysis

All data has been presented with Means ± Standard Deviation. IBM SPSS statistics v.24 (IBM, Armonk, NY) was used for all statistical tests. Statistical tests used within the current study (within-subject factors design), were the fully repeated measures analysis of variance (ANOVA) (exercise bout * drink) Pearson correlation coefficient and post-hoc paired t-tests. The alpha level for all statistical tests was set at 5% (<0.05), with effect size and power being reported. [29-32]

Results

Performance measures

Repeated sprints & Modified Tennis Skills Test

There was no significant interaction or main effects between CM and water in either the repeated sprints protocol (H_2O bout 1, 20.4±.6 & bout 2, 20.1±.8; CM bout 1, 20.3±1.1 & bout 2, 20.6±1.5) or the modified tennis skills test (H_2O bout 1, 43.8±13.8 & bout 2, 43.5±13.8; CM bout 1,45.2±14.7 & bout 2, 44.0±9.4).

Time to exhaustion (Modified Loughborough Intermittent Tennis Test)

Significant interactions were reported ($F_{(1, 7)}$=74.34, p<0.001, ES = 0.91) and main effects for exercise bout ($F_{(1, 7)}$=18.48, p=.004, ES = 0.72) and drink ($F_{(1, 7)}$=9.04, p=.02, ES = 0.56). Participants completed a similar amount of work in their baseline testing (Water, 485±214 seconds; CM 517±147 seconds), there was no significant difference ($t_{(7)}$=-0.86, p=.41). In the water condition performance was lower in the consecutive bout (466±201 seconds), but not significantly ($t_{(7)}$=0.90, p=.39). In the CM consecutive bout a significant increase in performance was reported ($t_{(7)}$=-10.36, p<0.001); with the mean time to exhaustion reaching 660±125 seconds (a 21.6% increase) (Figure 1).

Significance was also found between drinks on the consecutive bout ($t_{(7)}$=-4.83, p=.002) and figure 2 shows that all participants (n=8) responded positively.

Physiological respons*e*

During the protocol pulse rate, RPE, blood lactate and glucose were measured both pre and post-MLITT. Two way fully repeated measures ANOVA found no significant different between post MLITT levels of pulse rate, RPE or blood lactate at any time point (Table 1).

Glucose change post-drink

Glucose was measure 1 minute and 10 minutes post drink consumption. The increase in blood glucose post-drink was calculated between two time points for both water (0.13±0.66mmol.L^{-1}) and CM (1.20±0.74mmol.L^{-1}). Paired samples t-tests found a significant difference ($t_{(7)}$=-5.18, p≤0.001). This shows CM delivers significantly higher levels of glucose into the blood used for both anabolic and catabolic pathways.

Delayed Onset Muscle Soreness

There was a significant interaction ($F_{(2, 6)}$=7.81, p=.02, ES = 0.72) (Power=.77) and there was a main effect for exercise bout ($F_{(2, 6)}$=6.10, p=.03, ES = 0.67) (Power=.66) and drink ($F_{(1, 7)}$=10.19, p=.01, ES = 0.59) (Power=.78). Indicating reduced perception muscle soreness (EIMD) following CM consumption. Paired sample t-tests (post-hoc t-tests) revealed no significant interactions or differences between drinks at any time point. However, a trend can be reported for lower muscle soreness on day three in the CM condition ($t_{(7)}$=2.187, p=0.065).

Dose response

There was a non-significant correlation between increases in time to exhaustion in the CM consecutive bout and millilitres consumed per kilo (mL/Kg) (r=0.46, p=0.26, R^2=0.21). However, mL/Kg did account for 21% of the variance in time to exhaustion, which could be considered beneficial (Figure 3)

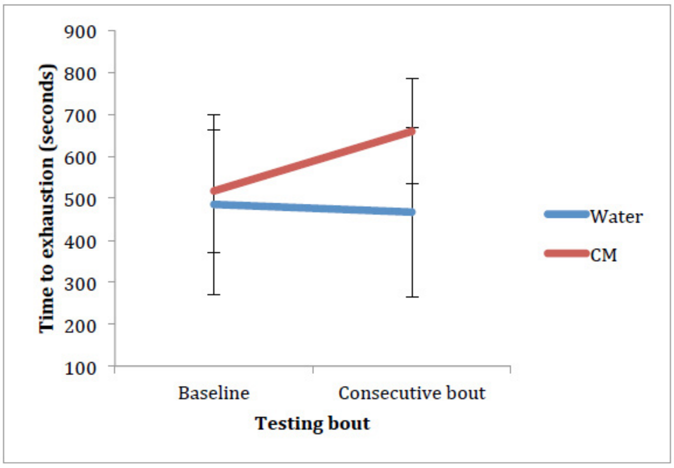

Figure 1: Time to exhaustion over exercise bout and drink.

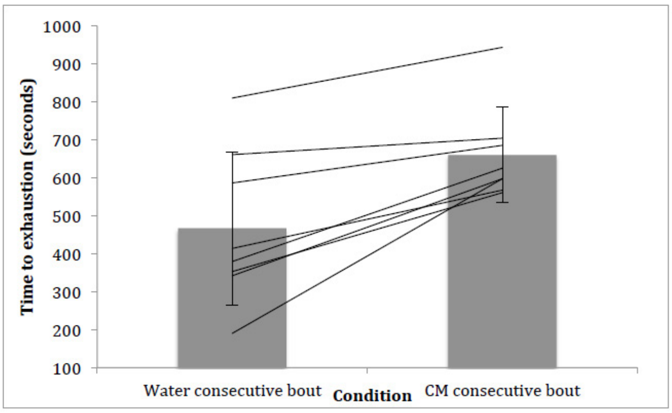

Figure 2. Comparisons of the consecutive bout, across conditions ($t_{(7)}$=-4.83, *p*=.002).

Discussion

The purpose of this research was to assess the efficacy of chocolate milk (CM) as a recovery aid for tennis players. The evidence suggests that over a 24-hour recovery period CM contributes to recovery significantly more than water. Faster recovery could be advantageous for professional tennis players, playing and training over consecutive days. In the current study CM was found to improve time to exhaustion by 21.6% in a consecutive exercise bout, demonstrating its ergogenic potential within tennis recovery. There was no additional physiological response using CM, suggesting the participants gave maximal effort in both CM and control conditions.

There was no significant interaction or main effects in the repeated sprints and tennis skills test (MLTST) protocol. Despite this, the repeated sprint protocol did achieve its aims within the current study, which was to start the fatiguing process, in order to ascertain the efficacy of CM as a recovery aid. Anecdotal reports from the MLTST data collection observed players during bout 2 of the water condition, would alter their technique and reduce the amount of power they were using, in order to increase their success in the protocol (accuracy over power). These behavioural changes, favouring getting the ball back in play at all-cost, has been observed in previous literature. [2]

This study did find a significant interaction and main effects for both exercise bout and drink in the MLITT protocol (Figure 1). Time to exhaustion significantly increased from bout one to two in the CM condition and CM produced significantly higher time to exhaustion in bout two compared to the control (Figure 2). No significant difference was reported between bout one and bout two of the water condition. From these results CM did not only attenuate the deleterious effects of fatigue, it improved time to exhaustion by 21.6% compared to baseline levels. In contrast performance decreased by 3.9% in the water condition.

Large effect sizes were reported and statistical power was found in interaction (1.00) and exercise bout (.95) and nearly achieved on drink (.73), despite a small sample size (n=8). It can be noted that not only did time to exhaustion improve but that the direction of change was consistently positive for all performers with performance increments ranging 78-188 seconds from baseline. This apparent 100% response rate is not typical for many nutritional supplements Figure 3 shows the dose response, although the volume of CM consumed relative to body size was not significantly associated with time to exhaustion, it did explain 21% of the variance in time to exhaustion, which could be meaningful in a recovering athlete.

These finding are similar to previous research, which found CM increased time to exhaustion by 20% in climbing. [5] An increase in time to exhaustion of around 20% could have significant effect in a player's ability to sustain longer rallies in tennis, crucial for players who adopt counter punching playing styles, longer match formats or slower court surfaces where rally duration is higher. An explanation for beyond baseline performance is consuming a carbohydrate rich diet beyond that of habitual feeding, this in combination with a high glycaemic product taken during an 'anabolic window' would have stimulated glycogenesis greatly.

One bottle of CM Yazoo (400ml) contains 40 grams of sugar (both natural and added) and 12.8 grams of protein; this

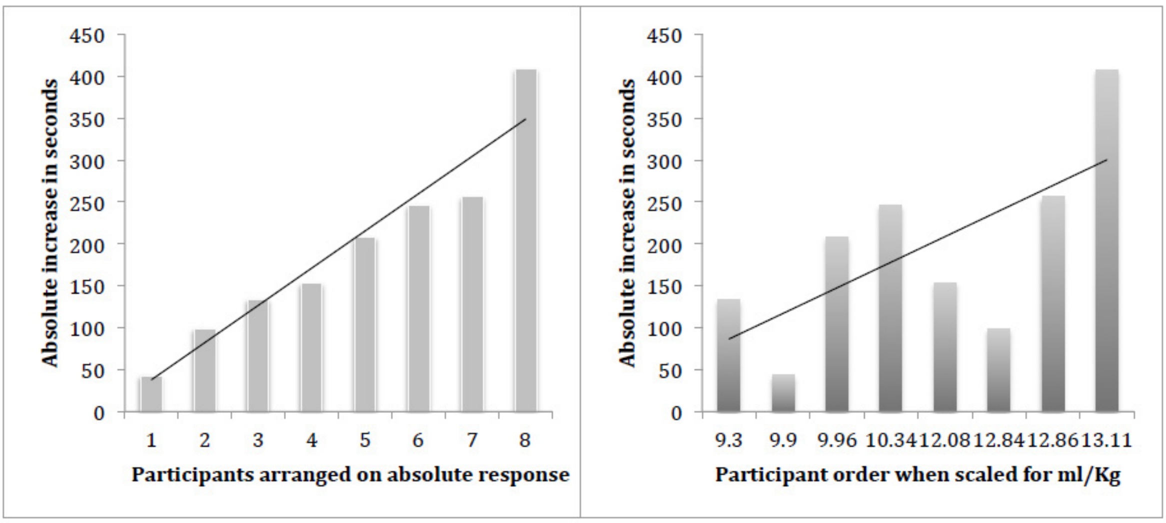

Figure 3. Performance increase in both absolute (left) relative to chocolate milk consumption in millilitres per kilogram (mL/Kg) (right).

	HR (BPM)	RPE	Lactate (mmol.L-1)	Significance
Bout 1 Water	164.6±16.9	18.0±0.7	3.9±1.6	*NS*
Bout 2 Water	165.5±16.3	18.0±1.0	3.3±1.3	*NS*
Bout 1 CM	174.8±9.7	17.6±6±1.5	3.9±2.3	*NS*
Bout 2 CM	**Bout & Drink** 178.0±15.23	18.3±1.0	3.4±1.8	*NS*

Table 1. Post exercise measures of physiological response (Means ± SD; *NS*= No significance for interaction or main effects P>0.05)

combination would be highly insulinotropic. The rise in blood glucose levels significantly increased after consumption of the CM by 1.20±0.74mmol.L^{-1}. Both glucose and milk proteins (in particular leucine) work in a synergistic manner to stimulate the secretion of insulin; this would help promote an anabolic environment for the uptake of both glucose and protein into the muscle. Once the two drinks of CM had been consumed after the fatiguing exercise, near optimum rates of CHO (1.1 g•kg) and protein (26.4 grams) would have been ingested ensuring ample substrate was in the blood ready to be absorbed into the muscle for glycogenesis and protein synthesis. [11 12 15]

Despite all the participants working for on average 21.6% longer during the second bout (of the CM condition) following the initial fatiguing day, there was no additional physiological response observed. This indicates that participants gave equal effort and worked to volitional exhaustion in all testing bouts and that CM has ergogenic properties when used as a recovery aid.

Muscle soreness showed a significant interaction and main effect for both exercise bout and drink. However, significance was not revealed between drinks in post-hoc t-tests, although significance close to an alpha level of 5% was found in day 3 (p=0.065), when muscle soreness is often identified as the most acute. Milk may have the ability to reduce the inflammatory response caused by the immune system or the proteins within the drink may help with muscle cell repair and regeneration, reduce the permeability of the sarcolemma where there is damage, consequently reducing soreness and stiffness. [33]

The implications for tennis are clear, less muscle soreness could potentially mean a greater amount of power and range of movement for both court movements and shot techniques, and greater levels of hydration enabling a better maintenance of homeostasis. This may lead to a player being able to train harder, perform better competition, or just recover more rapidly between matches.

This study could be advanced by finding a suitable placebo for CM and a double blind design. There currently is no placebo that offers the same taste, texture and consistency as CM, leading to multiple studies not using a placebo. [5 8 28] Participants replicated their habitual diets, offering an ecological design, this could be further developed. Future research could assess CM's hydrating potential post-exercise of fatigued tennis players.

Conclusion

This study assessed the efficacy of CM as a post-tennis recovery aid. Although no differences were seen in repeated sprint ability or skills level. The participants time to exhaustion was much greater after CM had been consumed, when compared with water or the participants baseline measure. Despite working for longer there were no changes in physiological response, indicating no increase in physiological disturbance despite a greater duration of work, which, is in line with previous literature. [5 16] Moreover, significant main effects for drink show that after CM participants had less muscle soreness, in the subsequent days which could promote a more rapid return to training and performance .

The data within the current study strongly indicates that CM is a very effective short-term recovery aid for tennis players over a 24-hour recovery period, this is highly suitable for both recreation and potentially professional players in consecutive match-play environments. There is the possibility of employing it as an ergogenic aid prior to competition: this warrants further investigation.

References

1. Mendez-Villanueva A, Fernandez-Fernandez J, Bishop D. Exercise-induced homeostatic perturbations provoked by singles tennis match play with reference to development of fatigue. British journal of Sports Medicine. 2007 Nov 1;41(11):717-22.
2. Gescheit DT, Duffield R, Skein M, Brydon N, Cormack SJ, Reid M. Effects of consecutive days of match play on technical performance in tennis. Journal of Sports Sciences. 2016 Oct 27:1-7.
3. Ranchordas MK, Rogerson D, Ruddock A, Killer SC, Winter EM. Nutrition for tennis: practical recommendations. J Sports Sci Med. 2013 Jun 1;12(2):211-4.
4. Ferguson-Stegall L, McCleave EL, Ding Z, Kammer LM, Wang B, Doerner PG, Liu Y, Ivy JL. The effect of a low carbohydrate beverage with added protein on cycling endurance performance in trained athletes. The Journal of Strength & Conditioning Research. 2010 Oct 1;24(10):2577-86.
5. Potter J, Fuller B. The effectiveness of chocolate milk as a post-climbing recovery aid. The Journal of sports medicine and physical fitness. 2015 Dec;55(12):1438-44.
6. Upshaw AU, Wong TS, Bandegan A, Lemon PW. Cycling Time Trial Performance 4 Hours After Glycogen-Lowering Exercise Is Similarly Enhanced by Recovery Nondairy Chocolate Beverages Versus Chocolate Milk. International journal of sport nutrition and exercise metabolism. 2016 Feb;26(1):65-70.
7. Gilson SF, Saunders MJ, Moran CW, Moore RW, Womack

CJ, Todd MK. Effects of chocolate milk consumption on markers of muscle recovery following soccer training: a randomized cross-over study. Journal of the International Society of Sports Nutrition. 2010 May 18;7(1):19.

8. Papacosta E, Nassis GP, Gleeson M. Effects of acute post exercise chocolate milk consumption during intensive judo training on the recovery of salivary hormones, salivary SIgA, mood state, muscle soreness, and judo-related performance. Applied Physiology, Nutrition, and Metabolism. 2015 Jul 20;40(11):1116-22.
9. Burke LM, Kiens B, Ivy JL. Carbohydrates and fat for training and recovery. Journal of sports sciences. 2004 Jan 1;22(1):15-30.
10. Reilly T, Ekblom B. The use of recovery methods post-exercise. Journal of sports sciences. 2005 Jun 1;23(6):619-27.
11. Burke LM, van Loon LJ, Hawley JA. Postexercise muscle glycogen resynthesis in humans. Journal of Applied Physiology. 2017 May 1;122(5):1055-67.
12. Jentjens RL, Van Loon LJ, Mann CH, Wagenmakers AJ, Jeukendrup AE. Addition of protein and amino acids to carbohydrates does not enhance postexercise muscle glycogen synthesis. Journal of Applied Physiology. 2001 Aug 1;91(2):839-46.
13. Van Loon LJ, Saris WH, Kruijshoop M, Wagenmakers AJ. Maximizing postexercise muscle glycogen synthesis: carbohydrate supplementation and the application of amino acid or protein hydrolysate mixtures. The American journal of clinical nutrition. 2000 Jul 1;72(1):106-11.
14. Phillips SM, Hartman JW, Wilkinson SB. Dietary protein to support anabolism with resistance exercise in young men. Journal of the American College of Nutrition. 2005 Apr 1;24(2):134S-9S
15. Phillips SM, Van Loon LJ. Dietary protein for athletes: from requirements to optimum adaptation. Journal of sports sciences. 2011 Jan 1;29(sup1):S29-38.
16. Saunders MJ, Kane MD, Todd MK. Effects of a carbohydrate-protein beverage on cycling endurance and muscle damage. Medicine And Science In Sports And Exercise. 2004 Jul 1;36(7):1233-8.
17. Rustad PI, Sailer M, Cumming KT, Jeppesen PB, Kolnes KJ, Sollie O, *et al.* Intake of protein plus carbohydrate during the first two hours after exhaustive cycling improves performance the following day. PloS one. 2016 Apr 14;11(4):e0153229.
18. Kovacs MS. Hydration and temperature in tennis–a practical review. Journal of Sports Science and Medicine. 2006 Mar 1;5:1-9.
19. Maughan RJ, Watson P, Cordery PA, Walsh NP, Oliver SJ, Dolci A, Rodriguez-Sanchez N, Galloway SD. A randomized trial to assess the potential of different beverages to affect hydration status: development of a beverage hydration index. The American journal of clinical nutrition. 2016 Mar 1;103(3):717-23.
20. Leger LA, Lambert J. A maximal multistage 20-m shuttle run test to predict\dot VO2 max. European journal of applied physiology and occupational physiology. 1982 Jun 1;49(1):1-2.
21. Ramsbottom R, Brewer J, Williams C. A progressive shuttle run test to estimate maximal oxygen uptake. British journal of sports medicine. 1988 Dec 1;22(4):141-4.
22. ATP. (2016). *The 2016 ATP® Official Rulebook.* United States of America: ATP Tour, Inc.
23. Davey PR, Thorpe RD, Williams C. Simulated tennis matchplay in a controlled environment. Journal of sports sciences. 2003 Jan 1;21(6):459-67.
24. Lyons M, Al-Nakeeb Y, Hankey J, Nevill A. The effect of moderate and high-intensity fatigue on groundstroke accuracy in expert and non-expert tennis players. Journal of sports science & medicine. 2013 Jun;12(2):298.
25. Davey PR, Thorpe RD, Williams C. Fatigue decreases skilled tennis performance. Journal of sports sciences. 2002 Jan 1;20(4):311-8.
26. Thomas J, Nelson J, Silverman S. *Research Methods in Physical Activity.* 5th ed. Champaign, IL: Human Kinetics; 2005.
27. Borg G. Perceived exertion as an indicator of somatic stress. Scandinavian journal of rehabilitation medicine. 1970;2(2):92.
28. Karp JR, Johnston JD, Tecklenburg S, Mickleborough TD, Fly AD, Stager JM. Chocolate milk as a post-exercise recovery aid. International journal of sport nutrition and exercise metabolism. 2006 Feb;16(1):78-91.
29. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988. 567 p.
30. Cohen J. A power primer. Psychological bulletin. 1992 Jul;112(1):155.
31. Curran-Everett D, Benos DJ. Guidelines for reporting statistics. The American Physiological Society. 2004; 287: 247–249.
32. Pallant J. *SPSS survival manual*. United Kingdom: McGraw-Hill Education; 2013.
33. Cheung K, Hume PA, Maxwell L. Delayed onset muscle soreness. Sports Medicine. 2003 Feb 1;33(2):145-64.