



DOSSIER · SUBSTANCE

Beetroot and Dietary Nitrate

Beetroot is a nitrate-rich vegetable; human studies show mixed effects on blood vessels, endurance and blood pressure.

1,095

STUDIES IN
TOTAL

502

IN HUMANS

306

OF WHICH
CONTROLLED

21

IN ANIMALS

34

IN THE LAB

Figures from the IHR study database · Last updated 2026-10-15

How to Read This Dossier

ESTABLISHED

measured in humans, with a comparison group

PLAUSIBLE

supported by mechanism, animal studies or observation

HYPOTHESIS

a likely connection that still needs to be tested

Beetroot and Dietary Nitrate at a Glance

In several controlled studies, peak performance after beetroot juice was above placebo or control, sometimes only in the first minutes ⁷⁰⁸¹¹⁰³. Several controlled studies found a longer walking distance after beetroot juice compared with placebo or training alone, in COPD and in postmenopausal women ²⁵⁶⁴¹⁰¹¹⁵⁰. Nitrate-rich beetroot juice lowered systolic blood pressure more than nitrate-poor placebo juice in several controlled studies ³⁶²⁵¹⁵⁰⁹⁷.

We evaluated 172 human studies on Beetroot and Dietary Nitrate, including 141 randomised controlled trials and 21 meta-analyses or systematic reviews; the controlled studies include 4,342 participants in total. As of 13 October 2026.

1. What Is Beetroot and Dietary Nitrate? Occurrence, Origin and Forms

Beetroot is the root of Beta vulgaris, a species in the amaranth family (Amaranthaceae). It naturally contains nitrate, which the body can convert via nitrite into nitric oxide. It is eaten as a vegetable and drunk as a juice, and it is studied where vascular function and physical exercise are measured. Beetroot is grown as a crop in temperate climates and used as a vegetable, juice or powder. Nitrate also occurs in many other leaf and root vegetables. Juice is pressed from the root, reduced to a concentrate or dried into a powder, and the cooked or raw root is eaten as well. Studies mostly examine juice and concentrate, alongside capsules and powder and nitrate salts, which allow the effect of nitrate alone to be examined.

Forms and Preparations Studied

- Beetroot juice
- Beetroot concentrate (shot)
- Beetroot powder
- Capsules with beetroot extract
- Nitrate salts (sodium nitrate, potassium nitrate)
- Cooked or raw beetroot as food

Not covered on this page:

- Organic nitrates used as medicines (for example glycerol trinitrate) release nitric oxide directly and are not the nitrate from food.
- Nitrite curing salt in meat products belongs to preservation and not to the beetroot topic.
- Studies on other nitrate-rich vegetables (for example spinach, rocket) are not studies on beetroot.
- Betaine and betanin are further constituents of the root and are studied separately from nitrate.

2. What Does Beetroot and Dietary Nitrate Do? Results by Area

AREA	RESULT IN CONTROLLED STUDIES	STRENGTH OF EVIDENCE	STUDIES	PARTICIPANTS
Exercise Performance and Endurance	mixed	high	9 meta-analyses · 79 controlled · 0 other	1,538
Blood Pressure	mostly no difference	high	9 meta-analyses · 56 controlled · 2 other	2,018
Vascular Function and Endothelium	mixed	high	3 meta-analyses · 49 controlled · 1 other	1,456
Oxygen Supply and Muscle Efficiency	mixed	high	4 meta-analyses · 27 controlled · 0 other	396
Oral Bacteria and Nitrate Metabolism	mostly improved	high	2 meta-analyses · 10 controlled · 0 other	229
Cerebral Blood Flow and Cognitive Performance	mostly improved	moderate	0 meta-analyses · 6 controlled · 0 other	154
Other investigations	mixed	high	4 meta-analyses · 47 controlled · 3 other	1,297

How to read the table: counted are human studies whose results concern the area. "High" means at least one meta-analysis and two controlled studies showing improvement, or at least three controlled studies of which three quarters show improvement, with at least 300 participants in total. "Moderate" means at least two controlled studies showing improvement, as a majority, or one meta-analysis alongside controlled studies. "Low" means one controlled study showing improvement. Where an area has no controlled study, the strength of evidence is at most "low" (result "reviews only" or "observational data only"). Everything else is "unclear". A study counts as showing improvement when at least half of its outcomes in this area improved. Reviews of combination products do not count as meta-analyses; results that only describe side effects or shares of users do not count as an effect. The same study is counted only once.

3. What the Studies Show in Detail

Beetroot and Dietary Nitrate, Exercise Performance and Endurance: Human Studies

Compared with placebo, beetroot juice and nitrate-rich beetroot extract increased muscle strength in two controlled studies ⁵⁵⁶⁸. In a further one, the rate of force development increased, but not maximal strength ⁷⁷. Muscle endurance, measured as repetitions or hold time to exhaustion, was higher in several controlled studies with beetroot juice or beetroot powder than on placebo ⁷⁶⁹³¹⁰⁹¹²⁰. Peak performance was above placebo or control after beetroot juice in several controlled studies, sometimes only briefly ⁷⁰⁸¹¹⁰³. Two meta-analyses found better exercise capacity with nitrate compared with placebo, in COPD and in young healthy men ⁸²¹. In women, in well-trained endurance athletes and in crossover studies in COPD, by contrast, no confirmed advantage was shown ⁸²¹. Concentrated beetroot juice prolonged the strength endurance of the leg extensors only in men ⁸⁷. The walking distance was longer in COPD and in postmenopausal women in several controlled studies than on placebo or training alone ²⁵⁶⁴¹⁰¹¹⁵⁰. In Long COVID, diabetes and in individual COPD studies, several controlled studies found no difference from placebo in walking distance and exercise endurance ⁸⁴⁵¹⁴⁴¹⁰⁵. Sprint and jump performance also remained unchanged in sprinters and female athletes ¹¹⁸¹⁰⁰. The findings apply only to the form and preparation studied in each case, since juice, concentrate, powder, capsules and nitrate salts are not interchangeable. A systematic review found the performance effect with beetroot juice and a nitrate-rich diet, but not with nitrate salts ³. In older people in training, beetroot extract did not change strength and endurance compared with placebo ⁴⁰. It remains open which form, nitrate amount and duration of intake are beneficial for which population group and type of exertion.

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
¹ Zeng et al. 2025	meta-analysis · 2,481 participants	nitrate as nutritional supplement (among other supplements); vs. other nutritional supplements and placebo/control
³ Silva et al. 2022	systematic review · 1,705 participants	Inorganic nitrate: nitrate salts, beetroot juice, high-nitrate diet; acute 5–14.9 mmol; ≥2 d 5–9.9 mmol/d; acute intake to pr
⁴ Gao et al. 2021	meta-analysis · 1,061 participants	Dietary nitrate supplementation (form not specified); vs. Placebo
⁶ Valiño-Marques et al. 2024	systematic review · 701 participants	Nitrate supplements, partly combined with caffeine; vs. Placebo
⁷ Eroglu et al. 2026	meta-analysis · 401 participants	Beetroot juice (BRJ), a dietary nitrate source; vs. Placebo or control
⁸ Chiappa et al. 2026	meta-analysis · 357 participants	Nitrate-rich beetroot juice; vs. Placebo/control; parallel vs. crossover RCTs
¹⁷ Kang et al. 2025	meta-analysis · 161 participants	Dietary nitrate supplements (form not specified); vs. Control (placebo/low-nitrate, not further described)
²⁰ Evangelista et al. 2024	meta-analysis	Beetroot-based supplements (BRS); acute or short-term administration; vs. Control (placebo or comparator, not specific

Further studies in this area: [21](#) [25](#) [31](#) [37](#) [40](#) [43](#) [44](#) [51](#) [52](#) [55](#) [58](#) [64](#) [66](#) [68](#) [69](#) [70](#) [72](#) [73](#) [74](#) [75](#) [76](#) [77](#) [78](#) [80](#) [81](#) [82](#) [83](#) [84](#) [86](#) [87](#) [88](#) [92](#) [93](#) [95](#) [100](#) [101](#) [103](#) [104](#) [105](#) [106](#) [109](#) [112](#) [113](#) [114](#) [115](#) [116](#) [118](#) [119](#) [120](#) [121](#) [122](#) [127](#) [128](#) [129](#) [130](#) [131](#) [132](#) [133](#) [134](#) [135](#) [136](#) [138](#) [139](#) [140](#) [141](#) [142](#) [143](#) [145](#) [147](#) [150](#) [152](#) [154](#) [155](#) [156](#) [159](#) [161](#) [162](#) [163](#) [164](#) [166](#)

Beetroot and Dietary Nitrate and Blood Pressure: Human Studies

Compared with low-nitrate placebo juice, nitrate-rich beetroot juice lowered systolic blood pressure in several controlled studies, in hypertension and in COPD also over weeks ³⁶²⁵¹⁵⁰. Diastolic blood pressure also fell more than with placebo in hypertension, in healthy men and in COPD ³⁶⁹⁷⁷³; in a further COPD study it fell only compared with baseline ¹⁰⁵. Two meta-analyses found a reduction in both values, one of them depending on the nitrate amount ²⁸, a meta-analysis on sodium nitrate alone, by contrast, found no confirmed reduction ¹⁶. In treated or incipient hypertension, however, beetroot juice did not lower long-term blood pressure in two controlled studies ⁵⁶³³. Resting blood pressure also remained unchanged in several controlled studies with beetroot juice or sodium nitrate ⁷⁰⁹¹¹¹⁷¹⁵⁴. Tablets made from beetroot extract, potassium nitrate, thiamine nitrate, vitamin C and plant extracts lowered blood pressure more than placebo; the finding applies to this mixture, not to beetroot alone ³⁸. The strength of evidence is high, but the majority of controlled individual studies found no difference, and most studies were small and short; it remains open whether the effect is confirmed with longer use and in already treated patients.

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
² Norouzzadeh et al. 2025	meta-analysis · 1,823 participants	Dietary nitrate (nitrate salts, nitrate-rich foods); per mmol nitrate intake (dose-dependent); acute, short-, medium- and
⁸ Chiappa et al. 2026	meta-analysis · 357 participants	Nitrate-rich beetroot juice; vs. Placebo/control; parallel vs. crossover RCTs
⁹ Grönroos et al. 2024	meta-analysis · 349 participants	Nitrate-rich beetroot juice (BRJ); 200–800 mg nitrate daily; vs. Placebo, water, or no intake

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
¹⁰ Ashor et al. 2017	meta-analysis · 325 participants	Inorganic nitrate or beetroot juice; 1 to 6 weeks; vs. Placebo control groups
¹² Siervo et al. 2013	systematic review · 254 participants	inorganic nitrate or beetroot juice; daily inorganic nitrate dose (meta-regression); 2 hours to 15 days; vs. placebo control groups
¹⁴ Benjamin et al. 2022	meta-analysis · 218 participants	Nitrate-rich beetroot juice; 70-250 mL beetroot juice daily; 3 to 60 days; vs. Control group (placebo/low-nitrate)
¹⁵ Cai et al. 2026	meta-analysis · 199 participants	Dietary nitrate supplementation (form not specified); vs. Control (placebo/no supplementation)
¹⁶ Forster et al. 2026	meta-analysis · 181 participants	Sodium nitrate (NO ₃ ⁻) supplementation; at least one week; vs. Placebo

Further studies in this area: [19](#) [22](#) [24](#) [25](#) [26](#) [27](#) [28](#) [29](#) [33](#) [36](#) [39](#) [41](#) [47](#) [49](#) [50](#) [53](#) [56](#) [60](#) [62](#) [65](#) [70](#) [73](#) [79](#) [83](#) [84](#) [85](#) [88](#) [89](#) [91](#) [94](#) [97](#) [99](#) [105](#) [107](#) [110](#) [111](#) [112](#) [117](#) [122](#) [123](#) [125](#) [126](#) [129](#) [133](#) [140](#) [142](#) [143](#) [146](#) [148](#) [150](#) [152](#) [153](#) [154](#) [156](#) [157](#) [158](#) [160](#) [161](#) [165](#)

Beetroot and Dietary Nitrate, Vascular Function and Endothelium: Human Studies

For vascular function and endothelium, a mixed picture emerges: several controlled studies found improved flow-mediated dilation after nitrate-rich beetroot juice [3563748283](#), and the meta-analysis on nitrate salts and nitrate-rich foods also reports an improvement in this parameter [2](#). Microvascular perfusion improved more with beetroot juice in addition to calorie restriction than with calorie restriction alone [53](#); in two further studies it increased only within the juice group [4148](#), and others found no difference [126146152](#). For endothelial function, two controlled studies found an improvement compared with placebo or calorie restriction alone [3653](#), while others showed no difference here [6062117](#). Arterial stiffness decreased in hypertension with nitrate-rich juice [36](#), and nitrate-rich beetroot powder abolished the caffeine-induced increase in vascular stiffness [62](#). Investigated were predominantly beetroot juice, as well as concentrate, powder, extract capsules and nitrate salts, mostly against nitrate-poor placebos. A meta-analysis that evaluated nitrate salts and beetroot preparations together also found better vascular function, weaker in older people [13](#). The strength of evidence is high, but the differences in form, nitrate amount, comparison and population leave open for which preparation and which population group the benefit applies.

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
² Norouzzadeh et al. 2025	meta-analysis · 1,823 participants	Dietary nitrate (nitrate salts, nitrate-rich foods); per mmol nitrate intake (dose-dependent); acute, short-, medium-term
¹³ Lara et al. 2016	meta-analysis · 246 participants	inorganic nitrate or beetroot supplementation; inorganic nitrate dose analysed as moderator; 1.5 hours to 28 days; vs. placebo
¹⁸ Josa et al. 2024	systematic review	Beetroot (form and nitrate amount not reported)
²² Rathod et al. 2024	randomised controlled · 300 participants	70 mL nitrate-containing beetroot juice daily; 70 mL daily; 6 months; vs. Placebo (nitrate-deplete juice)
²⁷ Faconti et al. 2019	randomised controlled · 105 participants	Active beetroot juice as nitrate source vs. nitrate-depleted placebo juice; ≤11.2 mmol nitrate daily; 6 months; vs. Placebo
²⁸ Morselli et al. 2021	randomised controlled · 93 participants	Nitrate-containing beetroot juice vs. nitrate-depleted placebo juice; 6 months; vs. Placebo (nitrate-depleted) juice; vs. Beetroot
³¹ Zamani et al. 2025	randomised controlled · 84 participants	Potassium nitrate (KNO ₃) versus equimolar potassium chloride (KCl); 6 mmol three times daily; 6 weeks per phase
³⁵ Velmurugan et al. 2016	randomised controlled · 69 participants	nitrate-rich beetroot juice vs. nitrate-depleted beetroot juice; once daily for 6 weeks; 6 weeks; vs. placebo (nitrate-depleted) juice

Further studies in this area: [36](#) [39](#) [41](#) [48](#) [49](#) [50](#) [51](#) [53](#) [60](#) [62](#) [63](#) [74](#) [82](#) [83](#) [88](#) [90](#) [91](#) [94](#) [99](#) [102](#) [104](#) [107](#) [108](#) [110](#) [111](#) [112](#) [117](#) [120](#) [122](#) [125](#) [126](#) [132](#) [134](#) [137](#) [140](#) [144](#) [146](#) [148](#) [150](#) [151](#) [152](#) [153](#) [154](#) [160](#) [165](#)

Beetroot and Dietary Nitrate, Oxygen Supply and Muscle Efficiency: Human Studies

Compared with placebo or training alone, nitrate-rich beetroot juice increased maximal oxygen uptake in several controlled studies, in mountaineers, rowers, older women and in heart failure [5564138145](#). Oxygen consumption at the same submaximal exertion was lower in several controlled studies with beetroot juice or nitrate than on placebo, sometimes only after longer exertion [73128130154](#). In female endurance athletes, maximal oxygen uptake increased after beetroot concentrate only within the juice group; the study does not report a group comparison [86](#). Muscle oxygen saturation during strength training was higher in two controlled studies with beetroot powder or beetroot juice than on placebo [120132](#). Exhaled nitric oxide was increased in several controlled studies with beetroot juice and beetroot concentrate [104131143](#). Maximal oxygen uptake, by contrast, remained unchanged in heart failure with preserved ejection fraction on potassium nitrate [31129](#) and in cancer survivors [154](#). Oxygen consumption under submaximal exertion also did not differ from placebo in several controlled

studies, for instance in diabetes, COPD and female athletes ⁴⁴¹⁰⁵¹²⁷. Investigated were mainly beetroot juice, concentrate (shot) and powder, more rarely capsules or nitrate salts. What remains open is the transferability to patient groups, the influence of accompanying circumstances such as mouth rinsing and training status, and the question of which form and nitrate amount are decisive for an effect.

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
³ Silva et al. 2022	systematic review · 1,705 participants	Inorganic nitrate: nitrate salts, beetroot juice, high-nitrate diet; acute 5–14.9 mmol; ≥2 d 5–9.9 mmol/d; acute intake
⁴ Gao et al. 2021	meta-analysis · 1,061 participants	Dietary nitrate supplementation (form not specified); vs. Placebo
⁵ Qin et al. 2026	meta-analysis · 703 participants	Beetroot juice or beetroot-derived nitrate; 6.4–12.8 mmol NO ₃ ⁻ ; at least 3 consecutive days; vs. Placebo
¹⁷ Kang et al. 2025	meta-analysis · 161 participants	Dietary nitrate supplements (form not specified); vs. Control (placebo/low-nitrate, not further described)
⁴³ Turner et al. 2022	randomised controlled · 51 participants	Beetroot juice containing nitrate and nitrite; 250 mg nitrate and 20 mg nitrite per day; 8 weeks; vs. Placebo, double
⁴⁴ Shepherd et al. 2015	randomised controlled · 48 participants	nitrate-rich beetroot juice vs. nitrate-depleted beetroot juice (placebo); 70 ml/day, 6.43 mmol nitrate/day (placebo)
⁵⁵ Daneshparvar et al. 2025	randomised controlled · 27 participants	70 mL beetroot juice with 400 mg nitrate; 70 mL (400 mg nitrate) 2.5 hours before ascent; Acute, single dose; post
⁶⁴ Carter et al. 2024	randomised controlled · 24 participants	beetroot juice (BRJ); 140 mL, 120–180 min before training; 7 weeks, then 1 week washout; vs. exercise only (EX)

Further studies in this area: ^{73 86 88 104 105 116 120 121 124 127 128 130 131 132 138 141 143 145 147 152 154 156 162}

Beetroot and Dietary Nitrate, Oral Bacteria and Nitrate Metabolism: Human Studies

Salivary nitrate and salivary nitrite rose significantly more with nitrate-rich beetroot juice than with placebo in several controlled studies ⁵⁶⁶⁹¹¹²¹¹⁸. In people with elevated cholesterol, the composition of salivary bacteria changed with nitrate-rich juice, and *Neisseria flavescens* increased compared with placebo ³⁵. A systematic review found that after nitrate administration, mostly as beetroot juice, there were more *Neisseria* and *Rothia*, a higher salivary pH and less gum inflammation ¹¹. As a mouth rinse for gum inflammation, plaque and gums improved with beetroot juice as well as with chlorhexidine; *Streptococcus* bacteria decreased more persistently with chlorhexidine ⁴⁵. In female athletes, a single dose did not change the composition of the oral flora ¹⁰⁰. Mostly beetroot juice and a beetroot concentrate were studied, sometimes as a mouth rinse. According to a systematic review, measures that harm oral bacteria weaken the performance effect of nitrate ³. The strength of evidence is high, but most studies are small and short, and the transferability to powder, capsules or the cooked beet is open.

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
³ Silva et al. 2022	systematic review · 1,705 participants	Inorganic nitrate: nitrate salts, beetroot juice, high-nitrate diet; acute 5–14.9 mmol; ≥2 d 5–9.9 mmol/d; acute intake to
¹¹ Alhulaefi et al. 2025	systematic review · 284 participants	Dietary nitrate, mostly via beetroot juice; 1 day to 6 weeks
³⁵ Velmurugan et al. 2016	randomised controlled · 69 participants	nitrate-rich beetroot juice vs. nitrate-depleted beetroot juice; once daily for 6 weeks; 6 weeks; vs. placebo (nitrate-de
⁴⁵ Kaushik et al. 2025	randomised controlled · 44 participants	beetroot juice mouthrinse; 1-week follow-up; vs. once-daily 0.2% chlorhexidine mouthrinse
⁵⁶ Bondonno et al. 2015	randomised controlled · 27 participants	nitrate-rich beetroot juice vs. nitrate-depleted beetroot juice; 1 week; vs. nitrate-depleted beetroot juice (placebo)
⁶⁹ Marshall et al. 2021	randomised controlled · 22 participants	beetroot juice (BRJ) vs. non-nitrate calorie-matched control drink; 2 × 70 ml/day, ~12.5 mmol nitrate/day; 20 days, st
⁹⁶ Fejes et al. 2025	randomised controlled · 15 participants	nitrate-rich vs. nitrate-depleted (placebo) beetroot juice; 4 weeks; vs. nitrate-depleted beetroot juice (placebo)
¹⁰⁰ Tan et al. 2024	randomised controlled · 15 participants	nitrate-rich beetroot juice (concentrate); 12.0 mmol nitrate; 2.5 h before exercise, acute; vs. nitrate-depleted beetroot

Further studies in this area: ^{112 118 123 165}

Beetroot and Dietary Nitrate, Cerebral Blood Flow and Cognitive Performance: Human Studies

Beetroot extract as a chewable tablet improved verbal memory, frontal brain functions and cognitive flexibility in a controlled study compared with placebo, but not working memory ⁴⁶. Beetroot juice in addition to calorie restriction improved cognitive flexibility more than calorie restriction alone ⁵³. In diabetes, nitrate-rich juice shortened only simple reaction time, while other tests remained unchanged ⁵⁷. Sodium nitrate increased cerebrovascular CO2 reactivity compared with placebo in a controlled study, but only in men ⁹¹. In metabolic syndrome, beetroot juice did not change cerebral autoregulation and cognition in the main analysis; only exploratory analyses showed improvements in individual frontal brain areas ⁶⁷. A randomized controlled study on fermented red cabbage with beetroot as a mixture found better attention and better working memory, but does not allow conclusions about beetroot alone ¹⁴⁹. The findings apply to the respective form studied — juice, extract chewable tablets, nitrate salt or fermented vegetable — and, because of small participant numbers and short duration, are only moderately robust; it remains open whether the effects persist with larger groups and longer intake.

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
⁴⁶ Vaccaro et al. 2024	randomised controlled · 44 participants	4 chewable tablets with 3 g Beta vulgaris extract (RedNite); 3 g extract as single dose; Single dose, testing after ingestion
⁵³ Alharbi et al. 2023	randomised controlled · 29 participants	Nitrate-rich beetroot juice plus caloric restriction; 14 days; vs. Caloric restriction alone
⁵⁷ Gilchrist et al. 2014	randomised controlled · 27 participants	beetroot juice, nitrate content 7.5 mmol per 250 ml; 7.5 mmol nitrate per day (250 ml juice); 2 weeks supplementation; vs.
⁶⁷ Gosalia et al. 2026	randomised controlled · 22 participants	nitrate-rich beetroot juice vs. nitrate-depleted placebo; 6.4 mmol NO3 ⁻ /day; 4 weeks; vs. nitrate-depleted placebo, double-blind
⁹¹ Fan et al. 2019	randomised controlled · 17 participants	sodium nitrate as dietary supplement; 0.1 mmol·kg ⁻¹ ·day ⁻¹ for 7 days; 7 days; vs. placebo, randomized, single-blinded, cross-over
¹⁰⁰ Tan et al. 2024	randomised controlled · 15 participants	nitrate-rich beetroot juice (concentrate); 12.0 mmol nitrate; 2.5 h before exercise, acute; vs. nitrate-depleted beetroot juice

Beetroot and Dietary Nitrate: Further Outcomes in Studies

Several controlled studies and a meta-analysis showed that beetroot juice, beetroot extract and sodium nitrate increased plasma nitrate levels ²⁴⁴⁶⁷⁷⁷⁹¹. Plasma nitrite levels also rose in several controlled studies ¹⁷⁴⁴⁶²⁷⁷¹⁰¹. Urinary nitrate excretion was increased in several controlled studies ²³²⁴⁵⁶⁶⁰. For blood lactate ⁴⁷¹¹³¹¹⁶¹¹⁹¹³⁴, heart rate ⁷¹⁶³⁷¹¹⁰ and muscle contraction ⁷⁷⁹³¹¹³¹¹⁸¹²⁷, several controlled studies and meta-analyses found no difference. The strength of evidence is overall high, but many studies are small and short, and the comparison conditions (placebo, low-nitrate juice, nitrate salt) differ.

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
⁴ Gao et al. 2021	meta-analysis · 1,061 participants	Dietary nitrate supplementation (form not specified); vs. Placebo
⁷ Eroglu et al. 2026	meta-analysis · 401 participants	Beetroot juice (BRJ), a dietary nitrate source; vs. Placebo or control
¹⁵ Cai et al. 2026	meta-analysis · 199 participants	Dietary nitrate supplementation (form not specified); vs. Control (placebo/no supplementation)
¹⁶ Forster et al. 2026	meta-analysis · 181 participants	Sodium nitrate (NO ₃ ⁻) supplementation; at least one week; vs. Placebo
²³ Bondonno et al. 2026	randomised controlled · 231 participants	potassium nitrate capsule (300 mg) or nitrate-rich leafy green vegetables; 300 mg nitrate daily; 5 weeks; vs. low-nitrate
²⁶ Smith et al. 2026	randomised controlled · 108 participants	Daily beetroot juice (dietary nitrate 400 mg); 400 mg nitrate daily; until after delivery (6-month follow-up); vs. standard

STUDY	DESIGN · PARTICIPANTS	PREPARATION · DOSE · DURATION · COMPARISON
30 Mansouri-Baseri et al. 2025	randomised controlled · 90 participants	beetroot capsules, some with vitamin C; 4 weeks; vs. placebo, double-blind, randomized, three groups
31 Zamani et al. 2025	randomised controlled · 84 participants	Potassium nitrate (KNO3) versus equimolar potassium chloride (KCl); 6 mmol three times daily; 6 weeks per phase, 1-week washout

Further studies in this area: [32](#) [34](#) [37](#) [39](#) [40](#) [42](#) [46](#) [47](#) [49](#) [51](#) [53](#) [55](#) [59](#) [62](#) [69](#) [70](#) [71](#) [77](#) [78](#) [85](#) [93](#) [96](#) [98](#) [103](#) [104](#) [109](#) [110](#) [111](#) [113](#) [116](#) [117](#) [118](#) [119](#) [121](#) [127](#) [129](#) [132](#) [134](#) [138](#) [146](#) [148](#) [155](#) [156](#) [161](#) [166](#) [167](#)

4. How Is Beetroot and Dietary Nitrate Dosed? Preparation, Dose and Duration in Studies

The studies used predominantly beetroot juice, as well as beetroot concentrate (shot), beetroot powder, capsules with beetroot extract, nitrate salts and cooked or raw beetroot as a food. The doses and nitrate amounts are listed in the table. Juice, concentrate, powder, capsules and nitrate salts are not interchangeable, and the findings apply in each case only to the form and preparation studied.

PREPARATION OR FORM	DOSE	DURATION	STUDY
70 mL nitrate-containing beetroot juice daily	70 mL daily	6 months	22
potassium nitrate capsule (300 mg) or nitrate-rich leafy green vegetables	300 mg nitrate daily	5 weeks	23
Potassium nitrate vs. potassium chloride (placebo)	300 mg potassium nitrate/day or 300 mg potassium chloride/day	5 weeks supplementation	24
Nitrate-rich beetroot juice vs. nitrate-deplete placebo juice	140 mL with 12.9 mmol nitrate, 3 h before each PR session	8 weeks, twice weekly PR programme	25
Daily beetroot juice (dietary nitrate 400 mg)	400 mg nitrate daily	until after delivery (6-month follow-up)	26
Active beetroot juice as nitrate source vs. nitrate-depleted placebo juice	≤11.2 mmol nitrate daily	6 months	27
Nitrate-containing beetroot juice vs. nitrate-depleted placebo juice	—	6 months	28
beetroot juice with nitrate, sodium and potassium chloride	beetroot juice 13 mmol nitrate/day; NaCl 130 mmol/day; KCl 40 mmol/day	one week	29
beetroot capsules, some with vitamin C	—	4 weeks	30
Potassium nitrate (KNO3) versus equimolar potassium chloride (KCl)	6 mmol three times daily	6 weeks per phase, 1-week washout	31
Oral sodium nitrate versus placebo (NaCl)	700 mg × 2	preoperative, follow-up up to 72 h	32
beetroot juice (400 mg nitrate/d) or nitrate-rich vegetables (~350–400 mg nitrate/d)	beetroot juice 400 mg nitrate/d; vegetables ~250–300 g/d	12 weeks	33
Nitrate-rich beetroot powder	5 g/d containing ~250 mg NO3-	24 weeks	34
nitrate-rich beetroot juice vs. nitrate-depleted beetroot juice	once daily for 6 weeks	6 weeks	35

PREPARATION OR FORM	DOSE	DURATION	STUDY
beetroot juice (dietary nitrate) vs. nitrate-free beetroot juice	250 mL daily	4-week intervention, 2-week run-in, 2-week washout	³⁶

5. Is Beetroot and Dietary Nitrate Safe? Side Effects in Studies

The studies report predominantly good tolerability; in several controlled studies no serious adverse events or side effects occurred ²⁵³¹³⁵³⁶⁶⁷. In a randomized study with pregnant women with chronic kidney disease, fewer women had serious adverse events on beetroot juice than on standard care ²⁶. In COPD, one participant experienced a drop in blood pressure on standing with symptoms after beetroot juice ⁸⁴; on potassium nitrate, no clinically significant hypotension and no methemoglobinemia occurred in heart failure ¹²⁹. Details on side effects and laboratory values are shown in the table.

STUDY	REPORTED SIDE EFFECTS
²⁵ Pavitt et al. 2020	No significant serious adverse events or side effects reported
²⁶ Smith et al. 2026	SAEs: 11 in 7/30 (23.3%) with nitrate vs. 53 in 27/53 (50.9%) with standard care, P = 0.02
³¹ Zamani et al. 2025	KNO3 was well tolerated
³² Eriksson et al. 2021	Perioperative bleeding 18% less with nitrate
³⁴ Bahadoran et al. 2021	Liver and renal function tests showed no undesirable changes
³⁵ Velmurugan et al. 2016	no adverse effects of dietary nitrate detected
³⁶ Kapil et al. 2015	intervention was well tolerated
⁴⁵ Kaushik et al. 2025	beetroot rinse well tolerated, considered exploratory adjunct
⁴⁷ Ormesher et al. 2018	Acceptable to 97% of women; no further data
⁵⁴ Nojoudi et al. 2026	none reported
⁶⁰ Rogerson et al. 2022	no adverse events reported
⁶¹ Collins et al. 2017	No significant differences in self-reported side effects

6. What Remains Open: Limits of the Evidence

- It remains open which form, nitrate amount and duration of intake are beneficial for which population group and type of exertion.
- Most studies were small and short; the transferability to larger groups and longer use is unclear.
- The comparison conditions (placebo, nitrate-poor juice, nitrate salt) differ, which makes it difficult to classify the effects.
- With mixed preparations containing additional substances such as nitrate salts, caffeine, l-arginine, nitrite, vitamin C or inulin, the effect cannot be attributed to beetroot alone.
- The transferability of the findings to powder, capsules or cooked beetroot is open, since most studies investigated juice or concentrate.

7. Bottom Line: What Is Established About Beetroot and Dietary Nitrate

In controlled studies, beetroot and preparations made from it reliably increase the plasma and salivary levels of nitrate and nitrite and thereby support the nitrate–nitrite pathway. For physical exertion, blood pressure, vascular function and oxygen supply, several controlled studies show improvements compared with placebo, but numerous results with no difference stand against these. The strength of evidence is high for several areas, but the results remain mixed because form, nitrate amount, comparison and population vary widely. Tolerability was predominantly good in the studies; serious adverse effects were rarely reported.

Frequently Asked Questions

How well has Beetroot and Dietary Nitrate been studied in humans?

We evaluated 172 human studies on Beetroot and Dietary Nitrate, including 141 randomised controlled trials and 21 meta-analyses or systematic reviews; the controlled studies include 4,342 participants in total. As of 13 October 2026.

Does Beetroot and Dietary Nitrate help with exercise Performance and Endurance? What the studies show

We evaluated 9 meta-analyses or systematic reviews and 79 controlled studies; the controlled studies include 1,538 participants in total. Result of the controlled studies: mixed. Strength of evidence under our published rules: high. Sources: [1346](#)

Does Beetroot and Dietary Nitrate help with blood Pressure? What the studies show

We evaluated 9 meta-analyses or systematic reviews, 56 controlled studies and 2 further studies; the controlled studies include 2,018 participants in total. Result of the controlled studies: mostly no difference. Strength of evidence under our published rules: high. Sources: [28910](#)

Does Beetroot and Dietary Nitrate help with vascular Function and Endothelium? What the studies show

We evaluated 3 meta-analyses or systematic reviews, 49 controlled studies and one further study; the controlled studies include 1,456 participants in total. Result of the controlled studies: mixed. Strength of evidence under our published rules: high. Sources: [2131822](#)

Does Beetroot and Dietary Nitrate help with oxygen Supply and Muscle Efficiency? What the studies show

We evaluated 4 meta-analyses or systematic reviews and 27 controlled studies; the controlled studies include 396 participants in total. Result of the controlled studies: mixed. Strength of evidence under our published rules: high. Sources: [34517](#)

Does Beetroot and Dietary Nitrate help with oral Bacteria and Nitrate Metabolism? What the studies show

We evaluated 2 meta-analyses or systematic reviews and 10 controlled studies; the controlled studies include 229 participants in total. Result of the controlled studies: mostly improved. Strength of evidence under our published rules: high. Sources: [3113545](#)

Does Beetroot and Dietary Nitrate help with cerebral Blood Flow and Cognitive Performance? What the studies show

We evaluated 6 controlled studies; the controlled studies include 154 participants in total. Result of the controlled studies: mostly improved. Strength of evidence under our published rules: moderate. Sources: [46535767](#)

Which forms of beetroot were investigated in the studies?

Investigated were mainly beetroot juice, beetroot concentrate (shot), beetroot powder, capsules with beetroot extract, nitrate salts and cooked or raw beetroot as a food. The findings apply in each case only to the form and preparation studied, since these are not interchangeable. The doses and nitrate amounts are listed in the table.

Do human studies show an improvement in athletic performance?

A meta-analysis found a small performance advantage of nitrate over placebo in young healthy adults, but not in women and well-trained endurance athletes ²¹. Several controlled studies in COPD, diabetes and Long COVID, by contrast, found no longer walking distance [845144105](#).

How does beetroot affect blood pressure?

Nitrate-rich beetroot juice lowered systolic blood pressure compared with placebo in hypertension and in COPD [3625150](#); in treated hypertension, by contrast, long-term blood pressure remained unchanged after one week ⁵⁶.

Are there studies on vascular function and the nitrate–nitrite pathway?

After nitrate-rich beetroot juice, beetroot extract or sodium nitrate, nitrate and nitrite in saliva and plasma increased markedly in several controlled studies [566911211844677791](#). Flow-mediated dilation improved compared with placebo in several controlled studies [356382](#).

Which side effects and safety aspects are known?

In a randomized study with pregnant women with chronic kidney disease, fewer women had serious adverse events on beetroot juice than on standard care ²⁶. In COPD, one participant experienced a drop in blood pressure on standing with symptoms after beetroot juice ⁸⁴; on potassium nitrate, no clinically significant hypotension and no methemoglobinemia occurred in heart failure ¹²⁹. Details are shown in the table.

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