Title page

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Abstract

Purpose: The aim was to investigate the effects of tart cherry juice supplementation (TCJ) on markers of recovery following intermittent exercise, under habitual dietary conditions.

Methods: Using a randomised, single-blind, placebo-controlled, independent groups design, 20 team sport players (n=8 male, n=12 female, age:26 ±4 years, height:175.4 ±9.6cm, body mass:70.2 ±12.6kg) were divided equally into two groups and consumed either TCJ or placebo twice per day for eight consecutive days whilst following their normal dietary habits. Participants completed an adapted version of the Loughborough Intermittent Shuttle Test (LIST) on day six of supplementation. Countermovement jump (CMJ), 20m-sprint, maximal voluntary isometric contraction (MVIC) and muscle soreness (DOMS) were assessed at baseline, 1h, 24h and 48h post-LIST. Blood markers of muscle damage (CK) and inflammation (CRP) were taken pre-supplementation, immediately pre-LIST and 1h, 24h and 48h post-LIST. Data were analysed using a repeated measures ANOVA.

Results: CMJ, 20m-sprint and MVIC showed significantly faster recovery with TCJ ($p<0.05$) at 24h and 48h post-LIST. A significant interaction effect ($p<0.05$) was observed for DOMS; however, Bonferroni *post hoc* analysis could not identify when the significant differences between TCJ and placebo occurred. There were no significant differences throughout recovery between TCJ and placebo for CRP and CK ($p>0.05$).

Conclusion: The results suggest that TCJ, in addition to habitual diets, can accelerate recovery following intermittent exercise and therefore extends the efficacy of TCJ in accelerating recovery to team sports.

Keywords: muscle damage, inflammation, team sport, anthocyanins, polyphenols

Introduction

Participation in athletic training and competition can cause exercise-induced muscle damage (EIMD). This phenomenon occurs as a result of mechanical and metabolic stress and is mainly associated with prolonged, high intensity, eccentric or unaccustomed exercise[1]. EIMD is associated with a number of symptoms which include, soreness, a decreased range of motion, swelling and a reduced ability of the affected muscle to produce force[2]. These symptoms can have a detrimental effect on performance, due to this strategies that can attenuate symptoms and accelerate recovery are desirable.

Tart cherry juice (TCJ) supplementation is growing in popularity due to claims it can aid recovery following damaging exercise due to its potent antioxidant and anti-inflammatory properties[3]. TCJ contains high concentrations of phytochemicals, including anthocyanins and flavonoids[4]. Anthocyanins possess antioxidant and anti-inflammatory properties and are proposed to scavenge reactive oxygen species (ROS), limit ROS production[5] and increase expression of endogenous antioxidant enzymes[6]. Additionally the anti-inflammatory properties of anthocyanins reduce activity of enzymes such as COX-1, COX-2 and phospholipase A2, thereby reducing the cyclooxygenase, prostaglandin and Inter-Leukin 6 (IL-6) pathway and the proteolytic and lipolytic cascade[7]. As such, TCJ may attenuate the inflammatory response and improve recovery following strenuous exercise[14].

The aetiology of resulting muscle damage differs depending on the exercise stimulus, with endurance modalities associated with high metabolic costs and relatively low mechanical stress[9] compared to eccentric exercise associated with larger mechanical stress[10]. In contrast to this, intermittent exercise is shown to induce both metabolic and mechanical stress. However, it has been proposed that team sports induce significantly less metabolic stress compared to endurance exercise and less mechanical stress compared to eccentric exercise[16]. TCJ has been shown to be an effective recovery strategy following exercise that induces high metabolic stress[4,12,13,14] and exercise that causes large mechanical stress[15,10,16,17]. Therefore, it is likely that supplementation will also benefit intermittent exercise, where reductions in performance are likely to be a result of both mechanical and metabolic stress[13].

A few studies have investigated the efficacy of TCJ following intermittent exercise but these studies have yielded conflicting results. No benefits of TCJ on functional performance, markers of inflammation (IL-6, CRP) or oxidative stress (uric acid) were demonstrated after water-polo simulation activity[11]. In contrast to this, positive effects of TCJ were observed in semi-professional soccer players following the Loughborough Intermittent Shuttle Test (LIST)[13]. Bell et al (2016)[13] observed improved recovery of maximal voluntary isometric contraction (MVIC), counter movement jump (CMJ) and agility alongside attenuated muscle soreness (DOMS) and reduced concentrations of IL-6 when athletes were supplemented with TCJ compared to a placebo. However, it is important to consider that athletes were required to follow a low phenolic diet throughout the study period beginning 48h prior to starting supplementation. It is questionable whether the same benefits would occur with TCJ consumption in addition to the typical diet of an athlete which may provide sufficient antioxidant and anti-inflammatory nutrients[18,19].

Overall, there is limited research into the benefits of TCJ in aiding recovery and performance following intermittent exercise and, due to dietary restrictions, current research into team sport lacks generalisability. Therefore, the current research aims to investigate the efficacy of TCJ without dietary restrictions, in aiding recovery following intermittent exercise. If TCJ

facilitates recovery from intermittent exercise it could be an effective recovery tool for team players given their crowded training and match schedules. It was hypothesised that consumption of TCJ for five days before, day of, and two days post a LIST test would attenuate markers of muscle damage and inflammation and facilitate the return of functional performance over the 48h recovery period.

Methods

Participants

Twenty team-sport players male (n=8) and female (n=12) (football, hockey or netball), volunteered to participate in the investigation. Participant characteristics are presented in Table 1. Following ethical approval, participants provided written informed consent and completed a health screening questionnaire. Participants presented for testing in a rested state, without caffeine or alcohol consumption in the previous 12 and 24 hours respectively, and were asked to refrain from using anti-inflammatory drugs for the duration of the study.

Experimental Overview

Using a single-blind, independent groups design, participants were randomly allocated to either a tart cherry juice blend (TCJ) or placebo (PLA) group. Participants attended for testing on four occasions over nine days. All testing was conducted in a sports hall, and at the same time of day, in the morning to minimise the effects of circadian rhythm. A standardised warm-up was conducted at the start of each visit. During the first visit to the laboratory pre-supplementation blood samples of CK and CRP were obtained. Participants then completed the multi-stage fitness test to establish levels, followed by familiarisation with the dependent variables and one, 15-minute section of the LIST Part-A.

Approximately 7 days later participants returned to the laboratory, baseline data were collected for the dependent variables CK, CRP, muscle soreness, counter movement jump (CMJ), 20m sprint and maximum voluntary isometric contraction (MVIC). This was immediately followed by completion of an adapted version of the LIST, an intermittent running exercise based on the physical demands of football[13]. The adapted LIST consisted of 6x15 minute sections from LIST Part-A, followed by 12x20m maximal sprints with a 10m deceleration zone, departing every 60s. These adaptations were to account for the stop/start/change of direction nature of team sports and to standardise distances covered and is a previously used successful protocol for inducing muscle damage and demonstrating improved recovery with TCJ[13]. Measurement of all dependent variables was repeated 1, 24 and 48h post adapted LIST.

Treatment groups

Participants were instructed to consume two servings of TCJ or placebo per day (morning and evening), for eight consecutive days (five days pre, day of, and two days post-LIST). The TCJ was a commercially available Montmorency tart cherry concentrate (Holland and Barrett Ltd, Warwickshire, England). One serving consisted of 30ml TCJ mixed with 70ml of water. This quantity of TCJ has previously demonstrated improved recovery[19]. The placebo was a commercially available, less than 5% fruit content squash (Robinsons Summer Fruits squash, Britvic plc, Hemel Hempstead, UK) mixed with maltodextrin (MyProtein Ltd, Northwich, UK) to match the carbohydrate content of the TCJ. One serving consisted of 25ml of squash and

15g of maltodextrin, mixed with 75ml of water. Both beverages were matched as closely as possible for colour and taste. Participants were instructed to follow their normal dietary habits and keep a food diary for the duration of the study.

Dependent variables

Muscle soreness was assessed using a 20cm Visual analogue scale (VAS) with 'no soreness' and 'unbearably painful' at either end. For each assessment, participants were instructed to perform a squat and immediately mark their perceived soreness along the scale. CMJ was measured using a jump mat (FSL Electronics, Co Tyrone, UK). Participants were instructed to stand on the mat with feet parallel and shoulder width apart and perform a maximal vertical jump, maintaining hands on their hips throughout. 20m sprint was timed using infra-red timing gates (Brower Timing Systems, Utah, USA). MVIC of the non-dominant knee extensors was measured using a strain gauge (MIE Medical Research Ltd., Leeds, UK). Participants sat on a platform with their non-dominant ankle attached to the strain gauge, with 90° flexion at the hip and knee joint. Participants were instructed to maximally extend the knee against the device. Contractions lasted for approximately three seconds with standardised verbal encouragement throughout. Dependent variables were always completed in the above order. Each test, except DOMS, was performed three times, with one-minute rest between repetitions and three minutes rest between tests. Peak performance in each test was used for data analysis. Plasma CK and CRP were determined using an automated analyser (Rx Daytona, Randox Laboratories Ltd., Crumlin, Antrim, UK). Normal reference values are 29-200 IU/L for CK and <0.8mg/L for CRP. Manufacturer's guidelines report intra-sample coefficient of variation (CV) for CK as <4% with previous intra-assay CV of 4.3% reported for CRP[20].

Statistical analysis

All statistical analyses were performed using SPSS (IBM SPSS statistics 24 Inc, USA) and reported as mean ± standard deviation. All dependent variables were assessed using a treatment by time repeated measures analysis of variance (ANOVA). Bonferroni *post hoc* analysis was used where significant differences for main effect (trial or time) were found. Statistical significance was considered when $p<0.05$. Cohen's d calculations were used to calculate effect size to indicate the magnitude of effect on the change from baseline at 1h, 24h and 48h post-LIST. Threshold values were set at 0.2, small; 0.5, moderate; 0.8, large.

Results

Effect sizes and 90% confidence intervals (CI) comparing change from baseline with 1h, 24h and 48h hours post-LIST are displayed for all dependent variables in Table 2. CK and CRP were not normally distributed so were log transformed.

CMJ showed a significant time ($F_{(3,54)}=19.250$, $p=0.001$), group ($F_{(1,18)}=17.452$, $p=0.001$) and interaction effect ($F_{(3,54)}=6.896$, $p=0.01$). P*ost hoc* analysis revealed that CMJ was significantly lower at all time points post-LIST compared to baseline. Additionally, large between group effect sizes were observed at 24 and 48h post LIST. CMJ decreased similarly in both groups 1h post-LIST (TCJ 91.5 ±6.5% of baseline, $p=0.007$; placebo 88.4 ±6.4%, $p=0.000$) but the return to baseline of CMJ was significantly faster with TCJ when

compared to PLA at 24h (p =0.02) and 48h (p=0.000). CMJ scores for TCJ returned to baseline at 48h whereas PLA scores remained suppressed throughout the post-trial period (Figure 1).

There was a significant time ($F_{(2.157,38.824)}$=22.433, p=0.000), group ($F_{(1,18)}$=23.856, p=0.000; Figure 2) and interaction effect ($F_{(2.157,38.824)}$=3.292, p =0.044) on 20m sprint. *Post hoc* analysis revealed that all time points post-LIST were significantly slower than baseline and the reduction in speed was significantly greater 1h post-LIST compared to 48h post. Large effect sizes were observed between groups for changes in 20m sprint times from baseline to 1h post-LIST, 24h and 48h post. Both groups showed similar reductions in speed 1h post-LIST however, with TCJ the reduction in speed was significantly attenuated at 24h (p =0.004) and 48h (p =0.019) post-LIST. 20m sprint times with TCJ were 1.95 ±2.86% and 0.31 ±1.67% slower at 24h and 48h respectively, whereas PLA times were 5.94 ±1.94% and 3.84 ±3.34% slower at 24h and 48h respectively.

Significant time ($F_{(3,54)}$, =22.484, p<0.001), group ($F_{(1,18)}$=7.895, p =0.012) and interaction ($F_{(3,54)}$=7.321, p=0.000) effects were observed for MVIC ($F_{(3,54)}$, =22.484, p<0.001). *Post hoc* analysis indicated significantly lower scores from baseline occurred at all time points post-LIST (p=0.001) and 1h post-LIST was significantly lower than 48h post (p =0.029). Large between group effect sizes were also observed at 24 and 48h post list. The decline 1h post-LIST was similar between groups however, with TCJ, the decline in MVIC was significantly attenuated at 24h (p =0.011) and 48h (p =0.003) post-LIST (Figure 3).

There was a significant effect of time ($F_{(3,54)}$=25.787, p=0.000) on DOMS; Bonferroni *post hoc* tests indicating significantly higher DOMS scores at all time points after baseline (p=0.001), with no significant differences between 1h post-LIST, 24h and 48h post (p=0.378, 0.054, 1.000 for 1h and 24h, 1h and 48h, and 24h and 48h; respectively). No significant group effects ($F_{(1,18)}$=1.338, p =0.262) were observed however, there was a significant group by time interaction ($F_{(3,54)}$=3.850, p =0.014) but further *post hoc* analysis failed to identify where the differences were (Table 3). Despite the observations around significance, moderate and large between group effect sizes were observed for DOMS at 24 and 48h post LIST, respectively.

With regards to creatine kinase (Figure 4), there was a significant time effect ($F_{(1.294,19.410)}$=13.399, p=0.001), with Bonferroni *post hoc* tests revealing CK was significantly elevated above pre-supplementation (p=0.07, 0.01, 0.04, for 1h, 24h and 48h respectively) and pre-LIST levels (p=0.00, 0.04, 0.49, for 1h, 24h and 48h respectively) in both groups at all time points following the trial. No significant group (F=4.449$_{(1,15)}$, p=0.052) or interaction ($F_{(1.294,19.410)}$=0.725, p=0.440) effects were observed. Whilst no significant group or interaction effect was observed, moderate effect sizes for between groups were seen at 1 and 24h post LIST. Although not significant, there was a clear trend for CK concentrations to be higher 24h post-LIST in the PLA group. At 24h, in comparison to pre-LIST, CRP had increased by 189.1 ±176.1 IU/L in TCJ vs 378.2 ±345.5 IU/L in PLA.

The inflammatory marker CRP (Table 3) showed no significant time (F= 2.601$_{(3,27)}$, p=0.073), group (F=0.140$_{(1,9),}$ p=0.717) or interaction effects (F=0.393$_{(3,27),}$ p=0.759). Effect sizes observed at 1h and 24h post were small, with 48h post being below threshold levels. Although not significant, there was a clear trend for CRP concentrations to be higher 24h post-LIST in the PLA group. At 24h, in comparison to pre-LIST, CRP had increased by 0.933 ±1.437mg/L in TCJ vs 0.554 ±0.983mg/L in PLA.

Discussion

The aim of this study was to investigate the efficacy of TCJ without dietary restrictions, on recovery following intermittent exercise. The main finding was that TCJ supplementation when compared to a placebo**,** accelerated recovery in indices of muscle function CMJ, 20m sprint and MVIC in the 48h recovery period following prolonged intermittent running. Additionally, there was a trend for reduced concentrations of CK following the LIST.

The decline in one-hour post-LIST functional performance measures were similar between TCJ and PLA groups, indicating that the initial muscle damage was unaffected by TCJ. However, the TCJ group showed more rapid recovery of CMJ, 20m-sprint and MVIC performance at 24h and 48h post-LIST. This observation was supported by large between group effect sizes, suggesting TCJ helped attenuate the muscle damage response which likely occurred via the inflammatory and oxidative stress pathways[4,13]. These findings are in agreement with Howatson et al. (2010)[4] and Bell et al. (2015)[19], reporting that TCJ enhanced recovery of strength following endurance running and cycling, respectively. Faster recovery of functional performance has also been previously reported following intermittent running[13]; however, to our knowledge the current study is the first to do so without implementation of a low phenolic diet.

Improved recovery of functional performance with TCJ has been attributed to reduced inflammation and oxidative damage[4]. The accelerated return of functional performance in the current study may be partly attributable to the antioxidant effects of polyphenolic compounds found in TCJ[21,22]. Previous research has suggested normal antioxidant defences may only protect against oxidative stress for less than 24h following exercise[4]. After this, to prevent further oxidative stress, increased antioxidant capacity may be needed; potentially provided via TCJ[1].

Supplementation with TCJ resulted in a significant interaction effect for DOMS, although *post hoc* analysis could not identify when the significant difference between TCJ and PLA occurred. Despite this observation, at 24h post-LIST, DOMS increased 255% in the PLA group compared to 91% in the TCJ group and at 48h post-LIST, DOMS had increased 267% in the PLA group compared to 44.8% in the TCJ group. These observations were accompanied by moderate and large effect sizes at 24 and 48h respectively, indicating that supplementation with TCJ may have a protective effect. The experience of DOMS arises as a result of damage to the soft tissue which leads to an inflammatory response causing swelling in the damaged tissue. The reduction in soreness observed with TCJ has been attributed to reduced inflammatory and oxidative tissue damage[12]. Via inhibition of the COX mediated production of prostaglandins, anthocyanins in TCJ may limit pain associated with inflammation[23].

The findings of this study are consistent with previous research from Bell et al (2016)[13] who demonstrated reduced soreness with TCJ following intermittent running. However it is important to note that reduced DOMS has not always been observed in research investigating TCJ[15,4,11]. Inconsistencies in findings are likely due to differences in study design, with the type of exercise and training status of participants having a large effect on outcomes.

Given the significant effect of TCJ on functional performance observed within this study it is surprising that no significant differences between groups were observed for CK and CRP. In

this study CK approached significance (p=0.052) and was accompanied by moderate effect sizes post exercise. Exercise induced muscle damage is associated with damage to membranes, partly induced by ROS[24]. One potential cause for reduced CK levels with TCJ is that ROS-induced membrane damage was attenuated, thus limiting muscle damage and facilitating recovery of functional performance. Research by Howatson et al. (2010)[4], Levers et al. (2016)[14] and Bell et al. (2014)[18] provides evidence of reduced oxidative stress with TCJ supplementation indicated via increased total antioxidant status and/or reduced thiobarbituric acid reactive substances (TBARS) or lipid hydroperoxides (LOOH). However, as the current study did not measure oxidative stress, the suggestion of TCJ reducing ROS and thus, oxidative damage/stress, cannot be confirmed.

Several studies have observed reductions in inflammation with the use of TCJ[4,19], however this study failed to observe a significant group difference for CRP. Additionally, no significant time effect for CRP was observed, thus it is possible that the LIST was not severe enough to cause an elevated inflammatory response. In this study, CRP was the only marker of inflammation that was assessed, future research could look at multiple inflammatory markers to build a better picture of what is happening with the inflammatory response.

Few studies have investigated the effect of TCJ on simulated team sport activity. Bell et al (2016)[13] observed attenuated symptoms of muscle damage with the use of TCJ following a low phenolic diet. Contrasting this McCormick et al (2016)[11] observed no beneficial effects of TJC following a simulated water polo game. However, the authors concluded that the lack of beneficial effects were due to the non-weight bearing nature of the exercise protocol, which failed to induce sufficient muscle damage[11]. This study adds to the body of literature, indicating that functional performance is improved in athletes without dietary restrictions. However it is important to highlight that the placebo supplement used within this study contained 5% fruit juice. It is possible that this juice contained some phytochemicals and is thus not a true placebo, this should be noted as a limitation.

Whilst this study demonstrates support for the use of TCJ as a recovery aid, it is important to note there are concerns that long-term antioxidant supplementation may blunt adaptation to training[25]. Interference effects have been observed in studies investigating supplementation with antioxidant vitamins C and E[26], however, to the author's knowledge no such findings have been observed when participants have been supplemented with a functional food such as TCJ. When recovery rather than adaptation is key, use of TCJ is unlikely to exert detrimental effects[27].

Practical applications

The results of this study suggest that TCJ, in addition to a 'normal' diet, may attenuate the decline in muscle function associated with muscle damage and therefore facilitate recovery following simulated team sport. Mohr et al (2016)[28] demonstrated that three days of recovery were inadequate for recovery from game-induced muscle damage and oxidative stress. The positive effects of TCJ on functional performance observed within this study has considerable implications for team sport players who complete intense daily training schedules and matches often several times a week. Therefore team sport athletes could highly benefit from using TCJ as a practical and effective strategy to accelerate recovery of muscle function. In addition to this, the large improvements observed in CMJ, 20m-sprint and MVIC may also make TCJ an

attractive supplement for athletes who compete in any strength or power based sport where there is need for these type of movements.

Conclusion

In conclusion, compared to a placebo, the addition of TCJ to habitual diets for five days pre, day of and two days post intermittent running, accelerated recovery of functional performance. This was evidenced by improved CMJ, 20m-sprint and MVIC throughout recovery and attenuated CK levels at 24h post-LIST. These changes are likely attributable to an attenuated damage response. This was likely achieved due to the antioxidant and anti-inflammatory properties of TCJ.

References

1. Slattery K, Bentley D, Coutts AJ. The role of oxidative, inflammatory and neuroendocrinological systems during exercise stress in athletes: Implications of antioxidant supplementation on physiological adaptation during intensified physical training. *Sports Med*. 2015; 45, 453-471.
2. Cleak MJ, Easton, RG. Muscle soreness, swelling, stiffness and strength loss following eccentric exercise. *Br J Sports Med.* 1992; 26, 267-272.
3. Bowtell J, Kelley, V. Fruit derived polyphenol supplementation for athlete recovery and performance. *Sports Med*. 2019; 49, 3-23.
4. Howatson G, McHugh MP, Hill JA, Brouner J, Jewell AP, Van Someren KA, Shave R E, Howatson, SA. Influence of tart cherry juice on indices of recovery following marathon running. *Scand J Med Sci Sport.* 2010; 20, 843-852.
5. Garcıa-Lafuente A, Guillamone E, Villares A, Rostagno MA, Martınez JA. Flavonoids as anti-inflammatory agents: implications in cancer and cardiovascular disease. *J Inflamm Res.* 2009; 58, 537–552.
6. Shing C, Peake J, Shannon A, Strobel N, Wilson G, Jenkins D, Coombes J. The effect of consecutive days of exercise on markers of oxidative stress. *Appl Physiol Nutr Metab.* 2007; *32*, 677-685.
7. Marzocchella L, Fantini M, Benvenuto M, Masueli L, Tresoldi I, Modesti A, Bei R. Dietary flavonoids: molecular mechanisms of action as anti-inflammatory agents. *Recent Pat Inflamm Allergy Drug Discovery.* 2011; 5, 200-220.
8. Sousa M, Teixeira VH, Soares J. Dietary strategies to recover from exercise-induced muscle damage. *Int J Food Sci Nutr*. 2014; 65, 151-163.
9. Vitale KC, Hueglin S, Broad E. Tart cherry juice in athletes: A literature review and commentary. *Curr Sports Med Rep.* 2017; 16, 230-239.
10. Levers K, Dalton R, Galvan E, Goodenough C, O'Connor A, Simbo A, Barringer N, Mertens-Talcott S, Rasmussen C, Greenwood M, Riechman S, Crouse S, Kreider R. Effects of powdered Montmorency tart cherry supplementation on an acute bout of intense lower body strength exercise in resistance trained males. *JISSN.* 2015; 12:41.
11. McCormick R, Peeling P, Binnie M, Dawson B, Sim M. Effect of tart cherry juice on recovery and next day performance in well-trained water polo players. *J Int Soc Sports Nutr.* 2016; 13:41.
12. Kuehl KS, Perrier ET, Elliot DL, Chesnutt JC. Efficacy of tart cherry juice in reducing muscle pain during running: a randomised controlled trial. *J Int Soc Sports Nutr. 2010;* 7:17.

13. Bell PG, Stevenson E, Davison GW, Howatson G. The effects of Montmorency tart cherry concentrate on recovery following prolonged intermittent exercise. *Nutrients.* 2016; 8:441.
14. Levers K, Dalton R, Galvan E, O'Connor A, Goodenough C, Simbo S, Mertens-Talcott S, Rasmussen C, Greenwood M, Riechman S, Crouse S, Kreider RB. Effects of powdered Montmorency tart cherry supplementation on acute endurance exercise performance in aerobically trained individuals. *J Int Soc Sports Nutr.* 2016; 13, 22-45.
15. Bowtell, J., Sumners, D., Dyer, A., Fox, P., & Mileva, K. (2011). Montmorency cherry juice reduces muscle damage caused by intensive strength exercise. *Med Sci Sports Exer*. 2011; *43*, 1544-1551.
16. Brown M, Stevenson E, Howatson G. *Montmorency tart cherry (Prunus cerasus L.) supplementation accelerates recovery from exercise-induced muscle damage in females. Eur J Sport Sci*. 2019; 19, 95-102
17. Beals K, Allison K, Darnell M, Lovalekar M, Baker R, Nieman D, Vodovotz Y, Lephart S. The effects of a tart cherry juice beverage on reducing exercise-induced muscle soreness. *IES.* 2017; *25*, 53-63.
18. Bell PG, Walshe IH, Davison GW, Stevenson E, Howatson G. Montmorency cherries reduce the oxidative stress and inflammatory responses to repeated days high-intensity stochastic cycling. *Nutrition.* 2014; 6, 829-843.
19. Bell PG, Walshe IH, Davison GW, Stevenson E, Howatson G.Recovery facilitation with Montmorency cherries following high-intensity, metabolically challenging exercise. *Appl Physiol Nutr Metab.* 2015; 40, 414-423.
20. Ganguli D, Das N, Saha I, Sanapala KR, Chaudhuri D, Ghosh S, Dey S. Association between Inflammatory Markers and Cardiovascular Risk Factors in Women from Kolkata, W.B India. *Arq. Bras. Cardiol*. 2011; 96, 38-46.
21. Braakhuis AJ, Hopkins WG. Impact of dietary antioxidants on sport performance: A review. *Sports Med.* 2015; 45, 939-955.
22. Peternelj TT, Coombes JS. Antioxidant supplementation during exercise training: Beneficial or detrimental. *Sports Med.* 2011; 41, 1043-1069.
23. Tall J, Seeram N, Zhao C, Nair M, Srinivasa A, Raja N. Tart cherry anthocyanins suppress inflammation induced pain behaviour in rat. *Behav Brain Res.* 2004; 153, 181-188.
24. Rahal A, Kumar A, Singh V, Yadav B, Tiwari R, Chakraborty S, Dhama K. Oxidative stress, prooxidants and antioxidants: the interplay. *Biomed Research International*. 2014; 2014, 1-9.
25. Owens DJ, Twist C, Cobley JN, Howatson G, Close GL. Exercise-induced muscle damage: what is it, what causes it, what are the nutritional solutions? *Eur J Sport Sci.* 2019; 19, 71-85
26. Paulsen G. Cumming KI, Holden G, Hallen J, Ronnestad BR, Sveen O, Skaug A, Paur I, Bastani NE, Ostgaard HN, Buer C, Midttun M, Freuchen F, Wiig H, Ulseth ET, Garthe I, Blomhoff R, Benestad HB, Raastad T. Vitamin C and E supplementation hampers cellular adaptation to endurance training in humans: a double blind, randomised, controlled trial. *J Physiol.* 2014; 592, 1887-1901.
27. Pingitore A, Lima GPPL, Mastorici F, Quinones A, Lervasi G, Vassalle C. Exercise and oxidative stress: Potential effects of antioxidant dietary strategies in sports. *Nutrition.* 2015; 31, 916-921.
28. Mohr M, Draganidis D, Chatzinikalaou A, Barbero-Alvarez J, Castagna C, Douroudos I, Avloniti A, Margeli A, Papassotiriou I, Flouris A, Jamurtas A, Krustrup P, Fatouros I. Muscle damage, inflammatory, immune and performance responses to three football

games in one week in competitive male players. *Eur J Appl Physiol*. 2016; 116, 179-193.

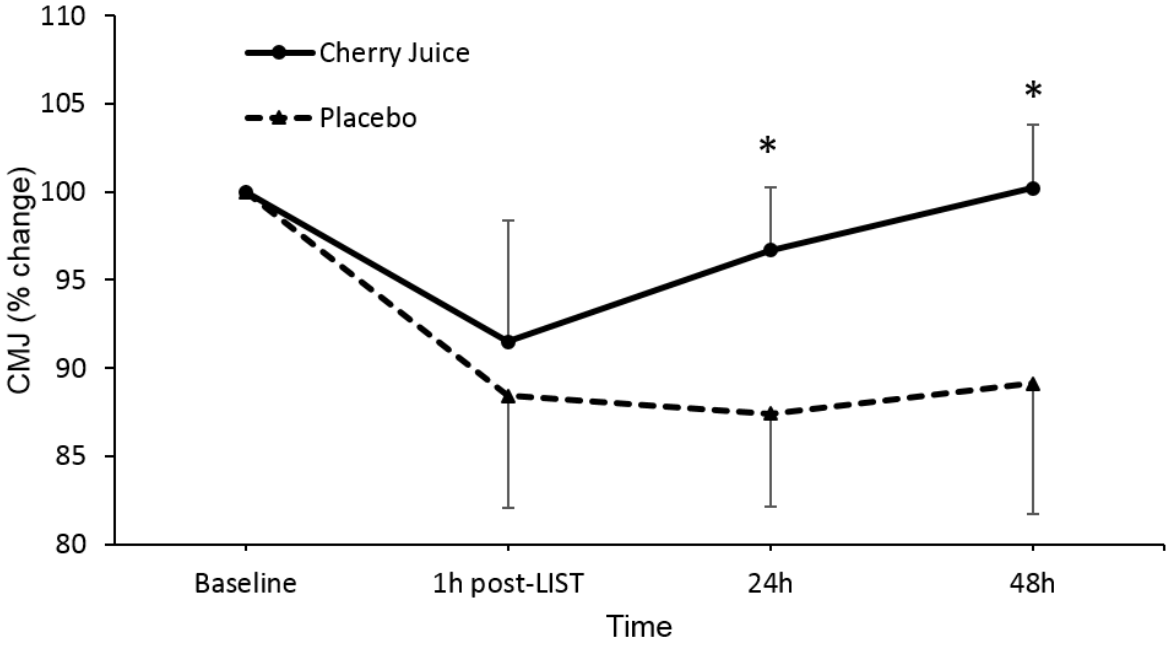

Figure 1. Counter-movement jump for the cherry juice and placebo groups at baseline and following the LIST. *Significantly greater recovery of CMJ performance was observed in the cherry juice group at 24h and 48h post-LIST (p<0.05); values are mean ± SD (n =10 per group).

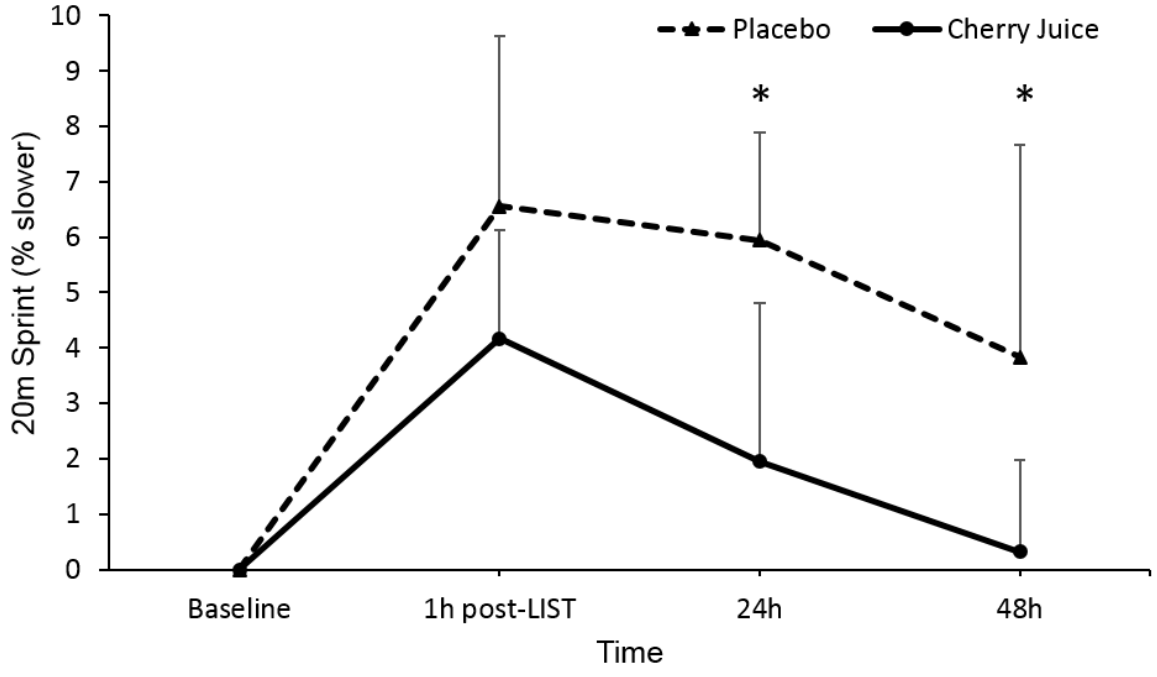

Figure 2. 20m sprint times for the cherry juice and placebo groups at baseline and following the LIST. * Significantly attenuated decline in 20m sprint in the cherry juice group than the placebo at 24h and 48h (p < 0.05); values are mean ± SD (n = 10 per group).

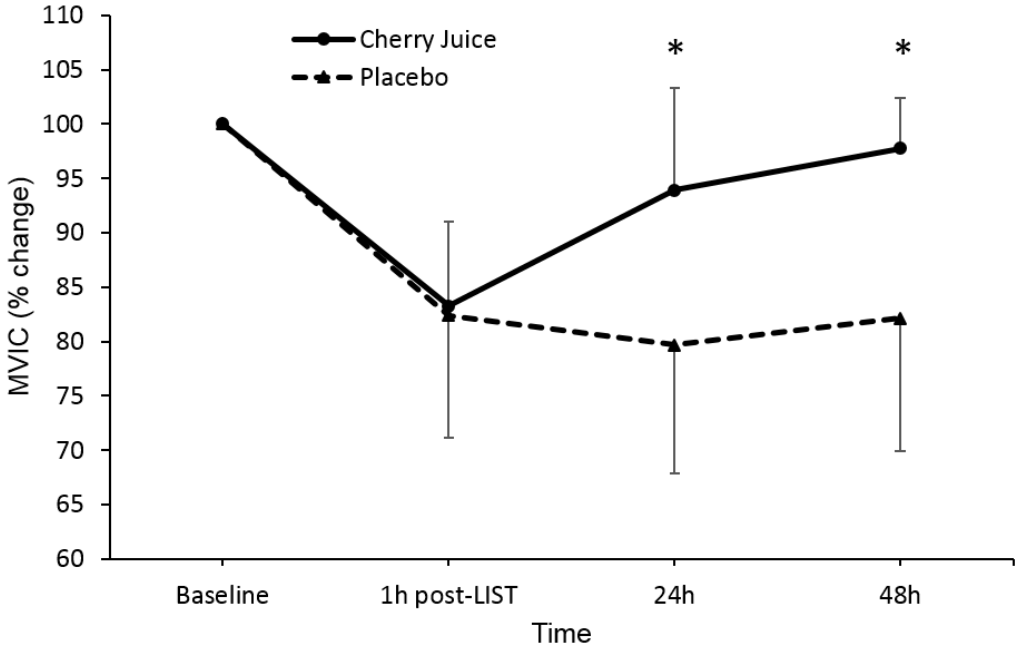

Figure 3. Maximal voluntary isometric contraction (MVIC) for the cherry juice and placebo groups at baseline and following the LIST. *Significantly greater recovery of force in the cherry juice group at 24h and 48h post-LIST ($p < 0.05$); values are mean ± SD (n = 10 per group).

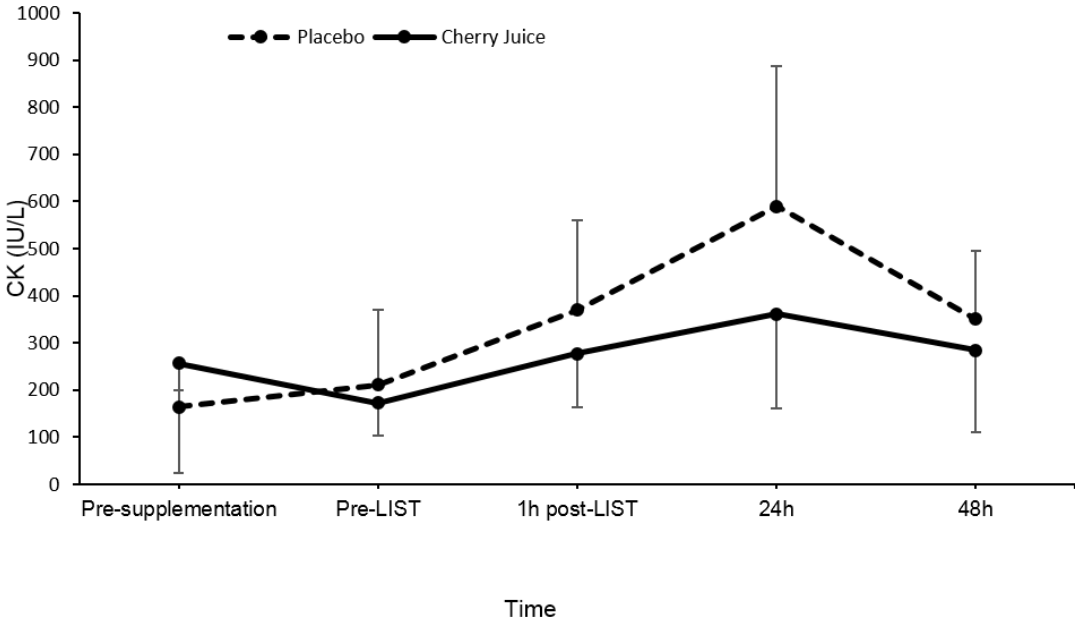

Figure 4. Serum creatine kinase (CK) concentrations for the cherry juice and placebo groups before and following the LIST. Values are mean ± SD (n = 10 per group).

Table 1. Participant characteristics. Values are mean ± standard deviations.

Group	Sport (=n)	Sex (M/F)	Age (years)	Height (cm)	Mass (kg)	Multistage Fitness Test Level	Predicted VO_2 Max ($ml.kg.min^{-1}$)
Cherry juice	Football (n=5) Netball (n=3) Hockey (n=2)	4/6	28 ± 4	175.9 ± 11.1	71.5 ± 13.1	9.4 ± 2.1	44.6 ± 7.2
Placebo	Football (n=9) Hockey (n=1)	4/6	25 ± 5	174.8 ± 8.4	68.9 ± 12.6	9.3 ± 2.6	44.2 ± 9

NOTE: =n: number of participants, M/F: male/female, m: metres, kg: kilograms, VO_2 max: maximal oxygen uptake.

Table 2. Summary of the differences between cherry juice and placebo for recovery indices following intermittent shuttle running

	Mean difference ± 90% CI	**Effect Size**
Change from baseline to post		
CMJ	-0.7 ± 0.6	-0.46 (moderate)
20m sprint	0.1 ± 0.0	0.86 (large)
MVIC	-4.8 ± 17.1	-0.1
Agility	0.1 ± 0.1	0.35 (small)
DOMS	14.1 ± 33.8	0.41 (small)
CK	52.7 ± 31.8	0.61 (moderate)
CRP	-0.3 ± 0.1	-0.41 (small)
Change from baseline to 24h		
CMJ	-2.2 ± 0.6	-1.39 (large)
20m sprint	0.1 ± 0.0	1.90 (large)
MVIC	-38.4 ± 17.8	-0.79 (large)
Agility	0.1 ± 0.0	1.24 (large)
DOMS	31.2 ± 31.8	0.72 (moderate)
CK	189.1 ± 100.9	0.69 (moderate)
CRP	0.4 ± 0.2	0.31 (small)
Change from baseline to 48h		
CMJ	-2.7 ± 0.6	-1.67 (large)
20m sprint	0.1 ± 0.0	1.40 (large)
MVIC	-49.8 ± 15.7	-1.16 (large)
Agility	0.1 ± 0.2	0.14
DOMS	54.9 ± 25.2	1.20 (large)
CK	26.0 ± 61.3	0.16 (small)
CRP	-0.2 ± 0.3	-0.1

NOTE: Mean difference refers to placebo minus cherry juice trial; 90% CI: 90% confidence interval; CMJ: countermovement jump; MVIC: maximal voluntary isometric contraction; DOMS: muscle soreness; CK: creatine kinase; CRP: C-reactive protein.

Table 3. Mean muscle soreness scores and CRP values for the cherry juice and placebo groups before and following intermittent shuttle running.

	Pre-supplementation	**Pre-LIST**	**Post-LIST**	**24h**	**48h**
DOMS (mm)					
Cherry Juice		43.3 ± 25.9	107.4 ± 36.0	83 ± 26.0	62.7 ± 35.4
Placebo		27.8 ± 20.0	106 ± 21.4	98.7 ± 31.2	102.1 ± 36.8
CRP (mg/L)					
Cherry Juice	0.563 ± 0.901	0.277 ± 0.186	0.57 ± 1.034	0.831 ± 1.145	1.201 ± 1.961
Placebo	1.292 ± 1.756	1.138 ± 1.29	1.176 ± 1.289	2.071 ± 2.03	1.897 ± 1.746

NOTE: Post-LIST: post Loughborough Intermittent Shuttle Test; DOMS: muscle soreness; CRP: C-Reactive Protein. Values are mean ± SD (n=10 per group)