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Original Scientific Article

Determining the Potential of L-Selenomethionine as a Protective Agent Against Exercise-Induced Muscle Damage

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Abstract

Background. Delayed-Onset Muscle Soreness (DOMS) is a phenomenon that arises from muscle damage following uncommon or intense eccentric exercise, with symptoms persisting for a few days. The condition is characterized by muscle pain, reduced muscle strength, limited range of motion, and general discomfort that affects performance and disrupts the exercise program.

Objectives. This study aimed to investigate the effect of Selenium supplementation on DOMS and muscle damage after performing heavy eccentric exercise.

Materials and methods. An experimental pre-post control group design was used in this study. A total of 44 male students from the Sports Science Department of the State University of Surabaya (Universitas Negeri Surabaya) were randomly and double-blindly assigned to either a selenium supplementation group (n = 22) or a placebo group (n = 22). The participants in both groups were instructed to consume one selenium or placebo capsule for 28 days. Following the 28-day supplementation period, both groups underwent a 10-set x 10-rep bench stepping-test. Delayed Onset Muscle Soreness (DOMS) and Creatine Kinase (CK) levels were assessed at 24 and 48 hours in the post-exercise phase.

Results. The findings of the study demonstrated that during the 24 to 48-hour period following heavy eccentric exercise, both groups experienced a reduction in Delayed Onset Muscle Soreness (DOMS) and CK plasma levels. However, the selenium supplementation group exhibited a significantly greater reduction in DOMS and CK levels compared to the placebo group ($p < 0.05$). This suggests that selenium supplementation may enhance the natural recovery process, rather than being solely responsible for the observed reduction in these markers.

Conclusions. In conclusion, Selenium supplementation may lower the likelihood of muscle injury following heavy eccentric exercise, as it effectively decreases plasma DOMS and CK levels in the bloodstream.

Keywords: eccentric exercise, muscle damage, inflammation, sports injured.

Introduction

Exercise-induced muscle damage (EIMD) is a physiological response that commonly occurs following unaccustomed or strenuous physical activity, particularly those involving high mechanical stress such as eccentric muscle contractions. One of the most recognizable clinical manifestations of EIMD is Delayed Onset Muscle Soreness (DOMS), a prevalent condition among athletes and physically active individuals (Ali et al., 2023). Unlike acute or immediate pain, DOMS is characterized by delayed muscular discomfort that typically begins 12–24 hours post-exercise, peaks between 24–72 hours, and gradually subsides within 5–7 days (Hotfiel et al., 2018; Kristensen et al., 2021; Zulaini et al., 2021). This condition frequently results from activities such as running, plyometrics, strength training, and other high-intensity exercises that involve eccentric contractions (Chang et al., 2021), which include muscle actions during lengthening, braking, or decelerating

movements. The underlying mechanism of EIMD involves structural disruption of muscle fibers, inflammation, oxidative stress, and subsequent repair processes. Symptoms include localized pain, stiffness, muscle tenderness, reduced range of motion, swelling, and temporary muscle weakness (Wilke & Behringer, 2021; Yoshida et al., 2022). The extent of muscle damage is influenced by factors such as exercise intensity, volume, and the predominance of eccentric loading. Understanding the mechanisms and outcomes of EIMD is essential for developing effective recovery strategies and protective interventions.

DOMS is often triggered by inflammation in the affected area due to muscle fiber damage, and it is usually assessed by tracking changes in creatine kinase and lactate dehydrogenase (LDH) levels in the bloodstream (Beba et al., 2022; Boukhris et al., 2020). Numerous reports indicate that exercise-induced muscle damage (EIMD) commonly occurs after strenuous, unaccustomed exercises, especially those involving high frequencies of eccentric contractions. Although not classified as a disease or disorder, DOMS can hinder athletes' participation in subsequent training sessions (Udani et al., 2009). The soreness and stiffness can restrict the range of motion, making it challenging for athletes to maintain proper technique and form during exercises (Rickards et al., 2021).

The specific mechanisms responsible for the damage caused by exercise have not been extensively explained (O'Malley et al., 2024). Nevertheless, prior research has shown that delayed-onset muscle damage is primarily triggered by mechanical stress, particularly eccentric muscle contractions (Markus et al., 2021). Heavy eccentric exercise has played a significant role in damaging cell membranes, leading to greater microtrauma within the muscle fibers (Tomalka, 2023). This microscopic muscle injury is initiated by mechanical disruptions to sarcomeres, which in turn cause an inflammatory response involving T-tubules, myofibrils, cytoskeletal proteins, and the sarcoplasmic reticulum (Toigo, 2023).

Several studies have focused on efforts to minimize the risk of DOMS and muscle damage (Angelopoulos et al., 2022; Anthony et al., 2021; Fedewa et al., 2019). These efforts involve the use of antioxidant supplements and other potential agents (Barker et al., 2023; McHugh et al., 1999). However, the outcomes from these studies differ, which underlines the need for additional research as an attempt to reduce the risk of DOMS and muscle damage. Taking these circumstances into account, it is crucial to explore alternative nutritional interventions that can be used to prevent DOMS and muscle damage resulting from heavy eccentric exercise. One such alternative that can be considered is L-Selenomethionine (L-Semet).

L-Semet was chosen as the intervention in this study due to its essential role as a trace element with significant antioxidant and anti-inflammatory properties (Williamson & Davison, 2020). As a key organic form of selenium, L-Semet is better absorbed and retained in the body compared to inorganic selenium compounds. It functions as a precursor for selenoproteins, playing a crucial role in mitigating oxidative stress and modulating inflammatory responses through its involvement in the glutathione peroxidase (GPx) and thioredoxin reductase (TrxR) enzyme systems (Mazloomi et al., 2021; Ringuet et al., 2021). These mechanisms are particularly relevant in the context of DOMS and EIMD, both of which are largely triggered by increased oxidative stress and inflammation following intense eccentric muscle contractions.

Previous studies have demonstrated that higher selenium levels can accelerate muscle recovery by reducing reactive oxygen species (ROS) production and inhibiting pro-inflammatory pathways, such as the NF-κB signaling cascade (Fernández-Lázaro et al., 2020; Prabhu et al., 2002). Additionally, L-Semet has been shown to contribute to maintaining cell membrane integrity, thereby minimizing exercise-induced muscle damage. Compared to other antioxidants, such as vitamins C and E, L-Semet offers a distinct advantage by interacting with the body's endogenous antioxidant defense system without impeding physiological adaptations to exercise.

The use of L-Selenomethionine (L-Semet) is anticipated to be a promising strategy for mitigating the adverse effects of intense eccentric exercise. As a natural trace element, L-Semet possesses potent anti-inflammatory properties and helps attenuate oxidative stress by suppressing the production of pro-inflammatory cytokines and reactive oxygen species. Moreover, L-Semet plays a vital role in various biological functions, including immune regulation and thyroid hormone metabolism. One of the key markers of exercise-induced muscle damage (EIMD) is the elevation of creatine kinase levels in the bloodstream (Lamb et al., 2019; Sánchez Díaz et al., 2022), which reflects sarcolemmal disruption and leakage of intracellular enzymes into the circulation (Stožer et al., 2020). Monitoring CK levels provides an objective biochemical measure of muscle damage severity.

Considering these factors, this study aims to investigate the potential of L-Selenomethionine (L-Semet) as a protective agent against exercise-induced muscle damage (EIMD), by evaluating its effectiveness in reducing delayed onset muscle soreness (DOMS) and the subsequent rise in creatine kinase (CK) levels following high-intensity eccentric exercise. The findings are expected to provide valuable insights into the role of L-Semet in enhancing muscle recovery and athletic performance.

Materials and Methods

Study Participants

This study utilized a randomized, double-blind, placebo-controlled experimental design with a pretest-posttest control group approach. A total of 44 recreationally active male students from the Sports Science Department of Universitas Negeri Surabaya participated in the study. The study aimed to evaluate the potential role of selenium supplementation in mitigating muscle soreness and damage, specifically focusing on its effects on individuals engaged in physical activity.

A power analysis using G*Power software (version 3.1.9.7) was conducted to determine the required sample size. Based on previous studies investigating the effects of antioxidant supplementation on muscle soreness and damage, we assumed an effect size of 0.8, a power of 0.80, and an alpha level of 0.05. The analysis determined a minimum of 20 participants per group to detect statistically significant differences. To account for potential dropout, the final sample size was increased to 22 participants per group (n = 44).

Participants who meet the inclusion criteria for this study are recreationally active males who engage in physical activity at least three times per week. They must be in good health,

have a normal Body Mass Index (BMI), be non-smokers, and not take any medications or dietary supplements during the study. Additionally, they must be willing to abstain from high-intensity physical activity throughout the study period.

Conversely, individuals with a history of musculoskeletal disorders or chronic injuries will be excluded. Those who are currently or have recently participated in a structured resistance training program, have used antioxidant supplements or anti-inflammatory medications within one month prior to the study, or have metabolic, cardiovascular, or neuromuscular diseases will also be ineligible. Furthermore, individuals with allergies or intolerances to selenium supplementation will not qualify for participation.

Participants were randomly assigned to either the L-Semet Group (n=22) or the Placebo Group (n = 22) using a computer-generated randomization list. Both participants and researchers involved in data collection and analysis were blinded to group assignments until the study was completed to minimize bias. The study was conducted in a double-blind manner, ensuring that neither participants nor researchers knew the group assignments until after data analysis.

Study Organization

This study was a randomized double-blind placebo-controlled experiment with a pretest-posttest control group design, aiming to assess the effectiveness of 200µg L-Selenomethionine (L-Semet) capsule supplementation for 4 weeks against DOMS and CK as markers of muscle damage following eccentric exercise. The research lasted a month, starting with an initial evaluation on the first day to determine participants' condition. Throughout the study, they were restricted from any exercise except on the experimental day.

During the screening day visit, participants filled out a physical fitness capacity form, providing details on their weekly running frequency and volume, injury and illness history, and medications used within two weeks before the study. At the first visit, both the L-Semet Group (LG) and the Placebo Group (PL) underwent baseline measurements including body weight, height, body fat percentage, physical activity, and VO_2Max. Body fat percentage was assessed using a Tanita BC-730 Bioelectrical Impedance Analyzer. VO_2Max was estimated through the multistage 20-meter shuttle run test and calculated using the Leger equation. Physical activity level was evaluated using the International Physical Activity Questionnaire (IPAQ) short form, and reported as metabolic equivalent task (MET)-minutes per week (MET-min/week).

Supplementation

The L-Semet Group (n = 22) received capsules containing 200 µg of L-Selenomethionine (L-Semet), while the Placebo Group (n = 22) received identical capsules containing 100 mg of corn starch. Both groups consumed one capsule daily with breakfast for 28 days. To minimize potential confounding variables, participants were instructed to avoid strenuous physical activity throughout the study period.

The 200 µg/day dose of L-Semet was selected based on prior research indicating its effectiveness in enhancing antioxidant enzyme activity, particularly glutathione peroxidase (GPx), without inducing toxicity (Kyrgios et al., 2019). Studies investigating selenium's impact on oxidative stress and inflammation in relation to exercise and muscle recovery have shown that doses between 200–400 µg/day can effectively reduce lipid peroxidation and enhance antioxidant capacity. Considering that the tolerable upper intake level (UL) for selenium is 400 µg/day, a 200 µg/day dose was chosen to ensure efficacy in mitigating delayed onset muscle soreness (DOMS) and reducing creatine kinase (CK) plasma levels while maintaining a safe intake threshold.

L-Selenomethionine (L-Semet) was selected due to its superior bioavailability compared to inorganic selenium forms such as selenite or selenate (Mal'tseva et al., 2022). This specific dose has been previously utilized in research examining selenium's effects on inflammation modulation and muscle recovery, supporting its application in the present study.

The L-Selenomethionine supplement used in this study was Solgar® L-Selenomethionine 100 mcg, manufactured by Solgar Inc., USA, a reputable company known for producing high-quality nutritional supplements in compliance with Good Manufacturing Practices (GMP). This product is commercially available over the counter and widely distributed in both physical and online markets. Each tablet contains 100 mcg of selenium in the bioavailable form of L-selenomethionine. Documentation confirming product quality and safety, including the Certificate of Analysis (COA) and labeling information, was obtained from the manufacturer and is available upon request. The supplement is free from gluten, dairy, soy, and artificial additives, and is suitable for vegetarians.

Exercise Protocol

After 28 days of supplementation, participants underwent damaging exercise during the second visit to assess the Exercise-Induced Muscle Damage (EIMD) effect. They performed a single bout of eccentric exercise using the Newham

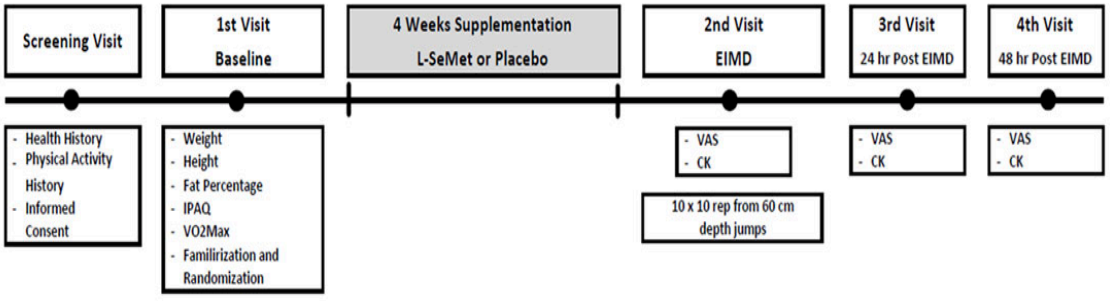

Fig. 1. Study Design

bench-stepping modification exercise protocol (Newham et al., 1983), which consists of 10 sets x 10 repetitions of bench-stepping tests with 1-minute intervals. This protocol has been proven to cause pain sensation (DOMS) in the quadriceps muscles of the leg that underwent eccentric exercise.

To assess DOMS and CK levels as muscle damage markers, participants were evaluated 24 hours (3rd visit) and 48 hours (4th visit) post-eccentric exercise. Throughout the 30-day study period, participants remained uninjured, avoided all physical activity, and were instructed not to consume anti-inflammatory drugs, treatments, or additional dietary supplements. A summary of the study design is presented in Figure 1.

This study followed ethical standards and received approval from the Health Research Ethics Committee, Faculty of Public Health, Airlangga University, and has been deemed ethically acceptable with the identity number: 104/EA/KEPK/2023.

Outcome Measure

This study used a Visual Analogue Scale (VAS) with a 100mm range to assess the level of pain sensation from DOMS. The VAS score ranged from 0mm (no pain) to 100mm (maximum tolerable pain) (Fleckenstein et al., 2021). This assessment was conducted 24 hours and 48 hours after the bench stepping test protocol to evaluate pain in the quadriceps muscle of the leg that underwent eccentric exercise. Using VAS is a common method in the literature for assessing acute exercise-induced pain.

Blood samples were collected from the cubital vein and treated with EDTA to assess plasma levels of CK. The samples were centrifuged at 3000 rpm for 15 minutes, and the resulting plasma was stored at -20°C in a freezer until analysis. CK levels were assessed 24 hours (3rd visit) and 48 hours (4th visit) post EIMD. The plasma samples were analyzed using the Glory Diagnostics (Barcelona, Spain) CK commercial ELISA kit. The assessment of CK plasma was conducted at the Institute of Tropical Disease and International Research Center Laboratory, Universitas Airlangga Indonesia, to obtain the CK plasma data.

Statistical Analysis

The normality of data distribution was assessed using the Shapiro-Wilk test. To compare VAS scores and CK plasma levels across three time points (1 hour before, 24 hours post, and 48 hours post) within each group, a repeated-measures ANOVA was performed. Additionally, a two-way ANOVA was conducted to assess the main effects of group (L-Semet vs. placebo), time (1 hour before, 24 hours post, and 48 hours post), and their interaction on VAS scores and CK plasma levels. If a significant time or interaction effect was detected, post hoc tests were conducted to identify specific differences. Independent t-tests were used to compare VAS scores and CK plasma levels between groups at each time point. All statistical analyses were performed using SPSS version 23, and data were reported as mean ± SD.

Results

Respondent Characteristic

A total of 44 students, with a mean age of 19.21 years (±0.79) and a mean BMI of 22.53 (±0.67), participated in this study. These male recreational students from the Sports Sciences Department at Universitas Negeri Surabaya voluntarily participated after providing informed consent. Participants were randomly divided into two groups: the L-Semet supplementation group and the placebo group. The mean age of the L-Semet group was 19.19 years (±0.65), while the placebo group had a mean age of 19.31 years (±0.87). Table 1 presents the baseline characteristics of both groups, including age, height, weight, BMI, fat percentage, IPAQ, and VO_2max.

The data in Table 1 confirm that both groups were comparable in terms of baseline characteristics, suggesting that any differences observed in later analyses are likely due to the effects of L-Semet supplementation rather than pre-existing variations.

Table 1. Respondent Characteristic

Variable	L-Semet Group Mean ± SD	Placebo Group Mean ± SD	p
Age (years)	19.19 ± 0.65	19.31 ± 0.87	0.130
Height (cm)	166.29 ± 4.50	167.86 ± 5.02	0.144
Weight (kg)	62.36 ±3 .52	63.43 ± 3.46	0.663
BMI (kg/m^2)	22.54 ± 0.67	22.51 ± 0.70	0.916
Fat Percentage (%)	21.35 ± 3.50	20.97 ± 3.13	0.534
IPAQ (MET-min/week)	1164.93 ± 230.26	1291.36 ± 137.0	0.432
VO_2max (mL/kg·min)	35.76 ± 4.31	37.50 ± 3.61	0.567

These baseline characteristics indicate that both groups were well-matched, ensuring fair comparisons in subsequent analyses.

Table 2 presents the Kolmogorov-Smirnov normality test results for DOMS and CK plasma levels. All p-values exceed 0.05, confirming that the data follow a normal distribution.

Table 2. Normality test result

Variable	Time Point	L-Semet Sig.	Conclusion	Placebo Sig.	Conclusion
DOMS	1-h before (Baseline)	0.137	Normal	0.117	Normal
	24-h post	0.085	Normal	0.159	Normal
	48-h post	0.200	Normal	0.135	Normal
CK	1-h before (Baseline)	0.200	Normal	0.200	Normal
	24-h post	0.200	Normal	0.200	Normal
	48-h post	0.200	Normal	0.200	Normal

The normality test results in Table 2 show that all measured variables had p-values greater than 0.05, indicating a normal distribution. This allows for the use of parametric tests in subsequent analyses.

Since all p-values exceeded 0.05, the data were considered normally distributed. Additionally, a Levene test was performed to assess homogeneity of variances, as shown in Table 3.

The results of the homogeneity test in Table 3 confirm that the variances were homogeneous across groups, meaning that statistical comparisons between the two groups can be conducted with confidence.

Table 3. Homogeneity test result. Levene test

Variable	1-h L-Semet – Placebo Sig.	24-h L-Semet – Placebo Sig.	48-h L-Semet – Placebo Sig.
DOMS	0.264	0.362	0.653
CK	0.448	0.838	0.999

The normality test (Kolmogorov-Smirnov) indicated that the data was normally distributed ($p > 0.05$), and the homogeneity test confirmed equal variances. To analyze differences in DOMS scores and CK plasma levels over time within each group, a repeated measures ANOVA with Bonferroni post-hoc correction was conducted. The Bonferroni correction was used to account for multiple comparisons and control the familywise error rate. This statistical approach was employed to determine if there was a significant decrease in DOMS and CK plasma levels over the 28-day L-Semet supplementation period compared to the placebo group.

Pain Assessment Result

Delayed onset muscle soreness (DOMS) typically occurs following intense or unfamiliar eccentric contractions and may persist for several days post-exercise. It is commonly associated with muscle damage. The intensity of DOMS was assessed in the quadriceps using the Visual Analog Scale (VAS) at 1 hour before, and at 24- and 48-hours post-exercise, as presented in Table 4.

Table 4. Pain Score Post Heavy Eccentric Exercise (VAS) (Values expressed in millimeters [mm] based on a 0–100 mm visual analog scale; values are presented as mean ± standard deviation [SD])

Group	1-h before Mean ± SD	24-h post Mean ± SD	48-h post Mean ± SD	p
L-Semet	4.50 ± 0.84	35.50 ± 1.25	21.00 ± 1.10	0.000
Placebo	4.30 ± 0.82	44.50 ± 1.14	34.66 ± 0.95	0.000

At baseline (1 hour prior to exercise), there was no statistically significant difference in DOMS scores between the L-Semet (4.50 ± 0.84 mm) and placebo groups (4.30 ± 0.82 mm; $p > 0.05$). At 24 hours post-exercise, the placebo group experienced significantly greater muscle soreness (44.50 ± 1.14 mm) compared to the L-Semet group (35.50 ± 1.25 mm; $p < 0.001$). This trend continued at 48 hours, where DOMS scores remained significantly lower in the L-Semet group (21.00 ± 1.10 mm) compared to the placebo group (34.66 ± 0.95 mm; $p < 0.001$).

To evaluate the effectiveness of L-Semet supplementation in reducing DOMS after heavy eccentric exercise, a two-way ANOVA was performed. This analysis assessed the main effects of two independent variables—group (L-Semet vs. Placebo) and time (1 hour before, 24 hours post, and 48 hours post-exercise)—on the dependent variable (DOMS scores), as well as their interaction effect.

The main effects determine whether there are significant differences in DOMS scores between groups and across time points. The interaction effect assesses whether the pattern of change in DOMS over time differs between the two groups. The results of the two-way ANOVA are presented in Table 5.

Table 5. Results of Two-Way ANOVA on DOMS Scores

Source of Variation	F	p	Significance
Group	1667.43	1.61×10^{-74}	Highly significant
Time	12998.95	1.12×10^{-146}	Highly significant
Group × Time	493.82	2.39×10^{-60}	Highly significant

The results of the two-way ANOVA indicate that there was a significant main effect of group on DOMS scores ($F = 1667.43$, $p = 1.61 \times 10^{-74}$), demonstrating a substantial difference in pain levels between the L-Semet and placebo groups. Additionally, there was a significant main effect of time ($F = 12998.95$, $p = 1.12 \times 10^{-146}$), indicating that DOMS scores changed significantly at different time points (1 hour before, 24 hours post, and 48 hours post-exercise).

Moreover, the analysis revealed a significant interaction effect between group and time ($F = 493.82$, $p = 2.39 \times 10^{-60}$). This interaction suggests that the pattern of change in DOMS scores over time differed significantly between the L-Semet and placebo groups, implying that the effectiveness of L-Semet in reducing DOMS varied at different post-exercise time points.

These findings demonstrate that L-Semet supplementation significantly reduces DOMS compared to the placebo, particularly at the post-exercise time points, indicating that the supplement's effectiveness is influenced by the duration of recovery.

Muscle Damage Assessment Result

Creatine Kinase (CK) is an enzyme released into the bloodstream when muscle fibers are damaged, commonly observed after intense or unfamiliar eccentric exercise. Elevated CK levels are widely used as a biomarker for muscle damage and recovery. In this study, CK plasma levels were measured at baseline (1 hour before exercise), as well as at 24 hours and 48 hours post-exercise, to assess the extent of muscle damage and recovery following L-Semet supplementation. The results are presented in Table 6.

Table 6. CK Plasma Levels Across Time Points (Values expressed in International Units per Liter [IU/L]; values are presented as mean ± standard deviation [SD])

Group	1-h before Mean ± SD	24-h post Mean ± SD	48-h post Mean ± SD	p
L-Semet (IU/L)	82.16 ± 4.58	349.16 ± 27.19	243.56 ± 17.81	0.000
Placebo (IU/L)	80.22 ± 0.64	354.81 ± 56.34	307.68 ± 41.52	0.000

At baseline (1 hour prior to exercise), CK levels were comparable between the L-Semet (82.16 ± 4.58 IU/L) and placebo groups (80.22 ± 0.64 IU/L; $p > 0.05$). At 24 hours post-exercise, CK levels peaked significantly in both groups, with the placebo group showing slightly higher levels (354.81 ± 56.34 IU/L) compared to the L-Semet group (349.16 ± 27.19 IU/L; $p < 0.001$). By 48 hours post-exercise, CK levels decreased in both groups; however, the L-Semet group exhibited a significantly greater reduction (243.56 ± 17.81 IU/L) compared to the placebo group (307.68 ± 41.52 IU/L; $p < 0.001$).

To assess the effects of L-Semet supplementation on CK levels following heavy eccentric exercise, a two-way ANOVA

was performed. This analysis examined the main effects of two independent variables—group (L-Semet vs. Placebo) and time (1 hour before, 24 hours post, and 48 hours post-exercise)—on the dependent variable (CK levels), as well as their interaction effect. The aim was to determine whether there were significant differences in CK levels between the two groups at the different time points, and whether the effect of time varied across groups. The results of the two-way ANOVA are presented in Table 7.

Table 7. Results of Two-Way ANOVA on CK Level

Source of Variation	F	p	Significance
Group	16.50	8.50×10^{-5}	Significant
Time	815.59	$< 1.00 \times 10^{-5}$	Significant
Group × Time	493.82	3.27×10^{-6}	Significant

The results of the two-way ANOVA indicate that there was a significant main effect of group on CK levels ($F = 16.50$, $p = 8.50 \times 10^{-5}$), demonstrating a substantial difference in CK concentrations between the L-Semet and placebo groups. Additionally, there was a significant main effect of time ($F = 815.59$, $p < 1.00 \times 10^{-5}$), indicating that CK levels changed significantly across the three time points (1 hour before, 24 hours post, and 48 hours post-exercise).

Furthermore, the analysis revealed a significant interaction effect between group and time ($F = 13.99$, $p = 3.27 \times 10^{-6}$). This interaction suggests that the pattern of change in CK levels over time differed significantly between the L-Semet and placebo groups, implying that the effectiveness of L-Semet supplementation in reducing CK levels varied at different post-exercise time points.

These findings demonstrate that L-Semet supplementation significantly reduces CK levels compared to the placebo, particularly at post-exercise time points, indicating that the supplement's effectiveness in attenuating muscle damage is influenced by the duration of the recovery period.

Discussion

Engaging in high-intensity eccentric exercise is well known to cause exercise-induced muscle damage (EIMD), leading to symptoms such as muscle soreness, stiffness, and reduced range of motion, ultimately affecting muscle force production (Martínez-Ferrán et al., 2022). One of the most common manifestations of EIMD is Delayed Onset Muscle Soreness (DOMS), which affects both elite and novice athletes, particularly after unaccustomed eccentric exercise (Chang et al., 2021; Fleckenstein et al., 2021). DOMS is characterized by muscle pain resulting from micro-injury events and has been associated with increased oxidative stress and inflammation (Sara, 2021). The damage induced by eccentric contractions is hypothesized to result from the simultaneous stretching and contracting of muscle fibers, causing structural disruption in Z-disks and myofibrils (Bontemps et al., 2020; Qian et al., 2023).

EIMD occurs primarily due to mechanical stress and metabolic disturbances (Tanabe et al., 2021). The repeated eccentric contractions lead to excessive strain on muscle fibers, particularly in the sarcomere structure, causing mechanical tearing of actin and myosin filaments (Stožer et al., 2020). Additionally, the disruption of sarcolemma integrity results in calcium influx into the cytoplasm, activating proteolytic enzymes such as calpains and caspases, which further degrade muscle proteins and exacerbate cellular damage (Cordingley et al., 2022). This process triggers an inflammatory response characterized by the release of pro-inflammatory cytokines such as IL-6, TNF-α, and IL-1β, which recruit immune cells like neutrophils and macrophages to the damaged tissue (Hotfiel et al., 2018). While this immune response is essential for muscle repair, excessive inflammation and oxidative stress can prolong recovery and impair muscle function (de Sousa et al., 2021).

Athletes frequently experience DOMS, which can hinder performance and muscle recovery (Angelopoulos et al., 2022). L-Selenomethionine (L-Semet) supplementation has the potential to accelerate post-exercise recovery and reduce muscle soreness, enabling individuals who regularly perform eccentric exercises to maintain performance levels. This study aimed to investigate the effects of L-Semet supplementation on muscle soreness and recovery following eccentric exercise.

The results of the pain score assessment of DOMS using the VAS indicated that at baseline (1 hour before exercise), there was no statistically significant difference in pain levels between the L-Semet (4.50 ± 0.84 mm) and placebo groups (4.30 ± 0.82 mm; $p > 0.05$). However, following eccentric exercise, the placebo group experienced a significantly greater increase in muscle soreness compared to the L-Semet group. Over time, the pain levels in the L-Semet group decreased more rapidly, indicating that selenium supplementation effectively reduces muscle soreness and accelerates recovery. This finding suggests that L-Semet may help mitigate the negative effects of eccentric exercise on muscle function, potentially allowing for more consistent training adaptations.

Similarly, the CK plasma analysis demonstrated that both groups exhibited a substantial increase in CK levels following exercise, indicative of muscle damage. However, during the recovery phase, CK levels declined more significantly in the L-Semet group compared to the placebo group. This suggests that L-Semet supplementation plays a role in mitigating muscle damage and promoting faster muscle recovery. However, compared to previous studies, the reduction in CK levels observed in this study was relatively modest, which may indicate a dose-dependent response or the influence of individual baseline L-Semet levels.

Statistical analyses further confirmed the significant differences between time points, supporting the hypothesis that L-Semet supplementation aids in muscle recovery. These findings align with previous research suggesting that L-Semet's antioxidant and anti-inflammatory properties contribute to muscle protection and faster recovery (Fernández-Lázaro et al., 2020; Khazdouz et al., 2023). Selenium is known to enhance endogenous antioxidant defense mechanisms by activating the Nrf2 pathway and modulating the inflammatory response through NF-κB inhibition (Wang et al., 2022; Zhao et al., 2021). This dual action helps protect muscle tissues from oxidative stress while maintaining essential physiological adaptations to exercise.

Eccentric exercise significantly increases mitochondrial activity and oxygen consumption, leading to elevated ROS production (Irawan et al., 2022; Jakubczyk et al.,

2020). While moderate ROS production is necessary for cell signaling and adaptation, excessive ROS levels can overwhelm endogenous antioxidant defenses, resulting in muscle damage and delayed recovery (Arazi et al., 2021; Thirupathi et al., 2021). The balance between oxidative stress and adaptive responses is crucial, as excessive antioxidant supplementation may blunt beneficial training adaptations (Zachariah et al., 2021). Future studies should explore whether L-Semet supplementation affects long-term muscle adaptation to exercise.

Athletes commonly use antioxidant supplementation to combat oxidative stress and reduce exercise-induced fatigue (Botek et al., 2020). Previous studies have shown that selenium supplementation can counteract oxidative stress induced by acute exercise, such as in swimming-induced muscle damage in rats (Akil et al., 2011; Hadrup et al., 2016). Consistent with these findings, our study demonstrated that bench-stepping exercise significantly increased CK plasma levels, indicating muscle damage in both groups. However, 28 days of L-Semet supplementation resulted in a significantly greater reduction in CK levels and DOMS ($p < 0.05$) compared to the placebo group, highlighting its potential role in mitigating exercise-induced muscle damage.

The results of this study support previous findings that L-Semet plays a role in reducing oxidative stress and inflammation following exercise (Cordingley et al., 2022; de Salazar et al., 2020). However, some prior studies have reported a greater reduction in CK plasma levels, possibly due to variations in dosage and supplementation duration. For example, Fernández-Lázaro found that selenium supplementation at higher doses (300–400 μg/day) significantly reduced CK plasma levels and accelerated recovery after eccentric exercise (Fernández-Lázaro et al., 2020). The difference in findings may be attributed to variations in dosage and supplementation duration, as this study used a 200 μg/day dose for 28 days. Additionally, factors such as baseline selenium status and differences in exercise protocols could also contribute to the discrepancies in results. Assessing baseline selenium levels in future studies could help clarify its role in muscle recovery.

Moreover, a study by Wesolowski et al. reported that selenium supplementation enhanced glutathione peroxidase (GPx) activity more significantly in populations with selenium deficiency, whereas individuals with sufficient selenium levels exhibited a less pronounced antioxidant response (Wesolowski et al., 2022). This study did not assess baseline L-Semet levels, which could explain why the protective effects of L-Semet on CK plasma were less pronounced in participants who might have already had adequate selenium intake. Further investigation is needed to determine the extent to which baseline selenium status influences supplementation outcomes.

Another key limitation of this study is the reliance on CK plasma as the primary biomarker of muscle damage. While CK is a widely used indicator, it does not provide a comprehensive picture of the inflammatory response to exercise. Future studies should incorporate additional inflammatory markers such as IL-6, TNF-α, or CRP to better understand selenium's full impact on exercise recovery.

The findings of this study suggest that L-Semet supplementation, particularly in the form of L-Selenomethionine (200 μg/day for 28 days), may offer a viable strategy to mitigate muscle soreness and accelerate post-exercise recovery. While its effects on CK plasma levels were moderate, the significant reduction in DOMS underscores its potential benefits for athletes and recreational exercisers. However, further research is needed to determine the optimal selenium dosage and supplementation duration, as well as its interactions with other nutritional strategies in muscle recovery. Additionally, the long-term effects of selenium supplementation on muscle adaptation and performance should be explored to ensure its benefits outweigh any potential risks associated with chronic antioxidant use.

Conclusions

The present study demonstrated that L-Selenomethionine (L-Semet) supplementation for 28 days significantly reduced delayed onset muscle soreness (DOMS) and plasma creatine kinase (CK) levels following heavy eccentric exercise. These findings indicate that L-Semet may serve as an effective nutritional strategy for mitigating muscle soreness and damage, thereby promoting faster recovery in individuals undergoing strenuous physical activity.

However, the extent of the reduction in CK levels observed in this study was moderate, suggesting a potential dose-dependent response. Further investigations are needed to optimize the dosage and duration of L-Semet supplementation to maximize its recovery benefits. Additionally, since this study primarily focused on DOMS and CK as muscle damage markers, future research should incorporate other physiological and biochemical indicators to comprehensively evaluate selenium's role in muscle recovery.

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Conflict of interest

The authors declare that there is no conflict of interest.

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Визначення потенціалу L-селенометіоніну як захисного засобу проти пошкодження м'язів, спричиненого фізичними вправами

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 7 табл., 1 рис., 52 джерел.

Історія питання. Синдром відстроченого м'язового болю (СВМБ) — це явище, що виникає внаслідок пошкодження м'язів після виконання незвичних або інтенсивних ексцентричних вправ, симптоми якого зберігаються протягом декількох днів. Цей стан характеризується м'язовим болем, зниженням м'язової сили, обмеженою амплітудою рухів та загальним дискомфортом, що негативно впливає на результативність та порушує режим програми тренувань.

Мета дослідження. Мета цього дослідження полягала у вивченні впливу приймання добавок із вмістом селену на СВМБ та пошкодження м'язів після виконання інтенсивних ексцентричних вправ.

Матеріали та методи. У представленому дослідженні використовувався експериментальний перед- та постконтрольний груповий дизайн. Загалом 44 студенти чоловічої статі з факультету спортивних наук Державного університету Сурабаї (Universitas Negeri Surabaya) було рандомізовано та розподілено за принципом подвійного сліпого методу на групу, яка приймала добавки із вмістом селену (n = 22), та групу, яка отримувала плацебо (n = 22). Учасникам обох груп було дано вказівку приймати одну капсулу селену або плацебо протягом 28 днів. Після 28-денного періоду саплементації обидві групи виконали степ-тест із 10 підходами по 10 повторень. Рівні синдрому відстроченого м'язового болю (СВМБ) та креатинкінази (КК) оцінювалися через 24 та 48 годин після проведення тренувальної фази.

Результати. Результати дослідження показали, що протягом періоду від 24 до 48 годин після виконання інтенсивних ексцентричних вправ в обох групах спостерігалося зниження рівнів синдрому відстроченого м'язового болю (СВМБ) та креатинкінази (КК) в плазмі крові. Однак група, яка приймала добавки із вмістом селену, продемонструвала значне зниження рівнів СВМБ та КК порівняно з групою, яка отримувала плацебо ($p < 0,05$). Це свідчить про те, що приймання добавок із вмістом селену може сприяти покращенню природного процесу відновлення, а не виключно відповідати за відмічене зниження зазначених показників.

Висновки. Підсумовуючи, саплементація селену сприяє зниженню ймовірності травмування м'язів після виконання інтенсивних ексцентричних вправ, оскільки приймання цих добавок ефективно зменшує рівні СВМБ і КК у кровотоці.

Ключові слова: ексцентричні вправи, пошкодження м'язів, запалення, спортивні травми.

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