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ORIGINAL RESEARCH

Effect of tart cherry juice supplement on lower extremity strength recovery performance after periodization resisted sled-based training

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Abstract

In this study, we investigated the impact of tart cherry (TC) juice on the recovery of lower extremity strength and characteristic movements following periodic Resisted Sled-Based Training (RST). A cohort of 24 male college soccer players (average height, 179.8 $\pm$ 6.4 cm; weight 75.9 $\pm$ 5.3 kg; age, 22 $\pm$ 3 years) was recruited and divided into two groups. During the experimental period, their dietary intake was controlled. Specifically, they were instructed to consume TC juice or a placebo (70 mL twice daily) for three weeks, followed by periodic RST in the fourth week. Baseline assessments and evaluations were conducted immediately, as well as 24, 48 and 72 hours post-exercise, measuring various test indices including counter-movement jump (CMJ), Knee Flexion Seated Position at 90°, Knee Flexion Prone position at 90° and Nordic Hamstring. The findings show TC juice supplementation effectively mitigates the extent of lower extremity strength decline following high-intensity sprint training within a specific cycle. Furthermore, it accelerates lower extremity strength recovery during high-intensity sprint training, with observed variations between the left and right sides. These findings confirm that TC juice, along with other polyphenol-rich foods, contributes to enhanced recovery following high-intensity sprint training within a specific cycle.

Keywords

Tart cherry juice; Periodization; Resisted sled-based training (RST); Lower extremity strength; Recovery

1. Introduction

Tart cherry (TC) fruit is a nutrient-rich food that is relatively low in calories. It contains essential nutrients and bioactive compounds, including fiber, vitamin C, carotenoids, potassium and polyphenols and represents a notable source of serotonin, tryptophan and melatonin, all of which have the potential to contribute to its antioxidant and anti-inflammatory properties [1, 2]. Exercise-induced pain, muscle damage and recovery are intricate phenomena influenced by various factors. Muscle function deterioration due to mechanical and immune stress primarily arises from heightened inflammation and oxidative stress. Given that TC contains significant concentrations of bioactive compounds like anthocyanins, hydroxycinnamates, 3-flavinols and melatonin, among others, known for their antioxidant and anti-inflammatory properties [3], TC can accelerate recovery after intermittent exercise, extending its effectiveness in accelerating recovery in team sports [4]. Therefore, TC supplementation holds promise as an effective strategy against oxidative stress and inflammation.

When examining meta-analytic studies utilizing Resisted Sled-Based Training (RST) [5, 6], it becomes evident that RST training represents an innovative approach with the potential to enhance sprint performance, particularly during the initial acceleration phase. In football, sprint acceleration capabilities are of paramount importance, and RST training demonstrates notable effectiveness in improving maximum speed and sprint times for short-distance sprints [7]. Varying sled loading conditions have been found to optimize the development of speed-related skills among highly trained soccer players [8]. Resistance training can also enhance lower body strength in athletes, with potential benefits transformed into improved sprint performance [9]. However, despite its advantages in sprinting, RST may lead to fatigue-related issues, such as limited muscle activity and stiffness in the leg muscles post-training [10]. Consequently, post-training recovery plays a pivotal role. Furthermore, evaluating neuromuscular fatigue through practical tests like CMJ [11], Knee Flexion [12], and Nordic Hamstring [13] assessments is essential to assess neuromuscular fatigue.

Upon reviewing both experimental and meta-analytic studies on TC juice [1–3, 14], we found that a consensus on the positive performance effects of TC juice supplements has not yet been reached. Moreover, given the increasing number of college football players in China, exploring the potential impact of these supplements on their athletic performance holds promise for further improvement in this field. The primary objective of this study was to evaluate the lower limb strength performance of 24 college football players following the intake of TC juice supplements followed by high-intensity RST. High-intensity running activities in football comprise a range of activities from jogging to high-speed running and sprinting ($\geq$14.4 km·h^{-1}), with extremely high-intensity running defined as high-speed running and sprinting at speeds of $\geq$19.8 km·h^{-1} [15]. Under such exertion, glycolysis becomes the primary energy source for muscle fibers, potentially leading to increased fatigue [16]. Existing literature reports an upregulation of antioxidant genes and proteins in skeletal muscle after TC juice supplementation [17]. Furthermore, it suggests a reduction in oxidative stress and markers of muscle and heart damage following strenuous resistance exercise [18].

In football, high-intensity sprints predominantly involve anaerobic exercises, and in this context, the antioxidant properties of TC juice could be beneficial to athletes [19]. While mechanical stress represents the primary factor responsible for skeletal muscle damage, it is important to acknowledge that elevations in reactive oxygen species can help repair skeletal muscle proteins, and antioxidants may help reduce biochemical damage [20].

During football training and competitions, intense physical exertion can lead to inadequate recovery in athletes and cause subpar performance and an elevated risk of injury. In this regard, it is important to create well-structured short- and long-term training and competition plans to support physical development [21]. The level of fatigue experienced in football matches and the duration required for recovery are influenced by various factors, including external factors like match outcomes, opponent strength, match location and playing surface, as well as internal factors such as an athlete's training level, age, gender and muscle fiber type [22]. Therefore, it is essential to develop effective and personalized recovery strategies. In this study, we employed a strategy involving supplementation, training and recovery to explore the potential benefits of adding TC juice to recovery after training sessions.

In this study, we tested the hypothesis that TC juice supplementation was associated with lower limb strength recovery capacity after RST. Besides, we divided participants into two groups which were TC supplementation group and control group respectively based on indicators of force production. Thereafter, we confirmed the differences by evaluating the CMJ, left and right knee seated extensors, left and right knee prone flexors, and bilateral Nordic hamstring test results.

2. Materials and methods

2.1 Experimental subjects

Twenty-four healthy male college soccer players, classified as National Level 2 Athletes, with 6–8 years of soccer training experience and a track record of top 8 provincial league performance during their student years, volunteered to participate in this study (average height: 179.8 $\pm$ 6.4 cm, weight: 75.9 $\pm$ 5.3 kg, and age: 22 $\pm$ 3 years). The study inclusion criteria were the absence of uncontrolled or severe diseases, no instances of bone or skeletal muscle damage within the preceding 6 months, and no prior participation in other clinical trials within the past 3 months, as determined through assessment and informed consent.

2.2 Study design

This study adopted a single-blind, placebo-controlled experimental design with independent groups, where the single-blind was maintained for the subjects. Recruitment for this study took place between 01 October 2022, and 30 November 2022. All participants provided written consent for participation, and guardian consent was not necessary for minors were not included in this study.

Participants entered the study at two distinct locations which were the functional testing laboratory and the training venue respectively. During the initial visit, participants were briefed on the functional testing procedures and the content of sled resistance training. Once participants gained a comprehensive understanding of the testing methods and theoretical aspects of the training content, practical sessions were conducted at both venues to ensure participants were proficient in meeting the study requirements. Then, they were randomly and equally assigned to either the TC juice or placebo groups based on random drawing.

During the participants' second visit to the functional testing laboratory, a series of functional measurements were conducted to assess motor performance, including CMJ, Seated Position Knee Flexion at 90°, Prone Position Knee Flexion at 90°, and Nordic Hamstring. Notably, all tests, except for CMJ, involved independent evaluations for the left and right legs. Initial data from these assessments were recorded as baseline measurements. Participants were provided with both TC juice and placebo drinks during this visit, with clear instructions on how to consume them. Additionally, they were given a list of beverages and foods which need to be avoided throughout the duration of the experiment. The choice of single-blind methodology was made to enhance supervision by the experimenters because this study involved college athletes, and stringent dietary restrictions were implemented to exclude polyphenolic foods and alcohol during the study. Concurrently, precautions were taken to ensure their safety, taking into consideration their academic commitments and professional sports training.

2.3 Functional performance tests

For the CMJ test, the participants were instructed to follow these steps: begin by standing upright on the test board with hands on hips, and maintaining a steady posture for 1–2 seconds. Stay as still as possible until the command is given. Then, perform a squat to a 90° angle, followed by a powerful jump, reaching as high as possible. Finally, land back on the test board and remain there while the data is collected. This test required two repetitions with a 30-second rest interval between each. The test result was recorded as the distance of the jump backward, measured in centimeters (cm). Following the completion of this test, participants were given a 3-minute rest period to prepare for the next assessment.

For the Seated Position Knee Flexion at 90° test, they were instructed to sit upright in a designated test chair with their knee joint flexed at 90°, followed by maintaining a relaxed overall posture. Upon hearing the commencement command, they were asked to assess maximal hamstring strength through the knee extensor test, starting from the left side. Each participant conducted three separate maximum tests on the left side, with each contraction lasting 5 seconds. A 15-second rest interval separated each contraction. Following the left-side tests, participants rested for 2 minutes and subsequently performed three maximum isometric contraction tests on the right side using the same protocol. Test results were quantified in terms of power produced when the knee joint was extended. Upon completion of this test, they were given a 3-minute rest period to prepare for the subsequent assessment.

The Prone Position Knee Flexion at 90° test required participants to lie face down on a designated test mat with their knee joint set at a 90° angle and were instructed to maintain a relaxed position throughout their entire body. Upon hearing the commencement command, they were asked to assess maximal hamstring strength through the knee flexors test, starting from the left side. Each participant conducted three separate maximum tests on the left side, each lasting 5 seconds, with a 15-second rest period between each contraction. Then, they were allowed to rest for 2 minutes before repeating the procedure on the right side. The right-side tests consisted of three maximum isometric contraction trials, each also lasting 5 seconds, with a 15-second rest interval between repetitions. Test results are quantified in terms of power produced when the knee joint is bent. Upon the end of this test, they were given a 3-minute rest interval to prepare for the next assessment.

The participants were asked to keep their hips fixed in a slightly flexed position throughout the whole range of motion, and to brake the forward fall as long as possible using their hamstrings. They were asked to use their arms and hands to buffer the fall, let the chest touch the surface, and immediately get back to the starting position by forcefully pushing with their hands to minimize loading in the concentric phase. With each lowering phase lasting 15 seconds, after the test, the test data was read by the resistance plate. A 30-second rest interval separated each lowering phase. If a participant completed the lowering phase in a duration shorter than the stipulated time, they were asked to repeat the test.

2.4 Supplement and dietary control

The supplement utilized in this study was a commercially available Montmorency cherry concentrate (Nature Tart Cherry 100, Gangwon-do, Korea), while the placebo consisted of commercially available purified water mixed with fruit components (Capri-Sun, Seoul, Korea) to match the energy content of TC juice (72 kcal). Participants received either TC juice or the placebo, with both supplements provided in individual 70 mL servings. All supplements were packaged together in the same box, with one box allocated per participant. The supplementation was given twice daily, 9:00 AM and 5:00 PM, for 3 weeks, as shown in Fig. 1. The total supplementation volume in this study was 2940 mL. The literature studies we referred to were about 10.5 fluid ounces of tart cherry juice supplementation and a dilute supplementation volume of about 3600 mL over 6 days a week, similar with prior research [23, 24]. To maintain a single-blind design, an uninvolved individual administered all supplements, and participants were instructed to keep the supplement type confidential. Throughout the supplementation period, participants were encouraged to maintain their usual physical activity and dietary habits to facilitate a polyphenol washout period, thereby preventing potential interference from similar substances when consuming TC juice.

2.5 Training

At the end of the 3-week supplement, the training regimen for the fourth week was structured based on the principles of periodic training. Sprint training took place on a designated training field. The weekly training schedule comprised sessions on Monday, followed by rest days on Tuesday and Wednesday, and concluding with training on Thursday. During each training session, participants started with a standardized warm-up routine before proceeding to perform RST at distances of 10, 20 and 30 meters. In this regimen, each participant experienced resistance equivalent to 13% of their body weight, in line with established protocols [25–27]. On the Thursday training sessions, exercise performance assessments were conducted immediately after training at the 24-, 48- and 72-hour intervals, as shown in Fig. 1.

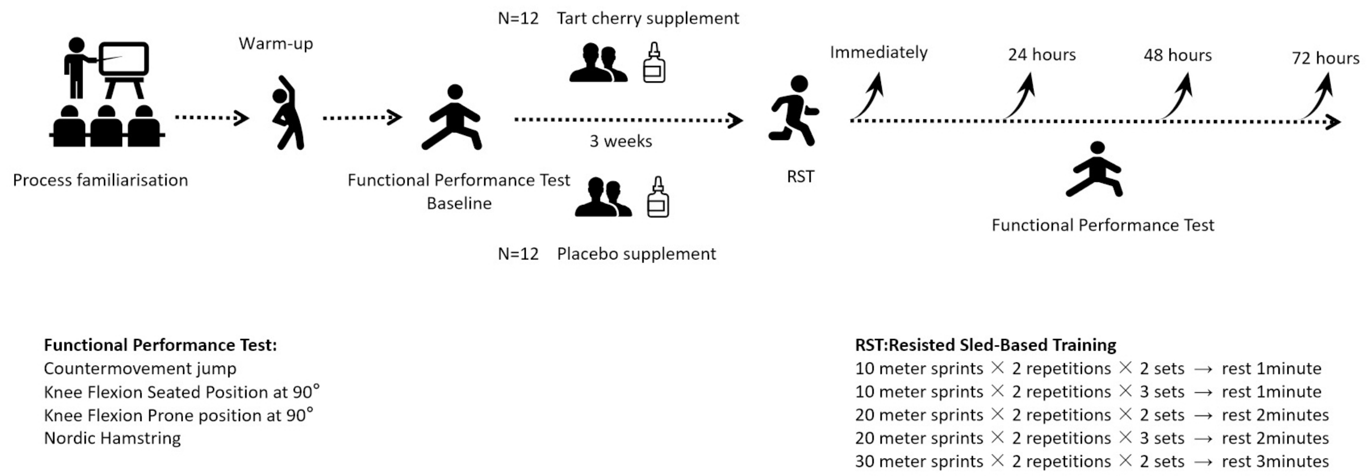

FIGURE 1. Visualization flow of the experimental procedure.

2.6 Statistical analysis

Data analysis was performed using Statistical Package for the Social Sciences software (SPSS version 25.0, IBM Co., Armonk, NY, USA), and results are expressed as mean ± standard deviation. Analysis of Variance (ANOVA) was conducted for a repeated-measures comparison between the tart cherry juice (TC) and placebo (PLAC) groups at multiple time points, including pre-supplemental baseline, immediately after training, and 24, 48 and 72 hours after training. *Post hoc* analysis using the Least Significant Difference (LSD) test was applied when necessary to identify specific differences. Significance level was set at $p < 0.05$ for all analyses. In cases where adjustments were needed to account for baseline differences, data were standardized using percentages.

3. Results

3.1 Counter-movement jump

A repeated measures analysis of variance was conducted to assess the CMJ performance of both groups at various time points (Table 1). The results indicated a significant interaction between group and time concerning the CMJ (F time = 11.584, $p < 0.001$; F group = 13.969, $p = 0.001$; F Interaction = 2.791, $p = 0.031$). From the results, we observed that following the RST, both groups displayed a decline in CMJ compared to their baseline measurements immediately and after 24 hours. Notably, the decline was more pronounced in the PLAC group than in the TC group. Subsequently, at the 48-hour mark, both groups exhibited a recovery trend, with TC nearly returning to baseline levels by the 72-hour mark, whereas a slower recovery pace was observed for participants in the PLAC group.

3.2 Left knee flexion seated position at 90°

Repeated measures analysis of variance was conducted to evaluate the left Knee Flexion Seated Position at 90° performance in the two groups at different time points (Table 2), and assessed hamstring and quadriceps strength. The results revealed a significant interaction between the group and time for the left Knee Flexion Seated Position at 90° (F time = 3.314, $p = 0.032$; F group = 12.805, $p = 0.002$; F Interaction = 0.829, $p = 0.523$). After the RST, the output power of the Left Knee Flexion Seated Position at 90° was declined. Notably, the TC group displayed a more gradual decline and recovery pattern compared to the PLAC group, which experienced a more pronounced decline in power and a slower recovery trajectory. Ultimately, both groups returned to baseline levels, with TC demonstrating superior output power at the 72-hour mark in contrast to PLAC.

3.3 Right knee flexion seated position at 90°

A repeated measures analysis of variance was applied to assess the right Knee Flexion Seated Position at 90° performance in the two groups across different time points (Table 3), and assessed hamstring and quadriceps strength. The analysis revealed a significant interaction between group and time concerning the right Knee Flexion Seated Position at 90° (F time = 7.035, $p < 0.001$; F group = 36.970, $p < 0.001$; F interaction = 2.695, $p = 0.036$). From the results, we can observe that following the RST, there was a reduction in the output power of the Right Knee Flexion Seated Position at 90°. The TC group experienced a smaller decline in power compared to the PLAC group. At the 48-hour mark, both groups demonstrated a minor decrease with a slight trend of recovery. Notably, the TC group could return to baseline levels by the 72-hour mark. Furthermore, the recovery on the right side was more pronounced compared to the left side.

3.4 Left knee flexion prone position at 90°

A repeated measures analysis of variance was conducted to assess left Knee Flexion Prone Position at 90° hamstring performance in the two groups across different time points (Table 4), and assessed hamstring and quadriceps strength. The analysis indicated a significant interaction between group and time for left Knee Flexion Prone Position at 90° hamstring (F time = 13.881, $p < 0.001$; F group = 18.814, $p < 0.001$; F interaction = 2.646, $p = 0.039$). From the results, we found that after the end of RST, the Left Knee Flexion Prone position at 90° decreased in both groups. At the 48-hour mark, there was a noticeable trend of recovery, with the TC group's recovery nearing baseline levels by the 72-hour mark. However, it is noteworthy that the degree of recovery in the PLAC group at 72 hours surpassed that of the TC group.

3.5 Right knee flexion prone position at 90°

A repeated-measures analysis of variance was conducted to assess the performance of the right hamstring muscles during right Knee Flexion Prone Position at 90° in the two groups across various time points (Table 5), and assessed hamstring and quadriceps strength. The analysis did not reveal a significant interaction between group and time for this parameter (F time = 6.074, $p < 0.001$; F group = 34.687, $p < 0.001$; F interaction = 1.016, $p = 0.403$). From the results, it can be seen that after the RST, both groups exhibited a decrease in the output power of the right Knee Flexion Prone Position at 90° hamstring. At the 48-hour mark, a trend of recovery became apparent, although the improvements in both groups were relatively small. However, by the 72-hour mark, the TC group had nearly returned to baseline levels, with a more pronounced recovery observed on the right side compared to the left side.

3.6 Left Nordic hamstring

A repeated measures analysis of variance was performed on the left kneeling forward centrifugation of the two groups at different time points (Table 6), and assessed hamstring and quadriceps strength, and the results showed an interaction between group and time in left kneeling forward centrifugation (F time = 12.060, $p < 0.001$; F group = 26.753, $p < 0.001$; F interaction = 3.668, $p = 0.022$). From the results, we observed that after the RST, the Left Nordic Hamstring of both groups had declined. The power decline and recovery level of the TC group was relatively mild, while the power level of PLAC was consistently at a lower level before 48 hours and took 72 hours to return to a better level.

TABLE 1. CMJ over different time periods.

Variables	Baseline mean ± SD	Immediately mean ± SD	24 H mean ± SD	48 H mean ± SD	72 H mean ± SD	*F*	*p*
TC	31.17 ± 6.42	27.33 ± 5.37	25.58 ± 6.05	26.58 ± 6.82	29.42 ± 4.98	1.661	0.200
PLAC	33.42 ± 7.76	20.50 ± 6.68^{a}	17.17 ± 5.78^{a}	20.33 ± 6.21^{a}	24.33 ± 6.62^{ac}	9.116	<0.001
F	0.598	7.631	12.135	5.511	4.514		
p	0.447	0.011	0.002	0.028	0.045		

F time = 11.584, p < 0.001; F group = 13.969, p = 0.001; F interact = 2.791, p = 0.031. ^{a} *means p < 0.05 compared with baseline,* ^{c} *means p < 0.05 compared with 24 h.*
Abbreviations: TC: Tart Cherry Juice; PLAC: placebo; H: Hour; mean ± SD, mean ± standard deviation; unit: centimeter.

TABLE 2. Left knee flexion seated position at 90° over different time periods.

Variables	Baseline mean ± SD	Immediately mean ± SD	24 H mean ± SD	48 H mean ± SD	72 H mean ± SD	*F*	*p*
TC	56.37 ± 17.57	51.23 ± 8.21	49.73 ± 9.48	49.49 ± 10.47	51.93 ± 8.99	0.429	0.786
PLAC	57.50 ± 15.55	42.45 ± 9.59^{a}	36.12 ± 8.00^{a}	38.39 ± 8.22^{a}	44.38 ± 7.61^{ac}	3.714	0.021
F	0.027	5.809	14.496	8.349	4.949		
p	0.870	0.025	0.001	0.009	0.037		

F time = 3.314, p = 0.032; F group = 12.805, p = 0.002; F interact = 0.829, p = 0.523. ^{a} *indicates p < 0.05 compared with baseline,* ^{c} *indicates p < 0.05 compared with 24 h post-training.*
Abbreviations: TC: Tart Cherry Juice; PLAC: placebo; H: Hour; mean ± SD: mean ± standard deviation; unit: kilogram.

TABLE 3. Right knee flexion seated position at 90° over different time periods.

Variables	Baseline mean ± SD	Immediately mean ± SD	24 H mean ± SD	48 H mean ± SD	72 H mean ± SD	*F*	*p*
TC	50.98 ± 11.75	46.48 ± 6.08	45.70 ± 9.79	47.88 ± 9.82	50.02 ± 8.64	0.954	0.455
PLAC	51.76 ± 9.85	38.28 ± 7.63^{a}	32.08 ± 5.07^{ab}	33.07 ± 10.01^{a}	42.04 ± 8.90^{acd}	8.452	<0.001
F	0.030	8.513	18.370	13.395	4.942		
p	0.864	0.008	<0.001	0.001	0.037		

F time = 7.035, p < 0.001; F group = 36.970, p < 0.001; F interact = 2.695, p = 0.036. ^{a} *indicates p < 0.05 compared with baseline,* ^{b} *indicates p < 0.05 compared with immediately after training,* ^{c} *indicates p < 0.05 compared with 24 h post-training, and* ^{d} *indicates p < 0.05 compared with 48 h post-training.*
Abbreviations: TC: Tart Cherry Juice; PLAC: placebo; H: Hour; mean ± SD: mean ± standard deviation; unit: kilogram.

TABLE 4. Left knee flexion prone position at 90° over different time periods.

Variables	Baseline mean ± SD	Immediately mean ± SD	24 H mean ± SD	48 H mean ± SD	72 H mean ± SD	*F*	*p*
TC	23.59 ± 6.02	21.18 ± 5.97	18.34 ± 5.20	18.73 ± 4.24	20.28 ± 5.00	1.615	0.212
PLAC	24.28 ± 6.27	15.30 ± 4.71^{a}	11.72 ± 3.28^{a}	12.29 ± 2.80^{a}	16.98 ± 3.40^{acd}	9.034	<0.001
F	0.076	7.174	13.949	19.318	3.593		
p	0.785	0.014	0.001	<0.001	0.071		

F time = 13.881, p < 0.001; F group = 18.814, p < 0.001; F interact = 2.646, p = 0.039. ^{a} *indicates p < 0.05 compared with baseline,* ^{c} *indicates p < 0.05 compared with 24 h post-training, and* ^{d} *indicates p < 0.05 compared with 48 h post-training.*
Abbreviations: TC: Tart Cherry Juice; PLAC: placebo; H: Hour; mean ± SD: mean ± standard deviation; unit: kilogram.

TABLE 5. Right knee flexion prone position at 90° over different time periods.

Variables	Baseline mean ± SD	Immediately mean ± SD	24 H mean ± SD	48 H mean ± SD	72 H mean ± SD	F	p
TC	23.88 ± 7.17	21.08 ± 5.14	20.06 ± 3.65	20.79 ± 6.12	22.22 ± 5.08	0.784	0.549
PLAC	21.97 ± 4.27	15.74 ± 3.55^a	13.30 ± 4.55^a	13.93 ± 2.96^a	16.66 ± 4.83^a	4.084	0.015
F	0.633	8.747	16.094	12.227	7.545		
p	0.435	0.007	0.001	0.002	0.012		

F time = 6.074, $p < 0.001$; F group = 34.687, $p < 0.001$; F interact = 1.016, $p = 0.403$. ^{a} indicates $p < 0.05$ compared with baseline.
Abbreviations: TC: Tart Cherry Juice; PLAC: placebo; H: Hour; mean ± SD: mean ± standard deviation; unit: kilogram.

TABLE 6. Left Nordic hamstring over different time periods.

Variables	Baseline mean ± SD	Immediately mean ± SD	24 H mean ± SD	48 H mean ± SD	72 H mean ± SD	F	p
TC	20.75 ± 4.75	18.36 ± 5.92	16.29 ± 7.02	15.91 ± 6.35	18.30 ± 4.28	1.880	0.155
PLAC	19.91 ± 5.23	10.38 ± 3.52^a	7.79 ± 1.96^a	8.87 ± 2.46^a	14.22 ± 5.47^{acd}	13.848	<0.001
F	0.171	16.106	16.338	12.839	4.149		
p	0.684	0.001	0.001	0.002	0.054		

F time = 12.060, $p < 0.001$; F group = 26.753, $p < 0.001$; F interact = 3.668, $p = 0.022$. ^{a} indicates $p < 0.05$ compared with baseline, ^{c} indicates $p < 0.05$ compared with 24 h post-training, and ^{d} indicates $p < 0.05$ compared with 48 h post-training.
Abbreviations: TC: Tart Cherry Juice; PLAC: placebo; H: Hour; mean ± SD: mean ± standard deviation; unit: kilogram.

3.7 Right Nordic hamstring

A repeated measures analysis of variance was conducted to assess the performance of the right Nordic Hamstring in the two groups at various time points (Table 7), and assessed hamstring and quadriceps strength, the analysis unveiled a significant interaction between group and time regarding right Nordic Hamstring (F time = 11.657, $p < 0.001$; F group = 22.601, $p < 0.001$; F Interaction = 2.521, $p = 0.047$). The results indicate that after the end of RST, there was a decline in the performance of the Right Nordic Hamstring in both groups. Notably, the TC group exhibited a more gradual decline, while the PLAC group experienced a significant drop immediately after the RST. However, by the 48-hour mark, PLAC displayed a trend similar to TC but with a more pronounced degree of recovery. Additionally, the recovery effect was better on the left side compared to the right side.

4. Discussion

The outcomes of this study support our initial hypothesis that administering TC juice as an early supplement can attenuate the reduction in lower body strength and accelerate recovery in football players.

Compared to other studies, our findings suggest that athletes who incorporate TC juice into their regimen may benefit from increased lower body strength performance, resulting in increased power output compared to placebo, which aligns with previous reports [23, 28, 29]. Existing literature indicates that the total volume of supplementation in our study, which amounted to 2940 mL, is comparable to the volumes reported in previous studies, which is typically around 10.5 fluid ounces of TC juice supplementation or approximately 3600 mL of diluted supplements [23, 30]. Participants ought to take 70 mL of supplement twice daily, at 9:00 AM and 5:00 PM, for 3 weeks. It's important to note that while the supplementation forms may differ, such as concentrated juice consumption [29–31] or the use of sour cherry powder [23], they have consistently demonstrated positive effects on recovery. Nevertheless, one study suggested that only 30 mL of TC juice might be adequate to achieve the maximum effect [32]. We speculate that this discrepancy may be attributed to the fact that overall healthy individuals who do not engage in high-intensity activities may require lower quantities for optimal results.

The importance of the timing of TC juice supplementation should be emphasized. Our literature review reveals the fact that providing supplementation before exercise tends to yield positive effects [23, 33, 34], while providing supplementation during and after exercise appears to have no significant positive impact [29, 30, 35–37]. Based on the results of our study, we hypothesize that TC juice supplementation may require prior accumulation and storage to exert its maximum effects, and taking supplementation during or after training potentially is less effective or ineffective.

Furthermore, our literature review highlights the significance of exercise intensity with TC juice supplementation. Following high-intensity RST, a decline in exercise performance across all measures was observed, which aligned with the findings in previous studies [33, 36]. This indicated that our exercise intensity met the anticipated requirements. Comparatively, previous studies involving non-intensive weight-bearing exercises reported no discernible differences in performance and recovery measures [29, 31, 38, 39]. In consequence, future investigations could consider investigating how exercise intensity may affect study outcomes.

After the RST, both groups experienced a decline in CMJ performance compared to baseline, which was more

TABLE 7. Right Nordic hamstring over different time periods.

Variables	Baseline mean ± SD	Immediately mean ± SD	24 H mean ± SD	48 H mean ± SD	72 H mean ± SD	F	p
TC	19.41 ± 8.43	15.53 ± 5.53	15.00 ± 4.46	15.85 ± 3.84	16.95 ± 7.60	0.903	0.482
PLAC	18.10 ± 5.48	7.66 ± 2.52^{a}	6.83 ± 2.28^{a}	8.21 ± 2.79^{a}	12.83 ± 4.38^{abcd}	6.458	0.002
F	0.203	20.109	31.885	31.106	2.645		
p	0.657	<0.001	<0.001	<0.001	0.118		

F time = 11.657, p < 0.001; F group = 22.601, p < 0.001; F interact = 2.521, p = 0.047. ^{a} *indicates p < 0.05 compared with baseline,* ^{b} *indicates p < 0.05 compared with immediately after training,* ^{c} *indicates p < 0.05 compared with 24 h post-training, and* ^{d} *indicates p < 0.05 compared with 48 h post-training.*
Abbreviations: TC: Tart Cherry Juice; PLAC: placebo; H: Hour; mean ± SD: mean ± standard deviation; unit: kilogram.

pronounced in the PLAC group. By the time of 48 hours after exercise, both groups began to show a trend of recovery, while the TC group nearly returned to baseline levels 72 hours later. Meanwhile, PLAC exhibited a slower recovery. Regarding other performance indicators, our study assessed and compared the left and right legs separately. For Knee Flexion Seated Position performance, we observed a gradual decline after RST, with the left side experiencing a milder decrease compared to the right side. The right side almost reached baseline levels 72 hours after exercise, surpassing the left side in recovery. In Knee Flexion Prone Position performance, there was also a decrease after RST, but the right side consistently maintained higher power output and almost returned to baseline 72 hours after exercise, displaying better recovery than the left side. In terms of Nordic Hamstring performance, a decline was observed after RST, with the right side experiencing a more significant decrease than the left side. 72 hours after exercise, the left side had returned to baseline levels and outperformed the right side. While TC juice supplementation generally contributed to a more favorable recovery trend, it is noteworthy that there were still differences in the evenness of power recovery between the left and right legs.

Our present study provides further evidence supporting the use of TC juice as an adjunct. Our findings indicate that TC juice supplementation can help restore performance indicators after sprint training within a specific cycle. In terms of practical application, while the current results are consistent with past research, most researches on nutritional supplement use focused on elite or professional athletes, and few focus on the collegiate level. College soccer players and professional athletes have different resources for nutritional supplements and injury prevention, which may result in health disparities between college soccer players and professional athletes. Professional athletes typically have the means to provide their athletes with nutritionists, strength coaches and supervised training while resources are scarce among college soccer players. Therefore, conducting this research among college soccer players in order to obtain the necessary improvements may be an opportunity to fill some gaps in existing research and contribute to the improvement of college soccer players' level abilities.

We acknowledge some limitations of this study. For greater accuracy, blood indicators should be added to the study results. Further studies with participants with different leg dominance could also be recommended which could aid in the development of symmetrical morphology. Additionally, our participants were in a regular training period when tested, and there was a chance that their strength and conditioning was not at their peak. Choosing to participate in the competition cycle may make the results more convincing. Therefore, we recommend further studies to account for this information. In addition, though dietary restrictions were enforced throughout the study, it should be acknowledged that nutritionists may need to adjust the dietary plan according to the specific needs of athletes during congested competition schedules with limited recovery time between events.

5. Conclusions

Compared with the control group, our experimental data demonstrate that TC supplementation can help maintain superior lower extremity strength and facilitate the recovery of working muscles to some extent, highlighting that TC juice supplementation may mitigate the decline in muscle function following intense exercise, accelerate recovery and enhance athletes' performance, which appears particularly beneficial for sports involving repetitive sprints.

AVAILABILITY OF DATA AND MATERIALS

Availability of Data and Materials is not applicable in this study, but if needed, they can be made available in a reasonable time. Please contact the main author or the correspondent and we will make them available in accordance with the regulations.

AUTHOR CONTRIBUTIONS

THY—designed the study and carried them out, prepared the manuscript for publication and reviewed the draft of the manuscript. THY, KD and LZJ—supervised the data collection, analyzed the data, interpreted the data. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Physical Education College of Henan Normal University (Approval no. HNSD-21-15). All subjects gave their informed consent for inclusion before they participated in the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] McHugh MP. "Precovery" versus recovery: understanding the role of cherry juice in exercise recovery. Scandinavian Journal of Medicine & Science in Sports. 2022; 32: 940–950.
[2] Gholami A, Amirkalali B, Baradaran HR, Hariri M. The beneficial effect of tart cherry on plasma levels of inflammatory mediators (not recovery after exercise): a systematic review and meta-analysis on randomized clinical trials. Complementary Therapies in Medicine. 2022; 68: 102842.
[3] Hill JA, Keane KM, Quinlan R, Howatson G. Tart cherry supplementation and recovery from strenuous exercise: a systematic review and meta-analysis. International Journal of Sport Nutrition and Exercise Metabolism. 2021; 31: 154–167.
[4] Quinlan R, Hill JA. The efficacy of tart cherry juice in aiding recovery after intermittent exercise. International Journal of Sports Physiology and Performance. 2020; 15: 368–374.
[5] Alcaraz PE, Carlos-Vivas J, Oponjuru BO, Martínez-Rodríguez A. The effectiveness of resisted sled training (RST) for sprint performance: a systematic review and meta-analysis. Sports Medicine. 2018; 48: 2143–2165.
[6] Petrakos G, Morin J, Egan B. Resisted sled sprint training to improve sprint performance: a systematic review. Sports Medicine. 2016; 46: 381–400.
[7] Edwards T, Piggott B, Banyard HG, Haff GG, Joyce C. The effect of a heavy resisted sled-pull mesocycle on sprint performance in junior Australian football players. Journal of Strength and Conditioning Research. 2023; 37: 388–393.
[8] Grazioli R, Loturco I, Veeck F, Setuain I, Zandavalli LA, Inácio M, *et al*. Speed-related abilities are similarly improved after sled training under different magnitudes of velocity loss in highly trained soccer players. International Journal of Sports Physiology and Performance. 2023; 18: 420–427.
[9] Appleby BB, Cormack SJ, Newton RU. Unilateral and bilateral lower-body resistance training does not transfer equally to sprint and change of direction performance. Journal of Strength and Conditioning Research. 2020; 34: 54–64.
[10] Zabaloy S, Carlos-Vivas J, Freitas TT, Pareja-Blanco F, Loturco I, Comyns T, *et al*. Muscle activity, leg stiffness, and kinematics during unresisted and resisted sprinting conditions. Journal of Strength and Conditioning Research. 2022; 36: 1839–1846.
[11] Gathercole RJ, Sporer BC, Stellingwerff T, Sleivert GG. Comparison of the capacity of different jump and sprint field tests to detect neuromuscular fatigue. Journal of Strength and Conditioning Research. 2015; 29: 2522–2531.
[12] Gear WS. Effect of different levels of localized muscle fatigue on knee position sense. Journal of Sports Science & Medicine. 2011; 10: 725–730.
[13] Ripley NJ, Cuthbert M, Comfort P, McMahon JJ. Effect of additional Nordic hamstring exercise or sprint training on the modifiable risk factors of hamstring strain injuries and performance. PLOS ONE. 2023; 18: e0281966.
[14] Ortega DR, López AM, Amaya HM, Berral de la Rosa F. Tart cherry and pomegranate supplementations enhance recovery from exercise-induced muscle damage: a systematic review. Biology of Sport. 2021; 38: 97–111.
[15] Bradley PS, Di Mascio M, Peart D, Olsen P, Sheldon B. High-intensity activity profiles of elite soccer players at different performance levels. Journal of Strength and Conditioning Research. 2010; 24: 2343–2351.
[16] Rabano-Muñoz A, Suarez-Arrones L, Requena B, Asian-Clemente JA. Internal and external loads of young elite soccer players during defensive small-sided games. Journal of Human Kinetics. 2023; 87: 179–188.
[17] Wangdi JT, O'Leary MF, Kelly VG, Jackman SR, Tang JCY, Dutton J, *et al*. Tart cherry supplement enhances skeletal muscle glutathione peroxidase expression and functional recovery after muscle damage. Medicine & Science in Sports & Exercise. 2022; 54: 609–621.
[18] Hooper DR, Orange T, Gruber MT, Darakjian AA, Conway KL, Hausenblas HA. Broad spectrum polyphenol supplementation from tart cherry extract on markers of recovery from intense resistance exercise. Journal of the International Society of Sports Nutrition. 2021; 18: 47.
[19] Santos HO, Genario R, Gomes GK, Schoenfeld BJ. Cherry intake as a dietary strategy in sport and diseases: a review of clinical applicability and mechanisms of action. Critical Reviews in Food Science and Nutrition. 2021; 61: 417–430.
[20] Rickards L, Lynn A, Barker ME, Russell M, Ranchordas MK. Comparison of the polyphenol content and *in vitro* antioxidant capacity of fruit-based nutritional supplements commonly consumed by athletic and recreationally active populations. Journal of the International Society of Sports Nutrition. 2022; 19: 336–348.
[21] Douchet T, Paizis C, Carling C, Cometti C, Babault N. Typical weekly physical periodization in French academy soccer teams: a survey. Biology of Sport. 2023; 40: 731–740.
[22] Nédélec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in soccer. Sports Medicine. 2012; 42: 997–1015.
[23] Levers K, Dalton R, Galvan E, Goodenough C, O'Connor A, Simbo S, *et al*. Effects of powdered Montmorency tart cherry supplementation on an acute bout of intense lower body strength exercise in resistance trained males. Journal of the International Society of Sports Nutrition. 2015; 12: 41.
[24] 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. Journal of the International Society of Sports Nutrition. 2016; 13: 41.
[25] Osterwald KM, Kelly DT, Comyns TM, Catháin CÓ. Resisted sled sprint kinematics: the acute effect of load and sporting population. Sports. 2021; 9: 137.
[26] Pareja-Blanco F, Pereira LA, Freitas TT, Alcaraz PE, Reis VP, Guerriero A, *et al*. Acute effects of progressive sled loading on resisted sprint performance and kinematics. Journal of Strength and Conditioning Research. 2022; 36: 1524–1531.
[27] Fernández-Galván LM, Casado A, García-Ramos A, Haff GG. Effects of vest and sled resisted sprint training on sprint performance in young soccer players: a systematic review and meta-analysis. Journal of Strength and Conditioning Research. 2022; 36: 2023–2034.
[28] Hooper DR, Orange T, Gruber MT, Darakjian AA, Conway KL, Hausenblas HA. Broad spectrum polyphenol supplementation from tart cherry extract on markers of recovery from intense resistance exercise. Journal of the International Society of Sports Nutrition. 2021; 18: 47.
[29] Howatson G, McHugh MP, Hill JA, Brouner J, Jewell AP, Van Someren KA, *et al*. Influence of tart cherry juice on indices of recovery following marathon running. Scandinavian Journal of Medicine & Science in Sports. 2010; 20: 843–852.
[30] 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. Nutrients. 2014; 6: 829–843.
[31] Lynn A, Mathew S, Moore CT, Russell J, Robinson E, Soumpasi V, *et al*. Effect of a tart cherry juice supplement on arterial stiffness and

inflammation in healthy adults: a randomised controlled trial. Plant Foods for Human Nutrition. 2014; 69: 122–127.
[32] Bell PG, Gaze DC, Davison GW, George TW, Scotter MJ, Howatson G. Montmorency tart cherry (*Prunus cerasus L.*) concentrate lowers uric acid, independent of plasma cyanidin-3-O-glucosiderutinoside. Journal of Functional Foods. 2014; 11: 82–90.
[33] Bell PG, Stevenson E, Davison GW, Howatson G. The effects of Montmorency tart cherry concentrate supplementation on recovery following prolonged, intermittent exercise. Nutrients. 2016; 8: 441.
[34] Brown MA, Stevenson EJ, Howatson G. Montmorency tart cherry (*Prunus cerasus L.*) supplementation accelerates recovery from exercise-induced muscle damage in females. European Journal of Sport Science. 2019; 19: 95–102.
[35] Drummer DJ, Many GM, Pritchett K, Young M, Connor KR, Tesfaye J, *et al*. Montmorency cherry juice consumption does not improve muscle soreness or inhibit pro-inflammatory monocyte responses following an acute bout of whole-body resistance training. International Journal of Exercise Science. 2022; 15: 686–701.
[36] Connolly DA, McHugh MP, Padilla-Zakour OI, Carlson L, Sayers SP. Efficacy of a tart cherry juice blend in preventing the symptoms of muscle damage. British Journal of Sports Medicine. 2006; 40: 679–683.
[37] Morehen JC, Clarke J, Batsford J, Barrow S, Brown AD, Stewart CE, *et al*. Montmorency tart cherry juice does not reduce markers of muscle soreness, function and inflammation following professional male rugby League match-play. European Journal of Sport Science. 2021; 21: 1003–1012.
[38] Schumacher HR, Pullman-Mooar S, Gupta SR, Dinnella JE, Kim R, McHugh MP. Randomized double-blind crossover study of the efficacy of a tart cherry juice blend in treatment of osteoarthritis (OA) of the knee. Osteoarthritis and Cartilage. 2013; 21: 1035–1041.
[39] Abbott W, Brashill C, Brett A, Clifford T. Tart cherry juice: no effect on muscle function loss or muscle soreness in professional soccer players after a match. International Journal of Sports Physiology and Performance. 2020; 15: 249–254.

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