

# Tart Cherry Juice in Athletes: A Literature Review and Commentary

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## Abstract

Tart cherry (TC) juice has many antioxidant and anti-inflammatory polyphenol compounds. TC lessens pain and accelerates strength recovery after exercise and decreases blood markers of inflammation/oxidative stress. These improvements occur in both strength and endurance exercise. TC supplementation may not be optimal during the adaptation/build stage of training. However, excessive inflammatory/oxidative stress during single-day intense training/competition or multiday tournaments may delay return to peak form. In this stage, where *recovery* (not adaptation) is the priority, TC may be beneficial. Timing and dosage vary widely, but most studies use 8 to 12 oz (1 oz if concentrate form) twice a day, 4- to 5-d loading phase before the event, and 2 to 3 d after to promote recovery. Therefore, for an athlete who has already peaked in training and looking to improve recovery and faster return to competition, TC may be beneficial.

and comment on the effects on muscle damage and recovery in the literature.

## Montmorency TC Juice

Montmorency, or tart cherries, *Prunus cerasus*, contains numerous phytochemicals including anthocyanins, flavonoids (quercetin, kaempferol, isorhamnetin), flavanols (catechin, epicatechin), gallic acid equivalents, procyanidins, and phenolic acids (30,31). Both tart cherries and sweet (Bing) cherries contain these compounds; however, they are present in higher concentrations in tart cherries. Montmorency and Balaton TC varieties have both been studied; however, most researchers have used Montmorency brands (more predominant and widely available commercially to athletes).

## Introduction

The use of tart cherry (TC) juice has been rapidly increasing in both elite athletes and the general population. However, supplement and ergogenic aid use in the general public often precedes and outpaces current available research. Clinicians involved in sports medicine often do not have formal nutrition training yet have to field questions from athletes on numerous products.

Over the last 10 yr, researchers have begun to investigate cherry juice's potential effects on various parameters, ranging from muscle damage, pain, vascular function, antioxidant activity, and sleep. The following review summarizes the current available data on TC in athletes, and provides recommendations and precautions for its potential uses in Sports Medicine. We also report our personal observations with TC

Exercise is well known to result in oxidative stress, inflammation, and decreased muscle force production. The high content of polyphenolic compounds in TC, via their antioxidant and anti-inflammatory effects, have been proposed to lessen muscle damage, reduce levels of pain, and improve recovery in athletes. It may be especially helpful in those undergoing intense exercise training that may overload the body's natural antioxidant capacity. Previous studies have looked at traditional antioxidants vitamins C and E on recovery from intense exercise with mixed results. Initial studies using cherries have demonstrated that consumption of high amounts of *whole* cherries (45 to 50 a day) can reduce blood inflammatory markers in the general population (16,17); however, little was known of its effects on exercise. TC juice represents a more convenient way to ingest a large quantity of these polyphenolic compounds.

## Methods

A literature search using PubMed/Medline, CINAHL, Embase, and Cochrane was performed on December 1, 2016, including all years prior. Additionally, reference lists of articles meeting search criteria and articles that cited these studies were screened. Additional articles were manually searched via Google Scholar. Keywords included Montmorency, TC juice, exercise, sport, athlete, inflammation, oxidative stress,

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1537-890X/1604/230-239

Current Sports Medicine Reports

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recovery, ergogenic aid, and variations of these search terms. No data restrictions were used for language, date, subject age. Studies that did not include relevance to exercise (e.g., cancer, neuropathy, diabetes, vascular function) and studies that involved multiple supplements in addition to TC were excluded. Abstracts of conference proceedings, as well as *in vitro* and animal studies, also were excluded.

The initial search produced 208 potential articles. A total of 11 randomized controlled trials met the eligibility criteria. Due to significant methodological heterogeneity (cherry juice brand, concentrate vs regular variety, total dose and timing, subjects, sport/activity, and outcomes), pooling of data was unable to be done. TC dose ranged from 1 oz of *concentrate* twice a day to 12 oz *nonconcentrate* twice a day and further varied in both number of days supplemented before and after an event. Subjects included recreationally active and well-trained individuals. Age widely ranged from 18.6 to 37 yr. Sport/activity included strength sports, endurance sports, and mixed activities. Outcomes included pain, inflammatory/oxidative stress blood markers, muscle catabolism markers, strength loss, recovery time, upper respiratory tract symptoms (URTS), and performance. Figure outlines the PRISMA search strategy.

Table highlights the main points of each study. To provide the reader with better context and perspective on the history

of cherry juice use with exercise, a brief chronological summary is presented here, with supporting literature, to help clarify the latest research in the last 10 yr.

### Timeline in TC Juice Research

#### I. 2006 to 2010: Initial Studies on Muscle Soreness and Strength After Eccentric Exercise

One of the first studies on exercise in humans by Connolly et al. (8) showed that 12 oz of TC twice a day for 4 d before and 4 d after eccentric exercise reduced pain and limited postexercise strength loss compared with placebo (22% loss of strength with placebo vs 4% loss with cherry juice) in recreationally active young college men. A later study by Kuehl (19) in well-trained men and women during a mountain relay running race (average distance/runner 26.3 km) similarly showed less pain and more satisfaction with pain reduction in those taking 10.5 oz of TC twice a day for 7 d before and on the day of the race. Like Connolly et al.'s research, this study involved significant eccentric contractions (downhill mountain running). It was theorized that the antioxidant and anti-inflammatory effects of cherry juice may be blunting the inflammation-induced damage after myofibrillar disruption from eccentric exercise, stabilizing calcium homeostasis in muscle, and limiting the further cascade of vascular



**Figure:** Flow diagram of literature search. Numbers in parentheses indicate number of research studies identified for each outcome.

**Table.**  
TC juice trials in athletes

Study	TC Juice Amount	Before/After Protocol (Besides Day of Event)	Average Age	Sex	Exercise Type	Athlete Type	Results	Comments
Connolly et al. (8)	12 oz twice a day	4 d before and 4 d after	22 yr	male	Eccentric elbow exercise, 2 × 20 maximum contractions	Recreationally active young college males	Reduced pain and less strength loss (4% loss) after exercise in TC group compared to placebo (22% strength loss). Relaxed elbow angle and muscle tenderness unchanged	Strength exercise; crossover trial with opposite arm to avoid repeated bout effect
Kuehl (20)	10.5 oz twice a day	7 d before and day of exercise	35.8 yr	male and female	26.3 km mountain running race	Well-trained male and female runners	Less pain with TC group compared to placebo (12 mm vs 37 mm on 100-point pain scale). TC group reported more satisfaction with their pain and more willing to use the drink again	Endurance exercise (distance running)
Howatson et al. (15)	8 oz twice a day	5 d before, 2 d after	37 yr	male and female	London marathon	Recreational male and female runners	Isometric knee extensor strength recovery faster with TC. Reduced inflammatory markers IL-6, CRP, and uric acid; 10% greater total antioxidant status; lower thiobarbituric acid reactive species (measure of oxidative stress) in TC group	Endurance exercise (marathon)
Bowtell et al. (6)	30 ml (~ 1 oz) of cherry juice concentrate twice a day	7 d before, 2 d after	27.8 yr	male	10 × 10 rep/set 80% 1 rep max knee extensor exercise	Resistance-trained male rugby, football, and taekwondo athletes	Faster recovery of maximal knee extensor strength at 24 h (90.9% vs 84.9%) and 48 h (92.9% vs 88.5%), percentage increase (23.8% vs 82.7%) and absolute increase (0.31 nmol·mg <sup>-1</sup> vs 0.60 nmol·mg <sup>-1</sup> ) in protein carbonyls (measure of oxidative stress) was less	Strength exercise; first to use concentrate

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**Table.**  
Continued

Study	TC Juice Amount	Before/After Protocol (Besides Day of Event)	Average Age	Sex	Exercise Type	Athlete Type	Results	Comments
Bell et al. (2)	1 oz cherry juice concentrate twice a day	7 d, with exercise on days 5, 6, 7	30 yr	male	109 min simulated high-intensity stochastic cycling trial, ×3	Well-trained male cyclists	Lipid hydroperoxides (measure of oxidative stress) was lower across all time points, including 29.8% lower at trial 3; IL-6 and hs-CRP rise was lower in TC group compared to placebo	First study to examine repeated days of exercise
Bell et al. (4)	1 oz concentrate twice a day	4 d before, 3 d after	30 yr	male	109 min high-intensity stochastic cycling time trial	Well-trained cyclists	Maximum isometric quadriceps strength loss after exercise was not reduced with TC up to 72 h after exercise (compared to 14% drop with placebo). IL-6 and hsCRP were lower with TC. First study showing improved performance in cycling efficiency (measured by oxygen consumption) after 24 h also was noted, in the form of a 4% lower VO <sub>2</sub> requirement with TC	Cycling time trial; First study that did not include a significant eccentric exercise component. First study to show improved performance
Dimitrou (9)	8 oz twice a day	5 d before, 2 d after	37 yr	male and female	London Marathon	Recreational male and female runners	Unique to this study, frequency of URTS during 44 °F (7 °C) marathon race conditions were measured. 50% of the placebo group experienced URTS 1 to 2 d after the marathon; zero subjects reported symptoms in TC group. Also, significantly lower levels of CRP in TC group	Endurance exercise (marathon)
Levers et al. (22)	480 mg/day powdered tart cherries	7 d before, 2 d after	20.9 yr	male	10 × 10 70% 1-RM back squat exercise	Resistance-trained males	Muscle soreness perception in quadriceps significantly lower up to 48-h postlift compared with placebo. Serum creatinine and total protein lower over time and smaller from prelift levels over time compared to placebo; AST, ALT, bilirubin	Strength exercise; First to use powdered cherry juice capsules

							and creatinine lower 48-h postlift compared to placebo. Serum inflammatory, anti-inflammatory, oxidative stress and antioxidant capacity markers unchanged.	
Livers (23)	480 mg/day powdered tart cherries	7 d before, 2 d after	21.8 yr	male and female	Half-marathon (21.1 km) in 111.98 min	Aerobically trained males and females (endurance runners or triathletes)	34% lower pruryn quadriceps soreness and lower postrun quad soreness in TC group. Lower creatinine, urea/blood urea nitrogen, total protein, and cortisol significantly lower compared with placebo. Statistically significant increase in antioxidant activity ( $\Delta$ TAS) at 24 and 48-h posttrace, and inflammatory/anti-inflammatory markers (IL-2, IL-6, IL-13) 47% improved in TC group. 13% faster half-marathon race finish times with TC juice compared to placebo.	Endurance exercise; similar results in endurance athletes using same protocol as strength athletes. Second study to demonstrate improved performance
Bell et al. (5)	1 oz concentrate twice a day	4 d before, 3 d after	25 yr	male	Intermittent sprinting (Loughborough Intermittent Shuttle Test)	Semi-professional men's soccer	Faster recovery in maximal voluntary isometric contraction, counter movement jump, agility with TC. Lower muscle soreness and lower IL-6 with TC juice compared to placebo.	Sprint exercise; First study on prolonged repeat sprinting
McCormick (24)	1 oz concentrate AM, 2 oz PM	6 d before (none day of or after)	18.6 yr	male	Vertical jump, 6 x 10 m sprints, WIST (water-based Yo-Yo intermittent recovery test), simulated water polo match	Well-trained men's water polo	IL-6, CRP and oxidative stress unchanged. No differences on performance or recovery.	Water exercise; Authors propose intermittent, non-weight-bearing demands of water polo may not create significant inflammatory/oxidative stress

permeability/neutrophil infiltration/oxidative stress that exceeds the body's natural antioxidant capacity.

## II. 2010 to 2014: Blood Markers of Inflammation and Muscle Damage

Howatson et al. (15) was one of the first to measure blood levels of inflammation, oxidative stress, and muscle damage in athletes. In recreational male and female runners competing in the London marathon, supplementation with 8 oz TC twice a day for 5 d before, day of, and 2 d after the marathon showed improvements in multiple parameters. Isometric knee extensor strength recovery was faster, inflammatory markers interleukin-6 (IL-6), C-reactive protein (CRP), and uric acid were reduced, total antioxidant status was 10% greater, and thiobarbituric acid reactive species (a measure of oxidative stress) were lower in the cherry juice group compared to placebo.

Bowtell et al. (6) studied TC *concentrate* effects on well-trained male rugby, football, and taekwondo athletes regularly performing resistance training. The study tested 30 mL (~1 oz) of cherry juice concentrate twice a day for 7 d before, day of, and 2 d after a 10 × 10 knee extensor exercise program at 80% of a 1 repetition maximum (1 RM) versus placebo. Maximal knee extensor strength recovery was faster and the percentage increase and absolute increase in protein carbonyls (a measure of oxidative stress) was less in those taking cherry juice concentrate compared with placebo.

Bell et al. (4) measured blood markers of inflammation in trained cyclists taking 7 d of TC concentrate after 3 d of simulated racing (109 min high-intensity, stochastic road cycling trials during days 5, 6, and 7 of TC supplementation). There were significant reductions in oxidative/inflammatory markers, including lipid hydroperoxides and high-sensitivity CRP (hs-CRP). Unique to this study is the only trial to assess TC on repeated days exercise, initially suggesting cherry juice's potential role in tournaments or other daily high-intensity exercise situations.

## III. 2013 to 2015: Early Literature Reviews

Kuehl (18) presented an excellent review on multiple effects of TC. The review outlined TC juice's antioxidant capacity primarily via its anthocyanins and reviewed cherry juice's anti-inflammatory effects via flavonoid inhibition of cyclooxygenase-1 and cyclooxygenase-2 enzymes and potential role in management of fibromyalgia and osteoarthritis.

Coelho Rabello Lima et al. (7) also reviewed TC juice's anti-inflammatory and antioxidant effects through its polyphenols such as anthocyanin, supporting the growing research indicating TC role in attenuating exercise-induced muscle damage and faster recovery after intense bouts of exercise.

In 2014, Bell et al. (2) published a very comprehensive article summarizing TC juice's potential role in four specific categories including muscle function, pain, inflammation, and oxidative stress, and highlighted some of its risks versus benefits. It is beyond the scope of this article to review in depth all the points of Bell et al.'s work; however, interested readers may find the detail of this review one of the most comprehensive on TC to date. The conclusions from the four categories are presented here:

- A. **Muscle function:** it is well accepted that eccentric exercise is a major cause of muscle damage leading to inflammation and impaired muscle function. Bell et al. concluded that supplementation with TC may reduce the effects of this damage and the subsequent strength loss after exercise, improve blood markers of muscle damage, and may promote faster recovery. This is consistent with other research (included in Table 1 below) showing that most studies measuring strength have shown a consistent benefit with TC versus placebo. Interestingly, this was seen not only after strength training but also endurance exercise. Bell et al. postulated that cherry juice's role is not in the prevention of mechanical damage after eccentric exercise, but in limiting the subsequent cascade of inflammation and oxidative stress, thereby promoting faster recovery. While the exact mechanisms of action have not fully been understood, TC supplementation clearly has direct muscle function benefits demonstrated across multiple studies.
- B. **Oxidative stress:** TC does seem to lower certain blood markers of oxidative stress. However, which markers are best to measure remains controversial, and which specific pathways TC exerts its antioxidant effects is still debated. One interesting conclusion is that TC appears to have an effect regardless of metabolic exercise stress (endurance) or mechanical exercise stress (eccentric exercise). Bell et al. emphasized the point that *high-intensity* or *exhaustive* exercise resulting in reactive oxygen and nitrogen species may overload the body's natural antioxidant capacity and result in cellular damage and decreased muscle function. However, *moderate* exercise increasing only a moderate level of oxidative stress appears to be a stimulant to increase the body's natural antioxidant levels.
- C. **Inflammation:** Recent research (10–13) suggests that inhibiting the initial inflammatory response may blunt the overall healing response. This may include inhibition of muscle protein synthesis after exercise, casting doubt on the routine use of NSAID in sports. Bell et al. therefore proposed that if the priority is not *adaptation*, but *recovery* after intense training, then the anti-inflammatory effects of TC may be beneficial. The high anthocyanin content in tart cherries, which inhibits cyclo-oxygenase-2 in the inflammatory pathway, appears to be the main factor in tart cherries' anti-inflammatory effects.
- D. **Pain:** The pain from delayed-onset muscle soreness (DOMS) is well known, while the reason for it still evades us. Inflammation may play a role. Anthocyanins present in tart cherries have been shown to inhibit inflammation-induced pain to a similar degree as indomethacin in preliminary animal studies (34); Connolly et al.'s 2006 study (8) and Kuehl's 2010 study (19) similarly showed pain reduction in humans after exercise. While the



research is in its early stages, there may be reduced DOMS with TC, allowing athletes to return to training and/or competition faster. Furthermore, while not an athlete population, Schumacher et al. found WOMAC score symptom improvement with TC supplementation in mild to moderate osteoarthritis patients, although it did not reach significance compared with placebo (29). This may be of interest as both elite athletes and weekend warriors alike often play with similar mild to moderate degenerative changes in the knee. Interestingly, Howatson et al.'s study (15) in marathon runners did not show reductions in pain despite faster strength recovery and lower inflammatory/oxidative stress markers. Future, more comprehensive, studies are clearly of interest.

Bell et al. also mentioned TC dose and timing. The loading phase in most studies is approximately 4 to 7 d before and 2 to 4 d after an exercise event; therefore, it has been impossible to differentiate between preexercise and postexercise effects based on available research. Anthocyanins may peak in the blood approximately 2 h postingestion and clear by 8 h. Timing in athletes therefore would suggest multiple doses a day, with a prerace dose ~2 h before competition. Future studies are likely to investigate these parameters further.

Lastly, Bell et al. pointed to studies on sleep, arterial stiffness, arthritis, gout, neuroprotection, and cancer, some of which are not commonly applicable to the athlete population. However, the importance of restful sleep cannot be understated in the athlete at risk for the overreaching and overtraining syndromes; tart cherries contain significant levels of melatonin, which has been extensively studied in sleep and may be of value to athletes undergoing intense training (discussed next).

#### IV. 2015 to 2016 The Latest: Sleep, Performance, and Possible Limitations

In the last 2 yr, we have seen even more studies in this ever-growing field. Dimitrou's 2015 study (9) on 8 oz TC twice a day, 5 d before and 2 d after the London Marathon tested the same cohort of recreational marathon runners as Howatson et al.'s 2010 study (15). Unique to this study however, he assessed URTS during 44°F (7°C) marathon race conditions. Perhaps, not surprisingly, 50% of the placebo group experienced URTS 1 to 2 d after the marathon, but interestingly *no* subjects reported symptoms in the TC group. This study also found significantly lower levels of CRP with TC.

Levers et al. (20) were first to report a beneficial effect of powdered cherry juice supplementation in athletes, and demonstrated rather elegantly similar findings in both strength and endurance events using the same cherry juice/study protocol. In the initial study, Levers showed that a once a day capsule given to well-trained males performing a 10 × 10 70% 1 RM back squat exercise showed less quadriceps soreness, less decrement in quadriceps strength loss, and lower markers of muscle breakdown, thus, demonstrating similar findings with a powdered capsule as previous studies with nonpowdered cherry juice. In 2016, Levers (21) repeated the same study but in aerobically trained individuals. Athletes had lower quad soreness, lower inflammatory markers, and increased antioxidant activity.

Bell et al. (3) in 2016 published another study, this time with prolonged repeat sprinting. Taking 1 oz TC concentrate twice a day (similar to the 2015 study) showed less muscle soreness, IL-6 levels, and a faster recovery of maximal voluntary contraction, countermovement jump, and agility scores.

#### *Sleep*

Nédélec (25) in 2015 proposed TC juice's potential use in a review paper highlighting sleep-promoting strategies in elite soccer players. Nédélec alluded to cherry juice's multiple potential roles in the overall recovery of the athlete, including rehydration, energy substrate replenishment, muscle repair, and restorative sleep. TC juice's beneficial effects on sleep also have been demonstrated in three other studies worth mentioning. Howatson et al. (14) showed 7 d of 1 oz TC *concentrate* twice a day increased exogenous urinary melatonin levels as well as increases in overall time in bed, total sleep time, and sleep efficiency. Similar findings in sleep time and sleep efficiency were found with 8 oz twice a day of nonconcentrate TC by an earlier study from Pigeon (26). St-Onge (29) reviewed various foods on sleep quality, including TC juice's effects on sleep architecture. Athletes that engage in intense exercise programs and have busy travel/competition schedules may often sacrifice sleep, so this may be a promising option given TC juice's additional beneficial effects on pain, inflammation, and muscle strength recovery. A cautionary note should be included here, however, as supplementation with melatonin, athlete or not, carries the potential risk of reductions in mental and physical performance (1). Of note, TC supplementation specifically (not melatonin) in two human studies (18,19) and one animal study (35) have not shown a negative effect on cognitive function, and two of the studies (18,35) showed positive effects on working memory and cognition.

#### *Performance*

Bell et al. (5) in 2015 published a study on the results of a 1-oz TC *concentrate* twice a day regimen including 4 d before and 3 d after a single 109-min time trial in male cyclists. Strength loss after exercise (maximum isometric quadriceps strength) was not reduced with TC (compared with a 14% drop with placebo), and this was the first study that did not include a significant eccentric exercise component. Plasma IL-6 and hs-CRP levels were lower with TC compared with placebo. And importantly, for the first time, improvements were seen in performance: improved cycling efficiency (measured by oxygen consumption) after 24 h also was noted, with athletes in the TC group having a 4% lower  $\dot{V}O_2$  requirement compared to placebo.

The previously mentioned Levers study (21) was the second study to demonstrate increased performance with cherry juice, namely, 13% faster half-marathon times in aerobically trained individuals performing a half-marathon.

#### *Possible limitations to TC juice*

In the most recent study on athletes to date, McCormick (22) was the first to examine TC juice's potential role in non-land-based sports. Men's water polo players were subject to an array of water-based performance tests as well as a simulated game after 6 d of TC concentrate compared with placebo. IL-6 and CRP rose from day 1 to day 7 in both groups.

and blood lactate was lower on day 7 compared with day 1, but interestingly, no significant differences were noted between groups in muscle soreness, IL-6 or CRP, and performance or recovery scores.

In personal communication with one of the authors, the limited positive outcomes produced in this study may have been attributable to the intermittent and weight-supported nature of a sport like water polo (*i.e.*, in performed in water), where it is hypothesized that a lower level of inflammatory stress is likely incurred, as compared with that which may result during land-based sports. The authors' recommendation/plan is to evaluate this hypothesis further in a study comparing cherry juice in land versus water sports.

The dosing regimen also is the first in the literature to supplement only before and not after an exercise event, because the goal of the study was specifically to assess next-day performance. It is unknown if there would be an effect during recovery.

Also of note is that the placebo used for this study was a combination of lime, cranberry, and raspberry juice to closely replicate the taste and carbohydrate content of TC. It is unknown if the antioxidant content of this placebo drink may not entirely be a true placebo, although these products were chosen due to manufacturers' claims of no anthocyanin content (believed to be one of the major antioxidant/anti-inflammatory compounds of TC). Furthermore, the study protocol used 3 oz of concentrate, more than the typical 2 oz of concentrate in previous studies, but it is difficult (if not impossible) to estimate the true total antioxidant content in the TC group compared with placebo, because many factors come into play during manufacturing (*e.g.*, processing, shelf-time before consumption, varying dilution of the concentrate, all of which can affect antioxidant content).

## Discussion

There are well-known risks and side effects with traditional pain relievers and anti-inflammatory drugs used by athletes. A natural, food-based alternative certainly appears to represent a safer potential alternative. In the last few years, many trials have investigated TC; however, unfortunately, there is significant heterogeneity in patient population, sport/activity, and cherry juice supplementation protocol. Clearly, this is a growing area of research, and our knowledge of TC juice's effects have not yet reached a consensus. Interested readers may consider the works of Bell and Howatson for further information.

Thus far, it appears that TC has significant anti-inflammatory and antioxidant effects with promising results for athletes. However, an important point should be addressed before formulating any practical recommendations for athletes. The well-known studies of Gomez-Cabrera *et al.* (10–13) have brought into question the use of antioxidants in athletes, due to the potential blunting of the training adaptation response in those taking high amounts of antioxidants before and during exhaustive/intensive training. Interestingly, these and other studies used supplements, such as vitamins C and E, in nonphysiologic high doses (*e.g.*, 1000 mg vitamin C, 235 mg vitamin E). These compounds inhibit the body's natural antioxidant enzymes (superoxide dismutase and glutathione peroxidase) and the pathways involved in mitochondrial biogenesis. Other studies have shown no effect however, and

some studies do not show any decrease in performance in athletes (26,28,33). As a result of these conflicting studies, it does not seem logical to recommend supraphysiologic, “unnatural” doses of antioxidant supplements to athletes at this time. And perhaps most important, these studies used vitamins C and E, which are not found in high quantities in TC, making a direct comparison between the high levels of vitamins C and E in the studies and the high levels of antioxidants in TC difficult in regard to training adaptations. The authors have not found research thus far that investigates blunting of adaptation with TC. It has been theorized, however, that use of “natural” food-based products (*e.g.*, TC, resveratrol in grapes), not synthetic supplements, do not necessarily inhibit the adaptation response (36), and furthermore, the polyphenolic compounds present in these foods may possibly even improve performance (37). Therefore, there is currently insufficient data to conclusively state if TC during training may inhibit (or facilitate, or have a neutral role in) the adaptation response.

Most of the studies used 8, 10.5, or 12 oz (equivalent of approximately 45 to 60 cherries depending on brand used) of TC (typically given twice a day), therefore totaling 90 to 120 cherries a day. Two studies used a concentrate form in 30-mL (1 oz) doses, and according to manufacturer specifications, a 30-mL (1 oz) dose contains 90 to 110 Montmorency tart cherries. However, both of these studies used twice a day dosing, thereby doubling the amount of cherries ingested. As mentioned previously, it is challenging to draw a conclusion on the optimal dose, as the antioxidant content can vary widely depending on factors such as product preparation, processing, and shelf-life. Using manufacturer specifications on amount of cherries used/dose may be an appropriate guide. Future research should clarify the optimal dose.

Both concentrate and nonconcentrate formulations are available commercially in America, typically in 8-oz, single-serving sizes or a 32-oz (four servings) container. The concentrate comes in a 16-oz container (16 servings of 1-oz concentrate). Loading phase ranged from approximately 4 to 7 d before, day of competition (usually 2 h before event), and 2 to 4 d after. Therefore, it is unknown how many days before/after exercise is optimal. Of note, athletes also may object to intake of any food or drink 2 h before an event due to the potential for gastrointestinal distress.

Subjects were either recreationally active or well-trained athletes. Average ages in the studies widely ranged from 20.9 to 37 yr old, and 5 of 11 included female and males (others only male). Activity included both strength sports and endurance events. This mixed population makes generalizability difficult. While it may not be applicable to the general population, this demographic may be closer to the high-level athlete community, and therefore, the research results may be of value to athletes currently in training and competition.

## Clinical Applications in Athletes

In the athlete looking to improve *training adaptations*, TC supplementation cannot be either recommended or discouraged, but supplementation at this stage may possibly raise the concern of blunting the training adaptation response. This may not be the optimal timing for TC, but research remains inconclusive.

However, after the base and build phases of training and periodization (once the athlete is in peak of their conditioning),



further adaptations may not be the priority (perhaps not even possible). If the focus is now on improving *recovery*, getting back into full race/competition form as fast as possible, then tart cherries may have a beneficial role. This would clearly be of value during multiday events and tournaments when the ability to recover and perform at a high level day to day is the main priority. Furthermore, in the athlete looking for something that may further improve performance at this stage, early studies do suggest TC juice's possible role. This may sound somewhat similar to the trend of ingesting beet juice before a major endurance event, because there may be some overlap in mechanisms of action (nitrates and polyphenol's vascular, oxygen consumption, and muscle homeostasis effects). Based on the available research, the author suggests 8 to 12 oz of TC (1 oz of concentrate) twice a day for at least 4 d before, day of, and 2 d after competition may be beneficial.

Perhaps, the only time during the *training adaptation* phase for TC may be to help recover after the "very long runs" or the very exhausting high-intensity interval training sessions that would otherwise leave an athlete overly fatigued, tired, and feeling weak. It may not be ideal to take regularly during training, due to the above concerns of possibly inhibiting the adaptation response via supra-physiologic antioxidant ingestion. Taking the equivalent of 90 to 120 cherries a day on a regular basis would certainly appear to be suprathysiologic intake in the author's opinion. However, this precisely may be why it can help after a very exhaustive, "suprathysiologic exercise," but would not be recommended as a daily routine supplement.

## Conclusion

From a clinician's standpoint, any food product would be favorable over a drug, and as "food is fuel" this inherently should be beneficial to the exercising athlete. It is the author's opinion that if a high-level athlete wants to try a product to improve his or her chances, but not expose their body to risks and side effects, TC is a natural food that may help. If taken during the right timing of training, it may give "the edge" that athletes desperately search for, without the numerous side effects and risks that accompany drugs, supplements, illicit performance-enhancing substances. Furthermore, TC may have some pleiotropic effects on the body via its wide-reaching antioxidant and anti-inflammatory effects. Further research should shed more light if this cherry juice truly is a "sweet success" (although tart), such as investigating efficacy of concentrate versus nonconcentrate versus powdered formulations. Overall, the use of any whole food or food-based product over artificial and processed items simply cannot be stressed enough to athletes in the modern age of doing (and taking) anything to win.

## Commentary: Shawn Hueglin, Senior Dietitian, United States Olympic Committee

After providing TC juice concentrate to a variety of Olympic level team sport athletes including differences in age, position, gender, and sport, there was a positive response both observationally and via self-report recovery logs. There seems to be a strong benefit on muscle soreness and sleep for athletes. Furthermore, the antioxidants and carbohydrate content may be additionally beneficial for certain athletes. The

concentrate is a useful and convenient formulation in preparation for and during international competitions as it is easily transported in luggage and can be provided on the road to a team in any environment. Many athletes "felt" a strong benefit of consistently drinking the juice. However, it can be a challenge to systematically evaluate the use of this type of drink in elite level athletes due to a multitude of factors: travel schedules, training schedules, influence of roster selection close to a tournament, athlete's ability to identify soreness, and athlete compliance. More investigation is warranted to better understand TC juice's role in exercise, recovery, and performance in Olympic athletes.

## Commentary: Liz Broad, Senior Dietitian, United States Olympic Committee

Based on this information, I believe that TC juice is worth trialing in my Paralympic athletes. This review highlights the proposed benefits and potential uses of TC juice, many of which apply to my high-level athletes. Some have soreness and pain after intense training; some have delayed recovery; some have sleep disturbances due to visual impairments and pain. This proposed action, plus the fact that it is food-based rather than a drug, makes cherry juice very practical and interesting as a potential treatment in the overall health of Paralympic athletes. The only limiting factor we have experienced to date is a laxative effect, and is important to mention to athletes (especially those with spinal cord injuries).

The authors would like to thank Peter Peeling for his comments and advice.

The authors declare no conflict of interest and do not have any financial disclosures.

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