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Original Article

A comprehensive review of the effects of cherry juice and chocolate milk supplementation on football performance and recovery

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Abstract
Background: Football matches and training sessions can induce metabolic and mechanical stress, leading to inflammation, oxidative stress, and muscle damage, all of which may negatively impact subsequent performance. Montmorency tart cherry, rich in phytochemicals and anthocyanins, is believed to aid in recovery and alleviate muscle soreness. Similarly, chocolate milk may promote glycogen synthesis, protein synthesis, and rehydration. The aim of this study is to review the effects of cherry juice and chocolate milk on athletes and summarize results to inform future research on football recovery. **Methods:** This comprehensive review identified relevant literature through an extensive search of the PubMed, Scopus, ScienceDirect, and SPORTDiscus databases, using combinations of keywords related to cherry juice, chocolate milk, and exercise. Studies were selected based on specific inclusion and exclusion criteria. **Results:** A total of 372 studies were identified through the search [Cherry juice: n = 137; Chocolate milk: n = 235]. After assessing eligibility, 27 studies were included based on the inclusion and exclusion criteria [Cherry juice: n = 14; Chocolate milk: n = 13]. These studies investigated the effects of cherry juice and chocolate milk on various aspects of post-training or post-competition recovery, including muscle damage, inflammation, oxidative stress, and physical performance in athletes from different sports. **Conclusion:** Based on the reviewed literature, the ingestion of cherry juice and chocolate milk has the potential to reduce muscle damage and soreness and enhance recovery after exercise and physical activities in athletes from various sports. These positive results suggest that cherry juice and chocolate milk may also benefit football players as recovery strategies. However, further research is needed to determine the optimal dosage, timing, and duration of supplementation, as well as the long-term effects on recovery and performance in football-specific contexts.
Keywords: **Montmorency cherry, Cocoa flavanols, Exercise, Recovery, Post-exercise, Muscle damage, Oxidative stress**

Introduction

Football is an intermittent team sport that requires high intensity actions (Akenhead et al. 2013). Players can cover approximately 9-12km at 80-90% of Maximal Heart Rate and 70% of maximum rate of oxygen consumption (VO2max) (Di Salvo et al., 2006 & Akenhead et al., 2013). The season takes nine months to complete and there can be up to 70 competitive matches. Thus, players perform at least one or two matches per week during the season (Nédélec et al., 2012).

Football match-play induces metabolic (Brownstein et al., 2017) and mechanical (Marqués-Jiménez et al., 2022) stress in players. As a result, players suffer from elevated post-match inflammation, oxidative stress, muscle damage, and a decrease in performance (Fatouros et al., 2010). Therefore, adequate recovery time for players of more than 72hrs and up to 120hrs is necessary to fully recover from the previous match, allowing muscle damage normalization, and restoration of the metabolic performance and treatment of inflammation (Ranchordas et al., 2017). However, as football players may suffer from chronic fatigue due to the high number of competitive matches and insufficient time for full recovery, (Fatouros et al., 2010, Nédélec et al., 2012, Ranchordas et al., 2017) recovery strategies are regarded as an essential component of the football performance periodisation model (Marqués Jiménez et al., 2017).

Various recovery strategies have been proposed to enhance recovery from post-match or post-training. However, some recovery strategies such as compression garments and cryotherapy require cost and specific tools (Thienpont, 2014). Also, massage or physiotherapy requires qualified experts. Consequently, those recovery strategies are hard to apply in all football teams regardless of the levels. Therefore, nutritional recovery strategies can be more accessible relative to other recovery strategies mentioned above and can be partially adopted

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according to budget constraints. Although nutritional recovery strategies relatively easy to adapt in sports, there are few studies in football for nutritional recovery during restricted recovery time due to repeated matches during the week (Ranchordas et al., 2017).

Cherry juice (CJ) supplements and Chocolate milk (CM) can be used as recovery aids. Previous research found that CM and CJ supplements are effective in athletes' recovery (Gilson et al., 2010, Howatson et al., 2010, Bell et al., 2015, Bell et al., 2016, Brown et al., 2019, Corr et al., 2020). It is well established that CJ contains a high concentration of phytochemicals and anthocyanins, which have been reported to enhance sleep, improve recovery, and reduce muscle damage and soreness after exercise (H Kuehl et al., 2010, Howatson et al., 2010, Bell et al., 2014). Moreover, the restoration of metabolic reserves and hydration is essential in the recovery process (Burke et al., 2017). CM is an effective post-exercise drinks because it contains up to 90% water with a 4:1 carbohydrate and protein ratio (Wadey et al., 2018). Therefore, CM ingestion can enhance recovery, glycogen synthesis, protein synthesis, and rehydration (Wadey et al., 2018).

The positive effect of CM and CJ supplements in various athletic populations was shown in previous studies (Pritchett et al., 2009, Thomas et al., 2009, Howatson et al., 2010, Kuehl et al., 2010, Peschek et al., 2013, Bell et al., 2014, Dimitrious et al., 2015, Papacosta et al., 2015, Levers et al., 2016, McCormick et al., 2016, Upshaw et al., 2016). Despite evidence found the effectiveness of CJ and CM for athletic population, there is surprisingly still a lack of studies providing collective information on the use of CJ and CM in team sports including football players. Therefore, the aims of this comprehensive review are to: 1) assess the effectiveness of CJ and CM in athletic population, 2) consolidate existing knowledge of the use of CJ and CM in different sports to apply in football players, and 3) map the results of previous studies regarding CJ and CM in sports which enables application to the real world, including youth, amateur, and professional football.

Methods

Search Strategy

The published literature was hand-searched using key terms from several online databases, which were mentioned below. The used key terms of this review were "Cocoa flavanols", "Chocolate milk", "Cherry juice", "Montmorency Cherry", "Tart Cherry", "Exercise", "Recovery", "Post-exercise", “Muscle damage". To enhance the search strategy, keywords were combined with the "OR" to gather the result maximally. Also, "AND" was used to focus on both recovery and Cherry juice or Chocolate milk. The articles were searched to classify based on following the inclusion criteria. Furthermore, only written in English literature was allowed to include this comprehensive review for appraisal of possible publication bias. The searching of literature was conducted separately by using keywords in each database.

Eligibility criteria

This review considered manually how search strategies, including what keywords were used, how inclusion and exclusion criteria were used, and what databases were used to search the articles, were used to identify the relevant studies by the authors for a comprehensive evaluation.

Inclusion and exclusion criteria

The searched literature was determined based on the inclusion and exclusion criteria. The selection of literature then proceeded based on inclusion and exclusion published year, criteria of titles and abstracts. When there was insufficient evidence from the abstract or title, the main text was reviewed to determine eligibility. The inclusion and exclusion criteria are detailed in Table 1.

Data extraction

Literature searching was conducted within large online databases including Scopus, SPORTDiscus, ScienceDirect and PubMed. Also, references were managed by the software programme: Zotero version 5.0. In total, 372 articles were identified using search strategies: 137 articles were related to Tart or CJ supplementation and 235 articles were about CM or cocoa flavanols. After eliminating duplicates, 277 articles regarding CJ and CM remained.

Results

A comprehensive search of databases spanning the last two decades yielded a total of 372 studies, which were identified using various combinations of relevant keywords. Of these, 137 studies were related to CJ supplementation, and 235 were related to CM supplementation. After removing duplicates, 95 studies on CJ supplementation and 182 studies on CM supplementation remained. Further exclusion based on the inclusion criteria left 35 studies on Cherry supplementation and 69 on CM supplementation. Studies unavailable as full-text articles were also excluded, leading to the removal of 11 studies from the Cherry supplementation category and 43 from the CM supplementation category.

Consequently, 24 studies on Cherry supplementation and 26 on CM supplementation were selected for full-text review. After the full-text review, 10 studies from Cherry supplementation and 13 from CM supplementation were excluded based on the exclusion criteria. Ultimately, 27 studies (14 on Cherry supplementation and 13 on CM supplementation) were selected for inclusion in this comprehensive review. The process of study selection is summarized in a flowchart using 'The PRISMA 2020 statement: An updated guideline for reporting systematic reviews' (Page et al., 2021) as shown in Figure 1.

Table 1.— *Inclusion and Exclusion criteria*

Inclusion criteria	• Written in English • Should be published after 2000 • Full-Text article should be available • Subjects: active or healthy population and athletes • Should examine nutritional recovery strategies • Should include the consumption of Montmorency tart Cherry juice or Powdered form with drink and Chocolate milk and Cocoa flavanol • Should include at least one variable: Functional and performance variable, Perceptual variable, Oxidative stress markers, Inflammatory markers, Muscle damage markers, Peripheral muscle fatigue markers
Exclusion criteria	• Written in other languages • Should be published before 2000 • Full-text article not available • Study design: Systematic review, Editorials and commentary • Cherry juice or Chocolate milk with other mixed contents (Example: Cherry juice + Carrot juice) • The variables of articles are not related to recovery or muscle damage • Written in other languages

Characteristic of studies with Cherry supplementation

The number of participants used in the CJ studies was between 10 and 54. Five studies recruited both male and female participants, and the number of female participants was between 9 and 18 participants. Also, eight studies recruited only male participants. The participants were varied age group, height and body mass in each study. The age of recruited participants in selected studies was 17.2 to 46.7 years old, height 161 to 188.71cm, and body mass 55.7 to 108kg in body mass. Three studies did not provide the information of height and two studies did not provide participants' body weight.

The participants involved sports and training level were varied. Two studies used trained cyclists, two studies used participants who were involved in team sports, including hockey, football and netball (one study used only semi-professional footballers), one study with water polo players, and three studies with endurance runners (one study was with recreational runners), one study was with non-resistance trained participants, one was with resistance-trained participants, and one study with just active participants and two studies did not mention specifically but trained participants.

In the reviewed studies, ten studies were conducted using a double-blind placebo-controlled design, three used a crossover study design, and one employed a single-blind placebo-controlled design. The dosage of Cherry supplementation varied across the studies. A dose of 30ml Cherry concentrate was equated to approximately 80 and 110 whole cherries (Connolly et al., 2006, Howatson et al., 2010, Kuehl et al., 2010, Bell et al., 2014, Bell et al., 2015, Dimitrious et al., 2015, Brown et al., 2019, McCormick et al., 2016). The content of Cherry in the supplements was calculated based on the number of cherries. Each study provided participants with drinking fluids containing diluted Cherry concentrate or powdered Cherry supplements, equivalent to about 100 to 270 whole Cherries, which contained between 600mg and 1200mg of phenolics.

The exercise protocols to induce muscle damage varied across the studies examining Cherry supplementation. Three studies employed marathon tasks to induce muscle damage. Two studies utilized high-intensity Stochastic cycling tasks. The Loughborough Intermittent Shuttle Test (LISTADAPT) featuring 12 sets of 20m sprinting was used in two studies. Eccentric elbow flexion contraction with 2 sets of 20 maximum contractions was employed in two studies. Additionally, one study each used the Hood to Coast relay race, 15 sets of 30m sprints, 10 sets of 10 back squats using a barbell at 70% of 1RM and fatiguing simulated team game activity as methods to induce muscle damage. The characteristics of these 14 included studies focusing on Cherry supplementation are summarized in Table 2.

Table 2 *Characteristics of the studies with CJ supplementation.*

Study	Subject	Group	Age	Height	Weight	Cherry Content	Intervention Duration	Exercise Protocol
Bell et al. (2014)	Trained Male Cyclist (n=16)	Tart Cherry: (n=8) Placebo: (n=8)	30 ± 8 Years	181.1 ± 6.7 cm	76.5 ± 9.2 kg	30mL x 2 Per day Approx. 180 ~ 220 cherries	7 Days (Exercise on days 5, 6, and 7)	A stimulated, High-intensity Stochastic Cycling task (Lasting 109 minutes)
Bell et al. (2015)	Trained Male Cyclist (n=16)	Tart Cherry: (n=8) Placebo: (n=8)	30 ± 8 Years	181.1 ± 6.7 cm	76.5 ± 9.2 kg	30mL x 2 Per day Approx. 180 ~ 220 cherries	7 Days (Exercise on days 5, 6, and 7)	A stimulated, High-intensity Stochastic Cycling task (Lasting 109 minutes)
Bell et al. (2016)	Semi-Professional Male Football Players (n=16)	Tart Cherry: (n=8) Placebo: (n=8)	25 ± 4 years	180.8 ± 7.4 cm	81.9 ± 6.6 kg	30mL x 2 Per day Approx. 180 ~ 220 cherries	7 Days (Exercise on day 5)	The Loughborough Intermittent Shuttle Run (LISTADAPT) and 12 x 20 m Sprint
Sumners et al. (2011)	Well-Trained Male Participant (High-intensity intermittent	Tart Cherry: (n=10)	27.8 ± 1.6 years	176 ± 3.0 cm	81.3 ± 4.3 kg	30mL x 2 Per day Approx. 180 ~ 220 cherries	10 Days (Exercise on day 8)	Single-leg Knee extension at 80% 1RM

	sport)							
Brown et al. (2019)	Physically active female (n=20)	Tart Cherry: (n=10) Placebo: (n=10)	19 ± 1 years	167 ± 6.0 cm	61.4 ± 5.7 kg	30mL x 2 Per day Approx. 180 ~ 220 cherries	8 Days (Exercise on day 5)	15 x 30m Sprint
Conolly et al. (2016)	Male College Students (n=14)	Tart Cherry: (n=14) Placebo: (n=14)	22 ± 4 years	178 ± 7.6 cm	90 ± 18 kg	12oz with at least 600mg Phenolic compound x 2 per day Approx. 100 ~ 120 cherries	8 days (Exercise on day 4)	Eccentric elbow flexion contraction 2 x 20 Max. contraction
Howatson et al. (2010)	Recreational Marathon runners Male: (n=13) Female: (n=7)	Tart Cherry (n=10) Male: (n=3) Female: (n=7) Placebo (n=10) Male: (n=6) Female: (n=4)	Tart Cherry 37 ± 13 years Placebo 38 ± 5 years	Tart Cherry 177 ± 0.6 cm Placebo 175 ± 0.9 cm	Tart Cherry 72.9 ± 9.8 kg Placebo 73.8 ± 9.5 kg	8oz with at least 600mg Phenolic compound x 2 per day Approx. 100 ~ 120 cherries	8 days (Exercise on day 6)	Marathon Running
Kuehl et al. (2010)	Healthy Male and Female Runner Male: (n=36) Female: (n=18)	Tart Cherry (n=26) Male: (n=13) Female: (n=7) Placebo (n=25) Male: (n=15) Female: (n=10)	Tart Cherry 38.2 ± 8.5 years Placebo 32.2 ± 9.8 years	–	–	10.5oz with at least 600mg Phenolic compound x 2 per day Approx. 100 ~ 120 cherries	8 days (Exercise on day 8)	Hood to Coast Relay race 3 running segment Each segment distance ranging (5.6 ~ 12.4km) Average total running distance (56.3 ± 2.5 km)
Lamb et al. (2019)	Non-resistance Trained men (n=26)	Tart cherry: (n=12) Placebo: (n=12)	Tart cherry 24 years IQR: 22 ~ 33 years Placebo 24 years IQR: 22.5 ~ 32 years	–	–	30mL x 2 per day Approx. 180 ~ 220 cherries	8 days (Exercise on day 5)	5 x 10 Eccentric MIVC Unilateral Eccentric Elbow Flexions using Non-dominant arm
Levers et al. (2015)	Healthy Resistance-Trained males (n=23)	Tart cherry: (n=11) Placebo: (n=12)	Tart Cherry 21.18 ± 3.34 years Placebo 20.58 ± 1.78 years	Tart Cherry 178 ± 10.71cm Placebo 177 ± 5.28 cm	Tart Cherry 80.64 ± 13.16 kg Placebo 80.64 ± 13.16 kg	480mg [CherryPURE®) Contain 1mg = 2.06mg Phenolic compounds 480mg = 993mg Phenolic compounds Approx.100 ~ 120 cherries	10 days (Exercise on day 8)	10 x 10 a Barbell Back squat at 70% 1RM with 3 minutes recovery between the sets
Levers et al. (2016)	Endurance-Trained runner or Triathletes Male: (n=18) Female: (n=9)	Tart cherry: (n=11) Placebo: (n=16)	Tart Cherry 20.82 ± 1.89 years Placebo 22.44 ± 4.86 years	Tart 175 ± 8.59 cm Placebo 173 ± 11.43 cm	Tart Cherry 80.64 ± 13.16 kg Placebo 82.62 ± 7.39 kg	480mg [CherryPURE®) Contain 1mg = 2.06mg Phenolic compounds 480mg = 993mg Phenolic compounds Approx.100 ~ 120 cherries"	10 days (Exercise on day 8)	Half-marathon Race (21.1km Under 2hours)
McCormick et al. (2016)	Highly-Trained Male water polo players (n=9)	Tart cherry: (n=9) Placebo: (n=9)	18.6 ± 1.4 years	–	82.7 ± 9.8 kg	30mL x 3 per day Approx. 270 cherries	10 days (Exercise at the end of day 6)	Fatiguing simulated team game activity
Dimitriou et al. (2015)	Male and Female Marathon runners Male: (n=13) Female: (n=7)	Tart cherry: (n=10) Male: (n=7) Female: (n=3) Placebo: (n=10) Male: (n=6) Female: (n=4)	Tart Cherry 37 ± 13 years Placebo 38 ± 5 years	Tart Cherry 177 ± 0.6 cm Placebo 175 ± 0.9 cm	Tart Cherry 72.9 ± 9.8 kg Placebo 73.8 ± 9.5 kg	236mL with at least 600mg Phenolic compound x 2 per day Approx. 100 ~ 200 cherries	8 days (Exercise on day 6)	Marathon Running
Quinlan and Hill (2016)	Male and Female Team-sport players Male: (n=8) Female: (n=12)	Tart cherry: (n=10) Placebo: (n=10)	26 ± 4 years	175 ± 9.6 cm	70.2 ± 12.6 kg	30mL x 2 per day Approx. 180 ~ 220 cherries	8 days (Exercise on day 6)	The Loughborough Intermittent Shuttle Test (LISTADAPT) and 12 x 20m sprint

Characteristics of studies with Chocolate milk supplementation

The number of participants used in CM studies were between 8 and 23 participants. Two studies recruited both female and male participants. 13 and 16 female participants were recruited. Ten recruited only male participants, and one study did not specify the participants' gender.

The characteristics of participants varied. The age range was between 13 and 35 years old, apart from one study which recruited old male participants aged 74.4 ± 5.4 years. The range of Participants' height and body mass between 157cm and 188.4cm and body mass 53kg and 89kg. One study measured Body Mass Index (BMI) instead of height and body mass.

The training levels and participants involved sport were different across studies. Participants from five studies were trained cyclists, and tennis players, runners, triathletes, footballers in NCAA division I, judo athletes (all trained in different levels). Two studies did not specify the training levels and involved sports. Lastly, one study untrained but recreationally active.

Eleven studies used a cross over study design, and two studies used double-blind placebo-controlled design and single-blind nutrient-controlled trial, respectively. Furthermore, the dose of supplementation was different across studies. Participants ingested either CM or Chocolate beverage with different amount of cocoa flavanols, with milk. One study used a different type of Chocolate beverages (Chocolate soy beverage and chocolate hemp beverage) with different CHO-protein ratio. Also, one study designated to provide a different amount of Chocolate milk based on body mass groups. Between 300ml and 2262ml of CM with water or the beverage with 830mg and 1245mg of cocoa flavanols, was ingested in each study.

The different exercise protocols to induce muscle damage to measure the effect of CM supplementation in recovery were used in each study. Glycogen lowering exercise, judo training, aerobic training with cycling, the protocol using Cybex norm isometric dynamometer, modified Loughborough tennis skill test, modified Loughborough intermittent tennis test, downhill running, and resistance training used across studies. The characteristics of CM supplementation studies are summarised in Table 3.

Table 3. — *Characteristi§cs of the studies with CM supplementation.*

Study	Subject	Group	Age	Height	Weight	Chocolate Content	Exercise Protocol	Study
Upshaw et al. (2016)	Trained-Male Cyclists (n=8)	Chocolate milk: (n=8) Placebo: (n=8)	21.8 ± 2.3 years	170 ± 10 cm	73.4 ± 10.5 kg	Chocolate Soy beverage 4:1 CHO:Protein ratio Chocolate Hemp beverage 6:1 CHO:Protein ratio Daily Chocolate milk 4:1 CHO:Protein ratio * All drink volume was equalised 2262 ± 148mL with ingesting water	Glycogen lowering exercise with 4hours recovery and performed 20km cycling time trial *Drinking time immediately post-glycogen lowering exercise at 30 minutes intervals for the first 2hours of a 4hours recovery	Upshaw et al. (2016)
Thomas et al. (2009)	Trained-Male Cyclists (n=9)	Chocolate milk: (n=9) Fluid replacement drink: (n=9) CHO replacement drink (n=9)	25.4 ± 8 years	180.3 ± 8.3 cm	72.8 ± 8.4 kg	Chocolate milk 459.2 ± 52.6 mL	Glycogen depletion trial * Drinking time Immediately post-glycogen depletion trial and 2 hours into the Recovery period	Thomas et al. (2009)
Pritchett et al. (2009)	Regional-Level Cyclist and Triathletes (n=10)	Chocolate milk: (n=10) CHO replacement drink: (n=10)	27.1 ± 7.9 years	176.5 ± 3.6 cm	72.1 ± 6.7 kg	Chocolate milk 17.3 ± 1.8 oz	Endurance cycling test *Drinking time Immediately post-exercise and 2hours into the recovery period	Pritchett et al. (2009)
Papacosta et al. (2015)	National-Level trained Judo athletes (n=12)	Chocolate milk: (n=12) Water: (n=12)	19 ± 4 years	175 ± 7 cm	77.4 ± 7.9 kg	Chocolate milk 1000mL	5 Days intensive judo training and a stimulated competition *Drinking Time	Papacosta et al. (2015)
Karp et al. (2004)	Highly Trained Male Cyclists (n=9)	Chocolate milk: (n=9) Fluid replacement drink: (n=9) CHO replacement drink: (n=9)	22.1 ± 2 years	179.9 ± 6.3 cm	73 ± 4.6 kg	Chocolate milk 509.1 ± 36mL	Glycogen depletion trial *Drinking Time Immediately Post-glycogen depletion Trial and 2hours into the recovery period	Karp et al. (2004)
Gilson et al. (2010)	NCAA Division I Male Football players (n=23)	Chocolate milk: (n=13) CHO replacement drink: (n=13)	–	–	–	Chocolate milk 672mL	Week 1: Baseline test Week 2: 4 Dyas ITD *Drinking time Immediately each post-ITP sessions	Gilson et al. (2010)
Ferguson-Stegall et al. (2011)	Recreationally untrained active males and females Male: (n=16) Female: (n=16)	Chocolate milk: (n=11) CHO drink (n=11) Placebo: (n=10)	Chocolate milk 22.1 ± 0.7 years CHO drink 22.3 ± 0.9 years Placebo 22.6 ± 1 years	Chocolate milk 169.1 ± 2.3 cm CHO drink 168 ± 2.7 cm Placebo 168.8 ± 3.1 cm	Chocolate milk 70.9 ± 5.1 kg CHO drink 71.2 ± 3.1 kg Placebo 73.2 ± 4.5 kg	Body mass < 63.6kg 250mL x 2 Body mass 63.6 ~ 77.2kg 200mL x 2 Body mass 77.2 ~ 90.9kg 350mL x 2 Body mass > 90.0kg 375mL x 2	4.5 weeks Aerobic training 60minutes cycling/Day/5Day/week at 75~80% VO2max *Drinking time Immediately and 1hour Post-exercise	Ferguson-Stegall et al. (2011)

Corr et al. (2020)	Male: (n=10) Female: (n=13)	High (CF830) Supra (CF1245) Placebo	High (CF830) 24 ± 4 years Supra (CF1245) 25 ± 5 years Placebo 24 ± 4 years	High (CF830) 168 ± 9 cm Supra (CF1245) 168 ± 11 cm Placebo 175 ± 8 cm	High (CF830) 68 ± 10 kg Supra (CF1245) 65 ± 12 kg Placebo 74 ± 15 kg	Flavanol High (CF830) 830mg Supra (CF1245) 1245mg	Induced muscle damage using The Cybex Norm Isokinetic Dynamometer	Corr et al. (2020)
Wadey et al. (2018)	Trained Male Tennis Players (n=8)	Chocolate milk: (n=8) Water: (n=8)	19.2 ± 1 years	181.1 ± 7.3 cm	72 ± 10.01 kg	Chocolate milk 400mL x 2	Modified Loughborough Tennis Skills Test (MLTST) Modified Loughborough Intermittent Tennis Test (MLITT) * Drinking time 15minutes after protocol cessation / 2 hours Post-exercise	Wadey et al. (2018)
Decroix et al. (2017)	Well Trained Male cyclist: [n=12]	Cocoa Flavanol with milk: (n=12) Placebo: (n=12)	30 ± 3 years	177.9 ± 8.8 cm	72.8 ± 7.8 kg	Flavanol 900mg with 300mL Skimmed milk	30 minutes Cycling time trial x 2 *Drinking time 10minutes before 1st time trial	Decroix et al. (2017)
Peschek et al. (2013)	Well Trained Male Runner and Triathletes: (n=8)	CHO Protein drink (CHOC) (n=8) Flavanols with CHOC (CocoaCHOC) (n=8)	Between 18 - 44 years	–	–	CHOC 240mL with 0mg Flavanols cocoa CHOC 240mL with 350mL Flavanols	Downhill running 5Km Time Trial * Drinking time post-downhill running 2hours into Recovery	Peschek et al. (2013)
Karp et al. (2006)	Trained Male Cyclists (n=9)	Chocolate milk: (n=9) Fluid Replacement drink: (n=9) CHO placement drink: (n=9)	22.1 ± 2 years	179.9 ± 6.3 cm	73 ± 4.6 kg	Chocolate milk 509.1 ± 36mL	Glycogen depletion trial *Immediately Post-glycogen depletion trial and 2 hours into the Recovery period	Karp et al. (2006)
Mitchell et al. (2015)	Healthy young men (n=16) Healthy older men (n=16)	Chocolate milk: (n=16) Placebo: (n=16)	Young men 22.4 ± 2.1 years Older men 74.4 ± 5.4 years	–	–	500mL of 1% Chocolate milk	Resistance training lower body and upper body sessions * Drinking time Immediately Post-exercise	Mitchell et al. (2015)

Effects of Cherry supplementation on functional performance

Eleven studies analyzed different functional performance variables using CJ supplementation (Connolly et al., 2006, Howatson et al., 2010, Sumners et al., 2011, Bell et al., 2015, Lever et al., 2015, Bell et al., 2016, Levers et al., 2016, McCormick et al., 2016, Brown et al., 2019, Lamb et al., 2019, Quinlan & Hill, 2020). The functional performance variables examined including Maximal voluntary Isometric Contraction (MIVC), relaxed elbow angle, cycling economy (CE), Range of Motion (ROM), Peak Cycling Power (PCP), Countermovement Jump (CMJ), Agility, Sprint (Repeated sprint test, 20m, 30m, and 10m), Drop jump (DJ), Reactive Strength Index (RSI), Flexibility, Vertical jump (VJ), Water polo Intermittent Shuttle Test (WIST), and half-marathon performance.

Nine studies analyzed Maximal Isometric Voluntary Contraction (MVIC), with six studies found that CJ groups had better recovery and less strength loss after exercise compared to placebo groups (Connolly et al., 2006, Howatson et al., 2010, Sumners et al., 2011, Bell et al., 2015, Bell et al., 2016, Quinlan & Hill, 2020). Additionally, four studies measured sprint times (10m, 20m, 30m, and Repeated Sprint Test), with two reporting faster 20m sprint times post induced muscle damage in the CJ group (Bell et al., 2016 & Quinlan & Hill. 2020). Jump performance, particularly Countermovement Jump (CMJ), was measured in four studies, with findings indicating significantly quicker recovery and lesser performance reduction in post-ingestion CJ (Bell et al., 2016, Brown et al., 2019, Quinlan & Hill. 2020). There were no significant differences found in other performance variables; flexibility, cycling economy (CE), Peak Cycling Power (PCP), Water polo Intermittent Shuttle Test (WIST), Range of Motion (ROM), and relaxed elbow angle. However, agility performance was better in CJ group (Bell et al., 2016 & Brown et al., 2019). One study found faster completed a half-marathon in CJ group than the placebo group (Levers et al., 2016). All the functional performance variables are summarized in Table 4.

Effects of Cherry supplementation on the perceptual variables

The perceptual variables of Cherry supplementation were analyzed across thirteen studies (Connolly et al., 2006, Howatson et al., 2010, Kuehl et al., 2010, Bell et al., 2015, Levers et al., 2015, Bell et al., 2016, Levers et al., 2016, McCormick et al., 2016, Brown et al., 2019, Lamb et al., 2019, Quinlan & Hill, 2020). The perceptual variables included delayed-onset muscle soreness (DOMS), Total quality of recovery (TQR), quadriceps soreness rating, subjective pain values, and pain pressure threshold (PPT). Seven studies measured

DOMS, but only three found lower DOMS during recovery in CJ group (Bell et al., 2015 & Brown et al., 2019). Also, four studies measured subjective rating of pain. All studies found the attenuated increase of pain in pre- and post-exercise after CJ ingestion and high satisfaction of CJ supplementation (Connolly et al., 2006, Kuehl et al., 2010, Levers et al., 2015, Levers et al., 2016). However, there was no significant differences in TQR and PPT (McCormick et al., 2016 & Brown et al., 2019). The completed summary of perceptual variables can be seen in Table 4.

Table 4. — *Variables measured and key findings of studies with CJ supplementations.*

Study	Supplementation	Functional and Performance Variables and Perceptual variables	Inflammatory and Oxidative stress markers	Significant difference in CJ group (vs PLA)
Bell et al. (2014)	CJ	Maximal Voluntary Isometric Contraction (MVIC) 20m Sprint Countermovement Jump (CMJ) Agility (5-0-5) Delayed Onset Muscle Soreness (DOMS)	Maximal Voluntary Isometric Contraction (MVIC) 20m Sprint Countermovement Jump (CMJ) Agility (5-0-5) Delayed Onset Muscle Soreness (DOMS)	< Serum LOOH across the trial period (Trial 3 - < 29.8% lower in CJ group) < IL-6 following trial 2 and 3 <hsCRP across all time-point after baseline
Bell et al. (2015)	CJ	Single leg Knee-extension Maximal voluntary Isometric contraction (MVIC)	Maximal Voluntary Isometric Contraction (MVIC) Cycling efficiency 6 seconds peak cycling power Delayed Onset Muscle Soreness (DOMS)	< MVIC 24, 48 and 72hrs Post-trial < IL-6 Post-trial <hsCRP in all time-points <DOMS (trends) but not significantly difference
Bell et al. (2016)	CJ	Maximal Voluntary Isometric Contraction (MVIC) 20m Sprint Countermovement Jump (CMJ) Agility (5-0-5) Delayed Onset Muscle Soreness (DOMS)	Lipid hydroperoxides (LOOH) Interleukin1-Beta (IL-1-β) Interkeukin-6 (IL-6) Interkeukin-8 (IL-8) Tumour Necrosis Factor-Alpha (TNF-α) High-Sensitivity C-Reactive Protein (hsCRP)	> MVIC 24, 48 and 72hrs Post-trial > CMJ 24, 48 and 72hrs Post-trial < DOMS across 72hrs post < Agility test time across 72hrs post < 20m Sprint time across 72hrs post < IL-6 (Overall treatment effect)
Sumners et al. (2011)	CJ	Single leg Knee-extension Maximal voluntary Isometric contraction (MVIC)	Creatine Kinase (CK) High-Sensitivity C-Reactive Protein (hsCRP) Total Nitrotryosin (TNit) Protein Carbonyls (PC) Total Antioxidant Status (TAS)	< PC 24 and 48hrs Post-trial <hsCRP in all time points (Trends) but not significantly difference
Brown et al. (2019)	CJ	Maximal Voluntary Isometric Contraction (MVIC) 20m Sprint Countermovement Jump (CMJ) Agility (5-0-5) Delayed Onset Muscle Soreness (DOMS)	Lipid hydroperoxides (LOOH) Interleukin1-Beta (IL-1-β) Interkeukin-6 (IL-6) Interkeukin-8 (IL-8) Tumour Necrosis Factor-Alpha (TNF-α) High-Sensitivity C-Reactive Protein (hsCRP)	> MVIC 24, 48 and 72hrs Post-trial > CMJ 24, 48 and 72hrs Post-trial < DOMS across 72hrs post < Agility test time across 72hrs post < 20m Sprint time across 72hrs post < IL-6 (Overall treatment effect)
Conolly et al. (2006)	CJ	Single leg Knee-extension Maximal voluntary Isometric contraction (MVIC)	Creatine Kinase (CK) High-Sensitivity C-Reactive Protein (hsCRP) Total Nitrotryosin (TNit) Protein Carbonyls (PC) Total Antioxidant Status (TAS)	< PC 24 and 48hrs Post-trial <hsCRP in all time points (Trends) but not significantly difference
Howatson et al. (2010)	CJ	Delayed Onset Muscle Soreness (DOMS) Maximum Voluntary Isometric Contraction (MVIC)	Creatine Kinase (CK) Lactate Dehydrogenase (LDH) Interkeukin-6 (IL-6) C-reactive Protein (CRP) Uric Acid (UA) Thiobarbituric Acid Reactive Species (TBARS) Total Anti-Oxidant Status (TAS) Protein Carbonyls (PC)	> MVIC 24 and 48hrs Post-Marathon < IL-6 24 and 48hrs Post-Marathon < CRP 24 and 48hrs Post-Marathon > TAS pre, Post, 24 and 48hrs Post-Marathon < TBARS 48hrs Post-Marathon < UA Post and 24hrs Post-Marathon
McCormick et al. (2016)	CJ	In-water vertical jump test (VJ) 10m Sprint Repeated Sprint Test (RST) Water polo Intermittent Shuttle Test (WIST) Total Quality of Recovery (TQR) Delayed Onset Muscle Soreness (DOMS)	Interleukin-6 (IL-6) C-Reactive Protein (CRP) Uric Acid (UA) F2-Isoprostance (F2-IsoP)	–
Levers et al. (2004)	CJ	Isokinetic Maximal Voluntary Isometric Contraction (MVIC) Quadriceps Muscle soreness rating (DOMS)	Interleukin1-Beta (IL-1-β) Interleukin-2 (IL-2) Interleukin-4 (IL-4) Interleukin-5 (IL-5) Interleukin-6 (IL-6) Interleukin-7 (IL-7) Interleukin-8 (IL-8) Interleukin-10 (IL-10)	< Quadriceps Muscle DOMS Post-lift, 24 and 48hrs Post-lift

			Interleukin-12p70 (IL-12p70) Interleukin-13 (IL-13) Tumor Necrosis Factor Alpha (TNF-α) Interferon-y (IFN-y) Granulocyte-Macrophage-Colony-Simulating Factor (GM-CSF) Superoxide Dismutase (SOD) Total Anti-oxidant Status (TAS) Malondialdehyde (MDA) Nitrotryosine (NT) Uric Acid (UA) Total Bilirubin (Tbil)	
Levers et al. (2006)	CJ	Isokinetic Maximal Voluntary Isometric Contraction (MVIC) Quadriceps Muscle soreness rating (DOMS)	IInterleukin1-Beta (IL-1-β) Interleukin-2 (IL-2) Interleukin-4 (IL-4) Interleukin-5 (IL-5) Interleukin-6 (IL-6) Interleukin-7 (IL-7) Interleukin-8 (IL-8) Interleukin-10 (IL-10) Interleukin-12p70 (IL-12p70) Interleukin-13 (IL-13) Tumour Necrosis Factor Alpha (TNF-α) Interferon-y (IFN-y) Granulocyte-Macrophage-Colony-Simulating Factor (GM-CSF) Superoxide Dismutase (SOD) Total Anti-oxidant Status (TAS) Malondialdehyde (MDA) Nitrotryosine (NT) Uric Acid (UA) Total Bilirubin (Tbil)	< Quadriceps Muscle DOMS > TAS 48hrs Post-run < IL-2 24 and 48hrs Post-rum < IL-13 24 and 48hrs Post-rum < IL-6 < Post-run
Dimitriou et al. (2015)	CJ	–	C-Reactive Protein (CRP) measurement time Pre-, and Post-race	< CRP 24 and 48hrs Post-race
Quinlan and Hill (2020)	CJ	Countermovement Jump (CMJ) 20m sprint Maximal Voluntary Isometric Contraction (MVIC)	Creatin Kinase (CK) C-Reactive Protein (CRP)	> CMJ across Post-trial period < 20m Sprint 24 and 48hrs Post-trial > 24 and 48hrs Post-trial
Upshaw et al. (2016)	CM	4hrs Recovery Cycling Time Trial	–	< 20km Cycling Time Trial performance
Thomas et al. (2009)	CM	4hrs Recovery Cycling Time Trial	Lactate	> Cycling Exhaustion time
Pritchett et al. (2009)	CM	Rating of Perceived Exertion (RPE) Delayed Onset Muscle Soreness (DOMS) Cycling Time to Exhaustion (TTE)	Creatine Kinase (CK)	–
Papacosta et al. (2015)	CM	Delayed Onset Muscle Soreness (DOMS) Subjective Fatigue Rate Special Judo Fitness Test (SJFT) Countermovement Jump (CMJ) Rating of Perceived Exertion (RPE)	–	> Mean Jump performance > Push Up performance < DOMS < Fatigue
Karp et al. (2006)	CM	4hrs Recovery Endurance performance trial Rating of Perceived Exertion (RPE) Cycling Time to Exhaustion (TTE)	Lactate	> TTE
Gilson et al. (2010)	CM	Maximal Voluntary Isometric Contraction (MVIC) Delayed Onset Muscle Soreness (DOMS) Rating of Perceived Exertion (RPE) Fatigue	Creatine Kinase (CK)	< CK
Ferguson-Stegall et al. (2011)	CM	Vo2max	Lactate Citrate Synthase (CS) PGC-1a	> VO2max
Corr et al. (2020)	CM	Maximal Voluntary Isometric Contraction (MVIC) Delayed Onset Muscle Soreness (DOMS) Lower-Extremity Function Scale (LEFS)	–	–
Wadey et al. (2018)	CM	Muscle Damage questionnaires (DOMS) Muscle Damage questionnaires (DOMS) Rating of Perceived Exertion	Lactate	> TTE < DOMS (Trend)

		(RPE) Time to Exhaustion (TTE)		
Decroix et al. (2017)	CM	Cycling Time Trial Rating of Perceived Exertion (RPE)	Lactate Uric acid (UA) Tumour Necrosis Factor (TNF-a) Interleukin-1 (IL-1) Interleukin-6 (IL-6) Malonaldehyde (MDA) Trolox Equivalent Anti-oxidative Capacity (TEAC)	–
Peschek et al. (2013)	CM	Delayed Onset Muscle Soreness (DOMS) Delayed Onset Muscle Soreness (DOMS) Lower-Extremity Function Scale (LEFS) Muscle Function - Isokinetic dynamometer Muscle Tenderness Time Trial	Creatine Kinase (CK)	–
Karp et al. (2004)	CM	4hrs Recovery endurance performance Trial 4hrs Recovery endurance performance Trial Time to Exhaustion (TTE) Rating of Perceived Exertion (RPE)	Lactate	> TTE < Mean RPE

Effects of Cherry supplementation on inflammation markers

Eleven studies analyzed Inflammation markers. Interleukin (IL) 1β, 2, 4, 5, 6, 7, 8, 10, 12P70, 13, Tumour necrosis factor (TNF) α, High-sensitivity C-reactive protein (hsCRP), Interferon (IFN) γ, Granulocyte-macrophage colony-stimulating factor (SM-CSF), C-reactive protein (CRP) were analyzed inflammation markers in selected studies (Howatson et al., 2010, Sumners et al., 2011, Bell et al., 2014, Bell et al., 2015, Dimitriou et al., 2015, Levers et al., 2015, Bell et al., 2016, Levers et al., 2016, McCormick et al., 2016, Brown et al., 2019, Quinlan & Hill, 2020). IL-6 was measured in seven studies (Howatson et al., 2010, Bell et al., 2014, Bell et al., 2015, Levers et al., 2015, Bell et al., 2016, Levers et al., 2016, McCormick et al., 2016) and five studies found lower IL-6 and attenuated response in CJ group. Five studies measured hsCRP (Bell et al., 2014, Sumners et al., 2011, Bell et al., 2015, Bell et al., 2016, Brown et al., 2019) and two studies showed lower hsCRP in CJ group (Bell et al., 2014 & Bell et al., 2015). One study found no significant effect on hsCRP, however, there was a trend of lower hsCRP in CJ group (Sumners et al., 2011). CRP was measured in four studies (Howatson et al., 2010, Dimitriou et al., 2015, McCormick et al., 2016, Quinlan & Hill. 2020). Two studies showed attenuated CRP increase in CJ group in post-exercise (Howatson et al., 2010 & Dimitriou et al., 2015) and one study did not find significant effects but showed a trendy of higher CRP in placebo group (Quinlan & Hill. 2020). Moreover, IL-2, 4, 5, 7, 10, 12P70, 13, IFN- γ and GM-CSF were analyzed in two studies (Levers et al., 2015 & Levers et al., 2016). One study did not find any effect of all markers (Levers et al., 2015). Whereas another study found lower IL-2, 13 and IFN- γ in CJ group (Levers et al., 2016). IL-8, IL-1β and TNF- α were measured in five studies (Bell et al., 2014, Bell et al., 2015, Bell et al., 2016, Levers et al., 2015, Levers et al., 2016). However, there was no significant effects of these inflammation markers. The completed summary of inflammation markers can be seen in table 4.

Effects of Cherry supplementation on oxidative stress markers

Eight studies analyzed oxidative stress marker including Lipid Hydroperoxides (LOOH), Total Nitrotryosin (TNit), Protein carbonyls (PC), Total antioxidant status (TAS), Uric acid (UA), Superoxide Dismutase (SOD), Malodialdehyde (MDA), Nitrotryosine (NT), Total bilirubin (Tbill) and F2-Isoprostance (F2-IsoP) (Howatson et al., 2010, Sumners et al., 2011, Bell et al., 2014, Bell et al., 2015, Levers et al., 2015, Bell et al., 2016, Levers et al., 2016, McCormick et al., 2016). Three studies analyzed LOOH (Bell et al., 2014, Bell et al., 2015, Bell et al., 2016). Only one study found significantly lower LOOH in CJ group (Bell et al., 2015). One study showed a trend of higher LOOH in Placebo (Bell et al., 2016). One study observed TNit and found no significant effects (Sumners et al., 2011). PC was measured in two studies (Howatson et al., 2010 & Sumners et al., 2011). Only one study (Sumners et al., 2011) resulted in lower PC in CJ group. Four studies analyzed TAS (Howatson et al., 2010, Sumners et al., 2011, Levers et al., 2015, Levers et al., 2016). Two studies (Howatson et al., 2010 & Levers et al., 2016) found higher and remained increase of TAS during recovery period in CJ group. UA was observed across the four studies (Howatson et al., 2010, Levers et al., 2015, McCormick et al., 2016, Levers et al., 2016) and only one study (Howatson et al., 2010) found no increase UA in CJ group. wo studies measured SOD, MDA, NT, Tbill (Levers et al., 2015 & Levers et al., 2016). Both studies did not find any significant effects of those markers. Also, only one study (McCormick et al., 2016) analyzed F2-IsoP and found no significant effect. The summary of oxidative stress markers can be seen in Table 4.

Effects of Cherry supplementation on muscle damage markers

Nine studies examined muscle damage markers including Creatine Kinase (CK), Thiobarbituric acid reactive species (TBARS) and Lactate dehydrogenase (LDH) (Howatson et al., 2010, Bell et al., 2014, Sumners et al., 2011, Bell et al., 2015, Bell et al., 2016, Brown et al., 2019, Lamb et al., 2019, Quinlan & Hill, 2020). CK

was measured across the studies Howatson et al., 2010, Sumners et al., 2011, Bell et al., 2014, Levers et al., 2015, Bell et al., 2015, Bell et al., 2016, Brown et al., 2019, Lamb et al., 2019, Quinlan & Hill, 2020). Only one study found significantly lower CK in CJ group (Levers et al., 2015). There was a higher CK trend in the Placebo group (Quinlan & Hill. 2020). LDH was observed in one study with no significant effect of LDH (Howatson et al., 2010). Also, TBARS was measured in two studies (Howatson et al., 2010 & Levers et al., 2015). Only one study found higher TBARS in the placebo group compared to CJ group (Howatson et al., 2010). The completed summary of muscle damage markers can be seen in Table 4.

Effects of Chocolate milk supplementation on the variables of functional performance

All studies analyzed functional performance variables, including Time to exhaustion (TTE), Isometric muscle force, Muscle tenderness, Time trial, MVIC, Special Judo Fitness Test (SJFT), CMJ, modified pro-agility test (T-drill), Maximum rate of oxygen consumption (VO2max), Push up performance in 30 seconds, modified Loughborough intermittent tennis test (LITT) and repeated sprints (Karp et al., 2004, Karp et al., 2006, Pritchett et al., 2009, Thomas et al., 2009, Gilson et al., 2010, Ferguson-Stegall et al., 2011, Peschek et al., 2013, Papacosta et al., 2015, Mitchell et al., 2015, Upshaw et al., 2016, Decroix et al., 2017, Wadey et al., 2018, Corr et al., 2020). TTE was performed and observed in four studies (Karp et al., 2004, 41, Pritchett et al., 2009, Thomas et al., 2009). Three studies found longer duration TTE performance in CM group (T Karp et al., 2004, Karp et al., 2006, Thomas et al., 2009). Time trial was analyzed in three studies (Peschek et al., 2013, Upshaw et al., 2016, Decroix et al., 2017). Only one study found reduced time trial performance with different types of CM drinks compared to PLA group (Upshaw et al., 2016). Three studies measured MVIC, (Gilson et al., 2010, Mitchell et al., 2015, Corr et al., 2020) however, there was no effects on CM. CMJ was measured in two studies (Gilson et al., 2010, & Papacosta et al., 2015). There was no significant effect of CMJ. Repeated sprint, T-drill, Muscle tenderness and Isometric muscle force were measured in one each study with no significant effect (Gilson et al., 2010, Peschek et al., 2013, Wadey et al., 2018). Furthermore, one each study examined SJFT, VO2max, TTE and push up performance (Ferguson-Stegall et al., 2011, Papacosta et al., 2015, Wadey et al., 2018). All studies found significant effect of functional and performance variables in CM group (Ferguson-Stegall et al., 2011, Papacosta et al., 2015, Wadey et al., 2018). The completed summary of functional performance variables in CM contents can be seen in Table 4.

Effects of Chocolate milk supplementation on the perceptual variables

Rating of Perceived Exertion (RPE), subjective fatigue rating and DOMS using Visual Analogue Scale (VAS) and Lower Extremity Functional Scale (LEFS) (Karp et al., 2004, Karp et al., 2006, Pritchett et al., 2009, Thomas et al., 2009, Gilson et al., 2010, Peschek et al., 2013, Papacosta et al., 2015, Decroix et al., 2017, Wadey et al., 2018, Corr et al., 2020). RPE resulted in eight studies with no significant effects (Karp et al., 2004, Karp et al., 2006, Pritchett et al., 2009, Thomas et al., 2009, Gilson et al., 2010, Peschek et al., 2013, Papacosta et al., 2015, Decroix et al., 2017). DOMS was examined across five studies (Pritchett et al., 2009, Peschek et al., 2013, Papacosta et al., 2015, Wadey et al., 2018, Corr et al., 2020). Two studies found lower DOMS in CJ group (Papacosta et al., 2015 & Wadey et al., 2018). Besides, one study measured subjective fatigue rating, however, it could not observe meaningful result of using CM consumption for fatigue reduction (Gilson et al., 2010). The completed summary of perceptual variables in CM contents can be seen in Table 4.

Effects of Chocolate milk supplementation on Peripheral muscle fatigue marker

Lactate (peripheral muscle fatigue marker) was analyzed in six studies. However, all studies did not observe any significant effect of lactate in CM group (Karp et al., 2004, Karp et al., 2006, Thomas et al., 2009, Ferguson-Stegall et al., 2011, Decroix et al., 2017, Wadey et al., 2018). The completed summary of Peripheral muscle fatigue marker in CM contents can be seen in Table 4.

Effects of Chocolate milk supplementation on oxidative stress markers

Inflammatory markers including CK, Serum myoglobin, Uric acid (UA), Malondialdehyde (MDA) and Trolox equivalent antioxidant capacity (TEAC) were measured across four studies (Pritchett et al., 2009, Gilson et al., 2010, Peschek et al., 2013, Decroix et al., 2017). Three studies (Pritchett et al., 2009, Gilson et al., 2010, Peschek et al., 2013) measured CK. Only one study found lower level of CK in CM group (Gilson et al., 2010). Serum myoglobin was measured in only one study, however, there was no significant effects on CM group (Gilson et al., 2010). Also, one study measured UA, MDA and TEAC with no significant effects of these oxidative stress markers on CM group (Decroix et al., 2017). The completed summary of oxidative stress markers in CM contents can be seen in Table 4.

Effects of Chocolate milk supplementation on inflammatory markers

Interleukin-6 (IL-6), Interleukin-1 (IL-1) Tumour necrosis factor (TNF- α), PGC-1-α, Citrate synthase (CS) and Succinate dehydrogenase (SDH) were measured in two studies (Ferguson-Stegall et al., 2011 & Decroix et al., 2017). IL-6, IL-1 and TNF- α were measured in one study (Ferguson-Stegall et al., 2011) and CS, SDH and PGC-1-α was measured in another study (Decroix et al., 2017). The two studies did not find any significant and meaningful effect on all of inflammatory markers in CM group (Ferguson-Stegall et al., 2011 & Decroix et al., 2017). The completed summary of inflammatory markers in CM contents can be seen in Table 4.

Discussion

This comprehensive review investigated the effect of Cherry and Chocolate supplement to enhance recovery and performance after exercise in athletes and potentially in football players. However, there were only two studies with footballers (Kratz et al., 2002 & Bell et al., 2016). Furthermore, only one study (Bell et al., 2016) focused on football player with CJ supplementation, and there were no CM studies with football player. Although there were not many studies with football players participants, all studies of these results were with athletes who involved in different sports or active and trained people. The effect of functional and performance variables of Cherry and Chocolate supplementation. The included studies measured various functional and performance variables, as can be seen in the result. Among 22 functional and performance parameters, ten parameters observed significant differences compared to the PLA group.

There were distinct effects of MVIC from only the Cherry supplement. Connolly et al. (2006) investigated the effect of Cherry supplementation on EIDM for the first time. An attenuated strength loss of elbow and more rapid recovery was found in the CJ group after eccentric exercise. Following studies of Connolly et al. (2006) similar results were identified in the following studies (Howatson et al., 2010, Bell et al., 2014, Bell et al., 2015, Quinlan & Hill, 2020). The recovery of knee extensor maximum isometric strength was investigated from all studies and showed enhanced recovery. However, Connolly et al. (2006) did not measure MVIC immediate after the eccentric elbow flexor exercise. Therefore, it was not available to compare the decrease of MVIC at immediate post-exercise.

The recovery of MVIC were returned to baseline within up to 96 hours and more rapid than the placebo group. Also, Bell et al. (Bell et al., 2014 & Bell et al., 2016) found no decrease in MVIC post-exercise in the CJ group. Besides, Gilson et al. (2010) found no significant result after exercise in CM group. However, CM had a minor effect which can underpin previous study (Rowlands et al., 2008). Consequently, this finding indicates the necessity of further investigation of the effect of CM supplementation in future studies.

All studies measured CMJ in the CJ group found significant difference compared to the placebo group. Bell et al. (2016) found reduced CMJ after exercise in both groups (vs baseline). However, the CMJ decrease in the CJ group at post-exercise was significantly attenuated. A similar conclusion was found in several studies. Brown et al. (2019), Stevenson et al. (2005) and Howatson et al. (2010) reported CMJ was decreased in both groups. However, the recovery of CMJ was accelerated compared to the placebo group. Thus, this study agrees with the previous study demonstrated improvement in CMJ during the recovery period in the CJ group (Bell et al., 2016). Furthermore, Quinlan and Hill (2020) showed CMJ returning to baseline, 24hrs and 48hrs was accelerated after exercise. Thus, this study supports the main finding of two previous studies (Bell et al., 2016 & Brown et al., 2019).

Sprint performance was shown as a significant effect in the CJ group. Bell et al. (2016) found the 20m sprint performance was decreased in both groups after exercise. However, sprint time were fasters in the CJ group than the control group at 48hrs recovery period. Also, Agility performance was better across 72hrs recovery period. Furthermore, Lever et al. (Levers et al., 2015 & Levers et al., 2016) investigated the effect of Montmorency Tart Cherry in powdered form instead of juice. This study showed longer distance coverage in CJ. This study was in agreement with the previous study which significantly elevated submaximal running time in the CJ group (Kang et al., 2012). Thus, CJ supplantation showed positive effect regardless of the form of CJ supplementations.

Such enhanced recovery and improvements of MVIC, CMJ, sprint, agility and half-marathon performance in the CJ group may be explained by protecting against injury of the recruitment of type II muscle fibres during those activities. Eccentric exercise damages type II muscle fibre preferentially, which has implications for muscle force-generating capacity (Macaluso et al., 2012). Moreover, enzymatic and non-enzymatic antioxidants play a role in protecting muscle fibres during increased oxidant production during exercise from oxidative injury (Powers et al., 2008). As a result, non-enzymatic antioxidants in Cherry reduce the free radical scavenging capacity of type II fibres and facilitate recovery (Brown et al., 2019).

The CM studies showed enhanced recovery and performance in endurance performance. Karp et al. (2004 & 2006) found greater TTE in the CM group than solely carbohydrate (CHO) drink group. CM group performed cycling 49% more than solely CHO drink group, although there were equitant CHO contents in CM and CHO drink. CM contained more sucrose than CHO drink. Also, this was underpinned by the previous study found improved liver glycogen resynthesis and enhanced subsequent exercise performance with sucrose ingestion (Casey et al., 2000). Thus, the absence of sucrose in CHO drinks contributes to shorter TTE due to less liver glycogen resynthesis in CHO drinks (Karp et al., 2004 & Karp et al., 2006). Following the study of Thomas et al. (2009) resulted in longer TTE in the CM group. It, therefore, showed the positive effect of CM with all types of CHO, including glucose, fructose, sucrose, and lactose in endurance performance.

Therefore, CM had high solution osmolarity and a similar peak oxidation rate with CHO drink during exercise (Wallis et al., 2005). Hence, those results underpinned the studies of Karp et al. (2004 & 2006) as sucrose ingestion resulted in greater liver glycogen repletion than glucose and influenced on TTE performance. Chocolate milk contains high fat. It, therefore, circulating free fatty acids concentration during TTE, which had already similar results in the previous studies of Pitsiladis et al. (1999) and Stevenson et al. (2005). Thus, Chocolate milk can be effective for post-exercise recovery at moderate endurance exercise (60%–75%, VO2

max) because it contains higher fat and CHO. Therefore, it is expected CM ingestion can enhance recovery and performance in football which players perform at approximately 70% of VO2max. The study by Wadey et al. (2018) found a similar result with improved TTE by 21.6%. Furthermore, significant increased blood glucose levels were shown after CM ingestion. The ingestion of CM can ample the blood ready to be absorbed into the muscle for glycogenesis and protein synthesis (Wadey et al., 2018).

Moreover, enhanced Push-ups performance was found in CM ingestion (Papacosta et al., 2015). This finding agrees with previous studies, (Karp et al., 2006, Thomas et al., 2009, Ferguson-Stegall et al., 2011) as CHO in CM was shown to maintain physical performance (Halson et al., 2004). Thus, the ingestion of CHO through CM can aid recovery with attenuated symptoms of training. The studies of Ferguson et al. (2011) found that ingesting CM during the first 2hrs of a 4hrs recovery after glycogen-lowering endurance exercise, participants performed 40km cycling post-exercise significantly faster, and an increase in intercellular signaling stimulus for proteins synthesis was found compared to the placebo group. Also, the same study found VO2max was shown significant higher in CM ingestion. The previous studies mentioned that VO2max determinants are related to an increased cardiovascular system, which transports oxygen to the skeletal muscles (Saltin, 1968). Hence, the primary reason of improvement in VO2max following CM ingestion was due to cardiovascular adaptation (Saltin, 1968). Thus, combined CHO and Protein may improve the VO2max. This evidence is an agreement with the previous study (Upshaw et al., 2016). Ingestion of Chocolate milk had significantly faster in 20km cycling time trial performance after 4hrs recovery (Upshaw et al., 2016). This study used different types of Chocolate milk (Soy, Hemp or Dairy), found performance improvement regardless of the type of protein in CM.

The effect of perceptual variables of Cherry and Chocolate supplementation

The significant effects of the perceptual variable were found in eight studies (six studies from Cherry juice and two studies from Chocolate milk). Only DOMS including self-reported pain rate, was observed with significant result. According to the result of Connolly et al. (2006), CJ juice had a significantly reduced pain in the college-aged male group in the elbow flexors after eccentric exercise using a VAS. Also, similar results of reduced pain can be found in the later studies. Kuehl et al. (2010) observed the effect of CJ juice in runners. The pain rate using VAS was less increased in the CJ group than the placebo group as 12mm increase and 37mm increased in CJ group and placebo group respectively, in post-race. Also, it was suggested potential benefit of CJ to protect the acute muscle pain caused after endurance exercise.

Lever et al. (2015 & 2016) used Tart Cherry powder supplementation. Consistent results were found in previous studies Connolly et al. (2006) and Kuehl et al. (2010). The main finding was that Tart Cherry powder supplementation could attenuate muscle soreness perceptions following the 48hrs post-exercise compared to the placebo group. Additionally, Lever et al. (2015 & 2016) showed a similar. Moreover, Bell et al. (2014 & 2015) agreed with the result of the protective effect on DOMS in CJ group (Connolly et al., 2006 & Kuehl et al., 2010). However, the previous study (Bell et al., 2014) resulted no significant, even though, CJ group showed the trend of lower DOMS. The possible reason for this discrepancy was that different types of exercise may induce different DOMS. Muscle activity during cycling in the study of Bell et al. (2016) concentric the repeated sprint and decelerations during LISTADAPT protocol was exclusive. However, it could incur greater mechanical stress on the same group muscle by placing a heavier eccentric load. Thus, this study showed a constantly higher rating of DOMS than other cycling studies (Bell et al., 2014 & Bell et al., 2015). The study of Brown et al. (2019) supported the previous studies with lower DOMS in the CJ group (Connolly et al., 2006, Kuehl et al., 2010, Levers et al., 2015, Bell et al., 2016). Those studies showed lower DOMS in CJ group with improving CMJ. This study mentioned the inconsistencies of no reduction of DOMS was due to the disparities in exercise protocol employed. The results showed lower or less DOMS in Chocolate milk ingestion compared to the placebo group. Reduced DOMS is related to the reduction of CK. Papacosta et al. (2015) found attenuated DOMS after CM ingestion. The previous study (Cockburn et al., 2010) showed reduced CK with attenuated increase of DOMS. As a result, enhanced muscle-related performance after induced-muscle damage protocol (Cockburn et al., 2010). The reduction of CK was investigated in previous studies (Gilson et al., 2010 & Peschek et al., 2013). The higher amount of muscle amino acid uptake, and increased muscle protein synthesis were related to the protein contents in CM (Wilkinson et al., 2007). Also, increased signalling proteins activation related to protein synthesis and attenuation of muscle protein degradation markers (Ferguson-Stegall et al., 2011).

A similar result could be found in the following study by Wadey et al. (2018). DOMS of tennis players were observed and Lower DOMS was found on day 3 when the peak of muscle soreness in CM ingestion, after the induced muscle damage protocol. The mechanism of this result is that the milk may play a role in the reduction of inflammatory response with the immune system or proteins, which may help to repair the muscle cells and have muscle regeneration and reduce the permeability of the sarcolemma of damaged muscle cells (Cheung & Hume, 2003). Therefore, muscle soreness and stiffness could be reduced.

As it can see, some studies found lower DOMS or attenuated DOMS increment at post-exercise by ingesting Cherry juice and Chocolate milk. However, not all included studies showed the same results. To support this, Mathur et al. (2010) mentioned that if DOMS is decreased without muscle improvement, it may support the presumption which muscle damage protocol was not sufficient enough to damage the muscle and remain unclear (Mathur et al., 2010).

The effect oxidative stress markers of Cherry and Chocolate supplementation

It has been established that oxidative stress is increased during exercise causing increases the production of free radicals. Thus, it provokes oxidative damage to muscle damage and fatigue. Also, oxidative stress arises usually in muscle tissues that are exposed to reactive oxygen species (ROS) (Spanidis et al., 2016). Therefore, oxidative stress markers and muscle damage markers were used to investigate the effect of CJ and CM supplementation and observe some significant effects in several studies. The result of the review, LOOH, PC, TAS, UA, and CK have identified the significant effects of CJ and CM studies.

LOOH is the valid measure of post-exercise-induced lipid peroxidation and cell membrane phospholipid damage (Girotti, 1998). Bell et al. (2014) observed oxidative stress with LOOH and found lower LOOH than baseline in both the CJ and placebo groups. The main finding of the study was not increased LOOH in the CJ group above baseline at any time point of post-exercise. In contrast, LOOH in the placebo group was sustained above baseline for the whole duration. This finding was in agreement with the previous study of Howatson et al. (2010) with regard to decreased LOOH in the CJ group and increased LOOH in the placebo group. Therefore, this supported the different of antioxidant capacity between the groups.

Currently, the mechanisms of these observations are unidentified yet. However, CJ ingestion may contribute to scavenging free radical species from damaging the cell, forming complexes resistant to free radical attack, up-regulation of the endogenous enzymatic antioxidant defence system (Bell et al., 2014). Thus, CJ ingestion can result in a greater capacity for removal, eliminating free radical species responsible for lipid peroxidation. However, the following study of Bell et al. (2015 & 2016) unlikely observed no differences in LOOH between the groups. This is, perhaps, due to single versus repeated days of exercise. Therefore, repeated exercise days may contribute to accumulated stress response than Bell et al. (2016). Also, it may indicate that the redox response can be different as the exercise challenges were different between single and repeated days of exercise.

According to Veskoukis et al. (2009), PC in blood and muscle after exercise (swimming) to exhaustion in animal models were correlated. Thus, it suggests that PC in the blood potentially show reliable indicators of skeletal muscle redox status in human. One of previous studies observed the elevation of PC after different exercise protocols (Ranchordas et al., 2017). However, PC showed significant attenuation in the CJ group after exercise induced in Sumners et al. (2011) Although the attenuated PC mechanisms in the CJ group are unclear in this study, consequently, PC was lower in the CJ group compared to the placebo group.

Furthermore, the previous study of Howatson et al. (2010) found no evidence of protein oxidation based on PC data after exercise, although the sign of inflammation and muscle damage was evident. Therefore, it, presumably, is indicated that CJ supplementation support for limited antioxidative actions, although the use of PC as a parameter of oxidative stress has been unreliable. Also, this may be somewhat controversial whether it could be a reliable marker of protein oxidation in exercise (Urso et al., 2003).

Howatson et al. (2010) observed plasma TAS after the full marathon with trained endurance runners. The main finding significantly greater TAS level in the CJ group than the placebo group up to 48hrs post-marathon. Unlike the CJ group, TAS in placebo group was below baseline across 48hrs post-exercise. It was indicated that redox balance was failed to maintain in the placebo group. Also, it showed that TAS or redox balance of placebo group after endurance exercise was failed to maintain. As a result, it showed antioxidant effectiveness on excessive ROS production in endurance exercise (Wang et al., 1999).

Moreover, the differences between the CJ group and the placebo group were shown that CJ ingestion has the potential to antioxidant effectiveness on excessive production of ROS during endurance exercise (Bell et al., 2014). Moreover, Lever et al. (2016) found a similar recovery result with Howatson et al. (2010) which TAS activity in the CJ group was more remarkable in a linear increase in 48hrs recovery. This is shown that CJ ingestion has the potential to a short-term antioxidant effect with a better redox balance.

Howatson et al. (2010) measured UA to investigate oxidative stress. The inflammatory response after the marathon was attenuated by CJ juice ingestion. This is indicated that the subsequent exacerbation of muscle damage was presumably limited. The lower value of UA by CJ ingestion may accelerate the recovery. Previous study showed the elevation of UA after endurance exercise (Rønsen et al., 2004).

However, the mechanism of this has not been clear yet. The elevation of UA after endurance exercise could reflect by three potential reasons. Firstly, decreased clearance of uric acid. Secondly, increased mobilization of UA as part of the antioxidant defence. Lastly, increased UA production is part of the inflammatory process (Suzuki et al., 2006 & Rietjens et al., 2007).

However, the weight loss of post-race was not different between CJ and placebo group. Thus, dehydration would not be attributed to the difference in UA. The previous studies (Mastaloudis et al., 2004 & Rietjens et al., 2007) found that the elevation of UA after exercise attribute to antioxidant defence mechanisms. Moreover, oxidative stress after exercise could be decreased and increase total antioxidant capacity by uric acid infusion (Waring et al., 2003). Based on Howatson et al. (2010) study, endurance running increased UA, and it may lead to the inflammatory response. Also, the CJ group showed an increased total antioxidant capacity. Consequently, oxidative stress was decreased when uric acid was low in CJ group compared to the placebo group.

The effect inflammatory markers of Cherry and Chocolate supplementation

A significant effect of inflammatory markers were found in only CJ studies. Howatson et al. (2010) analyzed inflammatory markers, and the response to a marathon of IL-6 and CRP were blunted and the subsequent exacerbated damage was limited by ingesting CJ. The increase of IL-6 was lower at 49% compared to the placebo group. Also, the increase of IL-6 was correlated with CK elevation. Indeed, CK was increased in 24hrs and 48hrs post-exercise and IL-6 were similarly elevated at the same time. The elevation of IL-6 after the race has been shown constantly in previous study with marathon runners (Quinlan & Hill. 2020). Also, the study of Howatson et al. (2010) presented IL-6 was returned to baseline within 24hrs after the race. Lever et al. (2016) used CJ powdered supplementation with runners, and it was shown an attenuated increase of inflammatory markers IL-2 and IL-13. Thus, powdered CJ have an equivalent effect to Tart Cherry juice.

Moreover, CRP was increased and peaked at 24hrs after the race, and this is an agreement with the previous study (Weight et al., 1991). Dimitrious et al. (2015) was similar to the previous study. The study observed CRP with marathon runners and found CRP in CJ group was lower in 24hrs and 48hrs with consistent with previous result (Kelley et al., 2006). CJ contains the bioactive food components that inhibit cyclooxygenase (COX)-1 and COX-2 enzyme activity and it can causes an inflammatory response by an average of 28 % and 47 %, respectively. According to Howatson et al. (2010), the increase of CRP in the CJ group was lower at 34% than the placebo group. Thus, these results show the positive effect of anti-inflammatory and enhanced recovery by CJ supplementation.

Attenuated IL-6 and CRP after exercise were observed in the following study in Bell et al. (2016, 2015 and 2014). It resulted that attenuated hsCRP. An attenuated increase of hsCRP was reduced secondary inflammatory response in the CJ group. Thus, the main finding was that hsCRP response plays a role in the attenuation of inflammation. Moreover, attenuated IL-6 and hsCRP was indicated that the acute inflammatory stress response was reduced by ingestion CJ (Bell et al., 2015). According to Bell et al. (2014, 2015, 2016), lower IL-6 after exercise may indicate that a lower acute inflammatory response to the exercise mode may contribute to the difference of performance between groups. Besides, COX, Prostaglandin and IL-6 pathway are activated to disrupt cells during the secondary inflammatory response. Those are associated with proteolytic and lipolytic processes (Trappe et al., 2013). Consequently, the muscular function can be inhibited (Bell et al., 2016). Therefore, CJ ingestion may have an effect on anti-inflammation by attenuating hsCRP and IL-6.

Conclusion

The present comprehensive review after reviewing included studies (CJ = 14 studies and CM = 13 studies) revealed that CJ and CM supplementation are effective post-exercise drinks to enhance recovery. Both CJ and CM ingestion showed an attenuation of muscle damage and soreness. Particularly, CM ingestion showed both accelerated recovery and enhanced endurance performance. Also, CJ ingestion showed faster recovery of inflammatory and oxidative stress variables. Despite the effective results of CM and CJ ingestion, some results were conflicting. Most of the studies in this comprehensive review were conducted on athletic groups, however, there were only a few studies on football players with football match simulation. Furthermore, the total amount of CM and CJ ingestion was very varied across the studies. Thus, future investigations using consistent football-specific protocol or football match simulation protocols and the same total content of CM and CJ on football players will help to elucidate the actual effect of CM and CJ ingestion on recovery on performance in football. Also, future studies are required to determine the optimal dosage of CM and CJ ingestion for football players.

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