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INVITED COMMENTARY

Dietary Sodium: Where Science and Policy Conflict: Impact of the 2013 IOM Report on Sodium Intake in Populations

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Abstract The 2013 Institute of Medicine (IOM) report "Sodium Intake in Populations: Assessment of Evidence" did not support the current recommendations of the IOM and the American Heart Association (AHA) to reduce daily dietary sodium intake to below 2300 mg. The report concluded that the population-based health outcome evidence was not sufficient to define a safe upper intake level for sodium. Recent studies have extended this conclusion to show that a sodium intake below 2300 mg/day is associated with increased mortality. In spite of this increasing body of evidence, the AHA, Centers for Disease Control (CDC), other public health advisory bodies, and major medical journals have continued to support the current policy of reducing dietary sodium.

Keywords Bias · Blood pressure · Cardiovascular disease · Mortality · Nutrition policy · Recommended dietary allowances · Sodium

Introduction

The upper level for daily dietary sodium intake of 2300 mg, recommended by the Institute of Medicine (IOM) in 2005, implies that 95 % of the world's inhabitants eat too much salt [1]. This recommendation is inconsistent with the IOM's own definition of an adequate intake of a nutrient, which is "the approximate intake found in apparently healthy populations" [2]. The 2013 IOM "Report on Sodium Intake in Populations" does not support the earlier position of the IOM on sodium reduction [3]. The 2013 IOM report was based on studies that directly linked estimated sodium intake to morbidity and mortality and concluded that the population-based health outcome evidence was not sufficient to define an upper intake level for sodium. The change in position provoked the sponsor, the Centers for Disease Control (CDC), to dissociate itself from the report [4], as did the American Heart Association (AHA) [5], which on a previous occasion had restated its position supporting aggressive dietary sodium reduction as a public health measure [6]. While new studies published in 2014 [7–9] reinforce the conclusions of the IOM report, the CDC, AHA, and other institutions continue to support the present policy on dietary sodium [4–6].

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The Blood Pressure Link Between Sodium Intake and Mortality

The CDC emphasizes "Of important note, the IOM committee did not include blood pressure in its review of potential health outcomes, although blood pressure is recognized and used as a key health outcome in much of the literature on sodium interventions" [4]. However, meta-analyses have shown that sodium reduction has a small effect on blood pressure in normotensive individuals [10, 11]. Specifically, a large meta-analysis including 83 references [10], updated to 96 references in 2003 as a Cochrane review and to 167 references in 2011 [11], showed a small blood pressure effect of about 1.2/0.3 mmHg in normotensives but a much more significant adverse effect on hormones and lipids. Further, reductions in blood pressure cannot necessarily be translated into beneficial effects on mortality, as illustrated by the observation that beta-blockers reduce blood pressure but not mortality [12]. The few randomized studies that directly compared health outcomes between lower sodium and normal sodium intake groups were

performed in overweight or obese persons with hypertension or prehypertension, a group that would be expected to be more salt sensitive than the general population. These studies showed a statistically nonsignificant trend towards a reduction in cardiovascular events in the low-sodium group but no reduction in mortality [13].

The large, Prospective Urban Rural Epidemiology (PURE) study enrolled more than 100,000 participants worldwide and assessed the relationship between estimated sodium intake (from second-voided morning urine specimens) and both blood pressure and cardiovascular disease outcomes. PURE demonstrated a complex relationship between estimated sodium intake, blood pressure, and mortality, such that at the low end, sodium intake was inversely associated with mortality and loosely associated with blood pressure, while at the high end, sodium intake was directly associated with both blood pressure and mortality [9, 14]. One explanation for the adverse effects of low-sodium diets is activation of counterregulatory systems such as the renin-angiotensin-aldosterone system and sympathetic nervous system that damage the heart and vasculature and lead to cardiovascular events [10, 15]. In this context, the conclusions of modeling studies, which translate exaggerated blood pressure effects obtained in prehypertensive and hypertensive study populations into saved lives in the general population without measurements directly linking sodium intake with outcomes and without considering adverse effects of sodium reduction, are questionable [16, 17].

Sodium Intake and Mortality: Direct Observations

Since no randomized trial has examined the effect of dietary sodium reduction below 2300 mg on mortality, this association can only be estimated on the basis of observational cohort studies. In the period 1985–2012, 25 such studies were performed. These were included in a recent meta-analysis [8]. Two of these studies [18, 19] showed a U-shaped association between sodium intake and mortality, which was confirmed in a subsequent meta-analysis of all 25 studies [8]. The recently published Norfolk and PURE studies [7, 9] have provided further confirmation of the U-shaped relationship between sodium intake and cardiovascular morbidity and mortality. Population studies of the sodium intake-mortality relationship have been criticized by representatives of the AHA and CDC [4–6] on grounds that they were flawed due to imprecise sodium measurements and confounders such as preexisting illnesses which could explain the inverse association of sodium intake with mortality because of reverse causality. However, imprecise sodium measurements would tend to dilute, not strengthen, the association between sodium intake and mortality, and most of the observational studies did adjust for multiple confounders. In fact, the PURE study showed that the risk of mortality in the low-sodium populations increased by 60 % when participants with preexisting illnesses were eliminated from the analysis [9], indicating that low-sodium intake is a distinct risk factor which can be weakened by confounders and not, as suggested by CDC and AHA, created by confounders. The risk of reverse causation due to residual confounding or unknown confounding can never be eliminated, but does not appear to play a major role in the PURE study.

Sodium Reduction Publication Policy

Many of the studies supporting sodium reduction as public health policy were designed in a way that overestimates the beneficial effects of the intervention on blood pressure. For instance, the blood pressure studies sponsored by the National Heart, Lung, and Blood Institute (NHLBI) and CDC [20–23] enrolled only overweight and borderline hypertensive or hypertensive persons, who would be expected to have exaggerated blood pressure responses to dietary sodium reduction compared to normotensive individuals. Further, in a meta-analysis supporting sodium reduction [24], 9 of 12 "normotensive" studies included prehypertensive participants with a blood pressure significantly higher than the mean blood pressure of adult Americans (119/71 mmHg) [25]. Thus, the results of these studies do not support a strategy of sodium reduction for the general population. Other studies supporting sodium reduction are repeat analyses of previously reported studies with revised inclusion criteria and confounders, but with addition of very little new data [24, 26–29]. Although none of the re-analyses demonstrated beneficial health effects of sodium reduction below 2300 mg in the general population, they are all used to support an upper level for sodium intake of 2300 mg. These re-analyses were possible because the data from the original studies appropriately were available. In contrast, attempts to re-analyze the DASH-sodium study [22] had to be abandoned because the authors did not wish to publish the raw data and even went through a litigation to avoid this [30]. Likewise, the authors of the recent Nutricode study that presented a linear association between the amount of sodium reduction and the blood pressure-lowering effect [17] did not respond to a request to publish individual study data [31], although this is common practice in meta-analyses.

Conclusion

There are no randomized trials to show that the minor reduction in blood pressure secondary to sodium reduction can be translated into reduced mortality or to show that a reduction of sodium intake to levels below 2300 mg has beneficial health effects. Dubious modeling studies do not change that fact. As concluded in the 2013 IOM report, observational studies

associating sodium intake with mortality are not sufficient to show beneficial health outcomes of a low-sodium intake. On the contrary, there is growing evidence from recent observational studies and a meta-analysis that a low-sodium diet in accordance with the national recommendations is associated with increased mortality, as is a high-sodium diet with sodium intake above 5–6000 mg. Thus, intake of sodium, just like every other essential nutrient, bears a "J"- or "U"-shaped relation to health outcomes with an optimal range approximating 2500–5000 mg/day. In spite of this, public institutions continue to promote sodium reduction and several major medical journals apparently support this questionable policy by publishing repeat analyses of previous reports which refocus the findings of the original studies without adding important new data, clinical studies which exaggerate blood pressure effects, and modeling studies, which are based on dubious premises.

References

1. IOM. (Institute of Medicine). Dietary reference intakes for water, potassium, sodium, chloride, and sulfate. Washington, DC: National Academies Press; 2005.
2. IOM. (Institute of Medicine). Dietary reference intakes: essential guide to nutrient requirements. Washington, DC: National Academies Press; 2006.
3. IOM. (Institute of Medicine). Sodium intake in populations: assessment of evidence. Washington, DC: National Academies Press; 2013.
4. Gunn JP, Barron JL, Bowman BA, Merritt RK, Cogswell ME, Angell SY, et al. Sodium reduction is a public health priority: reflections on the Institute of Medicine's report, sodium intake in populations: assessment of evidence. AJH. 2013;26:1178–80.
5. Cobb LK, Anderson CA, Elliott P, Hu FB, Liu K, Neaton JD, et al. Methodological issues in cohort studies that relate sodium intake to cardiovascular disease outcomes: a science advisory from the American Heart Association. Circulation. 2014;129:1173–86.
6. Whelton PK, Appel LJ, Sacco RL, Anderson CA, Antman EM, Campbell N, et al. Sodium, blood pressure, and cardiovascular disease: further evidence supporting the American Heart Association sodium reduction recommendations. Circulation. 2012;126:2880–9.
7. Pfister R, Michels G, Sharp SJ, Luben R, Wareham NJ, Khaw KT. Estimated urinary sodium excretion and risk of heart failure in men and women in the EPIC-Norfolk study. Eur J Heart Fail. 2014 Jan 20. doi:10.1002/ejhf.56. [Epub ahead of print].
8. Graudal N, Jürgens G, Baslund B, Alderman MH. Compared with usual sodium intake, low- and excessive-sodium diets are associated with increased mortality: a meta-analysis. Am J Hypertens. 2014;27:1129–37.
9. O'Donnell M, Mente A, Rangarajan S, McQueen MJ, Wang X, Liu L, et al. Urinary sodium and potassium excretion, mortality, and cardiovascular events. N Engl J Med. 2014;371:612–23.
10. Graudal NA, Galløe AM, Garred P. Effects of sodium restriction on blood pressure, renin, aldosterone, catecholamines, cholesterols. JAMA. 1998;279:1383–91.
11. Graudal NA, Hubeck-Graudal T, Jurgens G. Effects of low sodium diet versus high sodium diet on blood pressure, renin, aldosterone, catecholamines, cholesterol, and triglyceride. Cochrane Database Syst Rev. 2011;11, CD004022.
12. Wiysonge CS, Bradley HA, Volmink J, Mayosi BM, Mbewu A, Opie LH. Beta-blockers for hypertension. Cochrane Database Syst Rev. 2012;11, CD002003.
13. Taylor RS, Ashton KE, Moxham T, Hooper L, Ebrahim S. Reduced dietary salt for the prevention of cardiovascular disease. Am J Hypertens. 2011;24:843–53.
14. Mente A, O'Donnell MJ, Rangarajan S, McQueen MJ, Poirier P, Wielgosz A, et al. Association of urinary sodium and potassium excretion with blood pressure. N Engl J Med. 2014;371:601–11.
15. Brunner HR, Laragh JH, Baer L, Newton MA, Goodwin FT, Krakoff LR, et al. Essential hypertension: renin and aldosterone, heart attack and stroke. N Engl J Med. 1972;286:441–9.
16. Bibbins-Domingo K, Chertow GM, Coxson PG, Moran A, Lightwood JM, Pletcher MJ, et al. Projected effect of dietary salt reductions on future cardiovascular disease. N Engl J Med. 2010;362:590–9.
17. Mozaffarian D, Fahimi S, Singh GM, Micha R, Khatibzadeh S, Engell RE, et al. Global sodium consumption and death from cardiovascular causes. N Engl J Med. 2014;371:624–34.
18. Thomas MC, Moran J, Forsblom C, Harjutsalo V, Thorn L, Ahola A, et al. The association between dietary sodium intake, ESRD, and all-cause mortality in patients with type 1 diabetes. Diabetes Care. 2011;34:861–6.
19. O'Donnell MJ, Yusuf S, Mente A, Gao P, Mann JF, Teo K, et al. Urinary sodium and potassium excretion and risk of cardiovascular events. JAMA. 2011;306:2229–38.
20. The Trials of Hypertension Prevention Collaborative Group. The effects of nonpharmacologic interventions on blood pressure of persons with high normal levels. JAMA. 1992;267:1213–20.
21. The Trials of Hypertension Prevention Collaborative Group. Effects of weight loss and sodium reduction intervention on blood pressure and hypertension incidence in overweight people with high-normal blood pressure. The Trials of Hypertension Prevention Phase II. Arch Intern Med. 1997;157:657–67.
22. Sacks FM, Svetkey LP, Vollmer WM, Appel LJ, Bray GA, Harsha D, et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH–Sodium Collaborative Research Group. NEJM. 2001;344:3–10.
23. Appel LJ, Espeland MA, Easter L, Wilson AC, Folmar S, Lacy CR. Effects of reduced sodium intake on hypertension control in older individuals: results from the Trial of Nonpharmacologic Interventions in the Elderly (TONE). Arch Intern Med. 2001;161:685–93.
24. He F, MacGregor G. Effect of modest salt reduction on blood pressure: a meta-analysis of randomized trials. Implications for public health. J Hum Hypertens. 2002;16:761–70.
25. Wright JD, Hughes JP, Ostchega Y, Yoon SS, Nwankwo T. Mean systolic and diastolic blood pressure in adults aged 18 and over in the United States; 2001–2008. National Health Statistics Report; 35: 1–24.
26. He FJ, MacGregor GA. Salt reduction lowers cardiovascular risk: meta-analysis of outcome trials. Lancet. 2011;378:380–2.
27. He J, Ogden LG, Vupputuri S, Bazzano LA, Loria C, Whelton PK. Dietary sodium intake and subsequent risk of cardiovascular disease in overweight adults. JAMA. 1999;282:2027–34.
28. Yang Q, Liu T, Kuklina EV, Flanders WD, Hong Y, Gillespie C et al. Sodium and potassium intake and mortality among US adults: prospective data from the Third National Health and Nutrition Examination Survey. Arch Intern Med. 2011;171:1183–91.
29. Elliott P, Stamler J, Nichols R, Dyer AR, Stamler R, Kesteloot H, et al. Intersalt revisited: further analyses of 24 hour sodium excretion and blood pressure within and across populations. Intersalt Cooperative Research Group. BMJ. 1996;312:1249–53.
30. Kaiser J. Industry groups petition for data on salt and hypertension. Science. 2003;300:1350.
31. Graudal N. Sodium and cardiovascular disease. N Engl J Med. 2014;371:2136–7.