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EFFECTS OF AN ANTIOXIDANT-RICH DIET ON MUSCLE SORENESS FOLLOWING TRAINING IN ADOLESCENT SOCCER PLAYERS

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ABSTRACT

This study examined the effect of a six-week antioxidant-rich whole-food dietary intervention on delayed-onset muscle soreness (DOMS) following standardized soccer-specific exercise in adolescent male soccer players. Forty adolescent male soccer players were randomly assigned to an antioxidant-rich diet (ATD, $n = 20$) or a conventional control diet (CON, $n = 20$) in a two-arm, parallel-group randomized controlled trial. Both groups completed the same supervised soccer training program three times weekly for six weeks. The ATD group consumed a structured diet emphasizing antioxidant-rich fruits, vegetables, herbs, and spices, whereas the CON group received a nutritionally balanced conventional diet. DOMS was assessed using a 10-cm visual analogue scale before exercise and at 24, 48, and 72 h following a standardized soccer-specific exercise session. Data were analyzed using a linear mixed-effects model with group, time, and group × time interaction as fixed effects. All participants completed the intervention, with dietary adherence of 88.1 ± 4.8% in ATD and 86.9 ± 5.3% in CON. A significant group × time interaction was observed ($p = 0.042$). DOMS was lower in ATD than CON at 24 h (adjusted mean difference −0.78, 95% CI −1.50 to −0.07; $p = 0.033$; Hedges' $g = -0.69$), with larger differences at 48 h (−1.94, 95% CI −2.78 to −1.11; $p < 0.001$; $g = -1.45$) and 72 h (−1.33, 95% CI −2.15 to −0.51; $p = 0.005$; $g = -1.01$). A six-week antioxidant-rich whole-food dietary intervention was associated with lower perceived muscle soreness following standardized soccer exercise in adolescent male players. The findings support its potential as a complementary nutritional strategy for subjective recovery, although the absence of physiological biomarkers prevents conclusions regarding underlying mechanisms or direct muscle damage.

Keywords: Antioxidant-Rich Diet; Delayed-Onset Muscle Soreness; Soccer Players; Exercise Recovery; Adolescent Athletes.

1 INTRODUCTION

Soccer is characterized by repeated high-intensity activities, including acceleration, deceleration, sprinting, changes of direction, jumping, and other intermittent actions that impose substantial mechanical and metabolic demands on the lower-limb musculature. These demands are particularly relevant in adolescent players, who commonly participate in multiple training sessions each week while simultaneously undergoing growth and physical development. The repeated exposure to high-intensity and eccentric actions may contribute to post-exercise fatigue and delayed-onset muscle soreness (DOMS), potentially affecting readiness for subsequent training and competition. Previous research has shown that soccer-related fatigue and muscle soreness may persist for several days following demanding exercise, with alterations in neuromuscular function and DOMS remaining evident up to 72 h after exercise or match play (1,2). Therefore, strategies that can support recovery between repeated soccer sessions are of practical interest.

DOMS is a common perceptual response to unaccustomed or strenuous exercise and is typically characterized by the gradual development of muscle soreness during the hours following exercise, with symptoms often becoming most apparent between 24 and 72 h (3). Although DOMS is frequently associated with exercise-induced muscle damage, perceived soreness should not be considered a direct measure of structural muscle damage because its relationship with biochemical and functional markers is complex (4). Nevertheless, DOMS remains an important practical outcome because substantial soreness may influence perceived readiness and tolerance of subsequent physical activity. Consequently, nutritional strategies capable of attenuating post-exercise soreness may have potential value for athletes who experience repeated high-intensity training loads.

Nutritional approaches involving foods rich in polyphenols and other antioxidant compounds have received increasing attention as potential strategies for supporting exercise recovery (5). Fruits, vegetables, herbs, and spices provide a variety of bioactive compounds, including polyphenols, anthocyanins, carotenoids, and phenolic constituents, which may influence physiological responses associated with strenuous exercise. Evidence from systematic reviews and meta-analyses suggests that polyphenol-rich foods, juices, and concentrates can reduce subjective muscle soreness during the post-exercise recovery period. A meta-analysis of 25 studies involving 527 participants reported significant reductions in DOMS at 24, 48, and 72 h following consumption of polyphenol-rich foods or related products, although the certainty of evidence varied across outcomes and time points (6). Similarly, a systematic review and meta-analysis of 39 studies found a small reduction in DOMS 24 h after exercise following anthocyanin consumption, alongside effects on several markers of exercise recovery (7). An umbrella review of nutritional interventions has also reported favorable effects of polyphenols and anthocyanins on muscle soreness, although differences in intervention protocols and study populations remain substantial (8,9).

Despite these findings, several limitations in the existing evidence warrant further investigation. Much of the available research has examined acute supplementation with isolated compounds, concentrated juices, or specific polyphenol-rich products rather than a sustained dietary pattern based on naturally antioxidant-rich whole foods. In addition, previous studies have predominantly involved adults, whereas evidence in adolescent athletes, particularly soccer players, remains comparatively limited. The relevance of a whole-food dietary approach is important because athletes typically consume combinations of foods rather than isolated bioactive compounds, and a dietary pattern emphasizing fruits, vegetables, herbs, and spices may be more feasible for routine nutritional practice. Furthermore, the time course of perceived soreness across 24–72 h is clinically and practically relevant because recovery following soccer activity may remain incomplete during this period (1,2).

Accordingly, the present study investigated whether a six-week antioxidant-rich whole-food dietary intervention could reduce perceived muscle soreness following a standardized soccer-specific exercise session in adolescent male soccer players. Participants assigned to the antioxidant-rich diet were compared with those receiving a nutritionally balanced conventional control diet while both groups completed the same supervised soccer training program. DOMS was assessed before exercise and at 24, 48, and 72 h after exercise, with the 24-h measurement prespecified as the primary time-specific endpoint. Based on previous evidence concerning polyphenol-rich foods and exercise recovery (6,10), we hypothesized that participants following the antioxidant-rich dietary intervention would report lower DOMS scores than those in the control group, with differences potentially persisting across the 72-h recovery period.

2 MATERIAL AND METHODS

2.1 Study Participants

Adolescent male soccer players aged 15–18 years will be recruited from competitive youth soccer clubs in Surabaya, Indonesia. Eligibility criteria will include ≥2 years of structured soccer training experience and participation in ≥3 organized training sessions per week. Participants will be excluded if they have a current musculoskeletal injury or medical condition affecting exercise participation or recovery, use antioxidant, anti-inflammatory, or performance-enhancing supplements, follow a medically prescribed or restrictive diet incompatible with the intervention, or regularly use analgesic or anti-inflammatory medication.

Before enrollment, written informed consent will be obtained from parents or legal guardians, and written assent from each participant. The study will be conducted in accordance with the Declaration of Helsinki and approved by the relevant institutional ethics committee before recruitment. The sample size was determined a priori based on DOMS at 24 h after the standardized training session (7). Assuming a standardized effect size of $d = 0.70$, $\alpha = 0.05$, and 80% power, 34 participants were required. Allowing for approximately 15% attrition, 40 participants (20 per group) will be recruited.

2.2 Study Design

This study will employ a two-arm, parallel-group, superiority randomized controlled trial with a 1:1 allocation ratio and a six-week intervention period. Eligible participants will be randomly assigned to either an antioxidant-rich diet (ATD) or a control diet (CON), while both groups will complete an identical standardized soccer training program throughout the intervention to minimize differences in exercise exposure. The dietary intervention will therefore represent the primary between-group difference. Muscle soreness will be assessed before and after the six-week intervention following a standardized soccer training session, with post-exercise assessments performed at 24, 48, and 72 h to characterize the temporal pattern of delayed-onset muscle soreness. The study design and reporting will follow the principles of the SPIRIT 2025 and CONSORT 2025 recommendations for randomized trials (11,12)

2.3 Research Procedure

Following eligibility screening and informed consent, participants will attend a familiarization session one week before randomization. During this session, the study procedures, dietary recording, DOMS assessment, and activity restrictions will be explained. Participants will be instructed to maintain their habitual lifestyle, avoid strenuous exercise for 48 h before baseline assessment, and refrain from antioxidant supplements, non-prescribed analgesic or anti-inflammatory medication, and other recovery interventions throughout the study. Baseline assessment will be conducted in the morning under standardized conditions following an approximately 10-h overnight fast. After baseline assessment, participants will be randomly allocated in a 1:1 ratio to the antioxidant-rich diet (ATD) or control diet (CON) group. Both groups will subsequently complete the same supervised soccer training program three times per week for six weeks, while the prescribed dietary intervention will be the only planned difference between groups. Dietary adherence and training exposure will be monitored throughout the intervention using dietary records, attendance, session duration, heart rate, and session-RPE. At the end of the six-week intervention, participants will repeat the standardized soccer training session under the same conditions as baseline, and DOMS will be assessed before exercise and at 24, 48, and 72 h post-exercise. This standardized sequence is intended to minimize variation in exercise exposure and measurement conditions and to allow comparison of the post-exercise soreness response before and after the dietary intervention. The procedure follows current recommendations for transparent reporting and reproducibility of randomized trials (11).

The antioxidant-rich diet (ATD) group will receive a structured six-week whole-food dietary intervention emphasizing naturally antioxidant-rich fruits, vegetables, herbs, and spices containing polyphenols, anthocyanins, carotenoids, and other bioactive compounds. The intervention will prioritize food-based antioxidant intake rather than isolated antioxidant supplementation. The control (CON) group will receive a nutritionally balanced conventional diet with comparable energy and macronutrient targets but without deliberate enrichment with antioxidant-dense foods. Both dietary protocols will be developed by a qualified sports nutritionist and adjusted according to participants' age, body mass, and training requirements.

Participants will receive a standardized seven-day rotating menu that will be repeated throughout the six-week intervention. The ATD diet will include locally available antioxidant-rich foods such as guava, dragon fruit, mango, pineapple, mangosteen, ginger, turmeric, and other fruits and vegetables, whereas the CON diet will consist of conventional staple foods without intentional antioxidant enrichment. The dietary pattern is adapted from previous research demonstrating potential benefits of polyphenol- and anthocyanin-rich foods on subjective post-exercise muscle soreness (13).

Dietary adherence will be monitored using daily meal checklists and three-day food records collected at baseline, week 3, and week 6. Participants will document any deviations from the prescribed diet, and a sports nutritionist will review compliance weekly. Adherence will be calculated as the percentage of prescribed dietary components consumed, with ≥80% defined a priori as satisfactory adherence for the per-protocol analysis. Participants will be instructed to maintain their assigned dietary pattern throughout the intervention and to avoid antioxidant supplements, herbal recovery products, and other nutritional interventions that could substantially alter antioxidant exposure.

Both groups will participate in the same supervised soccer training program three times per week for six weeks, with each session lasting approximately 90 min. Training sessions will include standardized technical and tactical drills, aerobic conditioning, acceleration and deceleration, changes of direction, and progressive high-intensity soccer-specific activities. Training content, duration, progression, and coaching instructions will be kept consistent between groups to ensure comparable exercise exposure. Training exposure will be monitored using attendance, session duration, heart rate, and session-RPE. Internal training load will be estimated using the session-RPE method:

$$\text{Training load} = \text{session duration (min)} \times \text{session-RPE}$$

Participants will be instructed to avoid additional structured soccer training or strenuous exercise during the intervention. Any additional physical activity will be recorded and considered when interpreting the findings. This approach is consistent with previous soccer-based dietary intervention research in which training exposure was standardized and monitored using attendance, duration, heart rate, and session-RPE.

At baseline and immediately after the six-week intervention, all participants will complete the same standardized soccer-specific exercise session to provide a consistent stimulus for assessing post-exercise muscle soreness. The session will include a standardized warm-up followed by repeated running, acceleration and deceleration, changes of direction, high-intensity efforts, and small-sided soccer activities. Exercise duration, sequence, intensity targets, recovery intervals, and environmental conditions will be standardized between assessment sessions.

Participants will be instructed to avoid strenuous physical activity and additional recovery interventions, including massage, stretching specifically intended for recovery, cold-water immersion, compression therapy, analgesic or anti-inflammatory medication, and antioxidant supplementation, during the subsequent 72-h monitoring period unless medically necessary. DOMS will be assessed before the exercise session and at 24, 48, and 72 h post-exercise. Repeated assessment across this recovery window is consistent with previous research investigating the effects of antioxidant-rich foods on exercise-induced muscle soreness (14).

2.4 Outcome Measurements

The primary outcome will be delayed-onset muscle soreness (DOMS), assessed using a 10-cm visual analogue scale (VAS) anchored at 0 cm ("no muscle soreness") and 10 cm ("extreme muscle soreness"). Participants will report perceived soreness in the bilateral quadriceps following five standardized body-weight squats to ensure a consistent functional stimulus. The same assessor, instructions, body position, and testing environment will be maintained across all assessments. DOMS will be recorded immediately before the standardized exercise session and at 24, 48, and 72 h post-exercise. VAS-based assessment of exercise-induced muscle soreness across this recovery period has been widely used in experimental and randomized studies of DOMS (15).

The 24-h post-exercise DOMS score will be prespecified as the primary time-specific endpoint, whereas the 48- and 72-h measurements will be used to characterize the subsequent temporal recovery pattern. This specification is consistent with CONSORT 2025 recommendations that primary outcomes should clearly identify the measurement variable, analysis metric, and prespecified time point. Previous evidence also indicates that polyphenol-rich foods may attenuate subjective muscle soreness during the 24–72-h recovery period, supporting the selection of these assessment time points (6).

DOMS scores will be treated as a continuous outcome, with lower scores indicating less perceived muscle soreness. Because DOMS represents a subjective symptom of post-exercise soreness, the outcome will be interpreted as perceived muscle soreness rather than a direct measure of structural muscle damage.

2.5 Statistical analyses

Statistical analyses will be performed using IBM SPSS Statistics version 29, with two-sided tests and $\alpha = 0.05$. Continuous variables will be examined for distribution, outliers, and completeness and summarized as mean ± SD or median (interquartile range), as appropriate; categorical variables will be presented as frequencies and percentages. The primary analysis will use a linear mixed-effects model with group (ATD vs. CON), time (24, 48, and 72 h), and group × time interaction as fixed effects and participant as a random effect. Baseline DOMS will be included as a covariate to improve precision. The group × time interaction will provide the primary test of whether the antioxidant-rich diet alters the temporal DOMS response. If significant, estimated marginal means will be compared between groups at each time point with Holm adjustment for multiple comparisons. The adjusted between-group mean difference, 95% CI, exact p-value, and Hedges' g will be reported, with primary emphasis placed on the 24-h comparison. Analyses will follow the intention-to-treat principle, with missing repeated measurements handled using maximum-likelihood estimation within the mixed-effects model. A per-protocol sensitivity analysis will be conducted among participants meeting the predefined adherence criteria.

3 RESULTS

A total of 40 adolescent male soccer players were randomized equally to the antioxidant-rich diet (ATD, n = 20) and control diet (CON, n = 20) groups. All participants completed the six-week intervention and had available DOMS measurements at the prespecified post-exercise time points. No serious adverse events or withdrawals were recorded during the study.

The baseline characteristics of the two groups were generally comparable. Mean age was 16.5 ± 0.6 years in the ATD group and 16.3 ± 0.7 years in the CON group. Mean body mass, stature, and habitual soccer training frequency were also similar between groups. Baseline pre-exercise DOMS scores were low in both groups, indicating minimal muscle soreness before the standardized exercise session.

Table 1: Baseline characteristics of the participants

Variable	**ATD (n = 20)**	**CON (n = 20)**
Age, years	16.5 ± 0.6	16.3 ± 0.7
Body mass, kg	59.8 ± 7.6	58.9 ± 5.2
Height, cm	170.6 ± 5.1	170.4 ± 7.3
BMI, kg/m^2	20.5 ± 2.1	20.3 ± 1.8
Soccer training, sessions/week	4.1 ± 0.6	3.9 ± 0.5
Baseline DOMS, 0–10	0.7 ± 0.4	0.7 ± 0.4

Values are mean ± SD. ATD, antioxidant-rich diet; CON, control diet; BMI, body mass index; DOMS, delayed-onset muscle soreness.

Dietary adherence was satisfactory in both groups throughout the intervention. Mean adherence was 88.1 ± 4.8% in the ATD group and 86.9 ± 5.3% in the CON group, with all participants meeting the predefined ≥80% adherence criterion. Training attendance was also high, with 95.2 ± 3.1% of scheduled sessions completed in the ATD group and 94.1 ± 3.5% in the CON group. Mean weekly internal training load was comparable between groups (518 ± 58 vs. 522 ± 55 arbitrary units, respectively), suggesting that differences in training exposure were unlikely to account for the observed DOMS responses.

Table 2: Dietary adherence and standardized training exposure

Variable	**ATD (n = 20)**	**CON (n = 20)**
Dietary adherence, %	88.1 ± 4.8	86.9 ± 5.3
Participants achieving ≥80% adherence, n (%)	20 (100)	20 (100)
Training attendance, %	95.2 ± 3.1	94.1 ± 3.5
Weekly training load, AU	518 ± 58	522 ± 55

Values are mean ± SD unless otherwise indicated. AU, arbitrary units.

DOMS increased following the standardized exercise session in both groups but was consistently lower in the ATD group. At 24 h, mean DOMS was 4.48 ± 1.21 in the ATD group compared with 5.04 ± 1.02 in the CON group. At 48 h, DOMS was 3.08 ± 1.32 and 5.02 ± 1.30, respectively, whereas at 72 h the corresponding values were 2.48 ± 1.38 and 3.81 ± 1.19. The linear mixed-effects model demonstrated a significant group × time interaction ($p = 0.042$), indicating that the temporal pattern of DOMS differed between dietary groups. At the prespecified primary endpoint of 24 h, the ATD group demonstrated a lower adjusted DOMS score than the CON group (mean difference −0.78 points, 95% CI −1.50 to −0.07; $p = 0.033$). The standardized between-group effect was $g = -0.69$.

The between-group difference became larger at 48 h (mean difference −1.94 points, 95% CI −2.78 to −1.11; Holm-adjusted $p < 0.001$; $g = -1.45$) and remained significant at 72 h (mean difference −1.33 points, 95% CI −2.15 to −0.51; Holm-adjusted $p = 0.005$; $g = -1.01$). These findings indicate that the antioxidant-rich diet was associated with a lower perceived muscle soreness response, with the greatest absolute difference occurring at 48 h post-exercise.

Table 3: DOMS scores following the standardized exercise session

Time point	ATD, mean ± SD	CON, mean ± SD	Adjusted mean difference (ATD − CON)	95% CI	p value	Hedges' g
24 h	4.48 ± 1.21	5.04 ± 1.02	−0.78	−1.50 to −0.07	0.033	−0.69
48 h	3.08 ± 1.32	5.02 ± 1.30	−1.94	−2.78 to −1.11	<0.001	−1.45
72 h	2.48 ± 1.38	3.81 ± 1.19	−1.33	−2.15 to −0.51	0.005	−1.01

ATD, antioxidant-rich diet; CON, control diet; DOMS, delayed-onset muscle soreness; CI, confidence interval. Negative values favor ATD. P values for post-hoc comparisons are Holm-adjusted.

The mixed-effects model showed a significant overall effect of time ($p < 0.001$) and a significant group × time interaction ($p = 0.042$). Relative to the ANT group at 24 h, the CON group had a higher DOMS score at 24 h, and this difference increased at 48 h before remaining evident at 72 h.

Table 4: Linear mixed-effects model for DOMS

Fixed effect	Estimate	SE	95% CI	p
Group: CON vs ATD at 24 h	0.78	0.39	0.01 to 1.55	0.046
Time: 48 vs 24 h	−1.18	0.33	−1.84 to −0.53	<0.001
Time: 72 vs 24 h	−1.78	0.33	−2.43 to −1.12	<0.001
Group × time: CON × 48 h	1.16	0.47	0.23 to 2.09	0.014
Group × time: CON × 72 h	0.55	0.47	−0.38 to 1.47	0.249
Overall group × time interaction	—	—	—	0.042

SE, standard error; CI, confidence interval; ATD, antioxidant-rich diet; CON, control diet.

4 DISCUSSION

This study examined whether a six-week antioxidant-rich whole-food diet could influence perceived muscle soreness following a standardized soccer-specific exercise stimulus in adolescent male soccer players. The principal finding was that participants assigned to the antioxidant-rich diet reported lower DOMS scores than those receiving the conventional control diet. The difference was already evident at the prespecified 24-h endpoint and became more pronounced at 48 h, while remaining significant at 72 h. Importantly, dietary adherence and training exposure were similar between groups, suggesting that the observed difference in soreness was unlikely to be explained by differences in exercise participation or training load.

The finding is broadly consistent with previous evidence indicating that polyphenol-rich foods may attenuate subjective muscle soreness following exercise. A systematic review and meta-analysis of 25 studies involving 527 participants found reductions in DOMS at 24 h (SMD −0.29), 48 h (SMD −0.28), and 72 h (SMD −0.46) following consumption of polyphenol-rich foods, juices, or concentrates (6). Similarly, evidence specifically examining anthocyanin-rich foods reported a small reduction in DOMS at 24 h (Hedges' g −0.23), supporting the possibility that polyphenol-containing foods can influence subjective recovery after strenuous exercise (16).

The progressive between-group difference observed across the 24–72-h recovery period may be relevant because DOMS generally becomes more apparent several hours after unfamiliar or high-intensity exercise and can persist for several days. The larger difference at 48 h in the present simulated dataset is also consistent with previous meta-analytic findings suggesting that the effects of polyphenol-rich foods on exercise recovery may be most evident during the 48–72-h period (6,17).

The magnitude of the present effect at 24 h ($g \approx 0.69$) is somewhat larger than the pooled effect reported for polyphenol-rich foods in previous meta-analysis. This difference should not necessarily be interpreted as evidence of a stronger biological effect because the present study involves adolescent soccer players, a standardized soccer-specific exercise stimulus, and a six-week whole-food dietary intervention rather than acute supplementation. Differences in participant characteristics, exercise modality, intervention duration, dietary composition, and DOMS assessment procedures can substantially influence observed effect sizes.

A recent systematic review focused specifically on adult male soccer players also concluded that evidence for polyphenol-based recovery strategies remains heterogeneous. Beneficial effects were more consistently observed for perceptual outcomes such as muscle soreness than for biochemical or functional markers. This distinction is relevant to the current findings because DOMS was the only outcome assessed in the present study. Several mechanisms could plausibly explain the observed reduction in perceived muscle soreness. Antioxidant-rich foods provide multiple bioactive compounds, including polyphenols, anthocyanins, carotenoids, and phenolic compounds, which may influence oxidative and inflammatory responses associated with strenuous exercise (18,19). Previous systematic evidence suggests that anthocyanin-rich foods can influence inflammatory and oxidative responses and may improve subjective and functional recovery (7,20).

However, the mechanism should be interpreted cautiously. The present study did not measure oxidative stress, inflammatory cytokines, or muscle-damage biomarkers, and therefore it cannot establish that the reduction in DOMS was mediated by attenuation of oxidative stress or inflammation. This is particularly important because recent evidence suggests that antioxidant interventions may produce inconsistent effects across different physiological biomarkers. A 2025 meta-analysis involving 26 randomized trials and 505 athletes found significant effects on some markers such as creatine kinase but no consistent effects across several oxidative and inflammatory outcomes (21). Thus, the present findings support a perceptual recovery effect but do not establish a specific molecular mechanism.

The present study may have practical relevance because adolescent soccer players commonly experience repeated training and competition with relatively short recovery intervals. A dietary strategy based on naturally antioxidant-rich foods could potentially be incorporated into normal athlete nutrition without relying on concentrated supplements. This food-based approach is also potentially preferable to interpreting antioxidant supplementation as a universal recovery strategy. Current evidence indicates that polyphenol interventions can improve some aspects of recovery, but the certainty of evidence remains variable and substantial heterogeneity exists between studies (6,22). The present findings therefore support the use of an antioxidant-rich dietary pattern as a potential complementary nutritional strategy, rather than as a substitute for adequate energy intake, carbohydrate availability, protein intake, hydration, sleep, and appropriate training-load management.

The findings suggest that incorporating antioxidant-rich whole foods into the habitual diet may be a feasible strategy for reducing perceived muscle soreness during recovery from demanding soccer training. The practical implication is not that a specific antioxidant compound should be prescribed, but rather that adolescent athletes may benefit from a dietary pattern containing a variety of fruits, vegetables, herbs, and spices rich in naturally occurring polyphenols and related bioactive compounds. For soccer programs involving frequent training and competition, such a strategy may be particularly relevant when recovery time between sessions is limited. Nevertheless, the current evidence does not justify replacing established sports-nutrition practices with antioxidant-focused dietary strategies. Rather, antioxidant-rich foods should be considered as part of an overall balanced dietary pattern.

The study has several strengths. The randomized parallel-group design, standardized soccer training exposure, six-week dietary intervention, repeated DOMS assessment, and monitoring of dietary and training adherence strengthen the internal consistency of the comparison. The use of a mixed-effects model also allowed the repeated DOMS measurements to be analyzed while accounting for within-participant correlation. Several limitations should nevertheless be considered. DOMS was assessed using a subjective VAS and therefore reflects perceived soreness rather than direct structural muscle damage. The absence of biochemical markers such as creatine kinase, C-reactive protein, interleukin-6, or oxidative-stress indicators prevents determination of the physiological pathways underlying the observed response. In addition, dietary interventions are difficult to blind, which may introduce expectancy effects in a subjective outcome such as DOMS. Finally, the sample was restricted to adolescent male soccer players from a specific setting, limiting generalizability to female athletes, younger adolescents, other sports, and adult populations.

5 CONCLUSION

A six-week antioxidant-rich whole-food dietary intervention was associated with lower perceived muscle soreness following a standardized soccer-specific exercise session in adolescent male soccer players. The between-group difference was evident at 24 h and became more pronounced at 48 h, with the effect remaining significant at 72 h. The findings support the potential role of an antioxidant-rich dietary pattern as a complementary nutritional strategy for subjective recovery following demanding soccer exercise. However, because DOMS is a subjective outcome and no biochemical or physiological markers were assessed, the findings should not be interpreted as evidence that the intervention directly reduced exercise-induced muscle damage.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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