Beyond Blood Pressure: New Paradigms in Sodium Intake Reduction and Health Outcomes[1–4]

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ABSTRACT

Since 1980, when inaugural national dietary guidance was to "avoid too much sodium," recommendations have evolved to the 2010 *Dietary Guidelines for Americans*' quantified guidance of 2300 and 1500 mg/d [USDA and U.S. Department of Health and Human Services. Dietary guidelines for Americans, 1st (http://www.cnpp.usda.gov/DGAs1980Guidelines.htm) and 7th (http://www.health.gov/dietaryguidelines/dga2010/dietaryguidelines2010.pdf) eds.]. Too much sodium remains a valid concern, but are current targets too low for optimal health? New research moves beyond sodium's effect on the surrogate marker of blood pressure to examine the relation between sodium intake and cardiovascular morbidity and mortality. Results show that sodium intakes both less than and greater than ~3000–5000 mg/d increase the risk of negative health outcomes. Additionally, newly compiled sodium intake data across populations show a uniformity that suggests that intake is physiologically set. Perhaps not coincidentally, the observed intakes fall within the range related to lowest risk. These findings are highly relevant to current efforts to achieve low sodium intakes across populations, because the data suggest that the efforts will be unsuccessful for healthy people and may cause harm to vulnerable populations. Remaining mindful of risks associated with both excessive and inadequate intakes is imperative with all nutrients, and sodium is no exception. Avoiding too much, and too little, sodium may be the best advice for Americans. *Adv. Nutr. 5: 550–552, 2014.*

Since 1980, national dietary guidance provided by the *Dietary Guidelines for Americans* (DGA)[7] has targeted sodium reduction (1). Early dietary recommendations were qualitative, but more recently, DRIs quantified recommendations for sodium. Defining specific intake amounts is helpful to translate guidance into policy; however, the presence of quantified intake recommendations suggests certainty, which, in turn, has the potential to impede revising the recommendations as new science accumulates. This may be the case with sodium. Before the development of the DRIs, sodium's estimated minimum average requirement for adults rested at 500 mg/d, the amount needed to maintain sodium balance under conditions of maximal adaptation and minimal loss. This level was never considered an amount to target for health, but it supported the framework that Americans' sodium intake was excessive and deficiency would be unlikely. The focus on sodium reduction with no concern for inadequate intakes commenced. The physiologic relation between sodium, fluid electrolyte balance, and blood pressure provided a plausible mechanism by which sodium reduction would reduce blood pressure and was logically linked to the well-established correlation between elevated blood pressure and cardiovascular disease (CVD). Thus, sodium reduction to reduce blood pressure, which was thought to reduce CVD, was embraced. The current public health goal is to reduce Americans' sodium intakes as much as possible, with the lower boundary of 1500 mg/d as the minimum amount of sodium required to consume in a nutritionally replete diet. But are current recommendations too low? Are these extremely low sodium intakes compatible with optimal health outcomes?

The purpose of this symposium was to review a growing body of evidence examining sodium intake and health outcomes that are highly relevant to sodium DRIs, the DGA, and numerous government- and nongovernmental organization–driven efforts to significantly reduce sodium in the entire population. These new data must be examined to ensure that the assumed benefits of population-wide sodium reduction outweigh the potential risks, especially in vulnerable and ill populations.

[1] This article is a summary of the symposium "Beyond Blood Pressure: New Paradigms in Sodium Intake Reduction and Health Outcomes" held 29 April 2014 at the ASN Scientific Sessions and Annual Meeting at Experimental Biology 2014 in San Diego, CA. The symposium was sponsored by the American Society for Nutrition (ASN) and supported by an educational grant from ConAgra Foods, Inc.

[2] The organizer has indicated that related reviews of this symposium will be submitted for publication in an upcoming issue of *Advances in Nutrition*. One related review appears in this issue.

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[7] Abbreviations used: CVD, cardiovascular disease; DGA, *Dietary Guidelines for Americans*; IOM, Institute of Medicine.

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Dr. King began the program with a general overview of sodium recommendations, highlighting the evolution from the 1980 DGA's guidance to "avoid too much sodium" to the 2010 DGA's quantified guidance of 2300 and 1500 mg/d for those aged ≥51 y, and all people who are African American or have hypertension, diabetes, or chronic kidney disease (2). She compared the DGA's to the historical Institute of Medicine (IOM) recommendations. The first time sodium recommendations were quantified appeared in the Food and Nutrition Board's 1989 publication *Diet and Health: Implications for Reducing Chronic Disease Risk* (3). The maximum intake goal was set at 2400 mg on the basis of observational data from the 1988 InterSalt study publication showing that blood pressure increased with age in individuals with intakes >2400 mg (4). The only groups who consumed less sodium were those living in primitive societies. In fact, when the primitive societies were omitted, there was no relation between sodium intake and increasing blood pressure with age. Nonetheless, the recommendation of 2400 mg as a maximum intake was adopted by authoritative bodies until 2005 when the DRI for sodium was set at 2300 mg as the upper level on the basis of 2 dose-response studies on blood pressure. The adequate intake was set at 1500 mg on the basis of modeling the minimum amount of sodium required to achieve a nutritionally adequate diet. (It should be noted that the modeled diet contained primarily reduced-sodium foods, many of which may not be readily available, such as reduced-sodium bread.) In 2005 and 2010 the DGA adopted these levels.

Perhaps due to the assumption that reducing sodium reduces blood pressure and therefore must reduce CVD, and assuredly because of the difficulty in conducting studies to examine sodium and health outcomes, the direct relation between sodium reduction and health outcomes had largely been overlooked in the literature until recently. Now, a critical mass of data relating both greater and lesser intakes of sodium to increased risk of outcomes such as death, CVD, and heart failure, has begun to emerge, and these data were reviewed in the 2013 IOM report "Sodium Intake in Populations: Evaluation of the Evidence" (5). Examination of the new evidence brought findings that were surprising, showing that current sodium intake recommendations may pose risk. But were they really surprising?

Dr. Heaney reminded the audience that these findings were exactly what could be expected based on the physiology of all nutrients. That is, the relation between a nutrient intake and health benefit is not a straight line that intersects with zero on the *x* and *y* axis, indicating that lower is better, but instead is a J-shaped curve that indicates risk at both ends of intake, with a rather wide range of "no harm" (or benefit) at intakes between these extremes. It is within this range, wherein the organism needs to exert minimal compensation, that nutrient requirements are typically set. Heaney outlined in his presentation the unexplained departure from the evidence-based approach for sodium. In fact, even with the use of blood pressure as a surrogate marker of benefit, the DASH (Dietary Approaches to Stop Hypertension) study shows that a focus on food and dietary patterns that provide adequate potassium, calcium, and magnesium create a more meaningful blood pressure effect and do not pose the potential harm of very low sodium intakes. Revisiting the sodium DRIs with consideration of the evidence on health outcomes and approaching the task adhering to the agreed-upon evidence-based process are critical to the integrity of nutrient recommendations, of which sodium should be no exception.

Dr. Alderman presented the historic path of health outcomes–related sodium intake research. Published research as well as plausible physiologic mechanisms such as the renin-angiotensin-aldosterone system have long existed that refute benefit of sodium reduction to low amounts, but these data have been overshadowed until recently. Alderman was among the first to report the inverse relation between renin and myocardial infarction. Reduced sodium intake leading to increased renin concentrations is an example of sodium restriction not exerting the singular physiologic effect of blood pressure reduction, but instead shows how it exerts multiple effects, including negative consequences such as increased plasma renin activity, increased insulin resistance and sympathetic nerve activity, and elevated aldosterone and TGs. The net health effect cannot be predicted by the consequence on blood pressure alone. Alderman was also the first to suggest the J-shaped risk curve for CVD and sodium intake, and this hypothesis was supported by the 2013 IOM report. Subsequent to the 2013 IOM report, several additional papers have supported the J-shaped risk curve, including the 2014 Graudal et al. meta-analysis summarizing findings from 274,683 individuals from 25 studies (6). The idea that the blood pressure effect of sodium restriction can be extrapolated to a health benefit no longer retains scientific credibility.

Dr. McCarron capped the session by presenting a body of data showing the narrow sodium intake ranges observed in 69,011 people from 45 countries around the world gathered over the past 50 y, which are remarkably constant and appear to be independent of the food supply. The mean intake is 3600–3700 mg/d, and the mean population minimum and maximum are 2622 and 4830 mg/d, respectively. Mean intakes of the Adequate Intake of 1500 mg or the Tolerable Upper Intake Level of 2300 mg are not observed in these free-living healthy populations. He pointed out that interpreting reductions in sodium intake caused by reducing sodium in commercially prepared foods, such as in the United Kingdom, are in fact small variations within 1 SD of the mean. The data support that intake of sodium is not mediated by the food supply but is physiologically controlled through sodium appetite. The risk of reducing sodium below this "set point" is consistent with the increased morbidity and mortality observed at the lowest sodium intakes (similar to current recommendations) that have been reported by several researchers and reiterated in the IOM report.

Common ground among all who study sodium intake and health outcomes is that excess sodium intake carries

increased risk of morbidity and mortality. The controversy focuses on the lower end of sodium intake. Although public health guidelines continue to promote intakes <2300 mg/d, data suggest that this amount may be too low for optimal health. The recommended intakes do not cause concern for free-living individuals who have access to salt, but they do have direct implications for hospitalized patients, nursing home residents, and school feeding programs and other government-funded feeding programs that must adhere to these guidelines. Additionally, if, in fact, sodium intake is set physiologically, current resources being poured into sodium reduction by public and commercial entities could be more effectively spent on important innovations related to public health, such as increasing demand for smaller portion sizes, improving availability of lower-energy-dense food, and replenishing food deserts.

This session helped bring awareness to the potential risk associated with intakes at currently recommended amounts, amounts of intake that are lower than any observed in modern free-living healthy populations regardless of food supply. New data support a J-shaped curve for risk, with the intakes related to least harm being those between ~3000 and 5000 mg, a range that includes the current usual intakes of the majority of healthy individuals in the world.

The convergence of new data from research focused on health outcomes and newly compiled sodium intake amounts suggests that enforcing very low sodium intakes will at best fail for most people and at worst cause harm for vulnerable or ill individuals subjected to the recommended levels. Perhaps the 1980 DGA statement of "avoid too much sodium" really had it right, with 1 revision: "avoid too much—and too little—sodium."

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