

Drinking Water: The Saltier The Better?

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Groundwater supplies nearly half of all drinking water in the world.¹ Freshwater from rain, lakes, and rivers absorbs into the ground by a process referred to as infiltration. The geological formations through which the water infiltrates can have varying mineral content, thereby impacting the groundwater salinity. However, global climate change likely has impacts on mineral composition of groundwater. Particularly in coastal regions at risk of rising sea levels, more frequent cyclones, and reduced upstream river flow,² changes in drinking water salinity should be expected. The varying mineral content that contributes to water salinity may also impact health. It is generally well accepted that increased dietary sodium intake is associated with hypertension in the general population.³ Higher drinking water salinity is also associated with elevated blood pressure.^{4,5} However, most published research has only measured sodium content as a proxy to water salinity, so it is unclear what effect the other minerals in groundwater may have on blood pressure.

In this issue of the *Journal of the American Heart Association (JAHA)*, Nasser et al explore the association between drinking water salinity and hypertension in the Southwest coastal population of Bangladesh.⁶ Using data from 2 cohorts (an observational study during pre-monsoon and monsoon seasons [when water salinity is low], and a stepped-wedge randomized trial during the dry season [when water salinity is high]), the investigators evaluated the association of 3 categories of drinking water salinity (fresh, mild, and moderate) with blood pressure in 1574 adults with a median age of 40 years. Using household drinking water samples, salinity was measured by electrical conductivity (EC),

which considers all dissolved ions as conductors.⁶ The major cations contributing to water EC are sodium, calcium, magnesium, and potassium. Contrary to their hypothesis, a negative association between salinity by EC and blood pressure was observed. Twenty-four-hour urinary excretion concentrations of contributing cations were also measured, to reflect intake of these minerals. As might be hypothesized, higher urinary sodium excretion was associated with slightly higher systolic blood pressure; however, higher urinary calcium and magnesium were associated with lower systolic blood pressure and diastolic blood pressure. Also contradictory to their hypothesis, mild-salinity water consumption was associated with lower risk of stage 1 and 2 hypertension as compared with the freshwater category. The authors concluded that this somewhat unexpected finding was because of protective effects of higher calcium and magnesium concentrations in mild- and moderate-salinity water.

The current literature is inconclusive with respect to these findings. Numerous studies have confirmed a link between high dietary sodium intake and blood pressure.^{3–5,7} This link is traditionally explained by the Guyton Hypothesis, whereby increased sodium intake promotes increased blood pressure via extracellular fluid volume expansion.⁸ More recent literature also supports a key role of the vasculature to elevate blood pressure in response to sodium intake, independent of renal sodium excretion.⁹ With regard to calcium, the literature is controversial. Some research supports that high urinary calcium excretion is associated with elevated blood pressure.^{10,11} Other evidence suggests that diets supplemented with calcium mildly reduce blood pressure, with a possible dose–response effect.¹² It should also be noted that high dietary calcium consumption may increase cardiovascular risk via promotion of arterial calcification.¹³ The role of magnesium in blood pressure control is less clear. However, magnesium supplementation has been used to prevent eclampsia.¹⁴ Although not completely characterized, magnesium likely acts as a vasodilator to reduce peripheral vascular resistance or to relieve vasoconstriction.¹⁵

While most published research has focused on individual mineral impact on health, the current study's measurement of water EC to assess the contribution of multiple cations to salinity was novel. In addition, a large sample size was included to assess an important global health question in the

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context of changing climate. However, it is important to consider several limitations when interpreting the results of the study. As the authors note, the concentrations of individual cations in the drinking water could not be measured, because of high cost. The association of mild-salinity drinking water with lower blood pressure was attributed to the protective effects of calcium and magnesium, because urinary levels of these cations associated negatively with blood pressure and differed across the 3 drinking water salinity categories. However, excretion cannot distinguish the source of these minerals, which may include alternate sources such as diet or supplements (Figure). It was assumed that the predominate source of measured minerals in the urine was from the drinking water, as a result of mineral deposition from the surrounding geology. There was also no direct measurement of consumed water volume. It is reasonable to hypothesize that participants who were drinking saltier water would tend to drink a higher volume of water; assuming normal renal function, this would increase both urine volume and sodium excretion, although information regarding kidney function was limited. Additionally, there may have been mineral loss to perspiration, particularly if activity level was high, which is challenging to quantify.

Because this study assessed water samples and blood pressure at a single time point, future research should explore the long-term effects of drinking water salinity on blood pressure, incident hypertension, and cardiovascular health. It is also important to note that while the association between salinity and blood pressure was in the opposite direction of what was hypothesized, the statistically significant difference was clinically small (moderate-salinity water drinkers had a -1.58 [95% CI: -3.13 , -0.03] mm Hg difference in systolic blood pressure). One possible explanation for the unexpected finding that higher drinking water salinity was associated with lower blood pressure is the small number of subjects consuming very high-salinity water. The distribution may have skewed towards samples in the mild-salinity and lower end of the moderate-salinity categories. However, the data presented in restricted cubic spline plots suggest a J-shape curve,⁶ demonstrating a trend of higher systolic blood pressure with higher water EC. An interesting follow-up study could assess blood pressure with more participants consuming higher-salinity water.

Despite some key limitations, this study offers interesting insights. With almost 40% of the world's population living within 100 km of an ocean or sea,¹⁶ there is a high demand for fresh groundwater extraction. In fact, half a billion people in the world face severe freshwater scarcity year-round.¹⁷ Sea level rise associated with global climate change, coupled with increased demand for groundwater, may increase water salinity via saltwater intrusion in coastal regions.² The severity of such saltwater intrusion may compromise groundwater

supply, increasing the need for consideration of water desalination. Managed aquifer recharge is a valuable technique to manage groundwater quantity and quality, including preventing some of the negative consequences of saltwater intrusion.¹⁸ Managed aquifer recharge is likely a key solution for managing salinity in the drinking water in southwest coastal Bangladesh, but effectiveness can vary by season, as well as management of the process.¹⁹ Another factor impacting groundwater supply is the location and depth of the well. The degree to which seawater infiltrates the groundwater can depend on the porosity or clay-like conditions of the surrounding soil. Shallow wells may be more susceptible to seawater intrusion than deeper-drilled wells.¹⁹ There can also be seasonal differences affecting the drinking water supply, which may be exacerbated by climate change. These are all important considerations, not only for future clinical research on this topic, but for geologists, hydrologists, and public health officials alike.

This study highlights an important public health issue. If more people will be consuming water with a higher salinity globally, the long-term impact of water salinity on blood pressure and cardiovascular health must be determined. Future studies, including randomized controlled trials, are needed to elucidate the blood pressure effects of each mineral in higher-salinity water. These studies should also assess the impact of potential confounding factors, including disease status, diet, and physical activity. It is still unclear how increased sodium content in the groundwater drinking supply may be offset by other mineral content, including calcium and magnesium. As such, the contribution of each individual mineral to overall health should be further examined. These questions represent an exciting area of future research with a potentially large impact on global health.

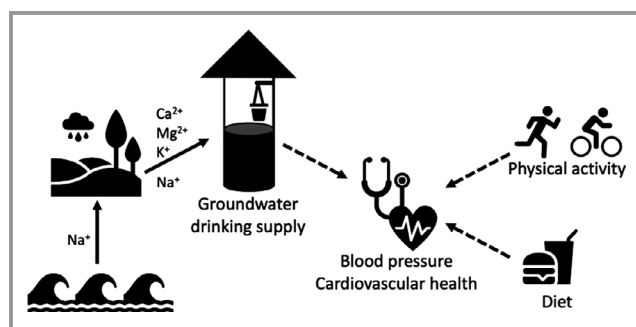


Figure. The network of minerals (sodium [Na^+], calcium [Ca^{2+}], magnesium [Mg^{2+}], and potassium [K^+]) infiltrating the drinking groundwater supply, potential sources of water and mineral intake through diet, potential water and mineral excretion through physical activity, and their incompletely understood role in blood pressure and cardiovascular health.

Disclosures

None.

References

1. United Nations Educational, Scientific and Cultural Organization (UNESCO). World Water Development Report (WWDR3). 2009.
2. Taylor RG, Scanlon B, Döll P, Rodell M, Van Beek R, Wada Y, Longuevergne L, Leblanc M, Famiglietti JS, Edmunds M. Ground water and climate change. *Nat Clim Chang*. 2013;3:322–329.
3. Ha SK. Dietary salt intake and hypertension. *Electrolyte Blood Press*. 2014;12:7–18.
4. Scheelbeek PF, Chowdhury MA, Haines A, Alam DS, Hoque MA, Butler AP, Khan AE, Mojumder SK, Blangiardo MA, Elliott P. Drinking water salinity and raised blood pressure: evidence from a cohort study in coastal Bangladesh. *Environ Health Perspect*. 2017;057007:1–8.
5. Scheelbeek PF, Khan AE, Mojumder S, Elliott P, Vineis P. Drinking water sodium and elevated blood pressure of healthy pregnant women in salinity-affected coastal areas. *Hypertension*. 2016;68:464–470.
6. Naser AM, Rahman M, Unicomb L, Doza S, Gazi MS, Alam GR, Karim MR, Uddin MN, Khan GK, Ahmed KM, Shamasudduha M, Anand S, Narayan KMV, Chang HH, Luby SP, Gribble MO, Clasen TF. Drinking water salinity, urinary macro-mineral excretions, and blood pressure in the southwest coastal population of Bangladesh. *J Am Heart Assoc*. 2019;8:e012007. DOI: 10.1161/JAHA.119.012007.
7. Drenjančević-Perić I, Jelaković B, Lombard JH, Kunert MP, Kibel A, Gros M. High-salt diet and hypertension: focus on the renin-angiotensin system. *Kidney Blood Press Res*. 2011;34:1–11.
8. Reilly R Jr, Perazella M. *Nephrology in 30 Days*. New York, NY: McGraw Hill; 2005.
9. Pao AC. Update on the Guytonian view of hypertension. *Curr Opin Nephrol Hypertens*. 2014;23:391–398.
10. Kasteloot H, Tzoulaki I, Brown I, Chan Q, Wijeyesekera A, Ueshima H, Zhao L, Dyer A, Unwin R, Stamler J, Elliott P. Relation of urinary calcium and magnesium excretion to blood pressure: The International Study of Macro- and Micro-Nutrients and Blood Pressure and the International Cooperative Study on Salt, Other Factors, and Blood Pressure. *Am J Epidemiol*. 2011;174:44–51.
11. Blackwood AM, Sagnella GA, Cook DG, Cappuccio FP. Urinary calcium excretion, sodium intake and blood pressure in a multi-ethnic population: results of the Wandsworth Heart and Stroke Study. *J Hum Hypertens*. 2001;15:226–237.
12. Cormick G, Giapponi A, Cafferata ML, Belizán JM. Calcium supplementation for prevention of primary hypertension. *Cochrane Database Syst Rev*. 2015;6. Art. No.: CD010037. DOI: 10.1002/14651858.CD010037.pub2.
13. Anderson J, Klemmer P. Risk of high dietary calcium for arterial calcification in older adults. *Nutrients*. 2013;5:3864–3974.
14. Altman D, Carroi G, Duley L, Farrell B, Moodley J, Neilson J, Smith D; Magpie Trial Collaboration Group. Do women with pre-eclampsia, and their babies, benefit from magnesium sulfate? The Magpie Trial: a randomised placebo-controlled trial. *Lancet*. 2002;359:1877–1890.
15. Euser AG, Cipolla MJ. Magnesium sulfate treatment for the prevention of eclampsia: a brief review. *Stroke*. 2009;40:1169–1175.
16. Ghaffour N, Missimer T, Amy G. Technical review and evaluation of the economics of water desalination: current and future challenges for better water supply sustainability. *Desalination*. 2012;309:197–207.
17. Mekonnen MM, Hoekstra AY. Four billion people facing severe water scarcity. *Sci Adv*. 2016;2:e1500323.
18. Casanova J, Devau N, Pettenati M. Managed aquifer recharge: an overview of issues and options. In Jakeman AJ, Barreteau O, Hunt RJ, Rinaudo J, Ross A., eds. *Integrated Groundwater Management*. Basel, Switzerland: Springer International Publishing; 2016:413–434.
19. Shammi M, Rahman MM, Bondad SE, Bodrud-Doza M. Impacts of salinity intrusion in community health: a review of experiences on drinking water sodium from coastal areas of Bangladesh. *Healthcare*. 2019;7:50.

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