

Review

Effect of citrulline on post-exercise rating of perceived exertion, muscle soreness, and blood lactate levels: A systematic review and meta-analysis

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Received 11 June 2019; revised 4 August 2019; accepted 30 December 2019

Available online 8 February 2020

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Abstract

Background: Citrulline is one of the non-essential amino acids that is thought to improve exercise performance and reduce post-exercise muscle soreness. We conducted a systematic review and meta-analysis to determine the effect of citrulline supplements on the post-exercise rating of perceived exertion (RPE), muscle soreness, and blood lactate levels.

Methods: A random effects model was used to calculate the effect sizes due to the high variability in the study design and study populations of the articles included. A systematic search of PubMed, Web of Science, and ClinicalTrials.gov was performed. Eligibility for study inclusion was limited to studies that were randomized controlled trials involving healthy individuals and that investigated the acute effect of citrulline supplements on RPE, muscle soreness, and blood lactate levels. The supplementation time frame was limited to 2 h before exercise. The types and number of participants, types of exercise tests performed, supplementation protocols for L-citrulline or citrulline malate, and primary (RPE and muscle soreness) and secondary (blood lactate level) study outcomes were extracted from the identified studies.

Results: The analysis included 13 eligible articles including a total of 206 participants. The most frequent dosage used in the studies was 8 g of citrulline malate. Citrulline supplementation significantly reduced RPE ($n = 7$, $p = 0.03$) and muscle soreness 24-h and 48-h after post-exercise ($n = 7$, $p = 0.04$; $n = 6$, $p = 0.25$, respectively). However, citrulline supplementation did not significantly reduce muscle soreness 72-h post-exercise ($n = 4$, $p = 0.62$) or lower blood lactate levels ($n = 8$, $p = 0.17$).

Conclusion: Citrulline supplements significantly reduced post-exercise RPE and muscle soreness without affecting blood lactate levels.

Keywords: Amino acids; Dietary supplements; Ergogenic aid; Nitric oxide; Watermelon juice

1. Introduction

L-citrulline is one of the non-essential amino acids mainly found in watermelon (*Citrullus vulgaris*).¹ Supplements containing L-citrulline have been manufactured in different forms, including pure L-citrulline, watermelon juice, and citrulline malate (CM), and their effects have been studied under clinical and applied exercise settings.^{2–14} Recently, Trexler et al.¹⁵ published a meta-analysis evaluating the acute effect of citrulline supplementation on high-intensity strength and power performance. According to the meta-analysis, citrulline supplementation significantly enhanced the performance of high-intensity and power exercises.¹⁵ Other recent studies have investigated the effect of citrulline supplements on the

rating of perceived exertion (RPE) and muscle soreness, as well as exercise performance.^{2–14}

The potential use of citrulline supplements to relieve fatigue or muscle soreness is based on 2 hypothetical mechanisms. First, L-citrulline, one of the amino acids involved in the urea-cycle, may facilitate the clearance of ammonia. Ammonia plays an important role in fatigue because its intracellular accumulation favors glycolysis while inhibiting the aerobic utilization of pyruvate.^{11,16} This modified energy metabolism results in the formation of lactate, which may contribute to fatigue.^{17,18} During high-intensity exercise, the rate of glycolysis is increased, and anaerobic glycolysis also leads to accumulation of blood lactate.¹⁸ The synthesis of lactate may be diminished via L-citrulline supplementation because it buffers ammonia through the urea cycle, thereby enhancing the aerobic utilization of pyruvate.¹⁹ Second, L-citrulline in the kidney can be converted to L-arginine,²⁰ which is a substrate for nitric oxide synthase (NOS).²¹ Unlike L-arginine, L-citrulline

Peer review under responsibility of Shanghai University of Sport.

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