

Review Article

The Impact of Beetroot Supplementation and Exercise Training on Performance and Health in the Elderly: A Narrative Review

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Abstract

Introduction: The elderly population is increasing globally, and the elderly are vulnerable to many ailments as the aging process negatively affects the body and physiological systems. Plants have been used to treat illnesses throughout history. The aim of this study was to investigate the beneficial effects of beetroot consumption with exercise training on aging in older adults.

Methods: Several databases (2002-2023) were searched, including Web of Science, Scopus, ScienceDirect, Google Scholar, and PubMed, using different keywords such as "Beetroot and Aging", "Beetroot and Older Adults", "Beetroot and Elderly", "Beetroot and Exercise", "Beetroot and Training", and "Beetroot and Physical Activity". The inclusion criteria were individuals aged 60 or more and full-texts available and written in English.

Results: Overall, 27 studies met the inclusion criteria, which reported beetroot and physical activity as a beneficial treatment in a range of chronic diseases associated with the aging process.

Conclusion: The findings indicated that beetroot consumption can slow the aging process, although there are also contradictory findings in this regard. Further studies are needed to provide more data on the optimal dosages of beetroot needed to provide health benefits in older adults.

Keywords: Beetroot, Performance, Aging, Older adults, Physical activity

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Introduction

According to the World Health Organization (WHO), 1 in 6 people in the world will be aged 60 years or older by 2030 (1). The number of elderly persons increased from 1 billion to 1.4 billion in 2020, and people aged 60 years and older will double to 2.1 billion by 2050. However, the number of people aged 80 years or older is expected to triple between 2020 and 2050 and reach 426 million. Aging results from the accumulation of various molecular and cellular changes over time, leading to gradual decreases in physical and mental capacity, a growing risk of disease, and ultimately death (1,2).

Plant products are used to treat several health issues, demonstrating that food is medicine (3). Beetroot, or *Beta vulgaris* L., is a medicinal plant belonging to the Chenopodiaceae family. Beetroot has recently become popular as a potential "functional food" (4), with benefits in regulating the immune system, antioxidant defenses, cardiovascular health, cancer, and the like

(5,6). Furthermore, beetroot supplementation has gained support from the Australian Institute of Sport, with beetroot juice (BJ) included in the Class A group (permitted and most likely to be beneficial according to the evidence) (7). Beetroot supplements and their products slow the aging process and the onset of age-related diseases (8,9).

Physical activity and exercise are other ways to aid healthy aging. The WHO defines physical activity as any bodily movement that requires energy expenditure by skeletal muscles. Physical activity refers to all movements with both moderate and vigorous intensity, including exercise during leisure time, walking to get to and from places, or as a part of a person's work (10). Exercise has been used in both the treatment and prevention of chronic conditions such as cardiovascular diseases, pulmonary disease, cancer, diabetes, and obesity, reaffirming the notion that "Exercise Is Medicine" (11).

Physical activity is a safe, effective, and cost-effective "medicine" for a wide variety of age-related diseases, while



lack of exercise contributes to accelerated aging and age-associated chronic disorders including cancer, obesity, and cardiovascular diseases. Our narrative review evaluates the effects of beetroot and its products combined with exercise on performance and health in the elderly (12).

Materials and Methods

Search Strategy

Data for this study were obtained from Web of Science, Scopus, Science Direct, Google Scholar, and PubMed databases (2002-2023) using the keywords “beetroot and aging”, “beetroot and older adults”, “beetroot and elderly”, “beetroot and exercise”, “beetroot and training”, and “beetroot and physical activity”. Only peer-reviewed articles published in English were included, and original reports were categorized and sorted for discussion.

Inclusion Criteria

Investigations (2002-2023) used at least one of the keywords “beetroot and cognitive function”, “beetroot and aging”, “beetroot and older adult diseases”, “beetroot and exercise tolerance”, “beetroot and cardiovascular diseases”, “beetroot and exercise performance”, “beetroot and O₂ volume”, or “beetroot supplement”. The inclusion criteria were studies with individuals aged 60 or more and full-texts available and written in English. Our search aimed to identify the benefits of BJ and physical activity in the elderly and further studies to investigate the benefits of beetroot that can improve the quality of life in older adults.

Exclusion Criteria

Studies were excluded if they did not meet the inclusion criteria, full texts were not available, were not written in English, did not include aging as a variable, did not use beetroot as a supplement, or were in the form of comments and letters to editors.

Data Extraction

After collecting data and assessing the eligibility of included papers (by M. M.), the selection process received final approval from the other co-authors, and the information was abstracted from eligible articles.

Historical Perspectives

Beets, which are believed to originate from the coasts of the Mediterranean (sea beets), were first cultivated for their edible leaves by the Greeks and Romans. By the end of the 15th century, cultivated forms of beets were found throughout Europe and used not only for their leaves but also for their roots. Beetroot was used in 812 BC for its medicinal value against digestive and blood disorders. The Talmud Book of the fourth and fifth centuries recommended beetroot usage for longevity. The Romans considered roots as a laxative or antidote against fever. Hippocrates and Theophrastus mentioned the beet varieties with fleshy-textured roots as medicinal plants,

and Hippocrates' beetroot leaves for dressing wounds (6).

Beetroot Compositions and Human Health Benefits

Many studies have reported that beetroot has various components that are highly beneficial for human health (Table 1). For instance, betalains (mainly betanin) are the most important and effective antioxidants extracted from beetroot. Several lines of evidence have shown that betalains might reduce the risk of some cancers, cardiovascular and cerebrovascular diseases, liver and kidney damage, and the like (13).

Nitrate is another effective component of beetroot. Several studies have demonstrated that dietary nitrate (principally as BJ) may confer favorable health/performance effects in younger and older individuals (14).

Other phytochemicals found in beetroot are flavonoids, which have health-promoting properties (15). Therefore, it has been reported that beetroot tubers and leaves have anti-oxidant properties, which may increase the protection against free radicals (16-18). Moreover, BJ is effective against oxidative stress by reducing DNA damage and liver injury biomarkers (19). Thus, beetroot can reduce age-related disease and improve the quality of life in older adults since it is a rich plant of flavonoid antioxidants.

Beetroot and Aging Brain

Cognition is critical for functional independence as people age and is an indicator to determine if someone can live independently, manage finances, take medications correctly, and drive safely. Cognitive abilities often decline with age (20). The effects of physical activity and beets on the brain and cognition have been investigated separately. However, this section focuses on the effects of combining physical activity with beetroot on cognitive function.

One study showed that consuming 450 mL of BJ improved cognitive performance in a cognitive task, activating their frontal cortex compared to the placebo group in healthy adults (21).

It was reported that short-term nitrate-rich concentrated BJ supplementation (3 days BJ at 2 × 70 mL/d, 9.6 mmol/d nitrate) could not improve scores on three cognitive tests (serial subtractions, rapid visual information processing, and number recall) in older adults (22). A more recent study indicated that subjects who participated in moderately intense exercise (RPE of 12–13), consisting of a walking program (three 50-minute sessions per week), and consumed BJ (70 mL containing 560 mg of nitrate) had greater consistency within the motor community and fewer secondary connections with the insular cortex compared with those who exercised without BJ. The exercise + BJ group had brain networks that more closely resembled those of younger adults, showing the potentially enhanced neuroplasticity conferred by combining exercise and BJ consumption (23). It has also been found that the consumption of beetroot for eight weeks improved cognitive reaction time and memory retrieval speed (24). These results suggest that the consumption of whole

Table 1. The Antioxidant Compounds, Minerals, Vitamins, and Other Constituents of Beetroot and its Role in the Maintenance of Human Health

Antioxidants/Minerals/Vitamins	Health Benefits
Phytochemicals (ascorbic acid, phenolic acids, flavonoids, and carotenoids)	Enhancing immune function and reducing oxidative stress and inflammation
Betalains and betacyanins (betanin and isobetanin)	Being important phytochemicals possessing antitoxic, antioxidant, and anti-inflammatory activity and acting as chemo-preventive agents for cancer
Saponins (oleanolic acid, hederagenin aglycone, and betavulgarosides I, II, III, IV, V, VI, VII, VIII, IX, and X)	Having viricidal, hypolipidemic, and hypoglycemic, antifungal, and antimicrobial activities
Steroid/triterpenes (β -amyryn acetate, boehmeryl acetate, and friedelin)	Inhibiting growth of oral mucosal, colon, and breast cancer and having anti-inflammatory, antioxidant, liver protection, and antibacterial activities
Sesquiterpenoids (Ipomeamarone 6-myoporol, and 4-hydroxydehydro-myoporone)	Having anti-inflammation and anti-tumorigenesis properties and preventing neurodegeneration and antimigraine, analgesic, and sedative activities
Alkaloid (Ipomine, calystegine B1, calystegine B2, calystegine B3, and calystegine C1)	Causing anti-progestogenic and alterations in the estrous cycle
Ferulic acid	Having antioxidant, anti-inflammatory, anticarcinogenic, antiallergic, antimicrobial, hepatoprotective, antiviral, antithrombotic, and vasodilatory effects and helping in sperm protection
Taurine	Reducing fat deposition, triglycerides, serum, and liver cholesterol
Nitrates	Maintaining systematic blood flow and heart health, improving the performance of athletes by the elevated efficacy of mitochondria, and maintaining cognitive and mental health of the brain
Magnesium	Being essential for the maintenance of the muscles, heart, nerves, and immune health. Participating in > 300 biochemical reactions in the body
Copper	Supporting bones, blood vessels, and the immune system and playing an important role in collagen formation
Phosphorous	Being necessary for bones, teeth, and cell repair
Zinc	Being necessary for normal growth, immune reactions, and wound healing
Sulfur	Being a component of structural and functional proteins
Iron	Being essential for the energy metabolism of each and every cell of the body by carrying oxygen as a component of hemoglobin present in red blood cells and reducing fatigue, shortness of breath, rapid heartbeat, dizziness, headache, and the like
Calcium	Mainly promoting bone growth and strength and being necessary for different metabolic aspects of the cell
Vitamin B ₆	Maintaining health by involving in the production of red blood cells and various cellular metabolic pathways
Folate (Vitamin B ₉)	Being a crucial component of DNA and cell death
Vitamin A	Maintaining improved vision and reducing night blindness
Vitamin C	Being a well-known antioxidant helping with immunity and skin health and converting nitrite to nitric oxide
Beet fibers and proteins	Improving digestion and lowering inflammatory bowel disease, thereby reducing the risk of heart disease, diabetes type 2, and colorectal cancer. Fibers are low in calories, with high water content, and moderate protein levels help in weight reduction

Source: Pandita et al (5) and Nayik & Gull (6).

beetroot has the potential to improve cognitive function in the aging population.

Beetroot and Daily Function in Older Adults

Functional dependence on activities of daily living and falls are significant challenges for a global aging population. Falls and the inability to perform activities of daily living impede a person from meeting the WHO definition of healthy aging. The WHO definition of healthy aging is elated to maintaining functional and cognitive abilities, including the ability to meet basic needs, learn, make reasonable decisions, remain mobile, build and maintain relationships, and contribute to society (25).

There are conflicting findings on the effects of beetroot on the performance of the elderly, and the positive effects of BJ consumption on the performance of healthy younger people (26) may not apply to older people. Short-term nitrate-rich concentrated BJ (2×70 mL/d for 3 days) reduced resting blood pressure (BP) and the VO₂ mean

response time during the walking exercise in a healthy senescent population. However, BJ did not alter steady-state O₂ consumption during walking, functional walking performance, or the muscle metabolic response to low-intensity exercise (22). Another study reported that BJ (70 mL/d, 6.43 mmol nitrate/day for 4 days) did not affect O₂ consumption during moderate-paced walking or could not improve performance in a 6-minute walking test (27). Supplementation for longer periods (70 mL×2/d containing ~12 mmol nitrates for 7 days) also did not alter resting or submaximal or maximal O₂ consumption during incremental exercise tests. In addition, measures of physical ability and physical activity levels (PAL) measured in free-living conditions were not modified by BJ (28).

However, other studies confirmed that beetroot improves performance in older adults. Acute supplementation with 500 mL of BJ increased exercise claudication onset time and peak walking time by almost

20% in subjects with peripheral artery disease and intermittent claudication while also increasing exercise tolerance in subjects with peripheral artery disease (29). Another study also suggested that a single dose of a beetroot-based nutritional gel (100 g containing 12.2 mmol/100 g nitrate) could improve muscle O_2 saturation status in the forearm of older adults by increasing muscle O_2 extraction during handgrip exercises and accelerating muscle O_2 resaturation during exercise recovery, thereby preventing the age-related prolongation in post-exercise recovery time of muscle O_2 resaturation and improving muscle function in older adults (30). A recent study has indicated that BJ (containing 13.4 nitrates) improves maximal knee extensor angular velocity and power in older individuals (31).

Beetroot and Sarcopenia

Sarcopenia was first described in the 1980s as an age-related decline in lean body mass affecting mobility, nutritional status, and independence. The definition has since evolved and is now considered a progressive and generalized skeletal muscle disorder involving accelerated loss of muscle mass and function. Sarcopenia is associated with increased adverse outcomes, including falls, functional decline, frailty, and mortality (32).

Our search identified only two studies related to exercise, beet, and sarcopenia. A report by Córdova et al investigated if supplementation with nitric oxide (NO) precursors (L-arginine, L-citrulline, and beetroot extract) following a physical activity program for 6 weeks modulated circulating levels of calcium, magnesium, vitamin D, and steroid hormones in elders suffering from sarcopenia. Supplementation with the L-arginine and nitrate-rich beetroot extracts (300 mg/d of beetroot extract rich in nitrate) increased circulating vitamin D levels in men and women over 60 years of age who were at risk of sarcopenia (33). Another study by Córdova-Martínez et al indicated that 3–3.5 g of the dry beetroot extract improved muscle function mainly in older women but did not improve the general fitness levels in older women and men except for walking speed (34).

Beetroot and Chronic Obstructive Pulmonary Disease

Chronic obstructive pulmonary disease (COPD) causes shortness of breath due to structural and functional changes in the airways and/or lung parenchyma (35,36) and can lead to exercise intolerance as a result of skeletal muscle deconditioning, tissue hypoxia, and psychological disturbances, limiting daily PAL (37–43). This limitation in physical activity may cause different cardiovascular and musculoskeletal diseases, leading to additional health concerns and decreases in physical activity (44–46). Dietary nitrate (NO_3^-) limits proton leakage and improves mitochondrial respiration, leading to improvements in the efficiency of energy production per unit of oxygen (O_2). This can reduce O_2 consumption during exercise in COPD patients while improving PAL (47–49).

Dietary NO_3^- supplementation obtained from beetroot can increase exercise endurance and improve exercise tolerance while reducing resting diastolic BP (DBP) in patients with COPD (50–52). Acute consumption of BJ (12.9 mmol nitrate) raised exercise endurance in COPD patients who needed supplemental oxygen (51), while exercise performance was enhanced and BP decreased in COPD patients by acute BJ supplementation (7.58 mmol of NO_3^-) (50). In contrast, another study reported that ingestion (for 7 days) of BJ containing 300 mg NO_3^- did not improve PALs in COPD patients, but that DBP was reduced after two trials of submaximal cycling and a 6-minute walk test (52).

There are several possible mechanisms to account for increases in exercise time. First, pulmonary hypertension is a common symptom in COPD patients that can lead to exercise intolerance; nitrate decreases pulmonary artery pressure during hypoxia, which can enhance exercise capacity. In addition, nitrate improves blood flow and oxygen delivery (22,53,54). In terms of BP, it has been shown that NO availability increases after nitrate ingestion, resulting in a significant reduction in SBP and DBP (55,56). Patients with COPD can benefit from beetroot as a natural dietary supplement for PAL and exercise capacity.

Beetroot and Cardiovascular Diseases

Aging is a significant risk factor for the development of atherosclerosis and cardiovascular diseases (57). Cardiac aging is characterized by changes in cardiovascular tissues, such as hypertrophy, alterations in left ventricular diastolic function and cardiac output, and increased arterial stiffness. Resting cardiac output in older adults remains intact due to increased left ventricular end-diastolic volume, resulting in a larger stroke volume. Older adults can achieve a higher stroke volume and mean arterial BP during exercise compared to younger individuals. Consequently, stroke volume during exercise in older adults is maintained by increased end-diastolic volume, whereas in younger individuals, it is sustained by a progressive decrease in end-systolic volume (58,59).

NO has pleiotropic effects on cardiac tissue, as it is synthesized by all myocardial cells and plays a role in the regulation of coronary vasodilation and cardiomyocyte contractility (57,60). It regulates vascular tone, platelet adhesion, angiogenesis, mitochondrial oxygen consumption, muscular performance, and immune and inflammation signaling pathways (61). Vasodilation that occurs as a compensatory response during hypoxic exercise is diminished in older adults, likely due to a decrease in NO signaling (62). A decrease in NO bioavailability causes hypertension, poor skeletal muscle perfusion, and exercise intolerance (63–66). Dietary nitrate reduces BP while enhancing exercise performance in patients with COPD and peripheral artery disease (29,50).

The findings on the effects of beetroot on aging seem contradictory. A study by Oggioni et al reported that 7

days of consuming BJ (2/d, ~12 mmol nitrate each day) did not affect resting SBP and DBP. Likewise, it could not improve the markers of central and peripheral cardiac functions during cardiopulmonary exercise testing and did not modify biomarkers of inflammation, oxidative stress, and endothelial integrity in older, healthy adults (67). In support of these findings are the results indicating that the consumption of concentrated BJ (containing 600 mg/d of inorganic nitrate) did not affect BP or peripheral arterial function in overweight and obese middle-aged and older adults (68). One study on heart failure with preserved ejection fraction and hypertension in older adult patients who completed aerobic exercise programs revealed that simultaneous administration of supervised exercise and BJ (6-8 mmol nitrates) did not improve exercise training and subsequent outcomes more than exercise training alone (69).

On the other hand, some studies have suggested the cardiovascular benefits of beetroot in the elderly. A single dose of nitrate-rich BJ improved blood flow and vasodilation of contracting skeletal muscle of older adults under hypoxic conditions (70), while a 1-week supplementation of nitrate-rich beetroot (6.1 mmol nitrates per day) in elderly patients with heart failure with preserved ejection could improve submaximal aerobic endurance and BP (71). The cardiovascular benefits of beetroot products have also been confirmed in long-term studies. The consumption of 10 g beetroot powder containing 20-250 mg nitrates per day for 4 weeks in a group of older normotensive adults blunted metaboreflex-mediated increases in BP due to skeletal muscle metaboreflex activation by exercise in older adults (72). An eight-week period of consuming whole beetroot improved BP in the elderly (24). In a pilot study, the consumption of 300 mg of dietary nitrate led to a reduction in BP in patients with chronic kidney disease, which might be due to the release of the vasodilator nitrate after intake (73).

Conclusion

Extensive research has been performed to explore the effects of beetroot supplementation and exercise on performance and health outcomes in older adults. The global population of people aged 60 or older has increased over the past few years, resulting in an increased risk of illnesses in the elderly. The current review highlighted the beneficial effects of beetroot and supplementation on performance and health outcomes, supporting the role of these interventions as treatments for older adults. The management of physiological changes during aging will benefit the elderly. Plants have a long history of being used as treatments for various diseases in humans. For example, beetroot compounds have positive effects on the immune system, cardiovascular health, and reduced oxidative stress. This narrative review summarizes some beneficial effects of beetroot consumption on aging. However, some studies have reported contradictory findings, implying that additional studies are required to better understand

the conditions under which beetroot consumption can improve health in older adults.

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Authors' Contribution

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Competing Interests

The author declares no conflict of interests to declare.

Ethical Approval

Not applicable.

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