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Effect of branched-chain amino acid supplementation on muscle recovery and delayed-onset muscle soreness in endurance runners: A double-blind crossover trial

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Abstract

Background: Delayed-onset muscle soreness (DOMS) is a well-recognized barrier to training consistency among endurance runners, particularly in the 24–72 hours following high-intensity or prolonged running bouts. Branched-chain amino acids (BCAAs) leucine, isoleucine, and valine have been proposed to attenuate exercise-induced muscle damage (EIMD) and accelerate recovery; however, evidence in endurance-specific contexts is inconsistent.

Objective: To assess whether six-week BCAA supplementation (10 g/day) reduces DOMS severity, creatine kinase (CK) elevation, and subjective recovery ratings compared to placebo in recreational long-distance runners.

Method: A double-blind, placebo-controlled crossover trial was conducted with 40 recreational runners (22 male, 18 female; Mage = 28.3 ± 4.6 years; weekly mileage ≥ 40 km). Following a standardized downhill running protocol, DOMS (11-point NRS scale), serum CK, and Total Quality Recovery (TQR) scores were assessed at 24, 48, and 72 hours post-exercise during each arm. A four-week washout separated the two intervention periods. SPSS v.28 was used for statistical analysis. This study uses a simulated dataset created for academic training purposes.

Key Results: BCAA supplementation significantly reduced peak DOMS scores at 48 hours (5.1 ± 1.2 vs. 6.8 ± 1.4; $p = 0.003$) and lowered CK activity at 24 hours by 22.4% relative to placebo. TQR scores were significantly higher in the BCAA condition at 72 hours post-exercise ($p = 0.018$).

Conclusion: BCAA supplementation at 10 g/day confers meaningful attenuation of DOMS and muscle damage markers in recreational endurance runners, supporting its inclusion in post-exercise nutritional strategies.

Keywords: BCAA, muscle recovery, DOMS, endurance running, sports nutrition, creatine kinase

Introduction

Endurance running exerts substantial mechanical and metabolic demands on skeletal muscle, particularly during eccentric loading phases on downhill terrain or the latter stages of prolonged exercise bouts [1]. The resultant exercise-induced muscle damage (EIMD) manifests clinically as delayed-onset muscle soreness (DOMS), peak tenderness and stiffness typically experienced between 24 and 72 hours post-exercise, accompanied by transient strength loss and elevated circulating inflammatory markers [2]. For competitive and recreational long-distance runners, DOMS represents not merely discomfort but a meaningful impediment to training consistency, session quality, and injury risk management [3].

Branched-chain amino acids (BCAAs) comprising leucine, isoleucine, and valine constitute approximately 35% of essential amino acids in muscle protein and have attracted considerable nutritional research interest for their proposed anti-catabolic and anabolic signaling functions [4]. Leucine, in particular, acts as a potent activator of the mammalian target of rapamycin complex 1 (mTORC1) pathway, which governs muscle protein synthesis — a critical upstream mediator of muscle repair following EIMD [5].

Despite the biochemical rationale, the empirical evidence base for BCAA supplementation in endurance sport recovery remains heterogeneous [6]. Studies have varied substantially in dosage (ranging from 3 to 20 g/day), timing (pre-, intra-, or post-exercise), duration (acute single-dose vs. chronic multi-week), and assessment methodology. The majority of trials with positive findings have been conducted in resistance-trained populations using strength-based outcomes, leaving a distinct evidence gap for endurance runner-specific DOMS and recovery research [7].

The present trial addresses this gap by employing an ecologically valid downhill running DOMS-induction protocol, a rigorous crossover design with washout period, and a multi-marker assessment approach encompassing subjective pain ratings, creatine kinase (CK) as an EIMD biomarker, and perceived recovery quality. The standardized daily BCAA dose of 10 g was selected to reflect commonly consumed commercial supplementation regimens while remaining within established safety parameters [8].

The findings will inform evidence-based nutritional recommendations for recreational runners, sports dietitians, and athletic coaches seeking practical recovery-optimization strategies within the framework of periodized endurance training [9].

Literature Review

The theoretical underpinning of BCAA supplementation in recovery contexts draws upon three primary mechanisms: (i) the mTORC1-mediated stimulation of muscle protein synthesis [10], (ii) the suppression of exercise-induced proteolysis through leucine-mediated inhibition of the ubiquitin-proteasome pathway [11], and (iii) the modulation of inflammatory cytokine cascades particularly interleukin-6 (IL-6) and tumour necrosis factor-alpha (TNF-α) which are critically implicated in the magnitude and duration of DOMS [12].

Howatson *et al* [13]. demonstrated in a double-blind RCT that BCAA supplementation (10 g/day for seven days before and two days after eccentric exercise) significantly attenuated markers of muscle damage and accelerated strength recovery compared to placebo in resistance-trained males. While this study remains foundational, its applicability to endurance running is constrained by the exercise modality and participant training background.

In contrast, Greer *et al* [14]. found no statistically significant differences in endurance performance or perceived exertion with acute BCAA supplementation during a cycling time trial, suggesting that performance — rather than recovery — may be less responsive to BCAA administration in aerobic exercise modalities. The distinction between performance and recovery outcomes is methodologically critical and has frequently been conflated in literature reviews.

Ra *et al* [15]. specifically examined BCAA supplementation in long-distance runners and reported moderate reductions in DOMS intensity (effect size d = 0.42) alongside significant decreases in serum CK and myoglobin, biological markers of sarcolemma disruption. However, this study employed a higher dose (20 g/day) without a crossover design, limiting internal validity.

The role of protein completeness in recovery optimization deserves methodological consideration. Jackman *et al* [16]. argued that isolated BCAA supplementation is biochemically inferior to complete protein sources (e.g., whey) for stimulating muscle protein synthesis, given the necessity of all essential amino acids for maximal mTORC1 activation. This perspective has informed recent meta-analyses [17] suggesting that BCAA's efficacy may be most pronounced when dietary protein intake is below recommended thresholds — a common occurrence in recreational athletes.

A persistent research gap concerns the dose-dependent relationship between BCAA supplementation and DOMS in running-specific contexts, the differential response between male and female athletes, and the interaction between supplementation and habitual dietary protein intake. The present study is uniquely positioned to address the first two of these gaps within a well-controlled crossover framework.

Methodology

1. Research design

A double-blind, placebo-controlled crossover design with a four-week washout period was employed. Participants and investigators administering assessments were blinded to supplement allocation throughout the trial.

2. Participants

Forty recreational long-distance runners (22 male, 18 female; Mage = 28.3 ± 4.6 years; running ≥ 40 km/week for ≥ 1 year) were recruited via running club networks. Exclusion criteria included current musculoskeletal injury, amino acid supplementation within 30 days, and dietary protein intake > 1.8 g/kg/day (assessed by 4-day food diary).

3. Supplementation protocol

Participants consumed 10 g of BCAA powder (2:1:1 ratio of leucine: isoleucine: valine) or matched isocaloric placebo (maltodextrin), dissolved in 250 mL water, within 30 minutes post-exercise and on non-training days, for six weeks per condition.

4. DOMS induction

A standardized downhill treadmill running protocol (30 minutes at 12% decline, 70% VO_2max) was performed at the end of each six-week supplementation arm to induce controlled EIMD. This protocol has been validated in previous research [18] for producing reproducible DOMS without injury risk.

5. Outcome measures

(i) DOMS: Assessed via visual analogue scale (0–10 NRS) at rest and upon palpation of the quadriceps at 24, 48, and 72 hours post-protocol. (ii) Serum CK: Fasted venous blood samples were drawn at 0, 24, 48, and 72 hours for CK activity analysis by automated colorimetric assay. (iii) Total Quality Recovery (TQR): Validated 6–20 Borg-type scale assessing perceived recovery completeness.

6. Statistical analysis

Linear mixed-effects models were applied using IBM SPSS v.28 with time, supplement condition, and sex as fixed effects. Bonferroni-corrected pairwise comparisons were performed for time-point analyses. Cohen's d was computed for between-condition effect sizes.

Note: This study uses a simulated dataset created for academic training purposes.

Results and Discussion

1. DOMS Scores Across Time Points

Table 1: DOMS Scores (0–10 NRS) at 24, 48, and 72 Hours Post-Exercise

Time Point	BCAA Mean ± SD	Placebo Mean ± SD	Difference	p-value
24 Hours	4.3 ± 1.1	5.6 ± 1.3	−1.3	0.021*
48 Hours	5.1 ± 1.2	6.8 ± 1.4	−1.7	0.003**
72 Hours	3.2 ± 1.0	4.9 ± 1.2	−1.7	0.001**

Source: Simulated training dataset (2026). *p < 0.05; **p < 0.01 (mixed-effects model)

DOMS scores were significantly lower in the BCAA condition at all three time points. The 48-hour time point produced the largest between-condition difference (Δ = −1.7 points, Cohen's d = 0.64), consistent with peak inflammatory activity and the characteristic temporal pattern of DOMS [20]. These findings replicate and extend previous work by Ra *et al* [15]. into the recreational running population.

2. Creatine Kinase Activity

Table 2: Serum Creatine Kinase Activity (U/L) by Condition and Time

Time Point	BCAA (U/L)	Placebo (U/L)	% Reduction	p-value
Baseline (0h)	112 ± 28	115 ± 31	—	0.74 (ns)
24 Hours	381 ± 94	491 ± 112	22.4%	0.008**
48 Hours	298 ± 78	402 ± 99	25.9%	0.004**
72 Hours	189 ± 55	274 ± 72	31.0%	0.002**

Source: Simulated training dataset (2026). ns = not significant; **p < 0.01

Creatine kinase, a biomarker of sarcolemma permeability and myofibrillar disruption, was significantly attenuated in the BCAA condition across all post-exercise time points.

The progressive reduction in the between-condition percentage difference from 22.4% at 24 hours to 31.0% at 72 hours suggests that BCAAs may accelerate the resolution of EIMD rather than simply blunting the initial inflammatory response.

Table 3: Total Quality Recovery (TQR) Scores by Condition and Time

Time Point	BCAA TQR	Placebo TQR	Cohen's d	p-value
24 Hours	11.4 ± 2.1	10.1 ± 2.3	0.33	0.071 (ns)
48 Hours	13.2 ± 2.4	11.6 ± 2.2	0.47	0.038*
72 Hours	15.8 ± 2.0	13.9 ± 2.1	0.54	0.018*

Source: Simulated training dataset (2026). *p < 0.05; ns = not significant

Perceived recovery quality (TQR) reached statistical significance in the BCAA condition by 48 hours and was most pronounced at 72 hours ($p = 0.018$, $d = 0.54$). This temporal lag — whereby objective CK reductions preceded subjective recovery improvements — is consistent with the known dissociation between biochemical muscle damage markers and the perceptual experience of recovery [21].

Conclusion

This double-blind crossover trial demonstrates that six weeks of BCAA supplementation at 10 g/day significantly attenuates DOMS severity, reduces serum creatine kinase activity, and improves perceived recovery quality in recreational endurance runners following an ecologically valid muscle-damaging exercise protocol. The effect sizes observed ($d = 0.47$–0.64 at peak outcome time points) are clinically meaningful in the context of recreational athletic recovery management.

These findings justify the incorporation of BCAA supplementation into post-exercise nutritional strategies for recreational endurance runners, particularly those with suboptimal dietary protein intake. Sports dietitians should consider BCAA supplementation as an adjunct to rather than a substitute for adequate habitual protein intake.

Limitations include the recreational athlete cohort (limiting generalizability to elite runners), the absence of dietary protein intake control during the trial, and the single DOMS-induction time point per arm. Future research should examine the interaction between BCAA supplementation, habitual protein intake, and sex, as well as whether similar attenuation effects are observed with longer competitive running events such as ultramarathons.

Ethical statement

This article was prepared as an original academic training document. No real participant data, real institutional datasets, or copyrighted instruments were reproduced without permission. The dataset referenced herein is explicitly simulated for educational and formatting practice purposes. All author and institution details are placeholders to be completed by the researcher.

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