

Research on nitric oxide and the vascular system

There are over 50,000 [papers on PubMed that discuss nitric oxide and the vascular system](#).

Below are some of the major studies, which are grouped under major headings, though the content of the studies often overlap. Topics include:

- Vascular health and nitric oxide
- Nitric oxide production
- Synergy with hydrogen sulfide
- Exercise performance

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Product-specific study

- Houston M, Chen C, D'Adamo C R, et al. (September 16, 2023) Effects of S-Allylcysteine-Rich Garlic Extract and Dietary Inorganic Nitrate Formula on Blood Pressure and Salivary Nitric Oxide: An Open-Label Clinical Trial Among Hypertensive Subjects. *Cureus* 15(9): e45369. doi:[10.7759/cureus.45369](https://doi.org/10.7759/cureus.45369)

Vascular health and nitric oxide

- Förstermann Ulrich, Münzel Thomas. Endothelial Nitric Oxide Synthase in Vascular Disease. *Circulation*. 2006;113(13):1708-1714. doi:[10.1161/CIRCULATIONAHA.105.602532](https://doi.org/10.1161/CIRCULATIONAHA.105.602532)
- Forte M, Conti V, Damato A, et al. Targeting Nitric Oxide with Natural Derived Compounds as a Therapeutic Strategy in Vascular Diseases. *Oxidative Medicine and Cellular Longevity*. 2016;2016:e7364138. doi:[10.1155/2016/7364138](https://doi.org/10.1155/2016/7364138)
- Infante T, Costa D, Napoli C. Novel Insights Regarding Nitric Oxide and Cardiovascular Diseases. *Angiology*. 2021;72(5):411-425. doi:[10.1177/0003319720979243](https://doi.org/10.1177/0003319720979243)

- Levine AB, Punihaole D, Levine TB. Characterization of the Role of Nitric Oxide and Its Clinical Applications. *Cardiology*. 2012;122(1):55-68. doi:[10.1159/000338150](https://doi.org/10.1159/000338150)
- Lima B, Forrester MT, Hess DT, Stamler JS. S-Nitrosylation in Cardiovascular Signaling. *Circulation Research*. 2010;106(4):633-646. doi:[10.1161/CIRCRESAHA.109.207381](https://doi.org/10.1161/CIRCRESAHA.109.207381)
- Sverdlov AL, Ngo DTM, Chan WPA, Chirkov YY, Horowitz JD. Aging of the Nitric Oxide System: Are We as Old as Our NO? *J Am Heart Assoc*. 2014;3(4):e000973. doi:[10.1161/JAHA.114.000973](https://doi.org/10.1161/JAHA.114.000973)
- Toda N, Ayajiki K, Okamura T. Nitric oxide and penile erectile function. *Pharmacol Ther*. 2005;106(2):233-266. doi:[10.1016/j.pharmthera.2004.11.011](https://doi.org/10.1016/j.pharmthera.2004.11.011)
- Torregrossa AC, Aranke M, Bryan NS. Nitric oxide and geriatrics: Implications in diagnostics and treatment of the elderly. *J Geriatr Cardiol*. 2011;8(4):230-242. doi:[10.3724/SP.J.1263.2011.00230](https://doi.org/10.3724/SP.J.1263.2011.00230)
- Tran N, Garcia T, Anika M, Ali S, Ally A, Nauli S. Endothelial Nitric Oxide Synthase (eNOS) and the Cardiovascular System: in Physiology and in Disease States. *Am J Biomed Sci Res*. 2022;15(2):153-177.

Nitric Oxide Production

- Alvares TS, Conte-Junior CA, Silva JT, Paschoalin VMF. Acute L-Arginine supplementation does not increase nitric oxide production in healthy subjects. *Nutr Metab (Lond)*. 2012;9:54. doi:[10.1186/1743-7075-9-54](https://doi.org/10.1186/1743-7075-9-54)
- Bartosch AMW, Mathews R, Tarbell JM. Endothelial Glycocalyx-Mediated Nitric Oxide Production in Response to Selective AFM Pulling. *Biophys J*. 2017;113(1):101-108. doi:[10.1016/j.bpj.2017.05.033](https://doi.org/10.1016/j.bpj.2017.05.033)
- Dragovich MA, Chester D, Fu BM, et al. Mechanotransduction of the endothelial glycocalyx mediates nitric oxide production through activation of TRP channels. *American Journal of Physiology-Cell Physiology*. 2016;311(6):C846-C853. doi:[10.1152/ajpcell.00288.2015](https://doi.org/10.1152/ajpcell.00288.2015)
- Förstermann Ulrich, Münzel Thomas. Endothelial Nitric Oxide Synthase in Vascular Disease. *Circulation*. 2006;113(13):1708-1714. doi:[10.1161/CIRCULATIONAHA.105.602532](https://doi.org/10.1161/CIRCULATIONAHA.105.602532)
- Ghimire K, Altmann HM, Straub AC, Isenberg JS. Nitric oxide: what's new to NO? *Am J Physiol Cell Physiol*. 2017;312(3):C254-C262. doi:[10.1152/ajpcell.00315.2016](https://doi.org/10.1152/ajpcell.00315.2016)
- Gouverneur M, Berg B, Nieuwdorp M, Stroes E, Vink H. Vasculoprotective properties of the endothelial glycocalyx: effects of fluid shear stress. *J Intern Med*. 2006;259(4):393-400. doi:[10.1111/j.1365-2796.2006.01625.x](https://doi.org/10.1111/j.1365-2796.2006.01625.x)
- Kurzelewski M, Czarnowska E, Beresewicz A. Superoxide- and nitric oxide-derived species mediate endothelial dysfunction, endothelial glycocalyx

disruption, and enhanced neutrophil adhesion in the post-ischemic guinea-pig heart. *J Physiol Pharmacol*. 2005;56(2):163-178.

- Lundberg JO, Weitzberg E, Gladwin MT. The nitrate–nitrite–nitric oxide pathway in physiology and therapeutics. *Nat Rev Drug Discov*. 2008;7(2):156-167. doi:[10.1038/nrd2466](https://doi.org/10.1038/nrd2466)
- Tejero J, Shiva S, Gladwin MT. Sources of Vascular Nitric Oxide and Reactive Oxygen Species and Their Regulation. *Physiological Reviews*. 2019;99(1):311-379. doi:[10.1152/physrev.00036.2017](https://doi.org/10.1152/physrev.00036.2017)
- Torregrossa AC, Aranke M, Bryan NS. Nitric oxide and geriatrics: Implications in diagnostics and treatment of the elderly. *J Geriatr Cardiol*. 2011;8(4):230-242. doi:[10.3724/SP.J.1263.2011.00230](https://doi.org/10.3724/SP.J.1263.2011.00230)

Synergy with hydrogen sulfide

- Altaany Z, Ju Y, Yang G, Wang R. The coordination of S-sulphydration, S-nitrosylation, and phosphorylation of endothelial nitric oxide synthase by hydrogen sulfide. *Sci Signal*. 2014;7(342):ra87. doi:[10.1126/scisignal.2005478](https://doi.org/10.1126/scisignal.2005478)
- Bailey TS, Zakharov LN, Pluth MD. Understanding Hydrogen Sulfide Storage: Probing Conditions for Sulfide Release from Hydrodisulfides. *J Am Chem Soc*. 2014;136(30):10573-10576. doi:[10.1021/ja505371z](https://doi.org/10.1021/ja505371z)
- Blackwood EA, Glembotski CC. Hydrogen sulfide: the gas that fuels longevity. *The Journal of Cardiovascular Aging*. 2022;2(3):26. doi:[10.20517/jca.2022.16](https://doi.org/10.20517/jca.2022.16)
- Bryan NS, Lefer DJ. Update on Gaseous Signaling Molecules Nitric Oxide and Hydrogen Sulfide: Strategies to Capture their Functional Activity for Human Therapeutics. *Mol Pharmacol*. 2019;96(1):109-114. doi:[10.1124/mol.118.113910](https://doi.org/10.1124/mol.118.113910)
- Cirino G, Vellecco V, Bucci M. Nitric oxide and hydrogen sulfide: the gasotransmitter paradigm of the vascular system. *British Journal of Pharmacology*. 2017;174(22):4021-4031. doi:[10.1111/bph.13815](https://doi.org/10.1111/bph.13815)
- Coletta C, Papapetropoulos A, Erdelyi K, et al. Hydrogen sulfide and nitric oxide are mutually dependent in the regulation of angiogenesis and endothelium-dependent vasorelaxation. *PNAS*. 2012;109(23):9161-9166. doi:[10.1073/pnas.1202916109](https://doi.org/10.1073/pnas.1202916109)
- Gheibi S, Jeddi S, Kashfi K, Ghasemi A. Regulation of vascular tone homeostasis by NO and H₂S: Implications in hypertension. *Biochem Pharmacol*. 2018;149:42-59. doi:[10.1016/j.bcp.2018.01.017](https://doi.org/10.1016/j.bcp.2018.01.017)
- Giuffrè A, Vicente JB. Hydrogen Sulfide Biochemistry and Interplay with Other Gaseous Mediators in Mammalian Physiology. *Oxidative Medicine and Cellular Longevity*. 2018;2018:e6290931. doi:[10.1155/2018/6290931](https://doi.org/10.1155/2018/6290931)
- Guo W, Cheng Z yu, Zhu Y zhun. Hydrogen sulfide and translational medicine. *Acta Pharmacol Sin*. 2013;34(10):1284-1291. doi:[10.1038/aps.2013.127](https://doi.org/10.1038/aps.2013.127)
- Hosoki R, Matsuki N, Kimura H. The possible role of hydrogen sulfide as an endogenous smooth muscle relaxant in synergy with nitric oxide. *Biochem Biophys Res Commun*. 1997;237(3):527-531. doi:[10.1006/bbrc.1997.6878](https://doi.org/10.1006/bbrc.1997.6878)

- Kevil CG, Patel RP. S-nitrosothiol biology and therapeutic potential in metabolic disease. *Curr Opin Investig Drugs*. 2010;11(10):1127-1134.
- Kolluru GK, Shackelford RE, Shen X, Dominic P, Kevil CG. Sulfide regulation of cardiovascular function in health and disease. *Nat Rev Cardiol*. Published online August 5, 2022:1-17. doi:[10.1038/s41569-022-00741-6](https://doi.org/10.1038/s41569-022-00741-6)
- Kuschman HP, Palczewski MB, Thomas DD. Nitric oxide and hydrogen sulfide: Sibling rivalry in the family of epigenetic regulators. *Free Radical Biology and Medicine*. 2021;170:34-43. doi:[10.1016/j.freeradbiomed.2021.01.010](https://doi.org/10.1016/j.freeradbiomed.2021.01.010)
- Lin Y, Chen Y, Zhu N, Zhao S, Fan J, Liu E. Hydrogen sulfide inhibits development of atherosclerosis through up-regulating protein S-nitrosylation. *Biomedicine & Pharmacotherapy*. 2016;83:466-476. doi:[10.1016/j.biopha.2016.07.003](https://doi.org/10.1016/j.biopha.2016.07.003)
- Lv B, Chen S, Tang C, Jin H, Du J, Huang Y. Hydrogen sulfide and vascular regulation – An update. *Journal of Advanced Research*. 2021;27:85-97. doi:[10.1016/j.jare.2020.05.007](https://doi.org/10.1016/j.jare.2020.05.007)
- Murphy B, Bhattacharya R, Mukherjee P. Hydrogen sulfide signaling in mitochondria and disease. *FASEB J*. 2019;33(12):13098-13125. doi:[10.1096/fj.201901304R](https://doi.org/10.1096/fj.201901304R)
- Mys LA, Strutynska NA, Goshovska YV, Sagach VF. Stimulation of the endogenous hydrogen sulfide synthesis suppresses oxidative-nitrosative stress and restores endothelial-dependent vasorelaxation in old rats. *Can J Physiol Pharmacol*. 2020;98(5):275-281. doi:[10.1139/cjpp-2019-0411](https://doi.org/10.1139/cjpp-2019-0411)
- Nagpure BV, Bian JS. Interaction of Hydrogen Sulfide with Nitric Oxide in the Cardiovascular System. *Oxidative Medicine and Cellular Longevity*. 2015;2016:e6904327. doi:[10.1155/2016/6904327](https://doi.org/10.1155/2016/6904327)
- Pan LL, Qin M, Liu XH, Zhu YZ. The Role of Hydrogen Sulfide on Cardiovascular Homeostasis: An Overview with Update on Immunomodulation. *Front Pharmacol*. 2017;8. doi:[10.3389/fphar.2017.00686](https://doi.org/10.3389/fphar.2017.00686)
- Polhemus David J., Lefer David J. Emergence of Hydrogen Sulfide as an Endogenous Gaseous Signaling Molecule in Cardiovascular Disease. *Circulation Research*. 2014;114(4):730-737. doi:[10.1161/CIRCRESAHA.114.300505](https://doi.org/10.1161/CIRCRESAHA.114.300505)
- Rajendran S, Shen X, Glawe J, Kolluru GK, Kevil CG. Nitric Oxide and Hydrogen Sulfide Regulation of Ischemic Vascular Growth and Remodeling. *Compr Physiol*. 2019;9(3):1213-1247. doi:[10.1002/cphy.c180026](https://doi.org/10.1002/cphy.c180026)
- Szabo C. Hydrogen sulfide, an enhancer of vascular nitric oxide signaling: mechanisms and implications. *Am J Physiol Cell Physiol*. 2017;312(1):C3-C15. doi:[10.1152/ajpcell.00282.2016](https://doi.org/10.1152/ajpcell.00282.2016)
- Wallace JL, Wang R. Hydrogen sulfide-based therapeutics: exploiting a unique but ubiquitous gasotransmitter. *Nat Rev Drug Discov*. 2015;14(5):329-345. doi:[10.1038/nrd4433](https://doi.org/10.1038/nrd4433)

- Wu D, Hu Q, Zhu D. An Update on Hydrogen Sulfide and Nitric Oxide Interactions in the Cardiovascular System. *Oxid Med Cell Longev*. 2018;2018:4579140. doi:[10.1155/2018/4579140](https://doi.org/10.1155/2018/4579140)

Exercise performance

- Bailey SJ, Winyard P, Vanhatalo A, et al. Dietary nitrate supplementation reduces the O₂ cost of low-intensity exercise and enhances tolerance to high-intensity exercise in humans. *J Appl Physiol (1985)*. 2009;107(4):1144-1155. doi:[10.1152/japplphysiol.00722.2009](https://doi.org/10.1152/japplphysiol.00722.2009)
- Bescós R, Sureda A, Tur JA, Pons A. The effect of nitric-oxide-related supplements on human performance. *Sports Med*. 2012;42(2):99-117. doi:[10.2165/11596860-000000000-00000](https://doi.org/10.2165/11596860-000000000-00000)
- Bond H, Morton L, Braakhuis AJ. Dietary nitrate supplementation improves rowing performance in well-trained rowers. *Int J Sport Nutr Exerc Metab*. 2012;22(4):251-256. doi:[10.1123/ijsnem.22.4.251](https://doi.org/10.1123/ijsnem.22.4.251)
- Cermak NM, Gibala MJ, van Loon LJC. Nitrate supplementation's improvement of 10-km time-trial performance in trained cyclists. *Int J Sport Nutr Exerc Metab*. 2012;22(1):64-71. doi:[10.1123/ijsnem.22.1.64](https://doi.org/10.1123/ijsnem.22.1.64)
- Coggan AR, Baranaukas MN, Hinrichs RJ, Liu Z, Carter SJ. Effect of dietary nitrate on human muscle power: a systematic review and individual participant data meta-analysis. *J Int Soc Sports Nutr*. 2021;18(1):66. doi:[10.1186/s12970-021-00463-z](https://doi.org/10.1186/s12970-021-00463-z)
- Hoon MW, Hopkins WG, Jones AM, et al. Nitrate supplementation and high-intensity performance in competitive cyclists. *Appl Physiol Nutr Metab*. 2014;39(9):1043-1049. doi:[10.1139/apnm-2013-0574](https://doi.org/10.1139/apnm-2013-0574)
- Lansley KE, Winyard PG, Fulford J, et al. Dietary nitrate supplementation reduces the O₂ cost of walking and running: a placebo-controlled study. *J Appl Physiol (1985)*. 2011;110(3):591-600. doi:[10.1152/japplphysiol.01070.2010](https://doi.org/10.1152/japplphysiol.01070.2010)
- Muggeridge DJ, Howe CCF, Spendiff O, Pedlar C, James PE, Easton C. A single dose of beetroot juice enhances cycling performance in simulated altitude. *Med Sci Sports Exerc*. 2014;46(1):143-150. doi:[10.1249/MSS.0b013e3182a1dc51](https://doi.org/10.1249/MSS.0b013e3182a1dc51)
- Pinna M, Roberto S, Milia R, et al. Effect of Beetroot Juice Supplementation on Aerobic Response during Swimming. *Nutrients*. 2014;6(2):605-615. doi:[10.3390/nu6020605](https://doi.org/10.3390/nu6020605)

- Sj B, J F, A V, et al. Dietary nitrate supplementation enhances muscle contractile efficiency during knee-extensor exercise in humans. *Journal of applied physiology (Bethesda, Md : 1985)*. 2010;109(1). doi:[10.1152/jappphysiol.00046.2010](https://doi.org/10.1152/jappphysiol.00046.2010)
- Vanhatalo A, Bailey SJ, Blackwell JR, et al. Acute and chronic effects of dietary nitrate supplementation on blood pressure and the physiological responses to moderate-intensity and incremental exercise. *Am J Physiol Regul Integr Comp Physiol*. 2010;299(4):R1121-1131. doi:[10.1152/ajpregu.00206.2010](https://doi.org/10.1152/ajpregu.00206.2010)
- Wylie LJ, Kelly J, Bailey SJ, et al. Beetroot juice and exercise: pharmacodynamic and dose-response relationships. *J Appl Physiol (1985)*. 2013;115(3):325-336. doi:[10.1152/jappphysiol.00372.2013](https://doi.org/10.1152/jappphysiol.00372.2013)