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Optimizing Female Rock-Climbing Performance through Royal Jelly Supplementation and Strength Training

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Abstract

Background: Including rock climbing in the Olympics has led to the development of research in this field.

Aim: The purpose of this study was to investigate the effectiveness of Royal Jelly (RJ) on the physical strength and muscle endurance of female rock climbers in an eight-week training program.

Materials and Methods: Twenty-four female rock climbers (30 ± 5 years) were randomized into three groups: physical exercise (PE), combined physical exercise and Royal Jelly (COM), and a control (CON). The training program was conducted three times a week for eight weeks. Handgrip strength, fatigue index, power index, and athletes' endurance were determined using a dynamometer device, the RAST test, the vertical Sargent jump test, and the traverse time on a 45-degree slope wall during pre- and post-tests.

Results: The results showed that the grip strength test (right hand) improved in the COM group compared with the PE and CON groups. In addition, the fatigue index results were significantly better in the COM group compared with the CON and PE groups. However, the peak power test outcomes indicated a significant improvement in both the COM and PE groups compared with the CON group.

Conclusion: According to the results of the present investigation, RJ had a significant positive impact on the performance of rock climbers.

Keywords: Royal Jelly, Handgrip Strength, Fatigue Index, Power Index, Rock Climbing

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1. Introduction

Rock climbing is a strength-based activity and a sub-discipline of mountaineering. The term encompasses several climbing sports, including sport climbing, bouldering, traditional climbing, alpine climbing, indoor climbing, and ice climbing [1]. There has been an increase in the popularity of rock climbing in recent years, especially since its inclusion in the Tokyo 2021 Olympics. Rock climbers possess whole-body strength, endurance, and flexibility owing to adaptations in fundamental physiological parameters, such as resistance to isometric fatigue and improved oxygen consumption during muscular contractions [2–4]. Because rock climbing involves sustained, intermittent isometric contractions, its primary energy supply comes from a combination of the aerobic and lactic systems, characterized by short relaxation phases and vigorous-intensity activity [5,6].

Although lactate production is much lower than in activities such as cycling and running, the anaerobic lactic system contributes more during maximal efforts lasting 20 s – 2 min, while the aerobic system plays only a secondary role [7]. Because only a small mass of active muscles—the arms and forearms—produces lactate, elimination is inefficient during isometric contractions. Impaired reabsorption by inactive muscles and arterial blockage caused by the high forces and short relaxation periods may prevent the athlete from ascending [6,8].

The power-to-weight ratio of elite climbers can improve because of dietary restrictions. However, prolonged energy restriction may reduce performance and, more importantly, threaten health; therefore, appropriate nutrition is critical for successful climbing [5]. Safe, legal, and effective nutritional supplements—including caffeine, creatine, milk protein, and beta-alanine—may enhance climbing performance by providing the required energy and specific prompts [9,10]. Previous studies have shown that caffeine, a stimulant, enhances resistance capacity during fatigue. Beyond its adenosine-receptor–blocking action, caffeine also improves neuromuscular function and reduces perceived exertion during exercise [9].

Royal jelly (RJ), a controversial dietary supplement, is a secretion of the cephalic glands of young worker bees. It is a complex blend of macronutrients, micronutrients, and antioxidants, consisting of water (60–70%), proteins (9–18%), carbohydrates (7–18%), and lipids (3–8%). RJ also contains polyphenols; vitamins such as riboflavin, thiamine, niacin, folic acid, biotin, and pyridoxine, with smaller amounts of vitamins C, D, A, and E; and minerals (0.8–3%) that include calcium, phosphorus, potassium, sulfur, iron, copper, and selenium [11,12]. The essential proteins, amino acids, and minerals in RJ can significantly promote muscle development and energy production in athletes. Vitamins participate in many biological and biochemical processes, including protein synthesis and antioxidant activity. Previous studies indicate that simultaneous intake of RJ and ubiquinone-10 can improve training effectiveness by modulating athletes' heart-rate variability [13] and enhanced high-intensity interval training (HIIT) in swimmers [14].

To date, no studies have evaluated the effect of royal jelly consumption on rock-climbing performance. Therefore, this study investigated the combined impact of royal jelly, as a legal and nutritious dietary supplement, with intensive endurance and strength training on the field-test performance of female rock climbers.

2. Methods and Materials

2.1. Participation

Twenty-four female intermediate climbers, aged 25–35 years and with comparable climbing performance, were recruited through convenience sampling. All participants underwent health screening, received a comprehensive explanation of the testing procedures, objectives, and possible risks, and signed an informed-consent form before the study began. The investigation was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee [15]. All climbers were instructed to avoid supplements, strenuous exercise, and medications during the month preceding the study. All participants were healthy and free of chronic diseases that could influence supplement intake or study outcomes.

2.2. Instrument

2.2.1. Isometric grip strength

Athletes' right and left isometric grip strength (indicator of overall upper-body strength) was measured using a dynamometer, the Saehan medical handgrip dynamometer (Model SH5001, Instrument Company Korea).

2.2.2. Lower-body explosive power

The explosive power index without lactic acid was also measured and evaluated using the Sargent jump test in both the pre-test and post-test phases. For this purpose, the maximum vertical height achieved by athletes before jumping was compared with the highest possible point subjects touched during a countermovement jump.

2.2.3. Fatigue index and peak power

The Running-based Anaerobic Sprint Test (RAST) was used to estimate and measure the athletes' fatigue index during both the pre-test and post-test. For this purpose, each athlete's body mass was recorded before testing. Subsequently, every subject completed a warm-up of at least 7 min. The RAST protocol consisted of six consecutive 35-m maximal sprints, each separated by a minimum 10-s rest. Immediately after each rest period, the athlete sprinted back over the same 35-m course. The time for every sprint was recorded with maximum precision to calculate anaerobic power and the fatigue index by means of Equations 1 and 2 [16–18];

Peak Power = Weight × 1225 / Time ^{3} (1)

Fatigue = maximum power-minimum power / total time (2)

2.2.4. Muscular endurance

Muscular endurance was examined by Traverse on a wall with a 45-degree slope using a Stopwatch chronometer (Model XL-5853).

2.3. Procedure

After providing informed consent, all participants completed baseline tests for handgrip strength, power index with and without lactic acid, fatigue index, and endurance. Based on these results, they were assigned to three comparable groups: (1) Physical Exercise Intervention (PE), (2) Combined Physical Exercise and Royal Jelly (COM), and (3) Control (CON). Each group was assessed separately in a climate-controlled laboratory under identical conditions. One day after the final intervention session, the participants returned for the post-test evaluation.

Intervention

Intervention- Exercise protocol

The PE intervention consisted of an 8-week, climbing-specific exercise program with 24 sessions (three sessions per week, structured by sets rather than time). Sessions were conducted in three different gyms by the same professional coach, assisted by two helpers, and took place immediately after the regular climbing practice.

The PE protocol comprised: (1) warm-up (20 min); (2) hanging with a stretched arm (40 s, 10 sets); (3) pull-ups (30 s, 2–3 sets); (4) lying side hip raises (2 sets, 15 reps); (5) push-ups (2 sets, 10 reps); (6) Superman exercise (2 sets, 8 reps); (7) knee crunches (2 sets, 20 reps); (8) indoor bouldering on a 30-hold trail on a 45° slope wall (2 sets, 2 min); followed by a cool-down. This protocol was performed twice per week [7].

Intervention- Exercise protocol - Supplement

Participants in the COM group ingested a 1000 mg royal jelly capsule 40 minutes before each exercise session. The capsules were supplied by Rasa Pharmed (Marny Co., Spain) and are approved by PEFC (Geneva, Switzerland) and the Iran Food and Drug Organization. The exercise protocol for the COM group was identical to that used in the PE group.

Control

Athletes in the CON group received no intervention beyond their usual climbing practice and were instructed to maintain their daily routines without engaging in any additional exercise programs.

2.4. Statistic

Data were analyzed with RStudio (v 4.1.2) using the ggpubr (v 0.6.0) and rstatix (v 0.7.2) packages. Statistical significance was set at $P \leq 0.05$, and results are presented as mean (M) ± standard deviation (SD). Normality was assessed with the Shapiro–Wilk test and Q–Q plots, as recommended in previous studies [1,3]. A mixed ANOVA was employed to examine both within- and between-group differences. This analysis assesses interactions between independent and dependent variables and the main effects of each factor. The findings clarify how these variables relate to and influence the outcome measures. When the data were not normally distributed, a robust ANOVA was applied.

3. Results

Descriptive statistics for all tests are presented in Table 1.

Table 1. Pre- and post-training performance parameters resulted from statistics analysis

	Pre-Test [M (SD)]			Post-Test [M (SD)]		
	PE (n = 8)	COM (n = 8)	CON (n = 8)	PE (n = 8)	COM (n = 8)	CON (n = 8)
Isometric grip strength (right hand)	28.875 ± 1.95	30.75 ± 3.57	28.25 ± 2.81	31.25 ± 1.48	37 ± 3.38	29.25 ± 1.48
Isometric grip strength (left hand)	25.125 ± 2.58	26.875 ± 3.22	25.5 ± 2.39	29.25 ± 3.8	30.25 ± 2.81	26.75 ± 1.48
Peak power	298.875 ± 25.68	297.12 ± 13.27	283.75 ± 22.16	373.5 ± 42.66	502.25 ± 12.26	297.50 ± 21.92
Fatigue index	4.2725 ± .68	4.0162 ± .76	4.06375 ± .53	5.79375 ± .67	7.8525 ± .79	5.36 ± .92
Muscular endurance	265 ± 63.91	212.12 ± 69.03	225.5 ± 82.09	291.5 ± 70.49	326.25 ± 86.59	230.25 ± 82.34
Lower-body explosive power	43.125 ± 9.26	46.25 ± 8.98	46.625 ± 8.70	50 ± 10.75	63.25 ± 8.89	48.25 ± 7.66

3.1. Lower-body explosive power

The mixed ANOVA reveals a significant main effect of time ($F(1, 21) = 138.6$, $p < 0.001$, $\eta^2 = 0.2$), indicating that there is a significant difference in scores between the pre and post-time points across all groups. There is no significant main effect of group ($F(2, 21) = 2.03$, $p = 0.156$, $\eta^2 = 0.16$), suggesting that the overall score difference between the three groups is insignificant. However, there is a significant interaction effect between group and time ($F(2, 21) = 39.053$, $p < 0.001$, $\eta^2 = 0.12$), indicating that the change in scores from pre- to post-time points is different between the groups.

Pairwise comparisons between group levels at each time point revealed a significant difference in scores between the CON group and the COM group ($p = 0.01$) and between the PE group and the COM group ($p = 0.03$) at the post time point. No significant differences were found between groups at the pre-time point ($p > 0.05$). (Figure 1).

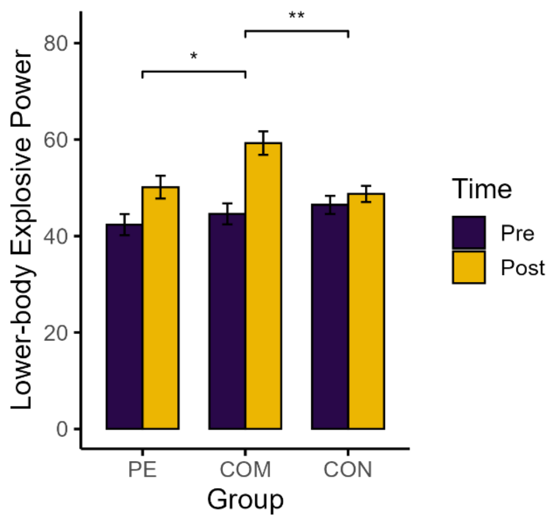

Figure 1. Pre- and post-training Power index without lactic acid in climbers. *PE* Physical Exercise, *COM* combined, *CON* control

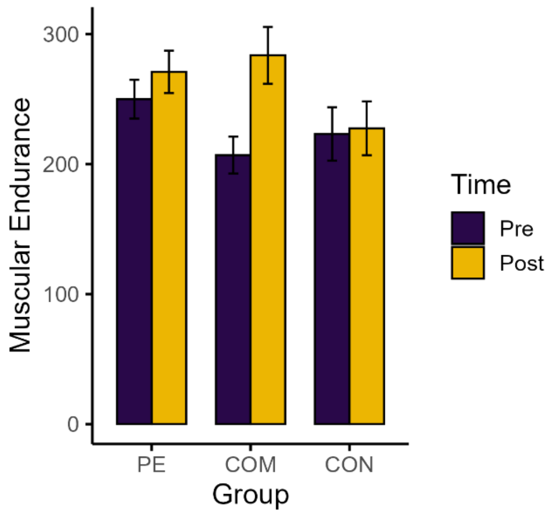

Figure. 2. Pre- and post-training power index with lactic acid in rock climbers. *PE* Physical Exercise, *COM* combined, *CON* control

3.2. *Muscular Endurance*

The main effect of time was statistically significant, with $F (1, 21) = 81.9$, $p < 0.001$, $\eta^2 = 0.80$. This suggests a significant difference in performance scores between pre-test and post-test measurements across all groups, and time accounted for approximately 80% of the variance in the dependent variable. The main effect of the group was not statistically significant, with $F (2, 21) = 1.024$, $p = 0.376$, $\eta^2 = 0.09$. This indicates no significant difference in performance scores among the three groups, and group membership accounted for only 9% of the variance in the dependent variable. The interaction effect between time and group was statistically significant, with $F (2, 21) = 38.97$, $p < 0.001$, $\eta^2 = 0.79$. This indicates that the effect of the group on performance scores differed significantly between pre-test and post-test measurements, and the interaction between time and group membership accounted for approximately 79% of the variance in the dependent variable.

The post-hoc tests with Bonferroni correction found that the COM group had significantly higher performance scores than the CON group at the post-test measurement ($p = 0.03$). However, there were no significant differences in performance scores between the exercise group and the other two groups (CON group and COM group) at both pre-test and post-test measurements. These results underscore the significance of the time*group interaction, which indicates that the effect of group membership on performance scores varied depending on the time of measurement.

3.3. *Peak power*

The results suggest significant differences between the groups across time points. The ANOVA revealed a significant main effect of group ($F(2,21) = 42.058$, $p < .001$, $\eta^2 = 0.784$), time ($F(1,21) = 971.741$, $p < .001$, $\eta^2 = 0.813$), and a significant interaction between group and time ($F(2,21) = 323.532$, $p < .001$, $\eta^2 = 0.743$).

Pairwise comparisons showed that at post-test, both the PE group and COM group had significantly higher scores than the CON group, with $p < 0.001$ and $p < 0.001$, respectively. Moreover, the COM group had significantly higher scores than the PE group, with $p < 0.001$.

3.4. Fatigue index

The ANOVA table shows that both the group ($F (2, 21) = 6.675$, $p = 0.006$, $\eta^2 = 0.358$) and time ($F (1, 21) = 431.110$, $p < 0.001$, $\eta^2 = 0.719$). Additionally, the interaction effect between group and time was significant ($F = 57.751$, df = 2, 21, $p < 0.001$, $\eta^2 = 0.406$).

Further analysis was conducted to examine the effect of the group at each time point separately. The results show that the group had a significant effect on the RAST fatigue score at the post-time point ($F = 21.8$, df = 2, 21, $p < 0.001$, $\eta^2 = 0.675$) but not at the pre-time point ($F = 0.331$, df = 2, 21, $p = 0.722$, $\eta^2 = 0.031$).

Pairwise comparisons were conducted to examine the differences between group levels. The results show that the fatigue index score for the COM group at the post-time point was significantly higher than the CON group ($p = 0.001$). No significant differences were found between the CON and PE or between the PE and COM groups. No significant differences were found between any group pairs at the pre-time point (Figure 3).

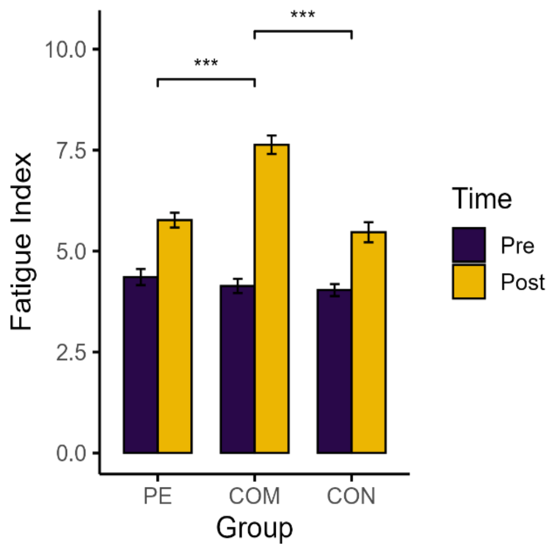

Figure 3. Pre- and post-training fatigue index in rock climbers. *PE* Physical Exercise, *COM* combined, *CON* control

3.5. Isometric grip strength (left hand)

The ANOVA revealed a statistically significant effect of time ($F(1,21) = 38.889$, $p<0.001$, $\eta2=0.235$) but no significant effect of group ($F(2,21) = 1.811$, $p=0.188$, $\eta^2=0.126$) or interaction between time and group ($F(2,21) = 3.389$, $p = 0.053$, $\eta^2 = 0.051$).

Pairwise comparisons showed that only the difference between the CON and COM groups at post-intervention was statistically significant ($p = 0.0235$) (Figure 4).

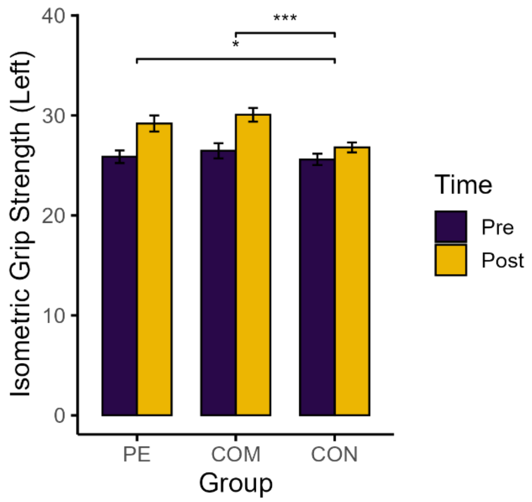

Figure 4. Pre- and post-training results for rock climbers' left grip strength. *PE* Physical Exercise, *COM* combined, *CON* control

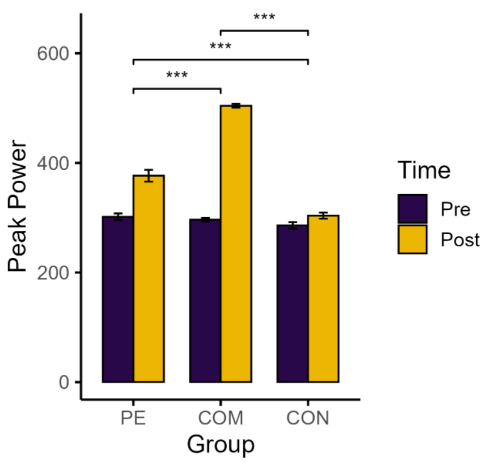

Figure 5. Pre- and post-training results for rock climbers' Peak Power. *PE* Physical Exercise, *COM* combined, *CON* control

3.6. Isometric grip strength (right hand)

Results revealed a significant main effect of group, $F(2, 21) = 9.332$, $p = 0.001$, $\eta^2 = 0.470$, indicating that group membership was associated with significant differences in handgrip strength. There was also a significant main effect of time, $F(1, 21) = 93.7$, $p < 0.001$, $\eta^2 = 0.817$, indicating that handgrip strength increased significantly from pre- to post-PE intervention. In addition, there was a significant interaction between group and time, $F(2, 21) = 22.485$, $p < 0.001$, $\eta^2 = 0.681$, suggesting that the effect of the PE intervention on handgrip strength differed significantly across the three groups. Pairwise comparisons revealed that the COM group had significantly higher post-intervention handgrip strength scores than both the CON ($p < 0.001$) and PE ($p = 0.0001$) groups, but there were no significant differences between groups pre-intervention. These findings suggest that the COM intervention was effective in improving handgrip strength compared to the other groups, and that the effect was significant and large, as indicated by the high eta-squared values (Figure 5).

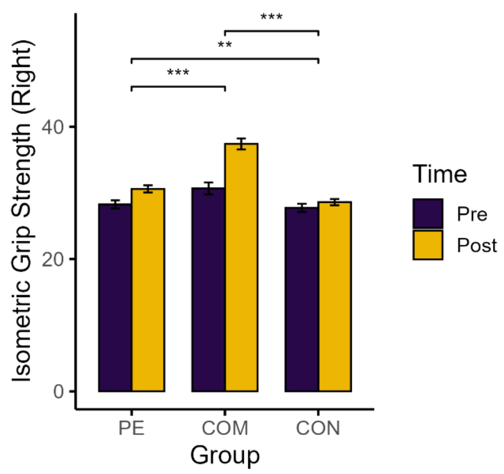

Figure 6. Pre- and post-training results for rock climbers' right grip strength. *PE* Physical Exercise, *COM* combined, *CON* control

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4. Discussion

The purpose of the present study was to examine the effect of royal jelly (RJ) supplementation combined with an eight-week exercise program on the power and strength of female rock climbers, as assessed by field tests. The primary findings showed that climbers in the COM group performed significantly better than the other two groups in the right-hand handgrip strength test and the RAST fatigue test. In the peak power test, both the COM and PE groups outperformed the CON group. These outcomes are consistent with previous research on swimmers [14] These results suggest that RJ supplementation may reduce muscle damage and lipid peroxidation after high-intensity interval training (HIIT). Previous studies have examined the effects of various supplements on muscle fatigue in many athletic contexts. For instance, a meta-analysis showed that branched-chain amino acid (BCAA) intake mitigates post-exercise muscle soreness by significantly lowering creatine kinase and lactate dehydrogenase levels [19]. Another review examined the effects of beta-alanine (BA) supplementation on performance and muscle fatigue in athletes and non-athletes. BA appeared to improve perceived exertion and biochemical markers related to fatigue; however, it did not enhance performance [20]. To date, no study has examined the effect of RJ on athletic performance. A possible mechanism is that RJ delays fatigue by enhancing blood flow to working tissues during muscle contraction. RJ reportedly has cardio vasodilatory properties because its acetylcholine content acts as a muscarinic receptor agonist. Acetylcholine induces arterial vasodilation by stimulating nitric oxide production in the vascular endothelium of healthy rats, leading to increased blood circulation in the rat's tail. These observations suggest that RJ may also improve peripheral blood flow in healthy humans[21]. RJ could also inhibit the accumulation of lactic acid in the organs being used and the resulting muscle pain by releasing nitric oxide and facilitating blood circulation [21].

Because of its rich composition of essential nutrients, RJ may accelerate recovery after training and enhance athletic performance. RJ contains a broad spectrum of vitamins, including B-complex vitamins such as pantothenic acid (B5), niacin (B3), riboflavin (B2), thiamine (B1), pyridoxine (B6), folate (B9), and small amounts of biotin (B7) and cobalamin (B12), as well as fat-soluble vitamins like vitamins A, D, and E. It also provides key minerals such as potassium, phosphorus, calcium, magnesium, iron, zinc, and copper. These nutrients support metabolic function, antioxidant defense, neuromuscular coordination, and energy production. In addition to improving physical capabilities, RJ may also enhance cognitive function, potentially benefiting climbers' decision-making under complex conditions, due to its neuroprotective vitamins and minerals that support both muscular and nervous system health. When faced with challenging conditions, making the right decision is crucial. RJ strengthens and coordinates the nerves and muscles during rock climbing, thereby improving nervous system function. Vitamins E, B6, B12, and others have demonstrated strong cognitive- and alertness-enhancing effects [22,23]. In a controlled field trial involving high-altitude mountaineers, 400 mg of vitamin E for ten weeks preserved—and eventually raised—their anaerobic threshold, while placebo climbers experienced a significant decline, demonstrating that vitamin E helps sustain sub-maximal power output under hypoxic stress [24]. A recent systematic review on vitamin D intake in athletes found that supplementation most notably enhanced aerobic capacity (as measured by VO_2max and PWC-170) and certain indicators of strength and power (including vertical jump and various upper body strength assessments). In contrast, the effect on sprint speed was less pronounced.

This study's design allowed us to assess how combining strength- and endurance-training with RJ influences improvements in rock climbers' strength and endurance. Although both exercise-training groups increased muscular strength and endurance, a substantial difference persisted between the PE and COM groups. As expected, the COM group produced the best performance, probably because of physiological adaptations that developed over time with RJ supplementation. Because higher fitness rankings and greater strength- and endurance-adaptations are associated with faster ascents, RJ may shorten climbing time and enhance overall athletic performance [4]. Rock climbing is a full-body activity that engages the upper extremities, trunk, and lower extremities; however, grip strength—an indicator of upper-body strength—shows the strongest correlation with climbing ability and sustained ascent [4,15]. This study confirmed that combined training and supplementation improved handgrip strength, underscoring the importance of RJ consumption for climber performance compared with exercise training alone.

Previous studies have demonstrated the antioxidant activity of RJ in several in-vitro models and its protective effect against oxidative stress during irradiation in rats [11,25]. After reviewing various studies, it is suggested that RJ's antioxidant properties may be due to its ability to enhance the activities of catalase, superoxide dismutase, glutathione peroxidase, and glutathione reductase. These effects are believed to account for the antioxidant capacity observed when RJ is used as a dietary supplement [26,27]. Another study showed that RJ exerted a significant protective effect by suppressing malondialdehyde production—a marker of oxidative stress—and by increasing levels of reduced glutathione, a key endogenous antioxidant. Moreover, three RJ dipeptides (Tyr–Tyr, Lys–Tyr, and Arg–Tyr), each with a C-terminal Tyr residue, displayed strong scavenging activity against hydroxyl radicals and hydrogen peroxide through hydrogen-atom donation [28]. Hence, the free-radical-scavenging activity of RJ appears to result from the combined actions of these mechanisms. During strenuous conditions and intensive exercise, antioxidant-enzyme levels fluctuate rapidly, and the accompanying rise in free radicals can impair muscle strength. Using RJ as an antioxidant may therefore support muscle function, enhance athletes' capability and quality of life, delay fatigue in rock climbers, and improve performance.

RJ has recently attracted attention as an anti-inflammatory agent because it inhibits the production of pro-inflammatory cytokines such as interleukin-1, interleukin-6, and TNF-α. Body pain—especially in the forearms—and minor muscle injuries experienced after strenuous exercise are linked to inflammatory processes [29]. RJ, owing to its potent anti-inflammatory and therapeutic properties, prevents these secondary problems after training, minimizes pain and inflammation, and facilitates recovery in rock climbers [30]. RJ, which contains fructose and glucose as its principal sugars, helps maintain healthy blood glucose levels during training and prevents athletes from becoming physically weak during competition and practice. These sugars participate in the body's energy-production and consumption cycles, a function that is crucial for rock climbers [31,32]. Rock climbers may experience joint degeneration, which RJ supplementation may help modulate.

5. Conclusion

In conclusion, the findings of this study demonstrate that RJ supplementation, combined with an eight-week strength and endurance training program, significantly enhances several key performance parameters in female rock climbers beyond training alone. Participants receiving RJ showed greater improvements in handgrip strength, anaerobic-lactic power, fatigue index, explosive power, and local muscular endurance. These benefits likely stem from RJ's nutrient-rich profile, particularly its antioxidant, anti-inflammatory, and vasodilatory properties, which may help delay fatigue and improve recovery. As rock climbers typically engage in rigorous exercise routines, the added performance gains from RJ underscore its potential as a safe, natural supplement to boost strength and endurance. Future research should explore the longer-term effects of RJ, optimal dosage strategies, and its efficacy across different athletic populations.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design. Authors have read and agreed to the published version of the manuscript.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc. Ethical approval was obtained from Payam Noor University, with the approval number: (IR.PNU.REC.1398.061).

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

References