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Effects of Black Maca Supplementation on Isokinetic Muscle Function and Inflammation in Elite Athletes and Non-Athletes

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Abstract: This study aimed to examine the effects of black maca supplementation on isokinetic muscle function and inflammatory markers in athletes and to extend these findings to non-athletes. The study involved 24 male participants, including 16 elite athletes (soft tennis and table tennis players) and 8 non-athletes (university students). Participants consumed capsules containing 2.5 g of 100% concentrated black maca extract over a 12-week period. Isokinetic muscle performance and physical fitness (strength, muscular endurance, flexibility, power, agility, cardiovascular endurance) assessments were conducted at baseline and after 12 weeks of supplementation. Two-way within-factor ANOVA showed a significant group × time interaction for 120°/s flexor movements ($p < 0.05$). Paired *t*-tests demonstrated significant improvements in 30°/s and 120°/s extensor and flexor movements in both athlete groups ($p < 0.05$, $p < 0.01$). Similarly, significant enhancements were observed in the non-athletes for the 30°/s flexor and 120°/s extensor and flexor movements ($p < 0.01$). Furthermore, reductions in interleukin-6 (from 137.9 ± 8.8 to 132.7 ± 4.6, $p < 0.05$) and tumor necrosis factor-alpha (from 274.1 ± 13.4 to 264.2 ± 3.2, $p < 0.05$) were noted in the soft tennis group. The table tennis group also showed significant decreases in interleukin-6 (from 135.9 ± 4.7 to 131.3 ± 2.5, $p < 0.01$) and tumor necrosis factor-alpha (from 282.1 ± 19.2 to 267.0 ± 6.4, $p < 0.05$). No significant changes were observed in the non-athlete group. Black maca supplementation may enhance isokinetic muscle function in elite athletes by reducing muscle contraction fatigue and improving anti-inflammatory responses.

Keywords: black maca; isokinetic; muscle; inflammation; athletes

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1. Introduction

The interplay between recovery and fatigue significantly influences athletic performance, a topic that has captivated the sports science community for decades. Achieving an optimal balance between stress—encompassing training, competition demands, and other life stressors—and recovery is crucial for athletes to maintain peak performance levels [1]. Recent research primarily explores how nutritional interventions can enhance athletic performance [2]. Sports nutrition professionals invest considerable effort in reviewing the literature, identifying the most effective products, and determining methods to provide essential nutrients [3]. Moreover, athletes' macronutrient needs vary based on their sport, the season, and the time of year, necessitating dietary adjustments or supplementation, especially for those who exclude certain food groups, such as vegetarians, to prevent nutritional deficiencies [4].

Furthermore, research on glutamine supplementation in professional basketball players has demonstrated its potential to reduce markers of muscle injury following eccentric muscle strain [5]. In rowing, athletes who were supplemented with a combination of 0.04 g/kg/day of creatine monohydrate and 3 g/day of β-hydroxy β-methylbutyrate during a 10-week training regimen experienced a synergistic improvement in aerobic capacity [6]. Athletes frequently complement their diets with supplements to boost performance.

In recent years, maca (*Lepidium meyenii*) has gained recognition among athletes as a natural supplement due to its beneficial properties. Maca thrives at altitudes ranging from 2800 to 5000 m above sea level, with Peru being a prominent producer [7]. The primary varieties of maca are yellow, red, and black [8]. Previous research indicates that spray-dried extracts of red and black maca enhance mood, energy, and overall health status [9]. Moreover, comparative studies of the three maca ecotypes—yellow, red, and black—suggest that black maca may particularly improve stamina [10].

Many athletes use supplements to boost their performance, but these often contain artificial chemicals that can cause side effects. In contrast, maca is a natural and safe alternative that has demonstrated performance-enhancing effects in animal studies [11,12]. Despite the focus on athletes in prior research, there remains a significant gap in understanding the benefits of maca. Thus, the aim of this study is to investigate the impact of black maca consumption on isokinetic muscle function and inflammatory markers in athletes and to expand this research to include non-athletes.

2. Methods

2.1. Participation

We recruited 24 participants for this study, comprising groups of soft tennis athletes (ST, n = 8), table tennis athletes (TT, n = 8), and non-athletes, who were university students (NA, n = 8).

In addition, in accordance with the ethical standards of the Declaration of Helsinki, the study was explained to all subjects who agreed to participate to ensure a complete understanding of its purpose and the methods used. The subjects also signed an informed consent form before participation. The Kangwon National University Review Board for Human Subjects approved this study (KWNUIRB-2021-04-013-001).

The characteristics of the participants are shown in Table 1.

Table 1. The characteristics of the participants.

Variable	ST (n = 8)	TT (n = 8)	NA (n = 8)
Age (years)	21.25 ± 1.28	21.25 ± 1.49	31.63 ± 5.04
Height (cm)	176.43 ± 3.59	176.99 ± 4.88	173.61 ± 5.88
Weight (kg)	73.49 ± 12.28	69.06 ± 6.36	79.60 ± 9.44
BMI (kg/m^2)	23.59 ± 3.82	22.09 ± 3.28	26.33 ± 2.17
% fat (%)	17.01 ± 5.24	17.68 ± 4.89	26.33 ± 4.23

Values are shown as means (SD). BMI, body mass index; ST, soft tennis; TT, table tennis; NA, non-athletes.

2.2. Inflammation Factors Analysis

Fasting venous blood samples were collected from all participants at baseline and 12 weeks. Participants were required to fast for 8 h prior to blood sample collection, which occurred the following morning. They were also instructed to ensure adequate sleep and to minimize rapid movements before sampling. All samples were drawn from the umbilical vein at 08:30 AM and immediately centrifuged at 3500× g for 10 min at 4 °C, and the serum was stored at −80 °C until analysis. Plasma levels of interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) were quantified using a Ducet™ enzyme-linked immunosorbent assay (ELISA) kit (R&D systems, Minneapolis, MN, USA), following the manufacturer's guidelines, as previously described.

2.3. Measurement of Physical Fitness

Physical fitness metrics for all participants were measured at the baseline and after 12 weeks. The fitness assessments encompassed several variables: strength, muscular endurance, flexibility, power, agility, cardiovascular endurance, and isokinetic trunk muscle function.

Measurements of physical fitness were obtained using the same method employed in an earlier study [13]. Muscle strength was measured by handgrip strength and muscular endurance by sit-ups. Flexibility was measured via a sit and reach procedure, power was measured with the standing long jump, agility was measured with the 10 m run, and cardiorespiratory endurance was measured with the 20 m shuttle run. The assessments of strength, muscular endurance, flexibility, and agility were performed twice, and the highest score was recorded.

An isokinetic dynamometer (Humac Norm Testing and Rehabilitation, CSMi Medical & Solution, Stoughton, MA, USA) was employed to measure trunk muscle strength and endurance. Before collecting data, the isokinetic dynamometer was calibrated following the manufacturer's guidelines. The maximal isokinetic trunk strength and trunk endurance were each measured three times at speeds of $30^\circ/s$ and $120^\circ/s$, respectively. The trunk range of motion was set from -10° to 70° during the tests. The result is the peak torque value, corrected for body weight.

2.4. Taking Black Maca Supplementation

Each capsule comprises 2.5 g of concentrated black maca extract. The nutritional composition of black maca includes 4.95 g/100 g of fiber, 63.82 g/100 g of carbohydrates, 7.7 g/100 g of protein, 38.18 g/100 g of starch, 7.02 g/100 g of soluble sugars, 0.76 mg/100 g of riboflavin, 1000 mg/100 g of potassium, and 86 mg/100 g of iron. Fillers such as crystalline cellulose, starch, calcium stearate, and silicon dioxide are also present in the capsules. Participants were advised to ingest one capsule twice daily with water over a period of 12 weeks, specifically in the morning and evening, although exact times were not prescribed.

2.5. Statistical Analysis

All results are reported as the mean $\pm$ standard deviation. All data were analyzed using SPSS version 25.0 (SPSS Inc., Chicago, IL, USA). Initially, a one-way ANOVA evaluated differences in baseline variables across the groups. In assessing the effects of black maca supplementation on three distinct groups, soft tennis (ST), table tennis (TT), and the general population (NO), over two time points (baseline and 12 weeks), a two-way factorial ANOVA was employed. For post hoc comparisons, a Bonferroni test was applied. Subsequently, paired *t*-tests compared the baseline and 12-week performance within the same groups. Statistical significance was established at an alpha level of 0.05.

3. Results

3.1. Change in Physical Fitness

The physical fitness changes in the participants of each group are presented in Table 2.

The two-way within-factor ANOVA showed no significant group $\times$ time interactions. However, paired *t*-test analysis indicated a significant increase in sit-ups ($p < 0.05$) in the ST group and in left grip strength ($p < 0.05$) and long jump ($p < 0.05$) in the TT group after 12 weeks of black maca supplementation. No significant changes were observed in the NA group.

Table 2. Measurements of physical fitness parameters by group and time.

Variable	Time	Group			*p*-Value	Post-Hoc
		ST (n = 8) [a]	TT (n = 8) [b]	NA (n = 8) [c]		
Left grip strength (kg)	Pre	41.01 ± 4.15	38.61 ± 4.81	43.02 ± 4.11	G: 0.220 T: 0.010 G × T: 0.602	-
	Post	44.30 ± 6.72	40.50 ± 4.93 *	44.43 ± 3.40		
Right grip strength (kg)	Pre	49.33 ± 4.81	43.49 ± 5.37	46.85 ± 4.17	G: 0.092 T: 0.501 G × T: 0.950	-
	Post	49.73 ± 4.56	44.25 ± 4.85	47.10 ± 5.71		
Sit-ups (rep)	Pre	36.57 ± 8.54	45.88 ± 8.08	37.00 ± 4.52	G: 0.122 T: <0.001 G × T: 0.128	-
	Post	46.71 ± 9.27 *	48.50 ± 7.21	42.33 ± 6.41		
Sit-and-reach (cm)	Pre	1.59 ± 11.12	11.58 ± 10.11	6.37 ± 11.65	G: 0.102 T: 0.015 G × T: 0.515	-
	Post	2.90 ± 11.36	15.99 ± 6.78	9.83 ± 9.53		
Long jump (cm)	Pre	235.0 ± 7.9	223.5 ± 16.2	206.5 ± 21.8	G: <0.001 T: 0.103 G × T: 0.210	a, b > c
	Post	243.4 ± 15.9	236.0 ± 8.9 *	203.5 ± 13.6		
10 m shuttle run (s)	Pre	9.44 ± 0.74	8.72 ± 0.58	10.23 ± 0.67	G: <0.001 T: 0.002 G × T: 0.185	a, b > c
	Post	9.59 ± 0.39	9.50 ± 0.51	10.92 ± 0.56		
20 m shuttle run (rep)	Pre	60.43 ± 13.8	65.00 ± 1.77	33.33 ± 3.61	G: <0.001 T: 0.229 G × T: 0.739	a, b > c
	Post	61.14 ± 17.2	66.75 ± 6.67	37.50 ± 8.02		

Values are expressed as mean ± SD. ST, soft tennis; TT, table tennis; NA, non-athletes; G, group; T, time; G × T, group × time. Results were analyzed using a paired *t*-test: * $p < 0.05$.

3.2. Change in Isokinetic Muscle Function of Trunk

The changes in isokinetic muscle function of the trunk across each group are shown in Table 3.

Table 3. Measurements of isokinetic muscle function of trunk parameters by group and time.

Variable	Time	Group			*p*-Value	Post Hoc
		ST (n = 8) [a]	TT (n = 8) [b]	NA (n = 8) [c]		
30°/s Extensor (%BW)	Pre	280.7 ± 47.2	312.0 ± 30.9	247.3 ± 27.1	G: < 0.001 T: < 0.001 G × T: 0.075	a, b > c
	Post	355.2 ± 31.8 *	376.3 ± 32.5 *	268.0 ± 15.9		
30°/s Flexor (%BW)	Pre	261.5 ± 46.5	300.5 ± 27.8	277.1 ± 42.7	G: 0.103 T: < 0.001 G × T: 0.342	-
	Post	328.5 ± 30.4 *	354.7 ± 30.5 *	312.1 ± 25.0 **		
120°/s Extensor (%BW)	Pre	222.2 ± 56.9	227.0 ± 74.1	161.0 ± 54.6	G: 0.012 T: < 0.001 G × T: 0.186	b > c
	Post	263.3 ± 56.5 *	333.0 ± 46.4 *	212.0 ± 45.4 *		
120°/s Flexor (%BW)	Pre	304.3 ± 44.0	259.3 ± 81.0	258.1 ± 110.4	G: 0.021 T: < 0.001 G × T: 0.021	-
	Post	405.8 ± 68.7 **	403.8 ± 38.8 **	311.1 ± 88.6 **		

Values are expressed as mean ± SD. ST, soft tennis; TT, table tennis; NA, non-athletes, G, group; T, time; G × T, group × time. Results were analyzed using a paired *t*-test: * $p < 0.05$, ** $p < 0.01$.

The two-way within-factor ANOVA identified significant group × time interactions for 120°/s flexor movement ($p < 0.05$). Paired *t*-tests revealed significant increases in 30°/s and 120°/s extensor (both $p < 0.05$) and flexor movement ($p < 0.05$ for 30°/s; $p < 0.01$ for 120°/s) in both ST and TT groups. Additionally, significant improvements were seen in 30°/s flexor ($p < 0.01$) and 120°/s extensor and flexor movement (both $p < 0.01$) in the NA group after 12 weeks of supplementation.

3.3. Change in Inflammation Factors

Changes in inflammation factors for each group are shown in Figure 1.

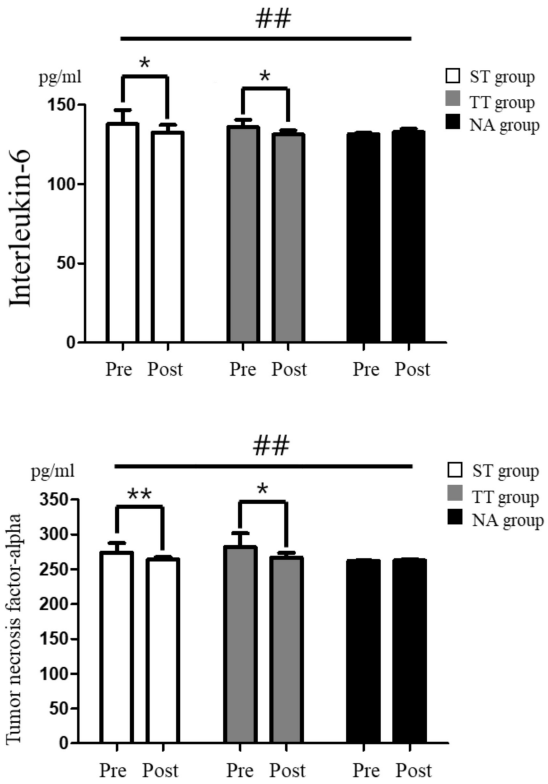

Figure 1. Measurements of inflammation factors by group and time. ST, soft tennis; TT, table tennis; NA, non-athletes. Results were analyzed using a paired *t*-test: * $p < 0.05$, ** $p < 0.01$. Group × time interaction: ## $p < 0.01$.

The two-way within-factor ANOVA demonstrated significant group × time interactions for IL-6 ($p < 0.01$) and TNF-α ($p < 0.05$). Paired *t*-test analysis revealed a significant reduction in IL-6 (from 137.9 ± 8.8 to 132.7 ± 4.6, $p < 0.05$) and TNF-α (from 274.1 ± 13.4 to 264.2 ± 3.2, $p < 0.05$) in the ST group, and in IL-6 (from 135.9 ± 4.7 to 131.3 ± 2.5, $p < 0.01$) and TNF-α (from 282.1 ± 19.2 to 267.0 ± 6.4, $p < 0.05$) in the TT group after 12 weeks of supplementation. No significant changes were noted in the NA group.

4. Discussion

In this study, we examined the effects of black maca (BM) supplementation on isokinetic muscular performance and inflammatory factors over a 12-week period. The primary outcome was a significant enhancement in trunk isokinetic muscle function among elite athletes following BM supplementation. However, no significant changes were observed in the non-athletes. Additionally, we noted reductions in the inflammatory markers IL-6 and TNF-α in elite athletes who received BM supplementation.

Isokinetic dynamometry has become the preferred method for assessing dynamic muscle function in both clinical and sports settings [14]. The widespread adoption of isokinetic devices is attributable to their validity, reliability, and the comprehensive nature of strength protocols. These devices facilitate the measurement of various muscle groups by controlling factors such as contraction type, angular velocity, range of motion, and body position, as well as the number of repetitions and sets [15]. The significance of trunk muscle function in elite athletes is exemplified by findings that cycling enhances aerobic pathways and improves the microvascular response to trunk extension exercises, whereas general exercise boosts trunk extension efficiency [16]. In sports that emphasize body rotation, such as soft tennis and table tennis, there is a notable prevalence of low back pain. This

condition correlates with limited hip internal rotation on the nondominant leg [17,18]. Accordingly, this study assessed the isokinetic muscle function of trunk muscles, revealing significant improvements in the 30°/s and 120°/s extensor and flexor functions after BM supplementation in ST and TT groups. Maca is known for its varied biological constituents, such as amino acids, amide and imidazolium alkaloids, and sugars, which differ depending on the type and concentration of active components like leucosinolates, essential oils, macamides, and macaenes. These constituents have been associated with enhanced reproductive functions, stress resistance, anti-osteoporotic, and anti-tumoral effects [19]. Specifically, in C2C12 skeletal muscle cells treated with H2O2, maca components mitigated the reduction in cell viability and the accumulation of reactive oxygen species (ROSs) [20]. Interestingly, while no changes were observed in the 30°/s extensor among non-athlete college students, variations were noted in other isokinetic variables and in the overall muscle function of the trunk among elite athletes. The study found no significant changes in physical fitness variables other than isokinetic muscle function. Notable exceptions were increases in sit-ups in the ST group and in handgrip strength and long jump in the TT group. Prior research has documented significant enhancements in cardiorespiratory endurance among fin swimming athletes, and in muscular endurance and agility among shooting and racket sports athletes following black maca supplementation [21]. In a placebo-controlled crossover study, elite handball players exhibited significant improvements in cardiorespiratory endurance [19], underlining the critical role of energy systems in competitive sports. It is noteworthy that soft tennis and table tennis players rely less on the aerobic energy system compared to athletes in other sports. Therefore, it is necessary to observe changes in the energy system (ATP-PCr, glycolytic and aerobic systems) of different athletes in different sports in response to BM supplementation.

The primary factor distinguishing an increase in cytokines following exercise from cytokine elevation due to inflammation is the elevation of TNF-α levels in inflammatory responses [22]. IL-6 is the first cytokine to increase in amount in response to exercise, with the magnitude of this increase being influenced by the type of exercise and the intensity of the effort. The underlying cause for this increase is that muscle damage from exercise serves as a potent trigger for an IL-6 response [23]. Light-intensity and regular exercise have been shown to positively influence the inflammatory response, whereas slow, prolonged exercise may impair T-lymphocyte cell function and natural killer cell activation, potentially disrupting cytokine balance and adversely affecting the inflammatory response [24,25]. High-intensity and long-duration exercise routines, typical of athletes who train regularly, can lead to increased immune and inflammatory responses that may negatively impact performance. This study demonstrated that 12 weeks of black maca supplementation significantly reduced IL-6 and TNF-α levels in the ST and TT groups, with no notable changes in the NA group. IL-6 typically binds to a cell surface receptor in classical signaling, the main pathway during exercise, whereas in trans signaling, IL-6 binds to a soluble version of the receptor, forming a complex with a longer half-life capable of signaling in all cell types. Trans signaling primarily drives the inflammatory actions of IL-6 and is a significant mechanism in disease pathology [26]. In this context, athletes' BMI percentiles showed an inverse correlation with increases in IL-6 and TNF-α, reflecting a shift toward a more inflammatory cytokine profile [27]. Overexertion and insufficient recovery can lead to musculoskeletal injuries, characterized by enhanced production and the release of inflammatory cytokines such as IL-6 and TNF-α, which in turn may diminish performance and negatively affect health [28]. Black maca extract, which is rich in saponins, phenols, and flavonoids and has antioxidant activity [29], may provide benefits. Oxidative stress from imbalanced metabolism in cells and tissues induced by high-intensity exercise can contribute to chronic inflammatory diseases [30]. Antioxidants are considered valuable adjunctive therapies for their role in mitigating inflammatory responses [31]. The study's findings indicate that reductions in inflammatory markers IL-6 and TNF-α were observed only in elite athletes who consistently engaged in regular exercise, suggesting that the antioxidant properties of black maca extract may play a key role in its efficacy.

To the best of our knowledge, previous research has validated the benefits of black maca in a crossover study in athletes [19]. In this study, we followed up by adding non-athletes to the experiment to confirm if black maca was effective in athletes who were training and/or exercise regularly. We discussed the results, but the only significant differences were found in athletes who were training and/or exercise regularly. This suggests that the effects of black maca alone are minimal but can be increased with regular training and/or exercise. There is also an age difference between the athletes and non-athletes groups in this study. However, age-related changes in black maca intake have not been studied, and this study focused on athletes who engage in regular training and/or exercise versus non-athletes who do not.

This study had several limitations. The small sample size limited our ability to determine the significance of the results. Future studies with larger sample sizes and control groups are needed to determine the effects of black maca supplementation on plasma composition changes and physical fitness in athletes and non-athletes. There was no control group in this study that did not take black maca, so we should be cautious about extrapolating from this study. Another limitation is the lack of analysis on the specific components of the black maca extract used, which was purchased from pharmacies. The composition was only known to the extent provided by the retailer and identified in the literature. A more detailed analysis of these components is required in further research. Additionally, we did not control for the athletes' daily routines; they were encouraged to maintain their normal lifestyles, including their usual behaviors, exercise amounts, etc. Future studies should control for lifestyle variables and assess the subjects under standardized conditions.

5. Conclusions

In conclusion, this study suggests that black maca supplementation may alter the isokinetic muscle function of the trunk and the inflammatory markers IL-6 and TNF-alpha in elite athletes. Elite athletes engaged in high-intensity training produce significant amounts of oxidants, which can impair muscle function or lead to muscle fatigue. The distribution of amino acids and arginine in black maca extract, which depends on the type and concentration of active ingredients, might contribute to anti-stress and antioxidant responses [19]. Therefore, black maca supplementation could beneficially impact isokinetic muscle function of the trunk in elite athletes by reducing muscle contraction fatigue and enhancing anti-inflammatory responses. This study only compared two groups (athletes and non-athletes) who took black maca, and there was no control group that did not take black maca. Therefore, it is necessary to be careful in generalizing beyond the study. What this study suggests is that taking black maca does not work if you do not training and/or exercise regularly.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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