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The Acute Ergogenic Effect of Citrulline Malate Supplementation on Upper-Limb Strength Indices in Trained Male Weightlifters: A Crossover Study

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ABSTRACT

Introduction: Citrulline malate is a nutritional supplement proposed to improve muscular performance by enhancing nitric oxide production, blood flow, and ammonia clearance. However, findings on its ergogenic benefits remain inconsistent. This study aimed to investigate the acute effects of citrulline malate supplementation on muscular strength and power in trained male weightlifters.

Material & Methods: A semi-experimental, single-blind, crossover design was used with twelve male weightlifters (age 18–25) having at least two years of resistance training experience. Each participant ingested either 8 grams of citrulline malate or a placebo in two separate sessions, with a washout period in between. Muscular strength and power were evaluated using bench press, lat pulldown, handgrip, and isokinetic dynamometry. Paired t-tests ($p \leq 0.05$) were used to compare outcomes across conditions.

Results: Overall, citrulline malate supplementation did not lead to statistically significant improvements in most strength and power indices compared to placebo. However, tow variables showed significant between-group differences: shoulder joint power during internal rotation ($p = 0.022$), and elbow joint strength during flexion ($p = 0.025$). All other improvements observed in both groups were not statistically significant.

Conclusion: Acute citrulline malate intake may enhance performance in specific upper-limb movements, particularly elbow and shoulder joint flexion, but does not appear to improve general muscular strength and power across the body. Further studies with larger samples and extended supplementation durations are recommended to clarify its effectiveness.

Keywords: Citrulline Malate, Muscular Strength, Muscular Power, Weightlifting.

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1. Introduction

In recent years, the use of citrulline malate—particularly as a supplement aimed at enhancing athletic performance and reducing muscular fatigue—has attracted considerable attention from researchers. This compound, which contains L-citrulline and malate, is believed to enhance anaerobic performance and muscular strength by increasing nitric oxide production and facilitating blood flow (1).

Studies have shown that acute consumption of 6 to 8 grams of citrulline malate approximately one hour before exercise may enhance repetition performance in resistance training and improve anaerobic performance. However, the actual effect is often modest (a 4–8% increase in power) and was not statistically significant in some studies (2).

However, results have been inconsistent across some studies, with several reporting no significant effects, indicating the need for further research into optimal dosing and individual responses (3). A study conducted on older tennis athletes reported that acute ingestion of 8 grams of citrulline malate led to improvements in grip strength and anaerobic power in the Wingate test, although the effect on vertical power was not significant (4).

Muscular strength and power are of great importance in sports such as weightlifting. These attributes help athletes generate maximum force in a short amount of time, which is essential for success in weightlifting. Research shows that increasing muscular strength can enhance athletic performance, and this effect is particularly evident in sports that require explosive power and speed, such as weightlifting (5, 6). The predominant energy system in weightlifting is the phosphagen system (ATP-CP), which provides energy for short-duration, high-intensity activities like weightlifting. This system rapidly supplies the energy needed for muscle contractions, enabling athletes to lift heavy weights in a short period of time (7).

In weightlifting, muscular strength and power are recognized as key factors in athletic success. Muscular strength enables athletes to lift heavy weights, while muscular power helps them perform these lifts with greater speed and efficiency. Improving these two attributes through targeted training and the use of dietary supplements can enhance performance and reduce the risk of injury (8, 9). Therefore, focusing on the development of muscular strength and power is essential in weightlifters' training programs to achieve peak performance.

Athletes in the sport of weightlifting employ various strategies to improve their performance records, including diverse training methods, different periodization approaches, and the use of sports supplements. One such supplement used to enhance athletic performance is citrulline malate. Citrulline malate is composed of L-citrulline (CIT) and malate, a salt naturally found in apples (10). L-citrulline is a non-essential amino acid, and supplements containing it are available in various forms, including pure L-citrulline and citrulline malate (11). Studies have shown that supplementation with L-citrulline (CIT) significantly increases plasma L-arginine levels at rest and during exercise. This is important because L-arginine serves as the primary substrate for nitric oxide synthesis, which is a key modulator of blood flow. Specifically, L-citrulline supplementation helps improve vascular function by enhancing the bioavailability of L-arginine and, consequently, increasing nitric oxide production (12, 13).

Therefore, citrulline malate supplementation may enhance muscular performance by increasing blood flow and improving nutrient delivery to muscles, as well as facilitating the removal of waste products such as lactate and ammonia (14). Ultimately contributing to improved muscular function (15). Additionally, L-arginine is an essential component of the urea cycle in the liver (16). Given that ammonia, produced during anaerobic glycolysis and lactate accumulation, is a contributing factor to muscle fatigue—and that urea is the final product of ammonia elimination—it has been proposed that citrulline malate supplementation may play an effective role in reducing ammonia buildup and preventing early onset of fatigue by enhancing the urea cycle and improving ammonia homeostasis (17). Based on these mechanisms, citrulline malate appears capable of improving muscle performance and recovery through various pathways, including reducing muscle fatigue and soreness, improving oxygen delivery to muscles, and decreasing lactate and ammonium production (18). In addition to these mechanisms, citrulline malate may also indirectly promote creatine synthesis and support the phosphocreatine system. Specifically, creatine is synthesized via the transfer of a guanidino group from arginine to glycine, followed by the addition of a methyl group from S-adenosylmethionine (SAM)—a methyl group donor involved in methylation, transsulfuration, and aminopropylation reactions. Hence, L-arginine has the potential to be converted into creatine within the body (15).

Research has shown that acute supplementation with citrulline malate can enhance upper- and lower-body resistance performance and reduce the rate of perceived exertion (RPE) during exercise. This effect is particularly noticeable among athletes competing in disciplines that demand muscular endurance, and acute intake of this supplement may help improve their athletic performance (19). It has also been reported that acute citrulline malate supplementation improves grip strength and anaerobic power in female tennis players, suggesting that pre-competition intake may have the potential to enhance tennis performance (11). A meta-analysis examines the impact of Citrulline Malate on the total number of repetitions performed during strength training. The results indicate that the consumption of 6-8 grams of Citrulline Malate 40-60 minutes prior to training increases the total repetitions by an average of 3 repetitions (6.4%) compared to a placebo. This effect is particularly pronounced in lower-body exercises. Overall, this study suggests that Citrulline Malate supplementation may delay fatigue and enhance muscular endurance during high-intensity strength training (2). In another study, the author investigates the effects of Citrulline Malate in combination with caffeine, revealing that while caffeine improves strength and endurance, Citrulline Malate alone does not exhibit significant ergogenic effects. These results imply that for enhancing performance in strength training, the combination of these two supplements may be more beneficial (20). Also a systematic review assesses the positive and negative outcomes of Citrulline and Citrulline Malate supplementation on athletic performance. Out of the 10 studies reviewed, six indicate that these supplements can increase the number of repetitions and reduce feelings of fatigue, while four other studies report negligible effects. These findings suggest that the impact of the supplements may depend on individual conditions and the type of sport (3). Similarly a review examines the effects of Citrulline Malate as a nitric oxide booster and concludes that there are conflicting results regarding its impact on exercise performance. The study emphasizes the need for further research to determine the optimal dosage and timing of supplementation, indicating that until more controlled studies are conducted, the efficacy of this supplement in enhancing athletic performance remains ambiguous(1)This trial compares the effects of L-Citrulline and Citrulline Malate on neuromuscular performance, concluding that neither significantly improves performance during resistance training. These results indicate that Citrulline Malate may be effective under specific conditions, but overall, its effects on strength training are limited (21).

Citrulline malate supplementation is used to improve skeletal muscle metabolism, increase contraction efficiency and strength, and help athletes—such as cyclists engaging in high-intensity training—resist fatigue more effectively (22). It may also be beneficial in enhancing athletic performance during resistance training among professional weightlifters (23). Based on existing research and the supplement’s effects on the aforementioned variables, it appears that its positive impact on arginine levels may lead to increased creatine production, thereby enhancing muscular strength and power. The present study aims to investigate whether the consumption of this supplement can have a significant effect on strength and power in weightlifters.

2. Methodology

2.1. Materials and methods

The aim of this study was to investigate the acute effects of citrulline malate supplementation on muscular strength and power in male weightlifters. This was a semi-experimental, single-blind crossover design study. In terms of data type, the research was quantitative, and in terms of purpose, it was applied. The study design included pre-test and post-test measurements in two separate conditions: supplement and placebo, conducted at different time intervals. All research procedures were carried out in Isfahan Province at the Sports Science Laboratory of the University of Isfahan.

2.2. Participants

Sampling was done using a convenient and purposive method. A total of 12 male weightlifters aged between 18 and 25 years, with at least two years of specialized training experience, were selected. In the crossover design, all participants were randomly assigned to both supplement and placebo conditions.

This study used a single-blind design, in which participants were blinded to the type of intervention (supplement vs. placebo). To achieve this, both the citrulline malate supplement and the placebo were dissolved in the same volume (250 mL) of flavored water with identical color, taste, and appearance. The researcher responsible for administering the supplements was aware of the allocation, but participants and the evaluators conducting performance tests remained blinded throughout the trial.

2.3. Measurements

Instruments: The following tools were used to assess muscular strength and power:

- Biodex Isokinetic Device for measuring the strength and power of the right shoulder and elbow joints at various angles;
- Handgrip Dynamometer for evaluating wrist strength;
- Bench Press Machine for assessing the strength of the pectoralis major muscles;
- Lat Pulldown Machine for measuring the strength of the latissimus dorsi muscles.

2.4. Intervention

Research Procedure: Each participant visited the laboratory three times, with a 48-hour interval between sessions. The visits were scheduled between 8:00 a.m. and 2:00 p.m. In the first session, participants completed a consent form and the PAR-Q health questionnaire, and were familiarized with the equipment and exercises. It was also emphasized that they should refrain from using other performance-enhancing supplements, including those containing NO, arginine, or foods high in citrulline. Anthropometric variables (height, weight, and BMI) were also measured in this session.

In the first session (pre-test), baseline performance was measured without any supplementation. After a warm-up, participants performed the test exercises, including the bench press, lat pulldown, handgrip test, and isokinetic movements.

In the second session, participants were randomly assigned to receive one of the two interventions (supplement or placebo). The supplement consisted of 8 grams of citrulline malate powder dissolved in 250 mL of water with an artificial sweetener. The placebo was a similar solution without the active ingredient. Fifty minutes after ingestion, participants performed the same set of exercises as in the first session.

In the third session, participants who had taken the supplement on the second day received the placebo, and vice versa (crossover design). The type of exercise, sequence of movements, and rest intervals were kept identical across all sessions to accurately measure the supplement's net effect.

2.5. Statistical Methods

The data were analyzed using descriptive statistics (mean and standard deviation) and paired t-tests to compare the participants' performance under supplement and placebo conditions. All analyses were performed using SPSS software, with a significance level set at $p \leq 0.05$.

3. Results

Table 1 presents the demographic characteristics of the study sample in terms of weight, height, age, and body mass index (BMI).

Table 1. *Demographic Characteristics of the Sample*

Variable	Frequency	Percentage (%)
Weight (kg)		
65–75	4	33.3
76–85	5	41.7
Over 85	3	25
Total	12	100
Height (cm)		
170–175	5	41.7
176–181	2	16.6
Over 181	5	41.7
Total	12	100
Age (years)		
18–20	7	58.4
21–23	4	33.3
24–26	1	8.3
Total	12	100
Body Mass Index (BMI)		
17–21	3	25
22–26	5	41.7
27–31	4	33.3
Total	12	100

The demographic data presented in Table 1 indicate a relatively balanced distribution across weight, height, age, and BMI categories within the sample of 12 participants. The majority of individuals (41.7%) fall within the 76–85 kg weight range, while only 25% weigh over 85 kg. In terms of height, the participants are evenly distributed, with 41.7% measuring between 170–175 cm and another 41.7% over 181 cm. Age-wise, the sample is predominantly composed of younger individuals, with 58.4% aged 18–20 years, suggesting a youthful population. Regarding BMI, the largest portion (41.7%) falls within the 22–26 range, indicating a tendency toward normal weight, although 33.3% have a BMI between 27–31, pointing to a notable proportion with overweight status. Overall, the sample displays moderate diversity in physical characteristics, with a slight skew toward younger and average-weight individuals.

Table 2. *Results of the T-Test on Muscle Strength during the Citrulline Malate Supplementation Phase*

Muscle Group	Phase	Mean	S.D.	Std. Error of Mean	P value
Pectoralis Major	Pre-test	72.95	10.14	4.459	0.2728
	Post-test	75.2	13.92	4.402	
Latissimus Dorsi	Pre-test	81.35	12.12	3.654	0.0062
	Post-test	85.46	12.43	3.748	
Wrist Muscles (Handgrip Strength)	Pre-test	55	5.2	1.504	0.0407
	Post-test	57.75	5.81	1.679	
Shoulder Joint (External Rotation)	Pre-test	37.13	9.46	2.733	0.0015
	Post-test	48.06	9.87	2.85	
Shoulder Joint (Internal Rotation)	Pre-test	40.29	7.72	2.23	0.0206
	Post-test	55.01	20.13	5.811	
Elbow Joint (Extension)	Pre-test	42.63	13.91	4.016	0.0989
	Post-test	50.39	10.68	3.083	
Elbow Joint (Flexion)	Pre-test	45.26	12.2	3.522	0.2739
	Post-test	50.38	10.46	3.019	

The paired t-test results demonstrate that citrulline malate supplementation led to statistically significant improvements in muscle strength in several muscle groups. Notably, the latissimus dorsi (p= 0.0062), wrist muscles (handgrip strength) (p= 0.0407), shoulder joint in external rotation (p= 0.0015), and internal rotation (p= 0.0206) all showed significant gains post-supplementation. These findings suggest that citrulline malate may enhance muscular performance, particularly in movements involving pulling, rotation, and grip strength. However, no statistically significant differences were observed in the pectoralis major (p= 0.2728), elbow extension (p= 0.0989), and elbow flexion (p= 0.2739), indicating a variable effect of the supplement depending on the muscle group and type of movement. Overall, citrulline malate appears to positively impact specific aspects of muscular strength, especially in upper-body dynamic and rotational actions.

Table 3. *T-Test Results for Muscle Strength in the Placebo Group*

Muscle	Stage	Mean	S.D	Std. Error of Mean	P value
Pectoralis Major	Pre-test	72.95	14.1	4.459	0.5611
	Post-test	74.34	12.56	3.97	
Latissimus Dorsi	Pre-test	81.35	12.12	3.654	0.024
	Post-test	85.37	12.5	3.77	
Wrist	Pre-test	5.55	5.2	1.504	0.0467
	Post-test	5.57	4.67	1.351	
Shoulder Joint (External Rot.)	Pre-test	37.13	9.46	2.733	0.0053
	Post-test	47.44	11.1	3.205	
Shoulder Joint (Internal Rot.)	Pre-test	40.29	7.72	2.23	0.2115
	Post-test	46.28	14.25	4.113	
Elbow (Extension)	Pre-test	42.63	13.91	4.016	0.3373
	Post-test	47.31	12.82	3.7	
Elbow (Flexion)	Pre-test	45.26	12.2	3.522	0.0015
	Post-test	69.78	25.3	7.303	

Based on the results of the T-test in the placebo phase, significant differences were observed in muscle strength between the pre-test and post-test in certain muscle groups. Specifically, the Latissimus Dorsi (P= 0.0240), Wrist (P= 0.0467), Shoulder Joint External Rotation (P= 0.0053), and Elbow Flexion (P= 0.0015) showed statistically significant increases in strength following the placebo intervention. These changes may be attributed to psychological effects of the placebo or external factors such as increased motivation or effort during testing. In contrast, no statistically significant differences were found in the Pectoralis Major (P= 0.5611), Shoulder Joint Internal Rotation (P= 0.2115), and Elbow Extension (P= 0.3373), despite slight increases in mean strength. Overall, the results suggest that the placebo effect may influence muscle strength perception and performance in certain muscle groups more than others.

Table 4. *T-Test Results for Muscle Power in the Citrulline Malate Supplementation Phase*

Muscle	Stage	Mean	S.D	Std. Error of Mean	P value
Shoulder Joint (External Rotation)	Pre-test	70.4	29.42	9.303	0.001
	Post-test	131.8	49.19	15.56	
Shoulder Joint (Internal Rotation)	Pre-test	124	26.48	8.372	0.088
	Post-test	182.3	89.94	28.44	
Elbow Joint (Extension)	Pre-test	81.08	26.42	7.626	0.068
	Post-test	112	42.97	12.4	
Elbow Joint (Flexion)	Pre-test	66.1	28.88	9.132	0.019
	Post-test	102	36.77	11.63	

Based on the T-test results for muscle power in the citrulline malate supplementation phase, a statistically significant increase in muscle strength was observed in Shoulder Joint External Rotation (P= 0.001) and Elbow Joint Flexion (P= 0.019), indicating a strong positive effect of citrulline malate on these muscle groups. While Shoulder Joint Internal Rotation (P= 0.088) and Elbow Joint Extension (P= 0.068) also showed noticeable increases in mean muscle power from pre- to post-test, the differences were not statistically significant at the conventional 0.05 level, though they approached significance. These results suggest that citrulline malate supplementation may enhance upper limb muscle power, particularly in specific movements such as shoulder external rotation and elbow flexion, and could potentially benefit other joint actions with further investigation or in larger sample sizes.

Table 5. *T-Test Results for Muscle Power in the Placebo Phase*

Muscle	Stage	Mean	S.D	Std. Error of Mean	P value
Shoulder Joint (External Rotation)	Pre-test Post-test	70.4 115.9	29.42 52.33	9.303 16.55	0.0035
Shoulder Joint (Internal Rotation)	Pre-test Post-test	124 130.7	26.48 78.73	8.372 23.47	0.6897
Elbow Joint (Extension)	Pre-test Post-test	81.08 124.9	26.42 55.45	7.626 16.01	0.0277
Elbow Joint (Flexion)	Pre-test Post-test	66.1 103.2	28.88 43.95	9.132 13.9	0.0519

The T-test results for muscle power in the placebo phase reveal significant improvements in Shoulder Joint External Rotation (P= 0.0035) and Elbow Joint Extension (P= 0.0277) from pre-test to post-test, indicating that even without active supplementation, some muscle strength gains were observed, possibly due to placebo effects or increased participant effort. However, changes in Shoulder Joint Internal Rotation (P= 0.6897) and Elbow Joint Flexion (P= 0.0519) were not statistically significant, although elbow flexion approached significance. These findings suggest that while placebo can influence certain aspects of muscle power, its effects are less consistent across different muscle groups compared to active supplementation.

Table 6. *Comparative analysis between supplement and placebo based on muscle strength and power*

Muscle / Functional Variable	Supplement (Pre)	Supplement (Post)	Δ Supplement	Placebo (Pre)	Placebo (Post)	Δ Placebo	Difference Between Changes	p-value	Statistical Result
Pectoralis Major Strength	72.95	75.2	2.25	72.95	74.34	1.39	0.86	0.989	Not Significant
Latissimus Dorsi Strength	81.35	85.46	4.11	81.35	85.37	4.02	0.09	0.52	Not Significant
Wrist Strength	55	57.75	2.75	55	57.25	2.25	0.5	0.43	Not Significant
Shoulder Joint Strength (External Rotation)	37.13	48.06	10.93	37.13	47.44	10.31	0.62	0.9	Not Significant
Shoulder Joint Strength (Internal Rotation)	40.29	55.01	14.72	40.29	46.28	6	8.72	0.078	Not Significant
Elbow Joint Strength (Extension)	42.63	50.39	7.76	42.63	47.31	4.68	3.08	0.458	Not Significant
Elbow Joint Strength (Flexion)	45.26	50.38	5.12	45.26	69.78	24.52	-19.4	0.025	Significant
Shoulder Joint Power (External Rotation)	70.4	131.8	61.4	70.4	115.9	45.5	15.9	0.38	Not Significant
Shoulder Joint Power (Internal Rotation)	124	182.3	58.3	124	130.7	6.7	51.6	0.042	Significant
Elbow Joint Power (Extension)	81.08	112	30.92	81.08	124.9	43.82	-12.9	0.68	Not Significant
Elbow Joint Power (Flexion)	66.1	102	35.9	66.1	103.2	37.1	-1.2	0.28	Not Significant

According to Table 6, which presents a comparative analysis between the Citrulline Malate supplement group and the placebo group, statistical analysis revealed that for most functional variables related to muscle strength and power, the changes observed in the two groups were not statistically significant ($p > 0.05$). However, tow specific variables showed statistically significant differences.

First, elbow joint strength during flexion showed an unusually sharp increase in the placebo group, which significantly differed from the supplement group (p= 0.025). Second, shoulder joint power during internal rotation increased more in the supplement group than in the placebo group (ΔSupplement= 58.30 vs. ΔPlacebo= 6.70; p= 0.42), indicating a positive effect of the supplement on this parameter.

Overall, although the data indicated improvements in muscle strength and power following supplementation, statistically significant differences were observed in only a limited number of variables. This may be attributed to factors such as small sample size, study design, or the functional nature of the variables assessed.

4. Discussion

In this study, the acute effect of Citrulline Malate supplementation on the muscular strength and power of male weightlifters was examined. The findings indicated that this supplement had no statistically significant impact on increasing the muscular strength of the pectoralis major, latissimus dorsi, wrist, shoulder, and elbow joints, nor on the muscular power of these joints. These results align with the findings of several other studies, including those by Uninivel et al. (2021), Chappell et al. (2018), Gonzalez et al. (2018), Canniff et al. (2016), Taica et al. (2014), and Wax et al. (2015 and 2016). These studies similarly concluded that Citrulline Malate supplementation did not have a significant positive effect on athletic performance.

In the aforementioned studies, it was generally observed that Citrulline Malate had no notable beneficial effects in athletes. Therefore, in light of the present findings being consistent with prior research, it can be concluded that the strength of the latissimus dorsi and pectoralis major muscles, the right elbow joint, the right shoulder joint, the right wrist, and the power of the muscles in the right elbow and shoulder joints showed no significant differences between weightlifters taking Citrulline Malate and those in the placebo group—even after the crossover of the two groups on the third day. This suggests that Citrulline Malate supplementation had no significant effect on muscular strength and power in the studied groups.

Intense physical activity leads to substantial accumulation of lactate, accompanied by acidosis and a reduction in the pH level of the active muscle, which can negatively affect muscle cell function. Research indicates that a decrease in pH inhibits various intracellular reactions. Therefore, the accumulation of lactic acid and the drop in pH during intense exercise can contribute to fatigue. However, studies show that lactate and pH are not the sole factors responsible for fatigue (24).

A decline in pH has an inhibitory effect on the activity of phosphorylase and phosphofructokinase—key enzymes that regulate the glycogenolysis and glycolysis pathways, respectively (25). In a study conducted by Wax et al. (2015) on 12 professional male weightlifters, the objective was to examine the acute effects of Citrulline Malate supplementation on resistance exercise performance, blood lactate levels, heart rate, and blood pressure during lower-body resistance training.

A significant increase in the number of repetitions was observed in the supplement phase compared to the placebo phase. Both blood lactate levels and heart rate showed a considerable increase in both phases compared to pre-exercise measurements. However, no significant differences were found between the Citrulline Malate and placebo groups. Similarly, no significant difference was observed in blood pressure measurements (26).

Blood lactate, heart rate, and blood pressure were measured prior to the exercise tests. Blood lactate was measured again immediately after the final test, while heart rate and blood pressure were measured at 5 and 10 minutes post-exercise. Citrulline Malate supplementation led to a significant increase in the number of repetitions performed in each exercise. Although blood lactate concentrations showed significant differences before and after exercise in both sessions, no significant differences were observed between the supplement and placebo sessions (23).

In a separate observation, Bate et al. found that a decrease in pH at 10°C significantly reduced force production; however, this reduction was minimal at 30°C. The same study demonstrated that acidosis, which had been considered a key factor in the slowing of muscle fiber shortening velocity, had no effect at 30°C. Nonetheless, it reduced the maximum shortening velocity by approximately 20% at 12°C (27).

Citrulline Malate is composed of two components: citrulline and malate. On one hand, malate acts as an intermediate in the tricarboxylic acid (TCA) cycle, and its supplementation has been shown to enhance energy production. On the other hand, citrulline is involved in the urea cycle and is thought to potentially accelerate the clearance of plasma lactate. By aiding in the elimination of muscle metabolic byproducts, it may help improve muscular performance.

Giannicchi et al. (2011), in a study on 24 Wistar rats, reported that Citrulline Malate supplementation increased muscular force production and decreased the energy cost of contraction. The rats were divided into supplement and placebo groups. The supplement group received 1 g/kg body weight of Citrulline Malate three times daily over a 48-hour period. The training protocol involved 7.5 minutes of rest, 7.5 minutes of electrical stimulation, and 16.6 minutes of recovery. During the stimulation phase, isometric muscle contractions were electrically induced at a frequency of 3.3 Hz for 7.5 minutes. The results showed a significant increase in the total force produced during the training in the supplement group (28).

Beyond the effects of malate, citrulline itself may act as a potential enhancer of anaerobic performance. As previously mentioned, during repetitive contractile activities, ATP is required for both contractile and non-contractile cellular processes. Citrulline Malate may accelerate the clearance of metabolic byproducts, thereby reducing energy consumption for non-contractile processes and redirecting more energy toward contractile force production. Therefore, the ergogenic effects of Citrulline Malate likely relate to increasing the energy allocation toward muscle contraction.

In another study, Glenn et al. (2017) evaluated the effect of Citrulline Malate on the Rate of Perceived Exertion (RPE). When RPE was measured after the bench press exercise, an 8% reduction in perceived fatigue was reported. This result is significant because it was accompanied by improved performance during bench press sets. The ability to experience less perceived exertion while achieving higher output has interesting implications for athletic performance. Participants were required to continue exercising to the point of exhaustion. Based on the results, the total number of repetitions increased, suggesting that Citrulline Malate reduces fatigue (11).

Muscular strength and power are crucial factors in weightlifting. Muscle groups in the shoulder and chest girdle, such as the pectoralis major and latissimus dorsi, must withstand and produce significant force to lift weights overhead. These muscles are also essential for maintaining balance and control during sustained, powerful, and rapid contractions.

In the present study, no differences were observed in explosive strength and power between the supplement and placebo sessions following Citrulline Malate supplementation. The findings of this study are not aligned with those of Glenn et al. (2016). A possible reason for the lack of effect on strength and power in our study could be the lower dosage of Citrulline Malate used.

This study was conducted exclusively on male weightlifters in Isfahan, and its findings are not fully generalizable due to geographic and methodological limitations. To improve reliability and generalizability, it is recommended that future research be conducted across different sports disciplines, with varied training protocols, and by comparing diverse performance tests.

5. Conclusion

Although, in theory, Citrulline Malate supplementation could enhance plasma L-arginine levels and nitric oxide production—leading to vasodilation and improved clearance of muscle metabolites—this study found that its acute consumption does not have a significant effect on increasing muscular strength and power in male weightlifters. These findings are consistent with many similar studies.

Given the lack of statistically significant differences between the supplement and placebo groups, yet some performance improvements compared to baseline, it can be hypothesized that psychological factors and the placebo effect play a key role in enhancing muscular strength and power. Therefore, further research with more rigorous designs, more diverse samples, and better control of psychological variables is recommended to more accurately assess the effects of Citrulline Malate supplementation.

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