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## Effect of beetroot juice supplementation on sports and physical exercise: A systematic review

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### Abstract

The increased utilization of natural and organic products/energy boosters has evoked interests in athletes and layman in advancing health and improving performance. Among these products, beetroot juice (BRJ) has been widely used by athletes to enhance sports performances. BRJ contains high nitrate concentrations, which can be converted into nitric oxide (NO) after consumption. Various studies have indicated that beetroot juice can improve performance and increase muscular activity. As beetroot is a significant source of NO, it has various effects on the human body, including a vasodilatory effect, which reduces blood pressure and increases oxygen- and nutrient delivery to various organs. These effects suggest that BRJ may have a relevant role in the prevention and treatment of multiple ailments. Besides, the intake of BRJ also has a significant function in oxygen transport to skeletal muscles, muscle efficiency, tolerance, and endurance and may thus impart a positive impact on sports performances. Foods rich in antioxidants and anti-inflammatory phytochemicals might recover skeletal muscle damage; therefore, the present study aims at reviewing the efficacy of BRJ to serve as an adjuvant in athletic performance. Several studies emphasize that BRJ may provide satisfactory performance enhancement, and studies on its action are somewhat limited. However, more data is needed to substantiate the mechanisms of action and proper intake patterns to maximize the performance benefits of BRJ.

**Keywords:** beetroot juice, nitrate, nitric oxide, anti-inflammatory phytochemicals, vasodilatory effect

### 1. Introduction

In the world of high competition, boundaries of triumph are becoming more diminutive, and in some instances, may come down to a fraction of a second or the ability to contract a single motor unit one more time. Consequently, athletes are often in the search for any support to enhance athletic performance. Some athletes intake nutritional supplements, from both natural and organic sources, to implement this list. One of the more traditional natural foods considered to help athletic performance is beetroot (*Beta vulgaris*), one of North America's most common beet varieties. Beetroot is an invaluable reservoir of antioxidants and micronutrients, including potassium, betaine, sodium, magnesium, vitamin C, and nitrate (NO<sub>3</sub>) and contains 29 kcal per 100 g (Escribano *et al.*, 1998) [12]. The beetroot color stems from its purple and yellow pigments (betacyanin and betaxanthin, respectively), known collectively as betalains. These betalains have potential antioxidant capabilities (Kanner *et al.*, 2001) [23]. Beetroot juice (BRJ) comprises a large concentration of nitrate (up to 11.4 g/L) (Zamani *et al.*, 2020 [45]; Vermeer & van Maanen, 2001; Wruss *et al.* 2015) [43]. As nitrate intake may improve sports performances, the application of BRJ by athletes has increased across the ages, especially in endurance sports (Arciero, Miller, and Ward 2015) [2]. A five percent rise several times in the global beetroot juice market has been reported, and this increase will presumably advance in the upcoming years (Growing Popularity of Beetroot Juice to Fuel the Global Market for Beetroot Powder During 2017 – 2027). Nitrate in BRJ is converted in the human body to nitrite and consequently to nitric oxide (NO), a compound that is perceived to have a vasodilatory effect, according to in reduced blood pressure and increased oxygen- and nutrient transportation to the intense muscle (Jones, Bailey, and Vanhatalo 2012) [22].

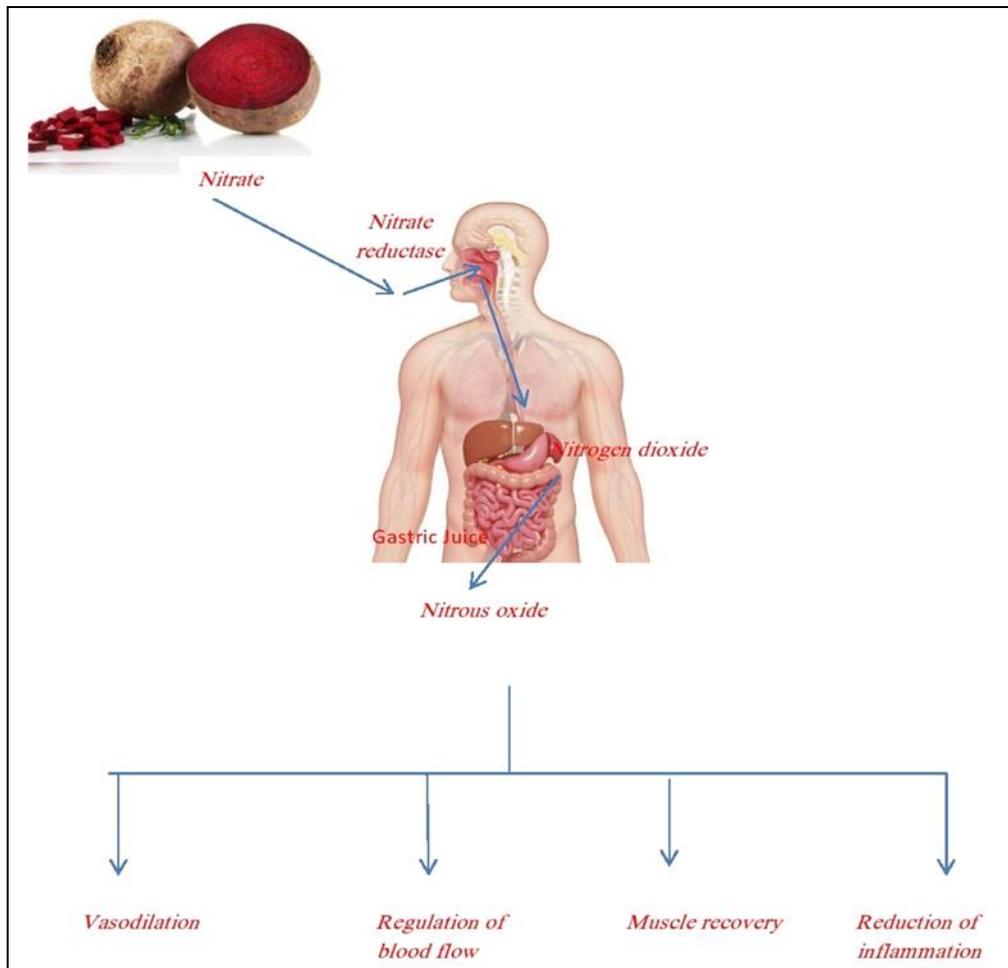
Interestingly, BRJ has been marketed to support digestive and blood health, improve energy, be a natural cleanser, and increase nitric oxide (NO) to improve blood flow. Besides, BRJ has been indicated to possess anticancer properties, reduces the risk of stroke and peripheral

vascular disease, lower blood pressure, and reduce inflammation. These claims have brought the popularity of BRJ. Hence, this review will investigate the positive effect of BRJ rather than its adverse effects on the body.

## 2. Mechanism of action of Beetroot juice

Several studies have been indicated the effect of BRJ

supplementation on blood pressure and sports performance. Besides the beneficial effects, some health risks may also be associated with its consumption. Nitrate intake contributes to N-nitroso compounds' endogenous formation (NOCs), a class of potential carcinogens. Consumption of a high concentration of nitrate may increase the amount of endogenous NOCs being formed (Berends *et al.* 2019) [45].



**Fig 1:** The schematic representation of the conversion of nitrate into nitrous oxide.

In the initial step, nitrate is converted by nitrate reductase to Nitrogen dioxide. Once it reaches the gut, Nitrogen dioxide enters the bloodstream and generates Nitrous oxide.

### 2.1 Effects of Beetroot juice on skeletal muscles and oxygen consumption

Researchers have examined the effect of BRJ on skeletal muscle and oxygen consumption and have found several parameters induced by intense or short-term supplementation. Physiologically, a high ATP turnover during muscle contractions leads to higher oxygen consumption ( $VO_2$ ). To compensate for this increased demand, NO-mediated vasodilation occurs (Ferguson *et al.* 2015) [14]. BRJ affects both these parameters by enhancing vasodilation and by influencing  $VO_2$ . Numerous investigations observed that BRJ progresses  $O_2$  kinetics in muscles, for example, by advancing up the  $VO_2$  mean response time, therefore stimulating the transition from non-oxidative to oxidative energy production in the muscle cell at the incipience of exercise or while hypoxia (Bailey *et al.* 2015; Breese *et al.* 2013 [7]; Craig *et al.*, 2018 [8]; Fulford *et al.* 2013 [15]; Kelly *et al.* 2014 [24]; Vanhatalo *et al.* 2011 [37]; Waldron *et al.* 2018) [41]. Ameliorated  $O_2$  kinetics can reduce metabolic disorder in

muscles caused by the accumulation of metabolites generated during anaerobic respiration (Bailey *et al.* 2015; Breese *et al.* 2013 [7]; Kelly, Fulford, *et al.* 2013 [15]; Kelly *et al.* 2014 [24]; Vanhatalo *et al.* 2011) [37]

BRJ can enhance sports performance through various mechanisms. These include a decrease in skeletal muscle oxygen consumption, acceleration in the transition between anaerobic and aerobic respiration, which can decrease muscle perturbation, slow the onset of fatigue, and improve power output and force.

### 2.2 Beetroot as an anti-inflammatory agent

Under normal conditions, inflammation is a process of the innate response to biological or physical stimuli such as trauma, infection, and other harmful pathogens that may affect the organism and upset homeostasis (Azvedo *et al.*, 2010) [3]. With that stated, immune activation may still have unacceptable consequences for the host. In the short duration, redness, swelling, pain, and diminished function may be experienced in the situation of inflammation; nevertheless, more disquieting is the potential long-term entanglements if inflammation continues and is dubious (Yoon *et al.*, 2005) [44]. Failure to eliminate the invading element and recover normal

immune function can cause chronic inflammation resulting in long-term cell dysfunction (Kundu *et al.*, 2012) [26]. Chronic inflammation is often implicated in the origin and progression of several clinical dysfunctions, such as obesity, liver disease, cancer, and heart disease (Byrne *et al.*, 2001) [30]. This imparts a positive ray that betanin rich beetroot supplements, in sufficient doses, could exhibit anti-inflammatory effects to rival synthetic drugs. A recent study from Vidal *et al.* 2014 [40] provided further support for the anti-inflammatory effects of betalains. The antioxidant and anti-inflammatory property of beetroot has also led to an interest in its potential use in diseases distinguished by abnormal immune cell function. Indeed, chronic inflammation is increasingly being implicated in the development of malignant tumors, and the proof is gathering to recommend betalain extracts concerned from beetroot may overcome these impressions.

### 2.3 Regulation of blood flow

Richards *et al.* 2018 confirmed that BRJ improves muscle blood flow through vasodilation while handgrip exercises in young adults (Bentley *et al.* 2017; Kent, Dawson, Cox, Abbiss, *et al.* 2018) [5, 25]. An animal study with rats also recorded an increment in muscle blood flow, but only nitrate (Ferguson *et al.*, 2014) [14]. However, Amano *et al.* (2018) [1] noted that BRJ intake, 140 ml for three days, does not affect skin blood flow (Amano *et al.* 2018) [1]. Some studies reported an increase in muscle oxygenation during exercise (Papadopoulos *et al.* 2018; Vanhatalo *et al.*, 2014) [31, 24] and reduced tissue oxygenation in latent muscles after BRJ supplementation (Horiuchi *et al.* 2017) [19].

### 2.4 Effect of beetroot juice on Athletes

Nitrous oxide has various physiological roles, including hemodynamic and metabolic actions (Fergusson *et al.*, 2015; Larsen *et al.*, 2007) [14, 27]. Mediated by guanylyl cyclase (Ignarro *et al.*, 1986) [21], NO must affect smooth muscle fibers producing blood vessel dilation (Furchgott & Jothianandan 1991) [16]. This vasodilation effect enhances blood flow to muscle fibers (Puype *et al.*, 2015) [33], improving gas exchange (Ezrum *et al.*, 2005). No also influences gene expression (Tong *et al.*, 2011) [35], improving biogenesis (Dejan *et al.*, 2004) and mitochondrial efficiency (Pinna *et al.*, 2014) [32]. A total of those effects can favor oxidative power metabolism (MacLeod *et al.*, 2015) [28]. Various studies have remarked that beetroot juice supplementation boosts performance in exercise modalities, including intensive persistence efforts in which the predominant type of energy metabolism is oxidative (Till this date, numerous reports of the literature have evaluated the effects of beetroot juice supplements on physical exercise (Bescos *et al.*, 2011) Clifford *et al.* (2016) [9] noted that the protocol of intermittent sprints turned to muscular fatigue. This fatigue can be the outcome of deficiencies in the muscle's contractile mechanism (Sanchez *et al.*, 2011). Alternatively, the hamstring muscles' strong actions during sprints may produce muscle damage (Mosteiro & Domínguez 2017) [29] and modify the muscle fiber's sarcomeres' structure accordingly. Therefore, any loss in counter-movement jump (CMJ) height could indicate muscle damage. A greater recovery of CMJ height was observed in the people consumed beetroot juice. This recommends that beetroot juice could help preserve muscle structure through high-intensity efforts. Another explanation could be linked to the vasodilation effect of beetroot juice (Dominguez *et al.*, 2017) [11]. Intake of beetroot juice has been conferred to reduce muscular fatigue

connected with high-intensity exercise efforts, though it is unknown if this is performed by reducing fatigue and muscle damage and/or promoting muscle recovery (postexercise). When confronted with exercise efforts that could considerably exhaust phosphocreatine reserves and phosphocreatine resynthesis needs an oxidative metabolism, beetroot juice could help recover phosphocreatine reserves to avoid depletion during repeated efforts (Hoon *et al.*, 2013) [20]. In correspondence, supplementation would limit the build-up of metabolites such as ADP and inorganic phosphates, which are known to induce muscular fatigue. Nonisokinetic ergometers (in which movement velocity is not assessed) are susceptible to such improvements in power generation (Clifford *et al.*, 2016; Whitefield *et al.*, 2016) [9, 42]. Beetroot juice has been shown to enhance the release and reuptake of calcium at the sarcoplasmic reticulum. This could serve the power production connected with improvements in muscle shortening velocity (Hernandez *et al.*, 2012) [18].

### 3. Negative effects of Beetroot juice in humans

Besides the formation of N-nitroso compounds in the body, it is known that ingestion of high levels of nitrate may stimulate the generation of NOC, which are potentially carcinogenic compounds (Vermier *et al.*, 1998) [38]. Nevertheless, the result of BRJ consumption on the endogenous generation of NOCs has hardly been investigated. Intake of BRJ may quickly increase nitrate intake above the acceptable daily intake (ADI). After consumption, part of the nitrate can be reduced to nitrite in the mouth by bacteria. In asphyxia, nitrate and nitrite can be condensed into NO. NO can also be oxidized into nitrate and nitrite, water-soluble, and excreted by the urine. Under certain acidic conditions, such as in the human stomach, nitrite will react with the H<sup>+</sup> and form HNO<sub>2</sub> (nitrous acid). In the stomach, two molecules HNO<sub>2</sub> can form N<sub>2</sub>O<sub>3</sub> (dinitrogen trioxide) by proton catalysis. As N<sub>2</sub>O<sub>3</sub> executes a function in the N-nitrosation rate, prolonged consumption of nitrate can increase the N-nitrosation rate (Henrhon *et al.*, 2018). Many extensive studies have been carried out on BRJ consumption concerning cancer risk. As BRJ comprises high nitrate levels, BRJ consumption sways a health risk due to the potential production of NOCs. Further research is strictly needed to investigate the connection between NOC formation and BRJ consumption for a shorter and longer time and its potential carcinogenic hazard. In the meantime, it is necessary to be careful with the chronic use of BRJ to enhance sports performances.

### 4. Conclusion

A broad range of investigations states the beneficial health effects of devouring BRJ, mainly sport enhancing effects. The high levels of nitrate explain this outcome in BRJ, which has a salubrious effect on different parameters, including NO, blood flow, platelet aggregation, heart rate, cardiac output, blood pressure, and performance. Because of its effect on the cardiovascular system, BRJ consumption could be used to supplement different cardiovascular disease treatments. However, a high intake of nitrate can also result in the formation of potentially carcinogenic NOCs. Intake of high nitrate levels via various routes has been shown to increase the risk of different cancer types.

Nevertheless, no detailed studies have been published which investigate the possible health risks of BRJ consumption. Hence, more detailed research is necessary for a comprehensive and reliable assessment of the adverse effects of BRJ consumption. In particular, more authentic human

studies are needed to secure that the amount of BRJ supplementation that is currently advised to lower blood pressure and enhance sports performances does not increase the endogenous formation of N-nitroso compounds (NOC) and associated health effects to guarantee that BRJ can be safely used.

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