



Effects of Royal Jelly Sports Gel on Exercise-Induced Muscle Damage: Evidence from Creatine Kinase and MDA

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ABSTRACT

Exercise-induced muscle damage (EIMD) commonly occurs after high-intensity resistance training, marked by elevated creatine kinase (CK) and malondialdehyde (MDA) levels, which reflect muscle damage and oxidative stress. Nutritional interventions such as royal jelly, known for its antioxidant and anti-inflammatory properties, may aid in post-exercise recovery. However, limited evidence exists regarding its effectiveness in sports gel form following intense resistance training. This study aimed to evaluate the effects of royal jelly-based sports gel on CK and MDA levels after high-intensity resistance exercise. This pilot randomized, single-blind crossover study included ten healthy male participants. Participants performed high-intensity squats and leg presses (80-90% of maximal capacity) in four sets with one-minute rest intervals. Baseline CK and MDA levels were measured 24 hours before consumption of either royal jelly-based sports gel or placebo. Post-intervention measurements were taken 24 hours later, followed by a washout period and crossover to the alternate treatment. The results revealed that royal jelly significantly reduced CK and MDA levels compared to placebo. At 96 hours post-exercise, CK decreased by approximately 10.3% in the royal jelly condition compared with 3.4% in placebo, while MDA decreased by 24.2% versus 6.2%, respectively. These findings provide preliminary evidence that royal jelly-based sports gel may contribute to improved recovery following high-intensity resistance exercise. However, results should be interpreted cautiously due to the small sample size.

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INTRODUCTION

The advantages of resistance training closely parallel those of aerobic exercise. Numerous prior studies have indicated that systematic and structured resistance training can enhance both muscle strength and cross-sectional area, while also improving various markers of health and functional capacity in daily activities (Abou Sawan et al., 2023; Falch et al., 2023; Maestroni et al., 2020). Resistance training offers the additional benefit of enhancing sports performance (Falch et al., 2023). Earlier studies have underscored that strength exercises can diminish acute exercise injuries by approximately one-third and injuries from overuse injuries by nearly half (Maestroni et al., 2020). Furthermore, strength training has been validated as an advanced risk reduction strategy, contingent on the dosage, and is deemed safe for both acute and excessive exercise injuries (Lauersen et al., 2018; Maestroni et al., 2020).

Despite the numerous benefits of resistance training, there exist adverse effects associated with intense and rigorous resistance training. Previous studies have concluded that high-intensity resistance training can cause muscle injury. These injuries occur not only in beginners who have just started high-intensity resistance training, but also in individuals who have not engaged in such training for a prolonged period (de Sousa Neto et al., 2022). Other studies have shown that even experienced athletes can experience muscle injury or damage due to excessive resistance training (Pearson et al., 2022). These injuries are generally caused by inadequate recovery processes (Peake, 2019) and a lack of understanding and information regarding effective recovery strategies (Wan et al., 2017).

Resistance training involving a large number of eccentric contractions can lead to metabolic stress, characterized by energy depletion and muscle damage (Allen et al., 2018; Harty et al., 2019). Exercise-induced muscle damage (EIMD), characterized by the onset of muscle pain, can adversely affect exercise performance (Wan et al., 2017). This condition causes damage to muscle fibres, leading to increased levels of creatine kinase (CK) [Engel et al., 2022; Vandusseldorp et al., 2018]. In addition, resistance training can increase oxygen consumption up to 10 times the resting level (Lushchak, 2015; Pharaoh et al., 2021). This metabolic process causes cells to produce free radicals, reflected by elevated levels of malondialdehyde (MDA) [Ilyas et al., 2017]. Several previous studies have demonstrated that CK and MDA levels rise sharply 24 hours after resistance exercise and may remain elevated for up to 72 hours (Markus et al., 2021; Tanabe et al., 2019). Creatine kinase is widely used as an indirect biochemical marker of skeletal muscle damage because strenuous resistance exercise can increase sarcolemmal permeability, allowing intracellular enzymes such as CK to leak into the bloodstream. Consequently, CK levels are commonly monitored to evaluate exercise-induced muscle damage and recovery following high-intensity resistance training (Radišić Biljak et al., 2025). In addition to structural muscle damage, high-intensity exercise also increases oxygen consumption and metabolic activity, leading to excessive production of reactive oxygen species. This process promotes lipid peroxidation of cellular membranes, which can be assessed through malondialdehyde (MDA), a widely used biomarker of oxidative stress (Spanidis et al., 2018).

Various interventions aimed at reducing the effects of resistance exercise-induced muscle damage have been carried out in recent years to promote proper and efficient recovery techniques. Several interventions, such as cold and hot water immersion (Xiao et al., 2023) and the consumption of non-herbal medicines (Duman et al., 2021), have been shown to reduce the effects of muscle damage. In addition, consumption of herbal-based ingredients such as green tea extract, caffeine, and cinnamon has been shown to reduce the effects of muscle damage (da Silva et al., 2018; Junaidi et al., 2020; Romdhani et al., 2022). However, the use of herbal-based ingredients derived from royal jelly remains very limited.

Royal jelly (RJ) functions as the main source of nutrition for larvae and is vital to the development of queen honey bees (Collazo et al., 2021; Sari et al., 2021). In addition, royal jelly (RJ) is secreted by young worker bees through their mandibular and hypopharyngeal glands. It is characterized by a yellowish-white color, soft texture, and comprises a unique composition of water, proteins, minerals, amino acids, lipids, sugars, and vitamins (Ecem Bayram et al., 2021; Mokaya et al., 2020; Ramanathan et al., 2018). Previous studies have shown that compounds with antioxidant and anti-inflammatory contents in food ingredients can reduce the adverse effects of exercise-induced muscle damage after strength training (Anugrah et al., 2024). This forms the basis for the use of royal jelly in nutritional intervention, considering that it contains amino acids and other bioactive compounds with antioxidant and anti-inflammatory activities (Botezan et al., 2023; Uthaibutra et al., 2020).

Research on the role of royal jelly in the recovery process is still limited, providing an interesting opportunity for further investigation into its potential as a food supplement for recovery. Although royal jelly has demonstrated antioxidant and anti-inflammatory properties, experimental evidence examining its efficacy in sports gel formulation following high-intensity resistance exercise remains lacking. To date, no randomized crossover studies have specifically investigated royal jelly administered in gel form for modulating biomarkers of exercise-induced muscle damage such as creatine kinase (CK) and malondialdehyde (MDA). However, the distinctive aroma and combination of sweet and sour taste of royal jelly make it less attractive for some individuals to consume directly. Therefore, to address these challenges, royal jelly is formulated into a sports gel by incorporating additional ingredients while maintaining its core nutritional composition. Thus, the objective of this study was to explore the potential impact of ingesting royal jelly-based sports gel on CK and MDA concentrations after high-intensity resistance training.

METHODS

Ethical clearance for this research was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Airlangga (Approval No. 223/EC/KEPK/FKUA/2022). The study was conducted using a randomized, single-blind crossover design and was structured as a pilot exploratory trial aimed at generating preliminary data for future adequately powered investigations. A 14-day washout period was implemented to minimize potential carryover effects; however, formal statistical testing for

carryover was not performed and should be considered in future trials. Due to the exploratory nature of this pilot study, an apriori power analysis was not conducted, and sample size was determined based on feasibility considerations.

The initial stage of the study involved coordinating administrative procedures, which encompassed securing ethical clearance, research authorization, and access to essential facilities and infrastructure from pertinent regulatory bodies, in accordance with ethical standards. The next phase entailed the selection of participants who met the predefined criteria for inclusion and exclusion. All participants were briefed on the research objectives and procedures and were provided with an informed consent form to formally indicate their willingness to participate in the study. One week prior to the commencement of the study, all participants were advised to abstain from consuming specific supplements or medications. Subsequently, on the day preceding the study, participants were also instructed to obtain adequate rest.

Participants

Ten healthy male individuals (age: 20.90 ± 0.83 years; height: 168.80 ± 2.23 cm; weight: 64.58 ± 5.30 kg; body mass index (BMI): 22.58 ± 1.33 kg/m²; body fat: $15.70 \pm 1.68\%$) were selected for this study. Inclusion criteria consisted of individuals aged between 19 and 25 years, with a normal BMI, and no prior experience in structured sports training. Participants were excluded if they were under the age of 20, exhibited abnormal blood pressure prior to high-intensity resistance training, or had medical conditions that could affect exercise performance.

Sampling Procedures

Purposive sampling was used to select participants based on criteria relevant to the study objectives. Drop-out criteria included the consumption of coffee, turmeric-containing foods, non-steroidal anti-inflammatory drugs (NSAIDs), or receiving massage therapy during the study period, as these factors may influence muscle recovery and inflammatory responses. All participants received detailed instructions regarding the study procedures and were required to sign informed consent prior to participation.

Procedures

During the first treatment period, anthropometric measurements were conducted on all participants on the first day, followed by baseline blood sampling to assess levels of creatine kinase (CK) and malondialdehyde (MDA). Subsequently, following the anthropometric measurements and blood sampling, all participants completed a 30-minute warm-up session, followed by high-intensity resistance training, comprising squat and leg press exercises performed at 80%-90% of their maximum capacity. Each exercise consisted of four sets with approximately one-minute rest intervals between sets.

At 24 hours post-exercise (Day 2), second blood sample was collected to assess CK and MDA levels. At 48 hours post-exercise (Day 3), a third blood sample was collected prior to supplementation. Following this, participants were instructed to consume either the assigned supplement or placebo. At 72 hours post-exercise (Day 4), a fourth blood sample was collected to evaluate post-intervention CK and MDA levels. At 96 hours post-exercise (day 5), a fifth and final blood sample was collected.

Following completion of the first treatment period, participants underwent a 14-day washout period before commencing the alternate supplementation condition in the second treatment period.

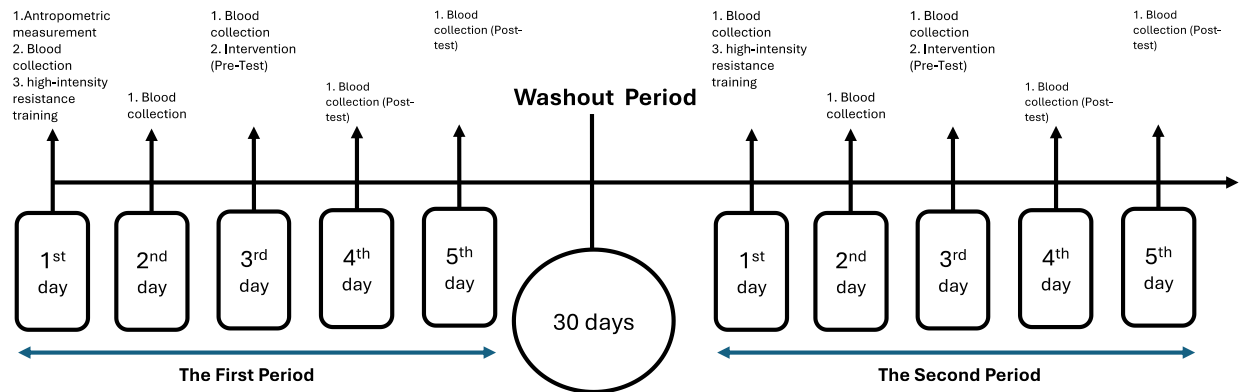


Figure 1. Experimental Design of The Randomized Single-Blind Crossover Study

Design or Data Analysis

An initial descriptive analysis was conducted to summarize the data by calculating the mean, standard deviation, and standard error for each variable. Prior to inferential testing, the distribution of the data was assessed to ensure compliance with the assumptions of parametric analysis. Data normality was evaluated using the Shapiro–Wilk test.

For variables that met the assumption of normality, comparisons between conditions were performed using a paired t-test. In addition, repeated-measures ANOVA was used as the primary analysis to evaluate time \times treatment interactions. When assumptions of sphericity or normality were violated, linear mixed-effects models were applied as an alternative approach to account for within-subject variability. For non-normally distributed data, the Wilcoxon signed-rank test was used for paired comparisons.

RESULTS

As illustrated in Figure 2, baseline creatine kinase (CK) levels did not differ between conditions. CK levels increased significantly at 24- and 48-hours post-exercise in both conditions ($p < 0.01$). A significant time \times treatment interaction was observed, with greater reductions in the royal jelly condition at 72 and 96 hours compared to placebo. Although statistically significant differences were observed at 72 and 96 hours, the magnitude of CK reduction (~ 25 U/L at 96 hours) should be interpreted within the context of normal post-exercise recovery variability.

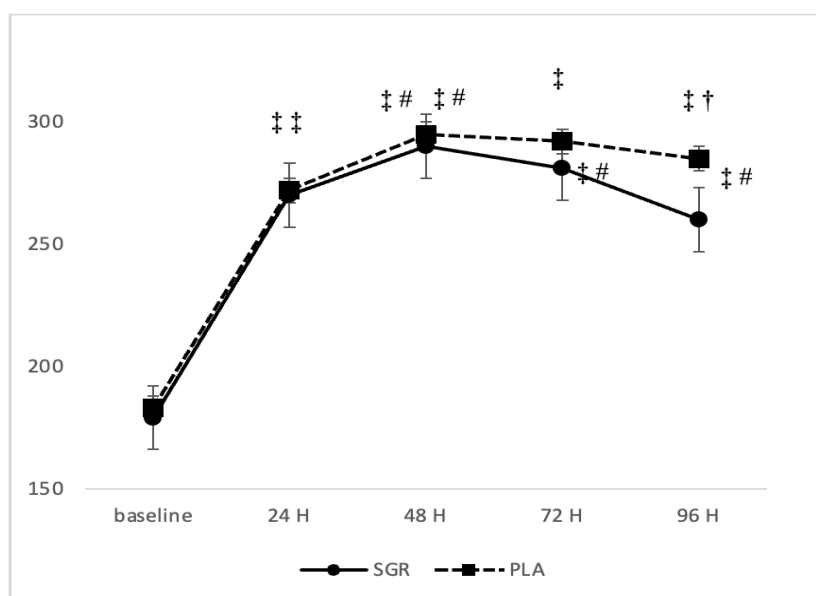


Figure 2. Creatine Kinase Levels

‡ Indicates statistical differences compared to baseline within the same group. # Indicates statistical differences compared to previous day within the same group. † Indicates statistical differences between groups.

As illustrated in Figure 3, baseline malondialdehyde (MDA) levels did not differ between conditions. MDA levels increased significantly at 24 and 48 hours following high-intensity resistance exercise in both conditions. A time × treatment interaction indicated greater reductions in the royal jelly condition at 72 and 96 hours compared to placebo. However, these differences should be interpreted within the context of the normal recovery process following high-intensity resistance exercise.

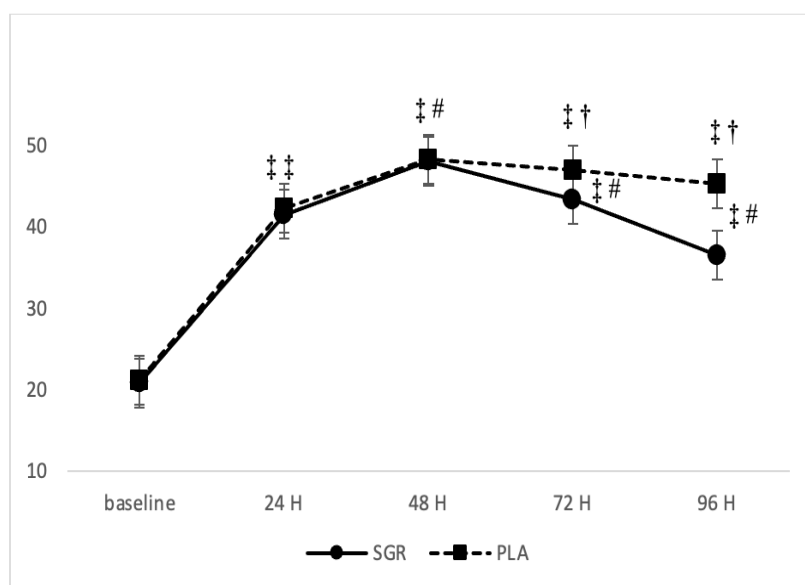


Figure 3. Malondialdehyde Levels

‡ Indicates statistical differences compared to baseline within the same group. # Indicates statistical differences compared to previous day within the same group. † Indicates statistical differences between groups.

DISCUSSION

This study aimed to evaluate the effects of ingesting a royal jelly–based sports gel on creatine kinase (CK) and malondialdehyde (MDA) levels following high-intensity resistance training in inactive individuals. To our knowledge, this study is among the limited number of investigations examining the effects of royal jelly–based sports gel consumption following high-intensity resistance exercise. Research exploring the role of royal jelly in modulating exercise-induced muscle damage (EIMD) in this context remains limited.

The findings of the present study showed that CK and MDA concentrations increased significantly at 24- and 48-hours post-exercise in both conditions compared with baseline values, indicating the occurrence of muscle damage and oxidative stress following high-intensity resistance training. These results are consistent with previous studies reporting increases in CK and MDA levels within 24 to 48 hours after intense physical activity (Devrnja & Matković, 2018; Junaidi et al., 2020) .

A significant reduction in CK levels was observed in the SGR group at 72 and 96 hours following resistance training, whereas the decrease in the placebo group was not statistically significant. The trend observed in the placebo group is consistent with previous findings indicating that CK levels naturally decline 72 to 96 hours after high-intensity resistance training, even in the absence of specific interventions (Osmond et al., 2019). These findings suggest that royal jelly–based sports gel may contribute to a faster recovery process following high-intensity resistance exercise; however, this interpretation should be made with caution given the exploratory nature of this study.

The potential mechanisms underlying these effects may be related to the bioactive components of royal jelly. Previous research has suggested that post-exercise amino acid intake can enhance muscle blood circulation, thereby improving oxygen delivery and nutrient transport to muscle tissues (Anugrah et al., 2023). The amino acid content in royal jelly may support muscle recovery by promoting protein synthesis and reducing muscle protein breakdown following intense exercise (Vandusseldorp et al., 2018).

Consistent with the trends observed in CK concentrations, similar patterns were found for MDA levels. At 72- and 96-hours post-exercise, both conditions showed a decline in MDA levels compared with the preceding time points. These findings align with previous studies reporting reductions in MDA levels 72 to 96 hours after high-intensity exercise, even without specific recovery interventions (Giechaskiel, 2020; Spanidis et al., 2018). Notably, the reduction in MDA levels was significantly greater in the SGR group compared with the placebo group.

This enhanced reduction may be attributed to the antioxidant properties of royal jelly. Bioactive compounds present in royal jelly, such as polyphenols and flavonoids, may facilitate the scavenging of reactive oxygen species (ROS), thereby reducing oxidative stress induced by high-intensity resistance training (Boyd et al., 2023; Xiao et al., 2023). These findings support

the potential role of royal jelly as an antioxidant agent in mitigating oxidative stress associated with exercise-induced muscle damage.

The observed decrease in MDA levels in the sports gel group further supports its potential role in attenuating oxidative stress. This finding is consistent with previous research demonstrating the antioxidant effects of royal jelly in individuals exposed to acute exercise-induced oxidative stress (Anugrah et al., 2024). The decrease in MDA levels following royal jelly supplementation may aid in improving recovery and enhancing the overall well-being of individuals participating in high-intensity exercise.

However, it is important to acknowledge the limitations of this study. The relatively small sample size and short duration of the intervention may limit the generalizability of the findings. In addition, individual variability in response to royal jelly supplementation may influence the outcomes, particularly factors such as genetic predisposition and baseline fitness levels. Future studies involving larger sample sizes, trained individuals, and female participants are warranted to confirm these findings and to further elucidate the mechanisms underlying the potential recovery benefits of royal jelly supplementation.

CONCLUSION

Consuming a royal jelly-based sports gel 24 hours after high-intensity resistance exercise was associated with reductions in creatine kinase (CK) and malondialdehyde (MDA) levels, suggesting its potential role in attenuating oxidative stress related to exercise-induced muscle damage. The reduction in these biomarkers may contribute to the recovery process following high-intensity exercise. This pilot study provides preliminary evidence that royal jelly-based sports gel may attenuate CK and MDA responses following high-intensity resistance exercise. However, larger randomized controlled trials are required before practical recommendations can be established.

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AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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