J Biochem Technol (2023) 14(2): 75-80
https://doi.org/10.51847/Gd16A1JnMz
ISSN: 0974-2328

Effectiveness of the Use of Citrulline Malate to Increase the Powerlifters Adaptive Potential and Physical Performance

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Received: 28 January 2023 / Received in revised form: 30 May 2023, Accepted: 04 June 2023, Published online: 20 June 2023

Abstract

Due to constant heavy loads and the need to provide a large volume of muscles with microelements, the athlete's body needs a special approach to nutrition. You can fill the deficiency of vitamins, minerals, and amino acids with the help of nutraceutical preparations. Citrulline malate is an interchangeable amino acid L-citrulline linked to an organic salt molecule (malate). The supplement is used in sports nutrition for powerlifters and bodybuilders to accelerate the growth of muscle mass and increase its functionality. The purpose of this study was a scientific substantiation and analysis of the effectiveness of the use of citrulline malate to increase the adaptive potential and physical performance of powerlifters at the preparatory stage of the annual cycle. A randomized study of 64 powerlifters was carried out. Athletes of the first group (control, n=32) trained as usual, enriching their diet with protein supplements and multivitamin complexes. Athletes of the second group (experienced, n=32) additionally received citrulline malate at a dose of 4 g 2 times a day for one month. Analysis of physical performance according to ergospirometry showed a more pronounced increase in physical performance in athletes of the experimental group.

Keywords: Powerlifter, Citrulline malate, L-citrulline, Biochemical indicators of metabolic status, Hormonal status indicators, Ergospirometry indicators

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Introduction

The athlete's body, due to constant heavy loads and the need to supply a large volume of muscles with micronutrients, needs a special approach to nutrition (Hemdan & Abdulmaguid, 2021). It is possible to satisfy the deficiency of vitamins, minerals, and amino acids with the help of nutraceutical preparations (Tardy *et al*., 2020; Alagawany *et al*., 2021; Todorova *et al*., 2021).

The progressive growth of training and competitive loads in the conditions of modern sports activity dictates the need to include in the process of training highly qualified athletes effective pharmacological and non-pharmacological ways to increase the adaptive capabilities of the body, and physical and athletic performance (Megna *et al*., 2012; Rzhepakovsky *et al*., 2022; Siddiqui *et al*., 2022). Today, despite the undoubted success of sports pharmacology, there is an urgent need to develop new drugs that can significantly increase the adaptive and physical capabilities of an athlete and at the same time are not doping (Nagdalyan *et al*., 2018; Dadaeva *et al*., 2023; Sánchez *et al*., 2023).

Citrulline malate or citrullus is an interchangeable amino acid L–citrulline bound to an organic salt molecule (malate). The supplement is used in the sports nutrition of powerlifters and bodybuilders to accelerate the growth of muscle mass and increase its functionality (Gough *et al*., 2021; Florina *et al*., 2022). Track and field athletes and athletes practicing intensive aerobic exercise use the supplement to increase endurance and normalize blood pressure (Pérez-Guisado & Jakeman, 2010).

Citrulline is an interchangeable amino acid that the body receives from protein products of plant origin. In its natural form, it is found in watermelons (Burton-Freeman *et al*., 2021). Due to its synergistic action together with other active trace elements, vitamins, and hormones, citrulline plays an important role in sports nutrition (Figueroa *et al*., 2017; Mekeres *et al*., 2023).

During intensive training, muscle fibers produce a large amount of ammonia, which, accumulating, causes a feeling of fatigue, heaviness, and weakness in the body (Graham *et al*., 1987). The artificial introduction of citrulline supplements into the diet helps to increase the formation of urea, and, consequently, bind free

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hydrogen nitrite before it causes asthenia (Vasenina *et al*., 2022). The presence of excess citrulline in the body leads to an increase in the level of arginine in the blood (Dumitru *et al*., 2022). The nitric oxide obtained as a by-product increases blood flow in the muscles and promotes their pumping (Suzuki *et al*., 2017).

With the help of malate (malic acid salt), mitochondria actively convert proteins, fats, and carbohydrates into energy. Thus, the additional introduction of malic acid into the diet can increase the energy output in striated cells (Gonzalez & Trexler, 2020). At the same time, malates are necessary for the processing and assimilation of lactic acid salts, and Citrulline Malate removes acid from the body, reducing the concentration of substances that cause fatigue and pain during and after training (Aguiar & Casonatto, 2022). The duration and intensity of aerobic and anaerobic loads can be increased, and the functionality and architecture of the musculature improved.

Citrulline Malate has a pronounced positive effect in solving problems related to:

- Protein deficiency, which has no endocrine causes and is associated with a violation of nutrition or a predominantly vegetarian diet.
- Chronic fatigue and fatigue due to physical exertion in sports or hard work.
- Erectile dysfunction, including those associated with complications of diabetes mellitus.
- Muscular asthenia of various etiologies.
- Metabolic disorders.
- Recovery after injuries and surgical operations.

The use of complexes containing citrulline and malic acid is advisable both during the regular training process and in preparation for competitions (Rhim *et al*., 2020). The supplement helps athletes maintain vigor and strength for longer, and get tired less. Such support is especially relevant for athletes whose loads are of an interval nature, for example, hockey players, football players, and swimmers.

Citrulline taken on an empty stomach increases the level of arginine in the blood after an hour and continues to keep it above average values for 24 hours (Cunniffe *et al*., 2016). The beneficial properties of an amino acid in combination with a stabilizer have a cumulative effect (Hwang *et al*., 2018).

The steady growth of muscle mass, endurance, and activity can be achieved after a month of systematic use. Citrulline malate is considered a relatively safe drug.

The purpose of this study was the scientific justification and analysis of the effectiveness of the use of citrulline malate to increase the adaptive potential and physical performance of powerlifters at the preparatory stage of the annual cycle.

Materials and Methods

A randomized examination of 64 powerlifter athletes was conducted. The average age of the participants was 28.05±3.16 years, of which 18 (28.1%) were women and 46 (71.9%) were men, with the qualification level of "candidate for master of sports" and higher. The athletes were divided into 2 groups, comparable in gender, age, and baseline clinical and functional data. Athletes of the first group (control, n=32) trained in their usual mode, enriching their nutrition with protein supplements and multivitamin complexes. Athletes of the second group (experienced, n=32) additionally received Citrulline malate at a dosage of 4 grams 2 times a day for one month. The study was conducted in accordance with the standards of the Helsinki Declaration of the World Association Ethical principles of conducting scientific medical research with human participants and Rules of Clinical Practice in the Russian Federation. All athletes gave their voluntary consent to participate in the study. Blood sampling was carried out in the morning, on an empty stomach, before training loads.

The study of blood biochemical parameters was carried out using the Olympus AU series biochemical analyzer (Germany). Hematological analysis was performed on a hematological analyzer MEK 7222 (NihonKohden, Japan). The level of cortisol and testosterone was determined on the immunochemical analyzer Immulite 1000 (DPS, USA). Functional diagnostic methods were carried out using the Cardiovit AT-104 Esp. stress test complex, complete with the ERG-911 BP bicycle ergometer (Schiller, Switzerland). General physical performance (PWC170 test) was determined by the method described in (Nagdalyan *et al*., 2018).

Results and Discussion

The analysis of the state of the oxygen-supplying blood system against the background of taking the studied drug showed the presence of positive dynamics only in athletes of the experienced group: the average volume of red blood cells and the level of erythropoietin significantly increased **(Table 1)**. In the group of athletes taking Citrulline malate, an increase in hemoglobin concentration was recorded in 52% of the examined, which significantly differed from the control group, where this indicator increased only in 34% of athletes. The increase in hemoglobin levels in the experienced group was observed to a greater extent in female athletes compared to male athletes.

It is known that one of the criteria for overtraining is a decrease in the level of glucose in the blood, which indicates intensive consumption by the tissues of the body and depletion of glycogen reserves in the liver (Suh *et al*., 2007).

Table 1. Indicators of the oxygen-supplying blood system in athletes of the experienced and control groups

Indicators	Control group			Experienced group		
	Before the reception	After the reception	Difference, %	Before the reception	After the reception	Difference, %

Hemoglobin, g/l (norm male: 130-175, female: 120-155)	146±15.6	146.4±14.3	+0.27	148.2±12.1	151.1±15.4	+1.96
Hematocrit, % (norm 36-56)	41.9±3.8	41.7±3.3	-0.48	42.4±2.8	43.4±4.3	-2.59
Red blood cells, 10^{12}/l (norm 3.5-5.3)	5.0±0.4	4.9±0.5	-2.0	4.9±0.3	4.9±0.5	0
MCV, fl (norm: 80-100)	83.7±4.3	85.3±3.5	+1.91	85.5±2.78	87.2±4.2	+1.98
Erythropoietin, male, mME/ml (norm 5,6-28,9)	13.9±14.6	33.9±7.9	+143.88	10.5±9.7	35.6±16.4	+239.05
Erythropoietin, female, mME/ml (norm 8-30)	8.3±1.6	53.2±20.7	+540.96	7.2±2.0	39.2±17.0	+444.44

The dynamics of an increase in glucose levels noted in the experienced group indirectly indicate the preservation of energy substrates. Analysis of the dynamics of such important indicators for athletes as creatine kinase activity and lactate concentration revealed the following: if at the beginning of the training cycle, the values of these indicators exceeded the norm in both groups, then after the course of taking drugs, the decrease occurred only in the experienced group of athletes. Creatine kinase activity in this group significantly decreased and reached the level of reference values, which was not observed in the control group, where the activity of this enzyme remained above the reference values **(Table 2)**.

Table 2. Biochemical indicators of the metabolic status of athletes of the experienced and control groups

Indicators	Control group			Experienced group		
	Before the reception	After the reception	Difference, %	Before the reception	After the reception	Difference, %
Total protein, g/l (norm 65-85)	76.3±2.9	74.5±3.8	-2.36	75.6±4.2	75.4±3.8	-0.26
Urea, mmol/l (norm 1,7-8,3)	4.8±1.3	4.3±1.1	-10.42	4.6±1.1	4.5±0.9	-2.17
Glucose, mmol/l (norm 4.0-6.1)	5.4±0.4	5.1±0.6	-5.55	5.3±0.9	5.5±0.7	+3.77
Creatine kinase, Units/l (norm 167-190)	277.6±196	218.9±176	-21.14	279.6±175	197.4±120.5	-29.40
Lactate, mmol/l (norm 0.5-2.2)	2.95±0.88	3.4±2.14	+15.25	2.9±1.4	2.6±1.1	-10.34

The average level of the final metabolite of anaerobic energy formation – lactate – against the background of ongoing training loads in the main group tended to decrease, while its decrease was observed in 56% of athletes in the control group, which significantly differs from the control group. This indirectly indicated the restoration of the main energy substrates against the background of increased oxygen uptake. In addition, a significant decrease in protein concentration was observed in the control group, indicating the insufficiency of anabolic processes, as indicated by a decrease in testosterone synthesis **(Table 3)**.

Table 3. Indicators of the hormonal status of athletes of the experienced and control groups

Indicators	Control group			Experienced group		
	Before the reception	After the reception	Difference, %	Before the reception	After the reception	Difference, %
Cortisol, mg/dl (norm 11.3-25)	16.4±5.6	18.6±8.9	+13.4	16.5±6.00	19.5±8.2	+18.19
Testosterone, ng/dl (norm male: 105-545, female: 20-40)	436.3±348.3	241.0±184.5	-44.76	354.3±252.4	266.9±221.2	-24.67
Testosterone/cortisol (male) conv. Un.*10^2	0.028±0.021	0.011±0.010	-60.71	0.022±0.02	0.015±0.01	-31.82

Such changes indicate a lack of adaptive potential of the body and the presence of signs of overtraining. The study of hormonal status showed that the studied indicators in the analyzed groups had no statistically significant dynamics and were within the reference values. However, in the control group, there was a significant decrease in the testosterone/cortisol ratio index, which characterizes the tension of metabolic processes and increased catabolism, while the cortisol level practically did not change, which can be regarded as the initial stage of maladaptation.

The analysis of physical performance according to ergospirometry data showed a more pronounced increase in physical performance in athletes of the experienced group. Taking into account the different levels of physical performance in athletes of different sexes, the parameters of ergospirometry were studied taking into account gender differences. It was revealed that in the experienced group, the increase in physical performance against the background of taking Citrulline malate was more pronounced in male athletes: an increase in the PWC170 test was noted in 80% of men and 40% of women. A similar dynamics was noted in terms of oxygen uptake per heartbeat: an increase was observed in 90% of male athletes and 40% of women. The women in the experienced group showed a significant increase in performance according to the PWC170 indicator, while the male athletes

showed a significant increase in the PWC150, PWC170, METs, O2-pulse, and VO2-peak indicators **(Table 4)**.

In the control group, the dynamics of physical performance indicators were observed only in male athletes in the form of an increase in the PWC150 index, in women, the dynamics of ergospirometry indicators were unreliable.

Table 4. Dynamics of ergospirometry indicators of the experienced and control groups in male powerlifters against the background of taking natural adaptogens

Indicators	Control group			Experienced group		
	Before the reception	After the reception	Difference, %	Before the reception	After the reception	Difference, %
Max. heating, W	175.0±26.7	175.0±26.7	0	186.4±20.0	193.2±19.1	+3.64
Metabolic equivalents	10.50±0.7	10.96±0.2	+4.38	11.1±0.8	11.7±1.3	+5.4
PWC150, W*	147.5±14.9	141.0±13.9	-4.41	151.2±17.9	164.7±20.9	+8.93
PWC170, W**	184.2±19.6	189.0±17.1	+2.61	189.5±19.5	199.4±23.5	+5.22
PWC150 relative, W/kg	2.1±0.1	2.0±0.1	-4.76	2.3±1.1	2.4±0.2	+4.35
PWC170 relative, W/kg	2.7±0.3	2.8±0.1	+3.70	2.8±0.2	2.9±0.2	+3.57
Peak power, W/kg	2.4±0.3	2.5±0.1	+4.17	2.8±0.3	2.9±0.2	+3.57
VO2 peak, l/min	36.4±2.6	38.2±0.7	4.95	38.2±2.8	40.2±4.3	+5.24
O2-pulse, ml/beat	15.2±1.5	15.4±1.2	1.32	15.2±1.9	16.3±2.5	+7.24

* PWC150 — determination of physical performance when the heart rate reaches 150 beats/min;
**PWC170 — determination of physical performance when the heart rate reaches 170 beats/min

Thus, taking Citrulline malate in the preparatory period of the annual cycle contributes to a more pronounced improvement in the state of the oxygen-providing blood system, increased physical performance, and prevention of overtraining. Given the presence of gender differences in the effectiveness of Citrulline malate, its use is more appropriate in male athletes.

Conclusion

A month after the start of the experiment, the athletes of the experimental group significantly increased the average volume of erythrocytes and the level of erythropoietin; an increase in hemoglobin concentration was recorded in 52% of the examined (against 34% in athletes of the control group). In the experimental group, an increase in the level of glucose is observed, and by the end of the experiment, the activity of creatine kinase and the concentration of lactate decreased. The study of the hormonal status showed that the studied parameters in the analyzed groups had no statistically significant dynamics and were within the reference values. However, in the control group, there was a significant decrease in the testosterone/cortisol ratio, which characterizes the intensity of metabolic processes, and increased catabolism, which can be regarded as the initial stage of maladaptation.

It was found that in the experimental group, the increase in physical performance while taking citrulline malate was more pronounced in male athletes: an increase in the PWC170 test was noted in 80% of men and 40% of women. Similar dynamics were noted for oxygen consumption per heartbeat: an increase was observed in 90% of male athletes and 40% of women. Thus, the intake of citrulline malate in the preparatory period of the annual cycle contributes to a more pronounced improvement in the state of the oxygen supply system of the blood, an increase in physical performance, and the prevention of overtraining. Given the presence of gender differences in the effectiveness of citrulline malate, its use is more appropriate in male athletes.

Acknowledgments: All the authors were involved in the conceptualization, methodology, formal analysis, writing, and editing of the manuscript.

Conflict of interest: None

Financial support: None

Ethics statement: The study was conducted in accordance with the standards of the Helsinki Declaration of the World Association Ethical principles of conducting scientific medical research with human participants and Rules of Clinical Practice in the Russian Federation. All athletes gave their voluntary consent to participate in the study.

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