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RELATIONSHIP BETWEEN NITRATE SUPPLEMENTATION AND SPORTS PERFORMANCE: AN INTEGRATIVE REVIEW

Júlia Figueiredo Juncal
Academic Education: Student of medicine course, ``Faculdade Ciências Médicas de Minas Gerais`` - FCMMG
Belo Horizonte - Minas Gerais
http://lattes.cnpq.br/0781292385708208

Karine Wajnsztok Brasileiro
Academic Education: Student of medicine course, ``Faculdade Ciências Médicas de Minas Gerais`` - FCMMG
Belo Horizonte - Minas Gerais
http://lattes.cnpq.br/9732759689344497

Leticia Santos e Pereira
Academic Education: Student of medicine course, ``Faculdade Ciências Médicas de Minas Gerais`` - FCMMG
Belo Horizonte - Minas Gerais
http://lattes.cnpq.br/0130019288509976

Etelvino Pereira Donato Neto
Academic education: Student of medicine course, ``Faculdade Ciências Médicas de Minas Gerais`` - FCMMG
Guanambi - Bahia
http://lattes.cnpq.br/8323120132294413

Abstract: Introduction: Nitric oxide emerges as a multifunctional signaling molecule that regulates cardiovascular, metabolic and contractile processes. Its enhanced synthesis through the support of exogenous intake of nitrate, one of its precursors, represents a promising field of investigation, highlighting its implications within sports performance, improving muscle bioenergetic capacity. Objective: To elucidate the complex relationship between nitrate supplementation and sports performance, exploring its impact on athletic performance. Methodology: This is an integrative review of the literature carried out through research in the Medline and Pubmed databases, with the descriptors "Nitrate", "Exercise Performance" and "Supplementation". Discussion: The sample for this review consisted of 6 articles that met the inclusion criteria. It was assessed that all the articles that constitute the sample of this study point out several benefits in relation to nitrate supplementation to improve sports performance. The ergogenic aid in question proved to be effective in reducing O2 expenditure during performance and also in increasing the maximum volume of oxygen consumption (VO2 maximum), representing a promising result. Conclusion: There is evidence of a beneficial relationship between chronic nitrate supplementation and sports performance.
Keywords: "Nitrate"; "Sports Performance"; "Supplementation".

INTRODUCTION

Nitric oxide (NO) is a ubiquitous signaling molecule that plays a critical role in the vascular and metabolic control of skeletal muscle, with emphasis on its vasodilation and systemic blood flow regulator function, especially for skeletal muscle during increased metabolic demand. In this sense, nitrate supplementation, a precursor of NO, suggests benefits for vascular control and oxygen delivery to skeletal muscle, with potential implications for sports performance.[1,6]

Both endogenous NO synthesis and exogenous nitrate intake can influence the efficiency of aerobic metabolism and reduce the overall adenosine triphosphate cost of muscle activity. The known pathway of endogenous NO synthesis involves the reduction of L-arginine to L-citrulline via nitric oxide synthase, while the exogenous pathway involves the conversion of nitrate to nitrite and subsequently to NO. From this, it would be possible to observe a possible improvement in bioenergetic capacity in skeletal muscle through enhanced NO synthesis supported by exogenous nitrate intake.[6]

Given the high physical demand in the context of sports performance, athletes resort to nutritional supplements to improve their performance. Studies demonstrate growing scientific evidence of the benefits of nitric oxide precursors, such as L-citrulline and nitrate-rich supplements, which include beetroot juice or extract, for sports performance. These ergogenic aids, notably nitrate, not only improve aerobic performance, but also benefit muscular blood flow, reduce oxygen costs and increase mitochondrial efficiency during exercise. [2]

These benefits expand beyond sports performance. In relation to Type 2 Diabetes Mellitus, substantial reductions in VO2 maximum make daily activities more demanding, which reinforces the need for

additional strategies that can have significant clinical implications, which include nitrate supplementation.[3] Aging contributes to reduction in NO bioavailability, with chronic supplementation of NO precursors having potential effects on vascular function and health, cerebral and muscular oxygenation and physical performance in healthy elderly people.[4] Furthermore, studies present the importance of modulating the oral and intestinal microbiota as influential for the conversion of nitrate to nitrite, affecting nitric oxide signaling and also potentially improving sports performance.[5]

Finally, NO emerges as a multifunctional molecule that regulates cardiovascular, metabolic and contractile processes. Its obtainment exogenously through nitrate supplementation represents a promising field of investigation, highlighting its implications within sports performance, which expand to the management of physical exercises within specific clinical conditions, which include senescence and diabetic patients. type 2 as examples.

GOAL

This integrative review article seeks to comprehensively and integrated analyze the available scientific evidence, in order to elucidate the complex relationship between nitrate supplementation and sports performance, exploring its potential physiological and practical implications for optimizing athletic performance.

METHODOLOGY

This is an integrative review of the literature carried out between August and October 2023, through searches in the databases: Medline and Pubmed. The descriptors were used: "Nitrate", "Exercise Performance" and "Supplementation". From this search, a total of 303 articles were found, subsequently submitted to the selection criteria.

The inclusion criteria included scientific articles published between 2018 and 2023, in Portuguese and English, which addressed the themes proposed for this research, had a clear methodology and were available completely and free of charge. The exclusion criteria were duplicate articles, case reports, systematic reviews and meta-analysis studies, available in abstract form, which did not directly address the proposal studied and which did not meet the other inclusion criteria. After the selection criteria, 42 articles remained and were submitted for abstract reading. Finally, 6 articles were selected blindly and independently.

DISCUSSION

In relation to the objective of this review, that is, to evaluate the relationship between nitrate supplementation and sports performance, it was observed in the articles that make up the sample that supplementation proved to be beneficial for improving effectiveness and performance during practice. of physical exercise.

Furthermore, the use of ergogenic aids proved to be effective both in reducing O2 expenditure during performance, a fact proven through the decrease in submaximal VO2, and in increasing the maximum volume of oxygen consumption (maximum VO2), which reflects an improvement in the individual's physical conditioning.

Dietary nitrate intake has an impact on the reserves of the compound in skeletal muscle. Although enzymes similar to nitric oxide synthase have been identified in certain enteric bacteria, the vast majority of luminal NO is produced by anaerobic bacteria through the reductive metabolism of nitrate and nitrite. However, the substance produced by this group of bacteria could act as an extra supply for its bioavailability in skeletal muscle,

RESULTS

Title	Author	Type of study	Goal	Method	Results
"Effects of Dietary Nitrate Supplementation on Performance and Muscle Oxygenation during Resistance Exercise in Men"	Tan *et al.* (2022)	Double blind randomized trial	To compare the long- and short-term effects of nitrate supplementation on skeletal muscle oxygenation, neuromuscular function, and muscular endurance performance during the back squat and bench press.	Evaluation for 4 days with beetroot juice rich in nitrate and low in nitrate (placebo).	There was an increase in repetitions completed before failure during the bench press, but not during squats and without influencing skeletal muscle oxygenation. Furthermore, no effects on strength and endurance during exercise were noted.
"Combined Effects of Citrulline Plus Nitrate-Rich Beetroot Extract Co-Supplementation on Maximal and Endurance-Strength and Aerobic Power in Trained Male Triathletes: A Randomized Double-Blind, Placebo-Controlled Trial"	Burgos *et al.* (2021)	Randomized Double Blind Placebo Controlled Trial	To evaluate the effects of the combination of 3 g/ day of L-citrulline (CIT) associated with 2.1 g/ day of beetroot juice rich in nitrate (300 mg/day of ⟦NO⟧^(-3)) (BR) on sports performance for 9 weeks through horizontal jump test, handgrip test, abdominal test and Cooper test.	Placebo group (PLAG), citrulline group (CITG), nitrate-rich beetroot juice group (BRG) and group associated with both (CIT-BRG).	There was an improvement in resistance, strength and aerobic training at CIT-BRG.
"Effects of Combined Inorganic Nitrate and Nitrite Supplementation on Cardiorespiratory Fitness and Skeletal Muscle Oxidative Capacity in Type 2 Diabetes: A Pilot Randomized Controlled Trial"	Turner *et al.* (2022)	Randomized Double Blind Placebo Controlled Trial	To evaluate the improvement in VO2max and respiratory function of skeletal muscle mitochondria in participants with DM2 with nitrite and nitrate supplementation for 8 weeks.	Comparison between individuals with type 2 diabetes and non-diabetics.	Supplementation proved to be beneficial for VO2 and reducing the risk of death in diabetic patients. Furthermore, there was an improvement in the oxidative capacity of skeletal muscle supported by carbohydrates and fatty acids.
"Effect of chronic nitrate and citrulline supplementation on vascular function and exercise performance in older individuals"	Le Roux-Mallouf *et al.* (2018)	Double blind randomized trial	To evaluate the effect of chronic nitrate supplementation on vascular function, muscle and brain oxygenation, and exercise performance in healthy elderly people.	Comparison between localized and whole-body exercises for 1 month with daily placebo or salad supplementation rich in nitrate (520mg) and citrulline (6g).	Chronic nitrate supplementation was beneficial as it reduced blood pressure and improved maximum exercise capacity by reducing O2 expenditure, proven by the decrease in submaximal VO2.
"Role of Oral and Gut Microbiota in Dietary Nitrate Metabolism and Its Impact on Sports Performance"	González-Soltero *et al.* (2020)	Narrative review	To evaluate the evidence of oral and intestinal microbiota in better sports performance mediated by nitrate consumption.	Analysis of studies that showed the effect of nitrate on the intestinal microbiota.	The intestinal microbiota can improve sports performance.
"The effects of multi-day VS. single pre-exercise nitrate supplement dosing on simulated cycling time trial performance and skeletal muscle oxygenation"	Edward Jo *et al.* (2019)	Randomized Double Blind Placebo Controlled Trial	Compare the effects of nitrate supplementation (500mg) for two weeks with a single pre-exercise dose.	To evaluate skeletal muscle oxygenation during cycling and during recreational training in young people.	Chronic nitrate supplementation improves exercise effectiveness and performance through greater energy production per oxygen consumed.

which may be linked to improved sports performance.[5]

Furthermore, it was experimentally demonstrated that bacteria of the genus Veillonella when applied to rats resulted in an increase in their running time compared to rats in the control group. It is known that the same genus of Veillonella sp. is present in the oral microbiota and is one of the main, if not the main, bacteria involved in the conversion of nitrate into nitrite. This gene thus appears to be strongly linked to sports performance, due to its participation in the conversion of nitrate in the oral cavity and its activity in the intestine as a producer of propionate from lactate generated during physical activity.[5]

The difference in effectiveness between chronic and acute nitrate supplementation for improving sports performance was compared in three studies included in this review.[4,6] From the results obtained with chronic administration, the significant reduction in mean arterial pressure, increase in maximum power and decrease in heart rate and oxygen expenditure during cycling stand out as benefits.[4] However, the supplementation in question had no influence on the following indices: arterial stiffness; vasodilation; muscle and brain oxygenation during exercise; cardiovascular and cerebrovascular responses to hypercapnia and hypoxia.[4]

Acute dietary supplementation of nitrate-rich beetroot juice has been shown to be effective for increasing the set of repetitions to failure during the bench press exercise and ineffective for improving muscle power, speed or oxygenation during back squats. any type of resistance exercise. Such results suggest that the supplementation in question would be more effective in improving performance during resistance exercise, continued until failure, of the upper body. [1]

Furthermore, it was proven that not only the form of administration was a determining factor in improving sports performance. The effectiveness of supplementation is also determined by other factors such as: training status, intensity of exercise performance and distribution of myofiber phenotype.[6]

Regarding the combined effect of ergogenic aids and nitric oxide precursors, the use of citrulline together with nitrate-rich beetroot extract (BR) was investigated in a study included in the sample of this review. It was observed that the combination promoted significant interactions in aerobic power performance, confirmed with higher estimated maximum VO2. Furthermore, the arrangement of both supplements, which, when used separately, are considered beneficial in sports performance, could act in a complementary way to improve maximum strength performance and resistance strength through improvement in excitation-contraction, coupling and preventing the accumulation of fatigue metabolites. [2]

Finally, in an evaluation focused on individuals with type 2 diabetes mellitus, combined nitrate and nitrite supplementation was presented as positive for improving cardiorespiratory fitness and the oxidative capacity of skeletal muscle, functions reportedly impaired due to the interruption of NO metabolism in diabetic patients. This finding has extremely important clinical and therapeutic implications, as it may reduce the risk of all-cause mortality in this population. Furthermore, the maximum oxidative capacity of skeletal muscle supported by carbohydrates and fatty acids was also strongly improved, in some individuals, by the supplementation in question, which also represents a promising result. [3]

CONCLUSION

Nitrate is a precursor to nitric oxide, which is responsible for regulating blood flow, muscle contraction and cellular respiration. From this, the improvement of performance and physical capacity results from the development of maximum VO2, vasodilation and the delivery of nutrients to the muscle, in addition to reducing the accumulation of fatigue metabolites, such as lactate, and stimulating mitochondrial biogenesis in the skeletal muscle.

Studies have shown improvements in aerobic training, resistance training and strength training, in addition to reducing the feeling of fatigue, through chronic supplementation of 300 to 500 mg/day of nitrate. Furthermore, it proved to be effective in reducing cardiovascular risks in patients with Diabetes Mellitus II.

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