Whole Beetroot Consumption Acutely Improves Running Performance

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ABSTRACT

Nitrate ingestion improves exercise performance; however, it has also been linked to adverse health effects, except when consumed in the form of vegetables. The purpose of this study was to determine, in a double-blind crossover study, whether whole beetroot consumption, as a means for increasing nitrate intake, improves endurance exercise performance. Eleven recreationally fit men and women were studied in a double-blind placebo controlled crossover trial performed in 2010. Participants underwent two 5-km treadmill time trials in random sequence, once 75 minutes after consuming baked beetroot (200 g with ≥500 mg nitrate) and once 75 minutes after consuming cranberry relish as a eucaloric placebo. Based on paired *t* tests, mean running velocity during the 5-km run tended to be faster after beetroot consumption (12.3±2.7 vs 11.9±2.6 km/hour; P=0.06). During the last 1.1 miles (1.8 km) of the 5-km run, running velocity was 5% faster (12.7±3.0 vs 12.1±2.8 km/hour; P=0.02) in the beetroot trial, with no differences in velocity (P≥0.25) in the earlier portions of the 5-km run. No differences in exercise heart rate were observed between trials; however, at 1.8 km into the 5-km run, rating of perceived exertion was lower with beetroot (13.0±2.1 vs 13.7±1.9; P=0.04). Consumption of nitrate-rich, whole beetroot improves running performance in healthy adults. Because whole vegetables have been shown to have health benefits, whereas nitrates from other sources may have detrimental health effects, it would be prudent for individuals seeking performance benefits to obtain nitrates from whole vegetables, such as beetroot.
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NITRATES ARE COMMONLY USED FOR FOOD PREservation, especially in processed meats such as sausage and bacon, but are also found in drinking water and other foods. Nitrates and their endogenously produced nitroso-derivatives have been linked to serious medical conditions such as cancer (1) and methemoglobinemia (2). In light of these potential adverse effects of nitrate ingestion, the US Environmental Protection Agency set the maximum contaminant level for nitrates in drinking water at 44 mg/L and the World Health Organization guidelines recommend ≤50 mg/L (3). Furthermore, the joint Food and Agricultural Organization/World Health Organization set the Acceptable Daily Intake for nitrates at 3.7 mg/kg body weight (4).

Nitrate intake has also been linked with beneficial effects, including enhanced endurance exercise performance (5-9), improved endothelial function (10), and lower blood pressure (9-11). Furthermore, large amounts of nitrates and nitrites are found in vegetables, which are known to reduce cardiovascular disease risk (12) and cancer risk (13). The mechanism for the beneficial effects of nitrates appears to involve enterosalivary circulation of ingested/absorbed nitrates to the oral cavity where they are reduced to nitrites by bacteria (14), swallowing and absorption of nitrites, and then reduction of circulating nitrites to nitric oxide by deoxyhemoglobin (15) and/or xanthine oxidoreductase (16), especially during hypoxia. Nitric oxide has potent effects on the vasculature, which could be responsible for the beneficial effects of nitrates (17,18). However, because nitric oxide has a broad array of other effects, such as gene expression regulation (19), mitochondrial biogenesis (20), immunomodulation (21), and cell cycle/apoptosis control (22), other mechanisms are also possible.

It is not known why dietary nitrate has been associated with healthful effects in some instances and harmful effects in others. However, it is possible that other components of nitrate-rich vegetables prevent the harmful effects of nitrates. For example, in addition to nitrates, whole vegetables are also rich sources of antioxidants, fiber, and phytochemicals, all of which have anticarcinogenic qualities. However, until the apparent paradox of nitrates being both harmful and healthful is better understood, it would be prudent for individuals who want to augment their nitrate intake for ergogenic purposes to obtain it from vegetables. Studies that tested exercise performance after nitrate supplementation have used nitrate doses ranging from 347 mg to 476 mg/day and have supplemented by using sodium nitrate capsules or beetroot juice (5,9). Similar nitrate doses are easily achieved by consuming whole beets, which contain ≥250 mg nitrate per 100-g portion (12). However, it is not known whether whole beet consumption, as a means for increasing nitrate intake, has ergogenic effects. Thus, the purpose of our study was to evaluate the hypothesis that the ingestion of 200 g whole beetroot (containing ~500 mg nitrates) before exercise improves running performance during a 5 km treadmill time trial.

METHODS

Participants

Men (n=5) and women (n=6) aged 18 to 55 years with no history or evidence of cardiovascular disease or hypertension were recruited from the St Louis Metropolitan area. Exclusion criteria were smoking, pregnancy/nursing, use of medications that could affect the outcomes, conditions that might interfere with the ability to run 5 km (eg, orthopedic problems, sedentary lifestyle) or comply with the dietary requirements of the study (eg, gastrointestinal distress or unwillingness to eat beetroot or cranberries), and moderate or high risk for medical complications during exercise based on American College of Sports Medicine criteria (23). Self-reported exercise habits were documented in terms of frequency, duration, intensity, and mode of exercise. The Saint Louis University Institutional Review Board approved the study protocol and all participants provided written informed consent.

Study Design

The study was a double-blind, placebo-controlled crossover trial. Participants underwent two experimental trials in random sequence separated by a 1-week washout period. In one trial, participants consumed beetroot before performing a treadmill time trial; in the other trial, cranberry relish was used as a placebo. Although the beetroot and cranberry relish were distinguishable, subjects did not have knowledge of which food was expected to enhance performance. For investigator blinding, test meal administration and the data collection procedures were performed by separate personnel. The sequence of events during each trial consisted of 0 to 15 minutes: beetroot or placebo consumption, 60 to 65 minutes: blood pressure assessment, 65 to 70 minutes: treadmill warm-up, 70 to 75 minutes: stretching exercise or continued warm-up, and 75 minutes start 5-km run.

Diet and Exercise Control

Participants were advised to refrain from taking dietary supplements and medications, and to avoid nitrate-rich foods for 72 hours before testing (a list of nitrate-rich foods was provided [12]). Participants were also asked to refrain from alcohol and caffeine intake and from exercise for 24 hours, and to refrain from resistance training for 72 hours before testing. No guidelines were given regarding use of sports nutrition products (ie, gels and drinks).

Meal Preparation and Administration

Fresh whole red beetroot and fresh whole cranberries were obtained from a local supermarket and were each prepared in a single batch to ensure uniform dosing of nitrates (and other nutrients) across participants. Beetroot was baked (90 minutes at 177°C) in a commercial oven (Wolf range/oven, ITW Food Equipment Corp, Glenview, IL), which does not alter nitrate content (24), peeled and chopped in a food processor (R2 Ultra, Robot Coupe Corp, Ridgeland, MS), and divided into 200-g portions. To each portion, 15 mL lemon juice and 2 mL each ground nutmeg and cinnamon were added for flavor. As determined by using computerized nutrient analysis (Food Processor SQL, version 10.7.0, 2010, ESHA Research Corp, Salem OR) and published nitrate concentration data (12), each beetroot portion contained 86 kcal energy, 19 g carbohydrate, and ≥500 mg nitrate. For the placebo, cranberries were simmered over stovetop until resembling a chunky sauce and were then weighed into 200-g portions with the same flavoring agents being added. Granular white sugar (12 g) was added to each portion to increase the carbohydrate and energy content to similar levels as those for the beetroot. Each placebo portion contained 92 kcal energy, 24 g carbohydrate, and negligible nitrate.

For each study trial, participants arrived at the laboratory fasted (≥8 hours) and were interviewed to confirm that they complied with the preparation instructions. Beetroot or placebo was administered; participants were asked to consume the entire meal within 15 minutes.

Exercise Performance

Exercise performance was evaluated with a self-paced 5-km treadmill (Trotter 900T, Cybex Corp, Medway, MA) time trial, which has been shown to correspond with comparable, although slightly greater, performance times as those obtained during a competitive outdoor 5-km track run (25). Furthermore, the 5-km treadmill time trial has been shown to have better reproducibility than time-to-exhaustion tests of performance (26,27). Participants completed a standardized 5-minute warm-up during which they self-selected the fastest speed that they thought they could sustain for the whole 5-km run; this speed would then be used as the starting speed for the run in both trials. Participants were then given an additional 5 minutes to stretch or continue treadmill warm-up, as desired. The 5-km run was initiated 75 minutes after meal initiation. The participants were only allowed to view run distance on the treadmill control panel (not time or speed) and were told to adjust the speed as frequently as desired, with the goal of completing the 5-km run in as little time as possible. Treadmill grade remained at 0% throughout the test. During the second trial for each participant, the treadmill speeds used during warm-up and at the start of the 5-km run were set by the technician to match those used in the first trial. Times were documented after each mile (1.6 km) and at the end of the 5-km run and were used to calculate running velocities.

Blood Pressure, Heart Rate (HR), and Ratings of Perceived Exertion

Sixty minutes after the meal was initiated, supine blood pressure (Trimline mercury sphygmomanometer, PyMaH Corp, Somerville, NJ) was measured in duplicate in the dominant arm and averaged. To minimize interference with the participant during the 5-km run, exercise blood pressures were not measured. Exercise HRs were measured with a Polar FS2c HR monitor (Polar Electro, Kempele, Finland). Maximal HR (HR_{max}) was calculated as 220 −age (in years) and was used for calculating exercise heart rates as a percentage of HR_{max}. Rating of perceived exertion was measured with the Borg 6- to

20-point scale. Both heart rate and rating of perceived exertion were recorded after the completion of each mile (1.6 km) and at the end of the 5-km run.

Statistical Analysis

Data from the beetroot and placebo trials were compared by using paired *t* tests. $P \leq 0.05$ was considered significant. An a priori power analysis indicated that with 10 participants, a ±23.7 second standard deviation for duplicate 5-km time trials (27), power of 80%, and α=.05, a 23.6 second difference between trials would be detectable with a paired *t* test. Eleven participants were enrolled to ensure that complete data would be available in the event of a drop out; however, all participant completed the study. Statistical analyses and power analyses were performed by using PASW Statistics (version 18.0.0, 2009, IBM Corporation, Armonk, NY) and PS Power and Sample Size Calculation software (version 2.1.30, 2003, Vanderbilt University, Nashville, TN) (28).

RESULTS AND DISCUSSION

Participants

Five male and six female volunteers (age 25±4 years; body mass index 23.7) were enrolled and completed the study. Participants reported 5±1 days/week of moderate to vigorous intensity exercise lasting 59±17 min/session for a total of 298±80 min/wk. All subjects self-reported full compliance with preparation instructions.

Exercise Performance and Perceived Exertion

Average 5-km run times ranged from 19.9 to 35.5 minutes, suggesting that the participants were moderately fit. Running velocity for the full 5 km was marginally faster after beetroot consumption as compared to placebo (12.3±2.7 vs 11.9±2.6 km/h; P=0.06). This 0.4 km/h (3%) faster velocity translates to a 41 second faster finishing time. During the last 1.1 miles (1.8 km), beetroot consumption resulted in a 0.6 km/hour (5%) faster running velocity, with no effect earlier in the 5-km run (see the Figure). Average rating of perceived exertion for the full 5 km did not differ between trials (beetroot 15.2±1.7; placebo 15.5±1.5; P=0.21). However, during the first mile (1.6 km), rating of perceived exertion was lower in the beetroot trial (see the Figure).

These findings support other research that has consistently shown performance-enhancing effects of nitrate consumption (5,7,9,11). Prior studies have demonstrated that nitrate supplementation reduces the oxygen cost of submaximal and maximal exercise (5-8,8,29) and increases exercise time to exhaustion (5,8,9). Similar effects appear to result from acute dosing and 15 days of daily supplementation (11). Results from our study add to previous findings by showing that whole foods, as a dietary nitrate source, have ergogenic effects and by demonstrating performance benefits during a 5 km running time trial, a test which has more direct relevance for endurance competition.

It is not clear why the ergogenic effect of beetroot occurred only late in the 5-km run. It is possible that the participants were reluctant to change the treadmill speed from the standardized starting speed until later in the run. Accordingly, early in the 5-km run, running velocity was similar in the two trials but perceived exertion was lower in the beetroot trial,

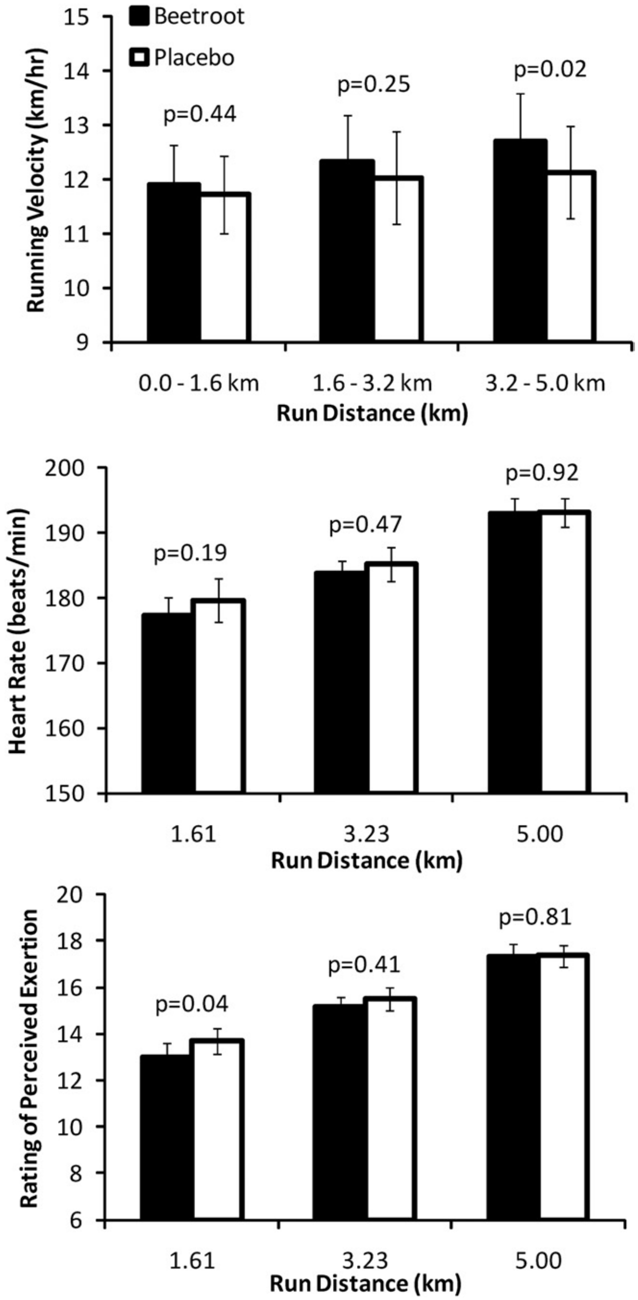

Figure. Average running velocity, heart rate, and rating of perceived exertion during each segment of a 5-km treadmill time trial. Data are means±standard error of the mean. *P* values reflect the significance of differences between trials with $P \leq 0.05$ considered significant. Rating of perceived exertion was based on the 6- to 20-point Borg scale.

suggesting that early in the run, the participants may have been able to run faster in the beetroot trial but opted not to. Then later in the 5-km run, perceived exertion was similar for the two trials but running velocity was greater in the beetroot trial. In addition, it is possible that during the 5-km run, serum nitrate, or more importantly, nitrite levels continued to rise to the point at which benefits became more pronounced late in the 5-km run.

Table. Resting blood pressure as measured before and 60 minutes after the consumption of 200 g of baked beetroot or placebo

Blood pressure	Beetroot	Placebo	*P* value[a]
	←—— *mean±standard deviation* ——→		
Systolic blood pressure (mm Hg)			
Before meal	107.9±4.6	113.5±4.9	
60 min after meal	108.7±6.0	112.0±7.3	
Change	−0.8±5.2	1.6±4.2	0.92
Diastolic blood pressure (mm Hg)			
Before meal	63.5±4.0	66.1±3.4	
60 min after meal	64.1±5.2	63.8±4.8	
Change	−0.6±4.4	2.3±6.4	0.69

[a]*P* values are from paired *t* tests to compare changes in blood pressure in response to beetroot ingestion to those in response to placebo ingestion.

Blood Pressure

Supine resting blood pressure, when measured 60 minutes after initiating the meal was not affected by beetroot (see the Table). In contrast, others have shown that nitrate ingestion lowers blood pressure (11,29), even in individuals with low blood pressure (~108/70 mm Hg) (10). However, studies that showed blood pressure–lowering effects used several days of nitrate loading (11,29) or did not see effects until 2.5 to 3.0 hours after acute nitrate loading (10,11). Therefore, it is not surprising that blood pressure in the present study did not change within 60 minutes of ingesting a single portion of beetroot.

HR

Exercise HR averaged 185±7 beats/minute (95±4% of HR_{max}) during the beetroot trial and 186±9 beats/minute (95±3% HR_{max}) during the placebo trial, with no difference between trials (P=0.42). Likewise, there were no between-trial differences in exercise heart rate during any of the intermediate measures made during the 5-km run (see the Figure).

Limitations

Our study has limitations. First, nitrate levels in the beetroot and in blood were not measured. However, unless an unknown component of beetroot was responsible for the observed performance enhancement, it is likely that beetroot consumption did increase serum nitrate levels. Second, the sample size was small. However, the low statistical power that results from small samples was offset by using a crossover design; as a result, power was sufficient to detect significant performance-enhancing effects. Thirdly, subject blinding was limited in that the experimental foods did not taste identical. However, it is unlikely that the observed effects could be explained by a placebo effect because none of the participants were aware of either food having ergogenic effects. Finally, although serum nitrate levels rise within 30 to 60 minutes after nitrate consumption (10,11), nitrite, which is more bioactive, does not peak until 2.5 to 3.0 hours after nitrate ingestion (10). Therefore, it is possible that the 60 minutes between beetroot consumption and the measurement of outcomes was not sufficient for the physiologic effects of nitrate ingestion to fully develop. This might explain the lack of effect on blood pressure and might have also resulted in an underestimate of the ergogenic effects of beetroot consumption.

CONCLUSIONS

Whole beetroot consumption improved 5 km running performance in healthy adults. Therefore, in addition to the multitude of health benefits of whole vegetables, nitrate-rich whole vegetables also improve exercise capacity. Although more isolated forms of dietary nitrates (eg, sodium nitrate) also have ergogenic effects, their long-term safety is questionable. Although these findings should be confirmed in elite athletes and in exercise tasks of different durations (eg, marathon running) and modes (eg, rowing or swimming), they have obvious implications for food and nutrition practitioners in the area of sports nutrition and athletes. In addition, these findings might have relevance in clinical dietetics if the ergogenic effects of nitrate-rich vegetables also benefit individuals with compromised functional capacity such as patients with heart failure and frail elderly persons. From a practical perspective, evidence from our study suggests that for ergogenic effects, 200 g baked beetroot, or an equivalent nitrate dose from other vegetables, should be consumed ~60 minutes before exercise.

References

1. Tricker AR, Preussmann R. Carcinogenic N-nitrosamines in the diet: Occurrence, formation, mechanisms and carcinogenic potential. *Mutat Res*. 1991;259(3-4):277-289.
2. Harris JC, Rumack BH, Peterson RG, McGuire BM. Methemoglobinemia resulting from absorption of nitrates. *JAMA*. 1979;242(26):2869-2871.
3. Grosse Y, Baan R, Straif K, Secretan B, El Ghissassi F, Cogliano V. Carcinogenicity of nitrate, nitrite, and cyanobacterial peptide toxins. *Lancet Oncol*. 2006;7(8):628-629.
4. Scientific Panel on Contaminants in the Food Chain. Nitrate in vegetables. Scientific opinion of the Panel on Contaminants in the Food Chain. *Euro Food Safety Authority J*. 2008;6891-6879.
5. Larsen FJ, Weitzberg E, Lundberg JO, Ekblom B. Dietary nitrate reduces maximal oxygen consumption while maintaining work performance in maximal exercise. *Free Radic Biol Med*. 2010;48(2):342-347.
6. Bescos R, Rodriguez FA, Iglesias X, Ferrer MD, Iborra E, Pons A. Acute administration of inorganic nitrate reduces VO_{2peak} in endurance athletes. *Med Sci Sports Exerc*. 2011;43(10):1979-1986.
7. Lansley KE, Winyard PG, Bailey SJ, et al. Acute dietary nitrate supplementation improves cycling time trial performance. *Med Sci Sports Exerc*. 2011;43(6):1125-1131.
8. Lansley KE, Winyard PG, Fulford J, et al. Dietary nitrate supplementation reduces the O_2 cost of walking and running: A placebo-controlled study. *J Appl Physiol*. 2011;110(3):591-600.
9. Bailey SJ, Winyard P, Vanhatalo A, et al. Dietary nitrate supplementation reduces the O_2 cost of low-intensity exercise and enhances tolerance to high-intensity exercise in humans. *J Appl Physiol*. 2009;107(4):1144-1155.
10. Webb AJ, Patel N, Loukogeorgakis S, et al. Acute blood pressure lowering, vasoprotective, and antiplatelet properties of dietary nitrate via bioconversion to nitrite. *Hypertension*. 2008;51(3):784-790.
11. Vanhatalo A, Bailey SJ, Blackwell JR, et al. Acute and chronic effects of dietary nitrate supplementation on blood pressure and the physio-

logical responses to moderate-intensity and incremental exercise. *Am J Physiol Regul Integr Comp Physiol*. 2010;299(4):R1121-R1131.

12. Hord NG, Tang Y, Bryan NS. Food sources of nitrates and nitrites: The physiologic context for potential health benefits. *Am J Clin Nutr*. 2009; 90(1):1-10.
13. van't Veer P, Jansen MC, Klerk M, Kok FJ. Fruits and vegetables in the prevention of cancer and cardiovascular disease. *Public Health Nutr*. 2000;3(1):103-107.
14. Lundberg JO, Govoni M. Inorganic nitrate is a possible source for systemic generation of nitric oxide. *Free Radic Biol Med*. 2004;37(3):395-400.
15. Cosby K, Partovi KS, Crawford JH, et al. Nitrite reduction to nitric oxide by deoxyhemoglobin vasodilates the human circulation. *Nat Med*. 2003;9(12):1498-1505.
16. Webb AJ, Milsom AB, Rathod KS, et al. Mechanisms underlying erythrocyte and endothelial nitrite reduction to nitric oxide in hypoxia: role for xanthine oxidoreductase and endothelial nitric oxide synthase. *Circ Res*. 2008;103(9):957-964.
17. Thomas DD, Liu X, Kantrow SP, Lancaster JR Jr. The biological lifetime of nitric oxide: Implications for the perivascular dynamics of NO and O2. *Proc Natl Acad Sci U S A*. 2001;98(1):355-360.
18. Jones AM, Wilkerson DP, Campbell IT. Nitric oxide synthase inhibition with L-NAME reduces maximal oxygen uptake but not gas exchange threshold during incremental cycle exercise in man. *J Physiol*. 2004; 560(pt 1):329-338.
19. Tong L, Heim RA, Wu S. Nitric oxide: A regulator of eukaryotic initiation factor 2 kinases. *Free Radic Biol Med*. 2011;50(12):1717-1725.
20. Nisoli E, Falcone S, Tonello C, et al. Mitochondrial biogenesis by NO yields functionally active mitochondria in mammals. *Proc Natl Acad Sci U S A*. 2004;101(47):16507-1612.
21. Wink DA, Hines HB, Cheng RY, et al. Nitric oxide and redox mechanisms in the immune response. *J Leukoc Biol*. 2011;89(6):873-891.
22. Filippin LI, Moreira AJ, Marroni NP, Xavier RM. Nitric oxide and repair of skeletal muscle injury. *Nitric Oxide*. 2009;21(3-4):157-163.
23. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*. Baltimore, MD: Williams & Wilkins; 2006.
24. van Velzen AG, Sips AJ, Schothorst RC, Lambers AC, Meulenbelt J. The oral bioavailability of nitrate from nitrate-rich vegetables in humans. *Toxicol Lett*. 2008;181(3):177-181.
25. Hopkins WG, Schabort EJ, Hawley JA. Reliability of power in physical performance tests. *Sports Med*. 2001;31(3):211-234.
26. Currell K, Jeukendrup AE. Validity, reliability and sensitivity of measures of sporting performance. *Sports Med*. 2008;38(4):297-316.
27. Laursen PB, Francis GT, Abbiss CR, Newton MJ, Nosaka K. Reliability of time-to-exhaustion versus time-trial running tests in runners. *Med Sci Sports Exerc*. 2007;39(8):1374-1379.
28. Dupont WD, Plummer WD. PS power and sample size program available for free on the Internet. *Controlled Clinical Trials*. 1997;18274
29. Larsen FJ, Weitzberg E, Lundberg JO, Ekblom B. Effects of dietary nitrate on oxygen cost during exercise. *Acta Physiol (Oxf)*. 2007;191(1): 59-66.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

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