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Beetroot and Its Therapeutic Effects on Hypertension: A Natural Remedy for Blood Pressure Management

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ABSTRACT

Beetroot (Beta vulgaris) is emerging as a functional food of wide therapeutic application for cardiovascular diseases. The review discusses its bioactive makeup, mode of action, and clinical utility in the management of hypertension and other diseases of a chronic nature. Beetroot is a rich source of dietary nitrates, which in the body are converted to nitric oxide a powerful vasodilator that enhances endothelial function, decreases arterial stiffness, and leads to substantial decreases in systolic and diastolic blood pressure. Several human trials and meta-analyses establish that regular beetroot juice intake can decrease blood pressure in normotensive, prehypertensive, and hypertensive patients. In addition to nitrates, beetroot is rich in betalains, phenolics, flavonoids, saponins, carotenoids, and other phytochemicals with high antioxidant, anti-inflammatory, and anticancer activities. These phytochemicals are responsible for beetroot's promise as a protector against or attenuator of chronic diseases like cancer, diabetes, and obesity. For example, betalains have demonstrated cytotoxicity against cancerous cells and antioxidant protective effects, whereas flavonoids and phenolics enhance glycemic management and metabolic well-being. Moreover, beetroot supplementation is also reported to support exercise performance through optimization of oxygen use and muscle efficiency, which has made it a favorite among sportsmen. Though variability in response among individuals depending upon oral microbiota and dosage has been observed, beetroot still stands as a promising non-pharmacological intervention. Nevertheless, discrepancies in study designs and findings indicate the necessity for standard protocols on dose, duration, and mode of intake (e.g., juice, powder, extract). Overall, beetroot provides a safe, low-cost, and readily available alternative to aid in the control of hypertension and enhance overall health outcomes. Further clinical studies are necessary to confirm these results and develop evidence-based guidelines for its therapeutic application in various populations.

INTRODUCTION

Red beetroot is a biennial herbaceous plant with more nutritional and therapeutic value than white beetroot. Since 1000 B.C., it has been regarded as a food source by all Mediterranean natives. Beetroot tubers were more popular with Romans in the past, but their leaves have also been used for a variety of culinary uses. Furthermore, the commercial relevance of this vegetable was discovered in Germany throughout the nineteenth century. Sugar beet (*Beta vulgaris* saccharifera), leaf beets (*Beta vulgaris* cicla), fodder beets (*Beta vulgaris* crassa), and garden beets (*Beta vulgaris* rubra) are all species of the Beta genus. Beet cultivation is mostly prevalent in Khyber Pakhtunkhwa and Punjab provinces in Pakistan, with borderline cultivation occurring in Sindh and Baluchistan (Mirmiran *et al*., 2020).

Beets are classified as Dicotyledonae, Caryophyllidae, Chenopodiaceae, and Beta in taxonomic terms. Furthermore, the genus Beta is classified into two groups: wild marine and cultivated beets, which provide plant morphological characteristics. Sea beets (*Beta vulgaris* maritime) are a unique species that are the ancestral form of all beet species. They are connected with the wild maritime group. Sugar beets (*Beta vulgaris* saccharifera), fodder beets (*Beta vulgaris* crassa), leaf beets (*Beta vulgaris* cicla), and garden beets (*Beta vulgaris* rubra) are grown beets. The order Caryophyllales has a large number of water-soluble colored moieties known as betalains Beetroot is a cultivated annual or biennial form that originated in the Middle East (Vasconcellos *et al*., 2016).

Beetroot is a biannual plant so leaf beets (*Beta vulgaris* cicla) are sown as a summer crop in the spring and then again in the summer for winter and spring crops. It necessitates broad oval leaves as well as robust roots. The roots and leaves are base chopped and the soil is buried for regrowth after harvesting. During the winter, nutrients are gathered in the roots, and in the spring, a new growth cycle begins. Plants generate glomeruli, which are gathered blooms with spikes at the apical sections of stems, in the previous summer. Plants generate seeds after that, they die and degrade, completing their life cycle. Because there are several seeds in each beet seed, they are termed polygerms. Various breeding strategies have yielded monogermity, fabrication, and polyploidy of commercial hybrids (Mirmiran *et al*., 2020).

Chenopodiaceae family has almost 1400 species that can be diverged into genera about 105 and the members of the dicotyledonous family. There are many varieties of beetroot having different colors ranging from yellow to red. Species of genus Beta are *B. vulgaris ssp. maritima*, *vulgaris*, *adanensis*, *B. macrocarpa*, *B. macrocarpa Guss*., *B. patula*, *B. patula Ait*., *B. intermedia*, *B. intermedia Bunge*, *B. macrorhiza*, *B. macrorhiza Stev*., *B. trygina*, *B. corolliflora*, *B. corolliflora Zoss*., *B. patellaris*, *B. patellaris Moq*., *B. procumbens*, *B. procumbens Chr. Sm*., *B. webbiana*, *B. webbiana Moq*., *B. tranzschel*, *B. lomatogona F*., *B. trigyna W*. and *B. nana Boiss* .The

root of the beetroot is the edible part. It contains a high number of phytochemicals and bioactive compounds which have a significant role in clinical and pathological studies (Chhikara *et al.*, 2019).

COMPOSITION

The composition of beetroot is mentioned in the table below. Beetroot is rich in nutrients that are necessary for health promotional properties as well as antioxidant and effective against inflammatory effects, cancer, and diabetic activities, and hepatoprotective, hypotensive, and relieving properties of wound (Mirmiran *et al.*, 2020). So, beetroot has a significant amount of nitrate (NO_3^-), a biologically active compound with the highest health benefits for cardiovascular diseases. Beetroot is also called a superfood because of its the concertation of vitamins (C, thiamin, B-6, β-carotene, A, K, and E), minerals (calcium, iron, magnesium, potassium, selenium, and zinc), phenolics, carotenoid, saponins and betalains (Fu *et al.*, 2020). In ancient Roman times, beetroot was used as a food with medicinal potential. So, scientists are interested in beetroot to check its therapeutic function (Hadipour *et al.*, 2020).

TABLE 1 - NUTRITIONAL VALUE OF BEETROOT OVER 100 GRAMS

Macronutrients		**Micronutrients -Vitamins and minerals**	
Energy	43 Kcal	Vitamin A	2 µ g
Proteins	1.68 g	Thiamine	0.031 mg
Water	87.58 g	Riboflavin	0.27 mg
Carbohydrates	9.96 g	Niacin	0.331 mg
Fat	0.18 g	Pantothenic acid	0.145 mg
Fatty acids	0.119 g	Vitamin B6	0.067 mg
Amino acids	1.216 g	Ascorbic acid	3.6 mg
Phytosterols	0.025 g	Folate	80 µ g
Minerals	0.483 g	Na	77 mg
Crude fiber	2 g	Ca	16 mg
Vitamins	4.805 mg	Fe	0.79 mg
Nitrate	25 mg	P	38 mg
Betalains	3.976 g	K	305 mg
-Betacyanin	2.075 g	Mg	23 mg
-Betaxanthins	1.901 g	Mn	0.329 mg
Phenolic	0.1899 g	Zn	0.35 mg

Source (Chen *et al.*, 2021) (Dhiman *et al.*, 2021)

Nowadays consumers are more interested in a healthy diet pattern and strongly prefer the "functional foods" the innovation of eating behavior and improving their health (Chen *et al.*, 2021). Today, different experiments increased consumer knowledge about the beetroot and its biological activity.

Therefore, the beetroot is grown to meet the demand. Hence beetroot was investigated to have the power of curing and preventing different diseases (Chen *et al.*, 2021).

Athletes are much interested due to the latest on the ergogenic properties of dietary nitrate and using beetroot juice as a supplement among athletes. The effects of dietary nitrate ingestion have been associated with the reduction of nitrite by bacteria, as well as a reduction in the circulation of nitric oxide (NO), especially in the lower oxygen and low pH conditions (Jonvik *et al.*, 2021).

BIOACTIVE COMPOUNDS

BETALAIN

Betalain is a major component in beetroot. Betalains are nitrogen-containing water-soluble pigments comprised of two major structural units: betacyanins ranging from red-violet (betanin, prebetanin, isobetanin, and neo-betanin) with maximum absorption of 538 nm, and betaxanthins ranging yellow-orange with a maximum wavelength of absorption of 480 nm (Fu *et al.*, 2020).

Betalains are highly susceptible to oxidation, heat, pH, light, and enzymes, all of which can affect their steadiness. Betalains (particularly betanin) are a type of antioxidant found in beets (Chen *et al.*, 2021). However, betalains have become famous due to their antioxidant property, anticarcinogenic, liver protective, antibacterial, and anti-inflammatory properties, as well as digestive and immunological regulatory effects (Fu *et al.*, 2020).

Beetroot betalains inhibit peroxidase, nitrite-induced oxidase, and human low-density lipoprotein by eliminating lipid-free radicals (Chen *et al.*, 2021). Betalain has also been found to inhibit neutrophil oxidative metabolism in humans. Betalain is being considered an alternative to therapeutic drugs with fewer side effects due to its broad spectrum of anti-inflammatory activities and proinflammatory signaling agent, particularly the Nuclear Factor-Kappa B (NF-B) cascade (Mirmiran *et al.*, 2020). In one experiment, betalains protected human erythrocytes from hemolysis by increasing endogenous glutathione levels and reducing oxidative stress markers like lipid hydroperoxide (Hadipour *et al.*, 2020).

PHENOLIC

Phenolic compounds are a significant group of secondary metabolites in plants that are essential for plant-based food quality. The phenolic compounds in beetroot are considerable (Chhikara *et al.*, 2019). Both polyphenols and anthocyanin are natural antioxidants, with polyphenols having a higher antioxidant potential than BHA and BHT. The maximum total phenolic, total flavonoid, and total antioxidant values were obtained in fresh, dried, and pureed beetroot (Chen *et al.*, 2021).

Phenols improved isometric strength recovery and reduced muscular soreness. In vitro, (poly)phenols are powerful antioxidants and anti-inflammatories (Jones *et al.*, 2021). The number of compounds available for absorption in the small intestine may be significantly

smaller. Chemicals that are unable to be absorbed in the small intestine, on the other hand, are transformed or destroyed by the microbiota of the colon. It has also been suggested that metabolites may have a favorable effect on large intestine cells or bacteria, as well as being absorbed and exhibiting biological activity outside of the large intestine (Guldiken *et al.*, 2016). Peel of beetroot also has the succeeding proportion of total phenol concentration by dry weight. (Chhikara *et al.*, 2019).

FLAVONOIDS

Flavonoids are compounds that are biologically active having a strong antioxidant ability and various healthy effects (Chhikara *et al.*, 2019). The same inhibitory effect shown by the active substances containing polyphenols, flavonoids, and anthocyanins (Mirmiran *et al.*, 2020) and are also causes the glucose-lowering effect. Flavonoids apigenin, luteolin, quercetin, kaempferitrin, and epicatechin are also involved as bioactive components (Chhikara *et al.*, 2019). The use of digestive enzymes in the intestinal process resulted in an excessive recovery and production of flavonoids, according to a study.

As a result, studies highlighted the beneficial effect of heating on flavonoids' bioaccessibility (Guldiken *et al.*, 2016). In probiotic drinks, flavonoids and antioxidant activity were improved (Panghal *et al.*, 2017). TFC (total flavonoid content) increased, which was associated with softening of tissues and producing more flavonoids. After pasteurization of beetroot-based jam at 75°C for 30 minutes, the TPC remained 86.2 % whereas TFC was unaffected. TBC (total betalain content) was lost by 12.5 percent after pasteurization (Dhiman *et al.*, 2021)

NITRATES

In beetroot juice, there is 25% nitrate content which is a significant proportion of beetroot (Bonilla Ocampo *et al.*, 2018). Beetroot contains more nitrate, which has a great nutritious value. Many people use fresh beetroot juice orally as a nitrate supplement and so improve physiological reactions and lower the threat of cardiac and cerebral vascular diseases (Chen *et al.*, 2021).

Beetroot juice is ingested as a diet supplement because it is thought to be a precursor to nitric oxide (NO) (Domínguez *et al.*, 2018). In the saliva, it is actively absorbed and concentrated. Bacteria in the mouth convert NO_3^- to nitrite (NO_2^-) here. As a result, NO_2 may be further reduced to nitric oxide in the digestive system and muscle (Garnacho-Castaño *et al.*, 2018) Besides proves that nitrate is the most important component of beetroot for regulating vascular function (Chen *et al.*, 2021).

SAPONINS

Biologically active molecules that plants make to protect themselves from infections and

herbivores are saponins. B. vulagris contains eleven triterpene saponins, according to early research. Oleanolic acid derivatives were present in all saponins (Chhikara *et al.*, 2019).

PHYTOCHEMICALS

Phytochemicals identified in peel extract included 5,5,6,6-tetrahydroxy-3,3-biindolylandin, whereas norisoprenoids (+)-dehydrovomifoliol and 3-hydroxy5,6-epoxy-–ionone were found in aerial parts of B. vulgaris. Beetroot was used to isolate the poly 3-hydroxyalkanoate component, which has a significant impact on human health due to its physiological function on the human. (Chhikara *et al.*, 2019)

CAROTENOIDS

A category of phytochemicals that are responsible for the various colors of fruits and vegetables, as well as have an important role in disease prevention is called carotenoids. Beetroot carotenoids are antioxidants, anticarcinogens, and immunostimulants. Beetroot contains a high of carotenoids, which are potent antioxidants. It has been observed that they have mutagenesis inhibition activity, which reduces the risk of cancer (Chhikara *et al.*, 2019). The antioxidant capabilities of carotenoids and anthocyanins, which have been extensively investigated, are claimed to be associated with Xenobiotic behavior and metabolic activity (Mirmiran *et al.*, 2020). Carotenoids and anthocyanins have been widely examined for their antioxidant qualities.

THERAPEUTIC EFFECT OF BEETROOT FOR HYPERTENSION

Beetroot (*Beta vulgaris*) has been extensively studied for its therapeutic effects on hypertension, primarily due to its rich nitrate (NO_3) content. After dietary nitrate ingestion oral bacteria reduce the substance to produce nitrite (NO_2^-) which then converts into nitric oxide (NO) in hypoxic conditions throughout the body. Vasodilatory effects of nitric oxide lead to vessel relaxation to enhance blood flow which results in pressure reduction. Studies indicate beetroot juice which contains high levels of nitrates leads to important blood pressure reductions in both systolic and diastolic readings for regular people and individuals with pre-hypertension and hypertension (Bonilla Ocampo *et al.*, 2018). Cardiovascular homeostasis depends heavily on endothelial function and arterial stiffness regulation which nitric oxide successfully accomplishes. Research performed by Zamani *et al.* (2021) and López-Samanes *et al.* (2020) confirms that beetroot supplementation functions reliably as a financial approach to hypertension control which complements standard medical treatments. Consuming beetroot juice or alternative beet-derived products helps maintain vascular health which might protect against the advancement of cardiovascular diseases.

Research exhibits that beetroot's blood pressure effects stem from both nitrate content alongside betalains and phenolic compounds found within the plant. The antioxidants present

in betalains particularly betacyanins help lower oxidative stress in the body which causes hypertension and endothelial dysfunction (Chen *et al.*, 2021). Multiple bioactive contents in beetroot enhance NO bioavailability through nitrates while simultaneously protecting vascular health by reducing oxidative damage which proves beetroot functions as a synergistic food for heart protection. Academic research has shown that consuming beetroot juice as a supplement enhances vascular compliance and minimizes systemic vascular resistance which are essential for controlling blood pressure (Domínguez *et al.*, 2018; Guldiken *et al.*, 2016).

Scientific research acknowledges the inconsistent effects of beetroot supplementation on people because factors like differences in oral microbiota and baseline blood pressure levels alongside variations in nitrate metabolism efficiency play determining roles (Ormesher *et al.*, 2018). The results of beetroot juice consumption rely significantly on consumption methods and dosage amounts and intake duration length and the individual diet composition. Research on standardization needs to improve for testing the benefits of beet-derived products including extracts and beverages as well as foods containing beetroot (Chen *et al.*, 2021; Hadipour *et al.*, 2020). The following diverse research shows beetroot maintains its potential as an effective natural dietary approach to manage hypertension when used as part of a healthy eating plan. The benefits of beetroot supplementation appeal especially to users because it offers multiple advantages at an affordable price while being easily accessible.

TABLE 2: CLINICAL STUDIES OF THERAPEUTIC EFFECT ON BEETROOT

Subject	Trial	Study Design	Duration	Protocols Used	Reported Measures	Major Results	Citation
N = 60 (30 intervention, 30 control), hypertensive patients with hyperlipidemia	Human	Quasi-experimental pretest-posttest design	30 days	200 mL beetroot juice daily for intervention group; control group received standard care	Systolic and diastolic BP, lipid profile	Significant reduction in SBP (13.06 mmHg) and DBP (5.40 mmHg); improvement in lipid profile	Soumya and Snehaleeza, 2020
N = 218, hypertensive adults (from 7 RCTs)	Human	Systematic review and meta-analysis of randomized controlled trials	3 to 60 days	Daily intake of 70–250 mL nitrate-rich beetroot juice; compared to placebo or control	Systolic and diastolic BP	Significant reduction in SBP by 4.95 mmHg; no significant change in DBP	Benjamim et al., 2022
N = 349, hypertensive adults (from 11 RCTs)	Human	Systematic review and meta-analysis of randomized controlled trials	3 to 90 days	Daily intake of 200–800 mg nitrate from beetroot juice; compared to placebo, water, or no intervention	Clinical systolic and diastolic BP, 24-hour BP	Significant reduction in clinical SBP by 5.31 mmHg; no significant effect on clinical DBP or 24-hour BP	Grönroos et al., 2024
N = 60, hypertensive adults with autosomal dominant polycystic	Human	Double-blind, randomized, placebo-controlled trial	4 weeks	Daily intake of 70 mL beetroot juice containing 400 mg nitrate vs. nitrate-depleted placebo; clinic and home BP	Change in clinic systolic and diastolic BP, home BP, biochemical markers	Study protocol; results pending	Sagar et al., 2023

kidney disease (ADPKD)				measurements, urinary albumin-to-creatinine ratio, serum and salivary nitrate/nitrite levels, serum asymmetric dimethylarginine levels			
N = 20, healthy older adults (mean age 63 ± 6 years)	Human	Randomized, double-blind, placebo-controlled pilot study	28 (±7) days	Daily intake of beetroot juice (BRJ) vs. placebo; assessments at baseline, week 2, and week 4; measurements included blood pressure, microvascular function via laser Doppler imaging (LDI) with iontophoresis, and large-vessel endothelial function via flow-mediated dilatation (FMD)	Systolic and diastolic BP, microvascular function, large-vessel endothelial function	Significant reductions in SBP (~6 mmHg) and DBP (~4 mmHg) after two weeks of BRJ supplementation; FMD increased by 1.5%; no significant changes in microvascular function	Jones et al., 2019
N = 30 postpartum mothers with	Human	Quasi-experimental control group	7 days	Intervention group received 1000 mg beetroot extract daily	Systolic and diastolic BP	Significant reduction in SBP by 27.4 mmHg in intervention group	Arma et al., 2020

grade I hypertension (15 intervention, 15 control)		pretest-posttest design		plus nifedipine; control group received nifedipine only		vs. 8.4 mmHg in control ($p<0.05$); no significant difference in DBP reduction between groups ($p>0.05$)	
N = 15, older adults with treated hypertension (aged 56–71 years)	Human	Randomized, placebo-controlled crossover study	4 weeks	Daily intake of 2 × ~400 mg nitrate via beetroot juice vs. nitrate-depleted placebo; assessments at baseline, 3 hours post-ingestion, and after 4 weeks; measurements included plasma and salivary nitrate/nitrite levels, endothelial-dependent and -independent forearm blood flow (FBF) responses, clinic, home, and 24-hour ambulatory blood pressure	Plasma and salivary nitrate/nitrite levels, endothelial function, systolic and diastolic BP	Significant increases in plasma and salivary nitrate/nitrite levels; no significant changes in endothelial function or blood pressure measurements	Fejes et al., 2024
N = 15, older adults with	Human	Randomized, placebo-	4 weeks	Daily intake of 2 × ~400 mg nitrate via	Plasma and salivary	Significant increases in plasma and salivary	Fejes et al., 2024

treated hypertension (aged 56–71 years)		controlled crossover study		beetroot juice vs. nitrate-depleted placebo; assessments at baseline, 3 hours post-ingestion, and after 4 weeks; measurements included plasma and salivary nitrate/nitrite levels, endothelial-dependent and -independent forearm blood flow (FBF) responses, clinic, home, and 24-hour ambulatory blood pressure	nitrate/nitrite levels, endothelial function, systolic and diastolic BP	nitrate/nitrite levels; no significant changes in endothelial function or blood pressure measurements	
N = 47, Tanzanian adults aged 50–70 years with elevated blood pressure	Human	Double-blind, randomized, placebo-controlled feasibility trial	60 days	Participants were randomly assigned to one of three groups: 1) high-nitrate beetroot juice (~400 mg nitrate) and folic acid (~5 mg folic acid) (N+F), 2) high-nitrate beetroot juice and placebo (N+P), or 3)	24-hour systolic and diastolic blood pressure, clinic-based blood pressure	After 60 days, the N+P group experienced a significant reduction in 24-hour systolic BP by − 10.8 ± 9.8 mm Hg (P < 0.001) and diastolic BP by − 5.4 ± 5.0 mm Hg (P = 0.004). The N+F	Siervo et al., 2020

				nitrate-depleted beetroot juice and placebo (P+P). Blood pressure was measured using 24-hour ambulatory blood pressure monitoring (ABPM) and clinic-based measurements.		group saw a reduction in systolic BP by − 6.1 ± 13.2 mm Hg (P = 0.03), while the P+P group showed no significant changes.	
N=30 hypertensive females	Human	Randomized, placebo-controlled	60 days	Group 0: Placebo; Group 1: 250 mg/day beetroot powder capsules; Group 2: 500 mg/day beetroot powder capsules	Weekly systolic and diastolic BP; serum sodium and potassium levels	500 mg/day group showed significant reductions in both SBP and DBP; improved electrolyte balance	Itrat *et al.*, 2024
N=68 hypertensive adults with ADPKD	Human	Randomized, double-blind, placebo-controlled	4 weeks	Daily 400 mg nitrate-replete beetroot juice vs. nitrate-depleted placebo	Clinic BP, home BP, urine albumin-to-creatinine ratio	Significant reduction in SBP in nitrate-replete group; no significant changes in other measures	Sagar *et al.*, 2024
N=38 young adults (18 Black, 20 White; ~equal male/female)	Human	Randomized, placebo-controlled, crossover	Single dose	12.8 mmol nitrate-rich beetroot juice vs. nitrate-depleted placebo	Resting brachial and central BP, arterial stiffness	Significant reduction in SBP in males; no significant effect in females; similar effects across races	Kim *et al.*, 2023
N=349 hypertensive	Human	Systematic review and	Up to 90 days	Daily ingestion of 200–800 mg nitrate	Clinical SBP, DBP, 24-h BP	Significant reduction in clinical SBP (mean	Kapil *et al.*, 2024

patients (meta-analysis of 11 RCTs)		meta-analysis		from beetroot juice		difference −5.31 mmHg); no significant effect on DBP or 24-h BP	
N=30 healthy older adults	Human	Randomized, double-blind, placebo-controlled	4 weeks	Daily 250 mL beetroot juice vs. placebo	Plasma nitrate levels, SBP, DBP, endothelial function	Within-group reductions in SBP and DBP after 2 weeks; no significant between-group differences	Gilchrist *et al.*, 2019
N=20 postmenopausal women with hypertension	Human	Triple-blind, randomized, placebo-controlled	Acute and short-term (duration not specified)	Nitrate-rich beetroot juice vs. placebo before submaximal aerobic exercise	Post-exercise BP, flow-mediated dilation, heart rate variability	Enhanced cardiovascular responses post-exercise; improved endothelial function; decreased BP after exercise	Oliveira *et al.*, 2024
N=68 hypertensive adults with ADPKD	Human	Randomized, double-blind, placebo-controlled	4 weeks	Daily 400 mg nitrate-replete beetroot juice vs. nitrate-depleted placebo	Clinic BP, home BP, urine albumin-to-creatinine ratio	Significant reduction in SBP in nitrate-replete group; no significant changes in other measures	Sagar *et al.*, 2024
N=14 postmenopausal women with hypertension	Human	Triple-blind, randomized, placebo-controlled, crossover	Acute and 1-week intervention	Acute: 800 mg nitrate-rich beetroot juice; Short-term: 400 mg/day for 6 days; Submaximal aerobic exercise performed post-ingestion	SBP, DBP, flow-mediated dilation (FMD), heart rate variability (HRV)	Acute ingestion reduced SBP by ~9 mmHg post-exercise; improved FMD and HRV observed after both acute and short-term interventions	Benjamim *et al.*, 2024

N=15 older adults with treated hypertension (56–71 years)	Human	Randomized, placebo-controlled, crossover	4 weeks	Daily intake of nitrate-rich vs. nitrate-depleted beetroot juice; measured plasma nitrate/nitrite, vascular function, and BP	Plasma nitrate/nitrite levels, vascular function, BP	Increased plasma nitrate/nitrite levels; no significant changes in vascular function or BP	Fejes *et al.*, 2024
N=349 hypertensive patients (meta-analysis of 11 RCTs)	Human	Systematic review and meta-analysis	Up to 90 days	Daily ingestion of 200–800 mg nitrate from beetroot juice	Clinical SBP, DBP, 24-h BP	Significant reduction in clinical SBP (mean difference −5.31 mmHg); no significant effect on DBP or 24-h BP	Grönroos *et al.*, 2024
N=38 young adults (18 Black, 20 White; ~equal male/female)	Human	Randomized, placebo-controlled, crossover	Single dose	12.8 mmol nitrate-rich beetroot juice vs. nitrate-depleted placebo	Resting brachial and central BP, arterial stiffness	Significant reduction in SBP in males; no significant effect in females; similar effects across races	Kim *et al.*, 2023
N=30 hypertensive females	Human	Randomized, placebo-controlled	60 days	Group 0: Placebo; Group 1: 250 mg/day beetroot powder capsules; Group 2: 500 mg/day beetroot powder capsules	Weekly SBP and DBP; serum sodium and potassium levels	500 mg/day group showed significant reductions in both SBP and DBP; improved electrolyte balance	Itrat *et al.*, 2024
N=60 hypertensive patients with	Human	Quasi-interventional pretest-	30 days	Daily 200 mL beetroot juice; measured BP and lipid	BP, lipid profiles	Significant reductions in SBP (−13.06 mmHg) and DBP;	Padmapriya *et al.*, 2024

hyperlipidemia		posttest		profiles before and after intervention		improved lipid profiles	
N=20 hypertensive men	Human	Single-blind quasi-experimental	Single session	Beetroot juice consumed before resistance training; cardiovascular parameters measured during and after exercise	BP, heart rate	Beetroot juice reduced SBP and DBP and heart rate during and after exercise	Afsharnezhad and Fazeli Sani, 2021
N=60 hypertensive individuals	Human	One-group pretest-posttest	Not specified	Beetroot juice consumed; BP measured before and after intervention	BP	Significant reduction in both SBP and DBP post-intervention	Vaishnavi, 2021
N=254 participants across 16 trials	Human	Systematic review and meta-analysis	2 hours to 15 days	Analysis of RCTs on inorganic nitrate and beetroot juice supplementation	Systolic and diastolic BP	Significant reduction in SBP; diastolic BP reduction not statistically significant	Siervo *et al.*, 2023

THERAPEUTIC EFFECT OF BEETROOT ON HYPERTENSION

A randomized, double-blind, placebo-controlled crossover study was conducted by Coles and Clifton (2021), which also included 30 healthy adults (15 men and 15 females) that had a systolic blood pressure (SBP) above 120 mmHg. Participants in the study received a single 500 mL dose of beetroot and apple juice (BJ) that provided them with between 15 and 17.5 mmol/L of nitrate or a taste and appearance identical placebo juice containing no nitrate. Ambulatory blood pressure monitoring was utilized to monitor blood pressure every hour for a period of 24-hour as ABPM. It was explained to the participants to refrain from moderate to high-level of physical activity during this monitoring period. The results of the conducted research indicated the trend of lowering SBP after 6 hours after BJ consumption, and a significant -4 to -5 mmHg decline of SBP in males.

Wightman *et al.*, (2022) carried out a single-blind randomized controlled crossover study of 25 normotensive adults (18 males and 7 females), who drank single doses of 100 mL, 250 mL, and 500 mL of beetroot juice (BJ) Participants consumed a low-nitrate diet for 2 days before each test day in order to minimize the background nitrate intake. ABPM method was applied to measure blood pressure over 24 hours, and samples of urine were also used in order to examine nitrate/nitrite levels. The trial showed dose dependent lowering of SBP (16.7 mmHg – 19.8 mmHg) and higher urinary nitrate/nitrite concentration; therefore increased nitric oxide availability.

Siervo *et al.*, (2018) carried out a randomized, double-blind, placebo-controlled study with 68 random individuals who were overweight or obese adults. Participants were given 70 mL beetroot juice (BJ) every day for 6 weeks, and the control group received a nitrate-depleted placebo of similar taste and appearance. Endothelial function was staged together with the quantification of the blood pressure. The BJ group had marked decreases in SBP as well as enhanced endothelial function as compared with the placebo group, indicative of a possible cardiovascular benefit of long-term BJ supplementation.

Ghosh *et al.*, (2020) in a randomized crossover pilot study, 24 hypertensive subjects were supplemented with250mL/day of raw beet juice and 250 g/day of cooked beetroot for two- week periods with a washout phase in between. Blood pressure and endothelial function was measured in the baseline and post-intervention. The study revealed a significant level of improvement in blood pressure and endothelial function as a result of ingestion of raw beet juice as opposed to the cooked beetroot, emphasizing the importance of preparation method in the effectiveness of beetroot intervention.

Padmapriya *et al.* (2024) performed a quasi-interventional pretest- posttest study that utilized the sample of 60 patients suffering from hypertension with hyperlipidemia. Three hundred days of daily 200 mL of beetroot juice consumption with an empty stomach were followed. Blood pressures and lipid profiles were determined before and after the intervention. According to the study, the supplementation benefited hypertensive patients that were hyperlipidaemic with a reduction in SBP (− 13.06mmHg) and DBP improvement of lipid profiles. A single-blind quasi-experimental study of beetroot juice consumption carried out by Afsharnezhad and Fazeli Sani (2021) was performed to determine how the consumption of beetroot juice (BJ) can influence the cardiovascular responses during resistance training on 20

hypertensive men. Subjects took a single dose of BJ before undergoing a structured resistance training program. Cardiovascular parameters in form of systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate were measured at the beginning, during exercise, and after exercise to evaluate the hemodynamic effects of BJ. It was determined that there were notable decreases in SBP, DBP, and heart rate levels, during, and also post resistance training exercise, compared with initial readings. These findings would therefore indicate that acute BJ intake can have the potential of increasing positive heart responses to physical activity in hypertensive persons. However, due to the small numbers of people studied and absence of placebo control group the results may not be generalizable.

Vaishnavi, (2021): conducted a research of one group pretest and posttest study, 60 hypertensive subjects underwent to determine the effects of BJ consumption on blood pressure. Participants used a particular amount of BJ everyday for an unspecified period of time. The measurements of SBP and DBP were taken before and after intervention to identify the changes in both. From the study, there were decreases in SBP and DBP levels post BJ intervention (which is suggestive of an antihypertensive effect of BJ. However, the study lacked the control group and randomization; hence there may arise biases and the inability to solely attribute observed effects to consumption of BJ. Moreover, lack of specific information about BJ dosing dose and length of intervention does not allow prototype of the research and its results' interpretation. In spite of these limitations, the findings concur with previous literature postulating the BP lowering capability of BJ. More randomized controlled trials will be needed to confirm these results and to formulate standardized BJ dosing regimens for treating hypertension.

Siervo *et al.*, 2019 in a systematic review and meta-analysis looked into the effect of inorganic nitrate and BJ supplementation in blood pressure on 16 randomized clinical trials, with 254 participants. The studies selected for the review used crossover design with an intervention between 2 hours and 15 days. Subjects were administered with differing doses of inorganic nitrate or BJ where the results reported on were any alterations in SBP and DBP. The meta-analysis found that there was a significant decrease in the levels of SBP for inorganic nitrate and BJ supplementation; mean reduction, 4.4 mm Hg. The decrease of DBP was smaller and not significant. We found a dose-response relation between the daily nitrate intake and SBP reduction in the meta regression analysis. Based on these findings, a reduction of SBP in the adults was made possible by short-term supplementation with inorganic nitrate or BJ. However, the studies' short durations and small sample sizes highlight the need for longer-term trials to assess the sustainability of these effects and their clinical relevance.

A systematic review and meta-analysis by Kapil *et al.*, (2024) explored the effect of the consumption of BJ on the blood pressure of hypertensive patients based on data from 11 randomized trials involving a total number of participants of 349 individuals. The interventions durations were different and some studies went up to 90 days. Consumed daily doses of BJ at a level of 200–800 mg nitrate were used by participants. Meta-analysis analysis reported a significant decrease in clinical SBP after BJ supplementation, with a mean difference of − 5.31 mmHg when compared with placebo. However, there were no significant effects in clinical DBP or the 24-hour ambulatory measurements of blood pressure. The heterogeneity among the studies varied and was considered as moderate to high and the certainty of evidence was low.

These findings indicate that by BJ could considerably reduce SBP among hypertensive people without the formation of tolerance with time. However, the absence of strong effects on DBP and 24-hour BP highlights the necessity of further research in order to understand the scale of the antihypertensive properties of BJ.

A randomized, placebo-controlled study was published by Itrat *et al.*, (2024) that examined the impacts of beetroot powder supplementation in the blood pressure and electrolyte balance in 30 hypertensive females during 60 days. There were three groups of participants. Group 0 was placebo group, Group 1 was given 250 mg/day beetroot powder capsules and Group 2 was given 500 mg/day. Monitoring of changes was done by weekly measurements of SBP, DBP, serum sodium, and potassium levels. The study revealed that the 500 mg/day group had a substantial decrease in the level of SBP and DBP as well as better balance of the electrolytes than the placebo group. The 250 mg/day group had moderate levels of improvements, suggesting a dose-dependent action of beetroot powder on blood pressure and electrolyte homeostasis. These findings suggest that beetroot powder supplementation can be an adjunct therapy for treating hypertension, and especially in females. However, the study's small sample size and short duration warrant further research to confirm these results and determine long-term efficacy and safety.

Sagar *et al.*, (2024) conducted a randomized, double-blind, placebo-controlled trial to look at the effect of nitrate-replete beetroot juice (BRJ) on blood pressure in 68 hypertensive adults with autosomal dominant polycystic kidney disease (ADPKD). For 4 weeks, participants were given 400 mg nitrate-replete BRJ daily or nitrate-depleted placebo. The main outcome was a change in clinic SBP; secondary outcomes were a home BP measurement and the urine albumin-to-creatinine ratio. Results showed a significant decrease in clinic SBP in the nitrate replete group compared with placebo group by a mean fall of 9.0 ± 7.8 to 0.1 ± 8.0 mmHg respectively. However, no significant differences occurred in the secondary measures like in diastolic BP. The research indicates that BRJ high in nitrate may help to reduce SBP in hypertensive individuals with ADPKD which may provide a new way of adjuvant treatment for controlling the hypertension in the population.

Kim *et al.*, 2023 in arandomized, placebo-controlled, crossover study, 38 young adults (18 Black and 20 White) participants. 40 healthy volunteers of approximately equal male/female distribution) were given a single dose of 12.8 mmol nitrate-rich BRJ or a nitrate-depleted placebo. The current research was conducted to evaluate the immediate effects of BRJ on the resting brachial and central BP, as well as the arterial stiffness. Measurement was done during rest, during exercise in a handgrip, and in post-exercise circulatory occlusion. It was found out that BRJ led to notable decrease in resting brachial SBP among males but could not exert the same effect in females with both racial groups demonstrating similar results. No remarkable changes were observed for diastolic BP and arterial stiffness. According to these results, acute BRJ supplementation can reduce SBP in young males without any regard to race though it might not be so in female.

A systematic review and meta-analysis by Kapil *et al.*, 2024, has reviewed the influence of BRJ on blood pressure in hypertensive patients whereby the data from 11 randomized controlled trials with individuals totaling 349 were analyzed. The lengths of intervention spanned with

some studies carried for up to 90 days. The subjects received doses of BRJ with 200-800 mg nitrate per day. The meta-analysis discovered that the BRJ supplementation resulted in a significant decrease of implementational SBP (mean difference of -5.31 mmHg) through the comparison with placebo. Nevertheless, there was no significant difference in terms of clinical diastolic BP and 24-hour ambulatory BP readings. Heterogeneity among studies were moderate to high, and certainty of evidence is rated as low. These findings indicate that BRJ can reduce the SBP in hypertensive patients without the occurrence of tolerance with time. However, this weak effect on diastolic BP and 24 hour BP explains the necessity for further investigations to fully appreciate the range of antihypertensive properties of BRJ.

Gilchrist *et al.*, (2019) carried out a randomized, double-blind, placebo controlled study to determine effects of daily consumption of BRJ on blood pressure and endothelial function in 30 healthy older adults over a period of 4 weeks. Participants were prescribed to drink 250 mL of nitrate-rich BRJ or a nitrate depleted placebo on a daily basis. Main results were plasma nitrate concentrations, SBP, DBP, as well as endothelial function by flow-mediated dilation. A significant decrease of SBP and DBP was found in BRJ group after 2 weeks. However, there was no significant difference between the groups as the study period ended. These findings indicate that although there may be early advantages of BRJ on the blood pressure of older adults, the advantage may not be maintained and may not differ significantly from placebo in a longer period. More studies are needed to validate these results as well as the long-term efficacy of BRJ in this population.

Oliveira *et al.*, (2024), Under triple-blind, randomized, placebo-controlled trial, the acute and short-term effects of nitrate-rich BRJ on cardiovascular responses were measured among 20 postmenopausal women with hypertension. Participants drank BRJ or placebo before performing submaximal aerobic exercise session. Outcome measure included post exercise BP, flow-mediated dilation and heart rate variability. The study reported that, consumption of BRJ augmented cardiovascular responses after the exercise, enhanced the endothelial function, and that the blood pressure levels reduced after exercise compared to the placebo. These findings reveal that BRJ could be a potential adjunct treatment to promote cardiovascular health and treat hypertension in postmenopausal women. However, the study was of a short duration and had participants in a small sample making further research required to confirm these findings and long-term effects.

In a triple-blind, randomized, double-blind, placebo-controlled, crossover study, Benjamim *et al.*, (2024) studied the acute and short-term effect of nitrate rich beetroot juice (BRJ) on cardiovascular response in postmeniopausal women (n = 14) with During the acute phase, participants received a one-shot dose of 800 mg of nitrate-rich BRJ before attending exercises with submaximal aerobic. In the short-term phase, they ingested 400mg/day nitrate-rich BRJ during six days with exercise done after-ingestion. The following measures were obtained in the study – systolic and diastolic blood pressure (SBP and DBP), flow-mediated dilation (FMD) and heart rate variability (HRV). It was found out that acute ingestion of BRJ resulted to a significant decrease of SBP with a value of about 9mmHg after exercise. Acute and short-term BRJ supplementation increased FMD and HRV, indicating improved state of endothelial function and better balance of autonomic function. These findings suggest that BRJ can be a non-pharmacological approach to enhancing cardiovascular health among postmenopausal women

with hypertension. However, the small sample size and duration require more research to substantiate these effects and establish long term benefits.

In a randomized, placebo-controlled, crossover study, Fejes *et al*, (2024), 15 older adults aged 56–71 years, with treated hypertension were evaluated to evaluate the effects of nitrate-rich BRJ on the vascular function and blood pressure over four weeks. Participants drank nitrate-rich BRJ on a daily basis, administering roughly 800 mg of nitrate each day, or a nitrate-depleted placebo. Measurements performed were plasma and salivary nitrate/nitrite levels, endothelial-dependent and -independent forearm blood flow responses and clinic, home and 24 hour ambulatory blood pressure. Plasma and salivary nitrate/nitrite levels were found to increase significantly after the consumption of BRJ, and this is indicative of effective nitrate metabolism. However, no significant changes of vascular functions or blood pressure readings were observed compared to the placebo. These findings indicate that although BRJ is able to raise nitrate bioavailability adequately, it might not reflect vascular and blood pressure improvement in older treated hypertension. Further researches with an increased sample size and duration are required to extend these findings.

In a systemic review and meta-analysis, Grönroos *et al.*, (2024) assessed the impact of nitrate-rich BRJ on blood pressure in hypertensive people based on the data extracted from 11 RCTs (349 participants). The interventions took a maximum of 90 days in duration with the daily nitrate intake ranging between 200-800 mg. From the meta-analysis, it was found that Systolic blood pressure was significantly decreased on the clinical level with a mean difference of − 5.31mmHg as compared to the placebo. Yet, there were no clinically significant changes on DBP measured in the clinical setting and on the 24-hour ambulatory BP. The heterogeneity between the studies was moderate to high while the certainty of the evidence was low. From these findings, BRJ can be said to have potential in positively affecting clinical SBP in hypertensive patients without the development of tolerance. However, the absence of significant effects on DBP and 24-hour BP notifies about the necessity for additional studies to comprehend the extent of BRJ's antihypertensive effects. According to the authors, the cautious reading of these results is recommended because of the low evidence certainty.

One-group pretest and post-test investigation was carried out by Vaishnavi (2021) with a group of 60 hypertensive people of Sothupakkam, Kanchipuram district, to test the effectiveness of beetroot juice (BRJ) on the level of reducing the blood pressure. The participants, 25-65 years of age, were given BRJ to consume once in a day and their blood pressure was recorded before and after the intervention. Based on the results, there was a significant drop in systolic and diastolic blood pressure after the treatment, mean difference of 30.66 mmHg and 17.33 mmHg respectively. Paired t-tests analysis of statistics validated the above findings, as demonstrating consumption of BRJ successfully reduced blood pressure among participants. This study indicates that BRJ can be used as a natural remedy to curb hypertension among rural population. However, the limitations of the study include non-randomized design and the absence of control group, and it can affect the results' generalizability. Additional randomized controlled trials are recommended to confirm these findings and find the long-term effects of BRJ on blood pressure.

Siervo *et al.*, (2023) in systematic review and meta-analysis, tried to evaluate the effect of inorganic nitrate and beetroot juice supplementation on blood pressure among adults. The

analysis involved data of 254 subjects involved in 16 randomized controlled trials with interventions of 2 hr to 15 days. The results showed a substantial decrease in SBP, mean difference, − 4.4 mmHg, but the difference in DBP was not significant. Meta-regression analysis showed that increased doses of inorganic nitrate on a daily basis promoted reductions in the SBP. This finding implies that temporary beetroot juice supplementation will be able to reduce SBP in adults. However, the study also called for further researches that will establish the best dosage and duration, and long term effects of such supplementation. Also, the inconsistency of the studies' designs and the diversity of the participants' characteristics in the studies that were included in this review may impact the generalizability of the findings.

BEETROOT BASED PRODUCTS

YOGURT

Firstly, heated the skim milk at 80-85° C for 15 minutes and then allowed it to cool up to 42-45° C before inoculating and put for incubation for 12 hours before placing in the refrigeration. Powder of beetroot was mixed at different concentrations according to the treatment plan (0, 6, 8, and 10 percent) and stored at 4° C to develop the colored yogurt (Chawla *et al.*, 2016)

BEETROOT ICE-CREAM

Ice cream of strawberry flavor was developed with the extract of beetroot and then stored. The basic component of ice cream is milk, butter, and skimmed milk, then added all ingredients and homogenized to 2500 and 500 psi, pasteurization was done at 80° C for 30 seconds, and cooled the added beetroot extract (Manoharan *et al.*, 2012)

BEETROOT SNACKS

Multigrain fortified by beetroot was developed by mixing white flour, defatted soy flour, and all other ingredients like salt and spices into a dough, putting hot oil and beetroot extract then allowed frying at the temperature of 170°C after the production of the desired shape (Dhadage *et al.*, 2020)

BEETROOT JUICE

Peeling of beetroot done and then sliced. slices of beetroot grind and extraction of juice were done hydraulic press and 4-layer cheesecloth was used to filter again and again. The extract was pasteurized at the temperature of 85°C for a time of 10 minutes (Kathiravan *et al.*, 2019)

JELLY

Jelly was prepared by heating clear beetroot extract with pectin having 2%, citric acid with having a concentration of 0.5 percent, and 60 percent sugar. The total soluble solids were heated with steady stirring till it gained 65° Brix and the desired thickness was reached (Chaudhari *et al.*, 2019)

CANDY

Candy made with beetroot was developed with sugar, pectin, and citric acid having the percentage of 65%, 3%, and 0.5% accordingly. Beetroot juice was heated with sugar, and pectin with continuous stirring for cooking for up to 55 minutes, then added the citric acid till desired thickness. Finally, the paste was allowed to cool up to 25 °C before being rolled into desired shapes (Fatma *et al.*, 2016)

THERAPEUTIC EFFECTS

CVD

These bioactive phytonutrients are effective in the treatment of a variety of chronic illnesses, including cardiovascular disease, and chronic respiratory diseases (Chen *et al.*, 2021). Nitrate in beetroot can control high blood pressure (López-Samanes *et al.*, 2020). According to current treatment methods, dietary nitrate supplementation with beetroot juice (BRJ) may help manage arterial BP in healthy persons, pre-hypertensive patients, and even patients identified and cured with medicines. This easily accessible and inexpensive dietary modification could assist to reduce the incidence of cardiovascular events and, as a result, the mortality rate linked with this pathology (Bonilla Ocampo *et al.*, 2018)

BRJ has high quantities of nitrate, which has a positive impact on a variety of indicators such as nitric oxide, VO_2, blood circulation, platelet activation, heartbeat, cardiac output, and blood pressure. Because of its effects on the cardiovascular system, BRJ ingestion could be employed as a diet supplement in many cardiovascular disease cures (Zamani *et al.*, 2021).

As a result, BRJ supplementation should be encouraged as an important part of a healthy lifestyle for those with high blood pressure, both healthy and hypertensive. Considering that high blood pressure appears to have a complicated relationship with vascular dysfunction, a phenotypical change in the vascular endothelium that occurs before the onset of cardiac disease could contribute to future cardiovascular risk. Nitric oxide (NO), a chemical produced mostly in the endothelium, may have a significant impact on vascular homeostasis, either by its powerful dilator effect, systemic blood pressure management, or atherogenesis delay. Beetroot improves blood pressure regulation in healthy people and hypertension patients, probably due to a higher synthesis of nitrates (NO). Supplementing with BRJ can lower systolic and di systolic blood pressure in both healthy people and those at risk of cardiovascular disease (pre-and hypertensive patients). Although additional research is needed to determine if other secondary metabolites of BRJ may mediate the action, the most likely mechanism is the $NO_3^-/NO_2^-/NO$ pathway (e.g., betalains) (Bonilla Ocampo *et al.*, 2018). Nitric oxide (NO) is a potent vasodilator that is essential for maintaining a low-resistance circulatory system and influencing maternal cardiovascular adaptations throughout pregnancy (Ormesher *et al.*, 2018). Supplementation with beetroot might be required to maintain positive cardiovascular benefits (Mirmiran *et al.*, 2020). Beetroot compounds (betalains and phenolic) were found to improve the resistance against oxidation of low-density lipoproteins (LDL) and to reduce the oxidation of free radicals on fat, hence preventing cancer and cardiovascular disease (Guldiken *et al.*, 2016)

CANCER

Betalain has anticancer qualities and protects cells from peroxidation and mutation. It also has a protective impact on the liver (Fu *et al.*, 2020). Beetroot has the potential to act as a chemopreventive medication, lowering the formation of multi-organ cancers while also causing less damage. We investigated the anticancer properties of the key ingredient in beetroot and concluded that employing it as a cancer treatment could be a viable option in the future (Chen *et al.*, 2021)

In ICR mice pre-treated with the tumor activator 12-O-tetradecanoylphorbol-13-acetate, oral treatment of betanin from beetroot led to the suppression of skin and lung cancers (TPA). The decrease rate was up to 60% in lung cancers. It was the first study to use an animal model to investigate beetroot's anticancer potential (Chen *et al.*, 2021).

The researchers discovered that betalain could prevent lung cancer in mice. It may be inoculated in humans to treat human lung cancer as a chemopreventive drug. Betalains have also been shown to have chemopreventive properties against cancer cells in recent research. Red beetroot juice was discovered to have cytotoxicity on male hormone sites in prostate cancer cells in a study, which led to more research into its anticancer activities. The research showed that red beetroot extract could be useful in reducing toxicity and as a possible anticancer therapy (Fu *et al*., 2020).

Compounds of betalains and phenolic found in dark beetroot have been shown to improve oxidation resistance and cancer prevention in low-density lipoproteins (LDL) (Guldiken *et al*., 2016). It has also been reported to have mutagenesis inhibition activity, which lowers the risk of cancer. Beetroot saponins are beneficial against a variety of human cancers, including prostate, kidney, chest, intestinal, lung, leukemia, and carcinoma (Chhikara *et al*., 2019). Red beetroot extract's anti-cancer properties have also been investigated. The incidence and multiplicity of tumors were significantly reduced when mice were given 0.0025 % betanin found in between 1 week of skin or liver tumor formation (Hadipour *et al*., 2020).

DIABETES

The risk of type 2 diabetes mellitus can be reduced by the consumption of vegetables (Vasconcellos *et al*., 2016). In two types of diabetes, the main trait is insulin resistance or elimination. In the case of Type 2 diabetes, genetics and obesity play a significant impact on the disease's progression. The body's capacity to utilize and digest entire glucose is slowed in those with diabetes. As a result, the level of blood glucose rises, resulting in hyperglycemia. Diabetes is expected to impact around 366 million people worldwide by 2020. Because diabetic patients have higher levels of oxidative factors than non-diabetic people, red beetroot has a protective impact against the condition. In several countries, including Turkey, red beetroots have traditionally been used to cure diabetes (Hadipour *et al*., 2020)

Supplementing with chronic and acute beetroot juice has been recommended as an economical technique for treating diabetes and insulin hemostasis (Mirmiran *et al*., 2020). Beet pulp can be used as a functional food source to fight disorders such as diabetes (Chhikara *et al*., 2019).

EXERCISE PERFORMANCE

According to various studies, supplementing with beet juice improves performance in exercise modalities that need long-term endurance in which oxidative energy metabolism is the dominant type of energy metabolism. Because NO promotes vasodilation and blood circulation with a positive impact on muscle function, many studies have revealed an ergogenic advantage of beetroot juice consumption on exercise attempts with high oxidative energy metabolism needs. Four of the experiments looked at the effect of supplementing with beetroot juice for five to seven days on high-intensity intermittent efforts or a hard training session (Domínguez *et al*., 2018) Exercise capacity can be restored due to nitrate-rich beetroot supplementation (Chen *et al*., 2021)

In the last years, there has been an increase in interest in various nutrients for boosting physical activity performance. Because of the positive effects of nitrate in the diet on physical performance, beetroot having high nitrate content has gotten a lot of interest. Nitrate in food decomposes into nitrite, which subsequently converts to nitric oxide (NO) and other nitrogen-

active intermediates, all of which have an impact on athletic performance (Chen *et al.*, 2021)

The benefits of beetroot juice supplementation for endurance exercise performance are arguable, especially when it comes to the very well-trained sportsman. In a cycle ergometer test, the load intensity was equal to the first and second ventilatory phases, greater dosages are required to improve performance in male players (Garnacho-Castaño *et al.*, 2018)

Supplementing with NO_3^- promotes vasodilation, boosting blood flow to the muscles, and facilitating force production in vivo, lowering the cost of ATP in exercised muscles (López-Samanes *et al.*, 2020)

OBESITY

The accumulation of fat in the waist causes an increase in the hip to waist ratio with excess body mass index is called obesity (Hadipour *et al.*, 2020). In obese people who had used beetroot supplements, the metabolism of neutrophil oxidation was suppressed, resulting in a reduction in body fat content (Chen *et al.*, 2021). Obesity is caused by the natural tendency of the body to store energy in the form of adipose fat. Obesity is due to excessive food intake, heredity, physical inactivity, mental and endocrine disorders, oxidative stress, and irritation. Red beetroot has been shown in studies to help people lose weight (Hadipour *et al.*, 2020).

The red beetroot had an additional anti-obesity benefit. Beetroot-based products have been shown to suppress neutrophil oxidative metabolism, promote apoptosis, and aid weight loss in obese people. As a result, beet juice, which has antioxidant and anti-inflammatory properties, could be useful in the treatment of obesity (Fu *et al.*, 2020)

FUTURE RECOMMENDATIONS AND CONCLUSION

Adding beetroot juice or powder to your diet should be considered as an early treatment approach for people with prehypertension or stage I hypertension.We should focus additional studies on figuring out the best way to use beetroot supplements for their antihypertensive and health benefits.Programs should educate people about how beetroot helps the heart and body to get people to choose healthier eating habits.It may be helpful for medical professionals to suggest including beetroot products along with regular treatments and to check for any problems they may cause.Over time, there should be more large-scale RCTs to show that beetroot keeps helping lower blood pressure and improve other important health markers.

Experts should test the impact of beetroot in various forms, including juice, powder and extract and analyze differences in how men and women respond.

In conclusion, beetroot, particularly in juice or powder form, has demonstrated significant potential as a natural and cost-effective intervention for managing hypertension due to its high nitrate content, which promotes nitric oxide production and enhances vascular function. Alongside its antihypertensive effects, beetroot exhibits additional therapeutic benefits for cardiovascular health, diabetes, obesity, and even cancer prevention, owing to its rich profile of bioactive compounds such as betalains, phenolics, and flavonoids. While its efficacy is influenced by dosage, individual physiology, and intake duration, the overall evidence supports incorporating beetroot into a balanced diet as a complementary approach to conventional treatment, with further research needed to standardize usage and confirm long-term benefits.

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