WSS-18-082: Review of the Science on Sodium and Health Outcomes and Sodium Reduction Progress in the Food Industry

Paper Track: Salt and Health

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Abstract: Sodium is an essential nutrient that helps regulate blood volume, which influences blood pressure. Elevated levels of blood pressure, or hypertension, is a risk factor for cardiovascular disease and stroke in adults. To date, more than 50 randomized trials have tested the effects of reducing dietary sodium intake on blood pressure in adults. The results suggest a dose-response relationships between reduced sodium intake and reduced blood pressure, with the effect being more pronounced for individuals with prehypertension or hypertension. Therefore, it is generally recommended that individuals make healthy food choices that are low in sodium and high in potassium, in conjunction with controlling other risk factors for cardiovascular disease, such as obesity and smoking, to lower blood pressure.

A global regulatory review of the recommended sodium intake can vary between 1500 to 2800 mg sodium per day depending on factors such as sex and physical state of a sub-population (e.g. chronic kidney disease). Geographies that do not have a recommendation tend to follow the World Health Organization's recommended dietary sodium intake of 2000 mg/day. In addition to recommended sodium intakes, some geographies have imposed a mandatory (e.g. South Africa) or voluntary (e.g. Australia, Canada) sodium targets in key food products. These recommendations determined based on the best science-based evidence of sodium and health outcome available at the time.

Recent studies have challenged the conventional wisdom of the relationship between sodium intake and cardiovascular disease. Observations from a population wide study suggest a significant and positive association between urinary sodium levels and blood pressure for individuals with high sodium excretion (>5 g/day) and no significant association for individuals with lower levels of sodium excretion (<3 g/day). Another study performed a pooled analysis of the combined data of 4 large prospective studies. The results suggest a J-shaped association between urinary sodium excretion and cardiovascular events and mortality in individuals with hypertension. For individuals without hypertension, there was a significant increased risk of cardiovascular events and mortality at lower sodium excretion (<3 g/day) and no apparent association at high levels of excretion (>7 g/day). Adjusting for blood pressure did not alter the outcome of the results, suggesting other mechanisms may be contributing to the increased risk. These observational studies suggests the need for additional research to better understand the relationship between sodium intake and the risk of cardiovascular events and mortality. In addition, there may be additional suitable biomarkers other than blood pressure to assess the overall risks.

Introduction

Hypertension, or high blood pressure, affects approximately 1 billion people worldwide and is considered to be a major risk factor for coronary heart disease and stroke.[1] According to the World Health Organization (WHO), ischemic heart disease and stroke remain to be the leading cause of mortality.[2] There are many risk factors for hypertension including age, race, tobacco use, physical activity level, stress, chronic conditions, alcohol consumption and nutrient intake (high sodium, low potassium and low Vitamin D).[3] Globally, sodium reduction in the food supply is a focus for many countries as a means to help reduce the risk of cardiovascular disease in

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the population. Systematic reviews suggests that up to 81 countries have implemented sodium reduction initiatives.[4,5] Considering the various strategies to reduce hypertension, the general recommendation is for individuals to consume a nutritious diet, including reducing sodium and increasing potassium intake, and properly manage the other risk factors.

According to Anderson et al. (2010), the major source of sodium in China was home cooking (76%).[6] In Japan 63% is from four categories, soy sauce (20%), processed fish (15%), salted soups (15%) and preserved vegetables (13%). Processed foods are the major source of sodium in United Kingdom (95%) and United States (71%), with salt being the main contributing ingredient. Due to its many functional roles, food scientist leverage salt to help create desired attributes in foods. Salt controls microbial growth (food safety, fermentation and preservation), modifies protein structure (impacts texture), and enhances flavors. In many underdeveloped and developing nations, salt is a critical vehicle for delivering other essential nutrients (e.g. iodine and fluoride) and certain medicines, such as diethylcarbamazine to control the spread of lymphatic filariasis. [7-9]

In general, research to date suggest that individuals with hypertension or pre-hypertension can reduce their blood pressure by decreasing dietary sodium intake and increasing the consumption of potassium-rich foods.[10-15] However for individuals with normal blood pressure, the benefits of decreasing sodium intake on blood pressure are less clear.[16-20] As a result, there are differences of opinions on the appropriate daily sodium intake, especially for normotensive individuals.

Global Sodium and Potassium Intake

Sodium is an essential nutrient that helps regulate blood volume, and blood volume can impact blood pressure. According to the WHO, consuming high levels of sodium (>2 g/day) and low levels of potassium (<3.5 g/day) contribute to high blood pressure. For adults, WHO recommends a sodium and potassium daily intake of less than 2 g and at least 3.51 g, respectively.[10,11] The global wide salt intake is between 9-12 g/day (3.6-4.8 g sodium).[10]

Powles et al. (2014) systematically reviewed 24-hour urinary sodium excretion (24-h UNaV) and dietary surveys to estimate the sodium intake of individuals from 66 countries.[21] In 2010, the global mean sodium intake was reported as 3.95 g per day, with the highest intake observed in Central Asia (5.51 g/day) and lowest in Eastern sub-Saharan Africa (2.18 g/day).[21]

In a similar review of studies conducted over 5 decades of individuals from 45 countries, McCarron et al. (2014) suggests there is a physiological need that drives sodium intake versus an environmental factor.[22] The reported global mean sodium intake was 159.4 mmol/day (3.67 g/day) with a range of 114-210 mmol/day (2.62 – 4.83 g/day).[22] The authors suggests there is a narrow range of sodium intake that does not vary much over time or across geographies.

Mente et al. (2014) estimated the mean 24-h UNaV and potassium (24-h UKV) of slightly over 100,000 adults from 18 countries to be 4.93 g/day and 2.12 g/day, respectively.[16] The 24-h UNaV ranged from 3.78 g/day (Malaysia) to 5.59 g/day (China) and the 24-h UKV ranged from 1.7 g/day (Bangladesh, India and Pakistan) to 2.46 g/day (Canada, Poland and Sweden).[16]

Dietary Sodium Intake and Health Outcomes

Since the early 1900's there have been many intervention (cause and effect) and observational (correlations) studies performed to understand the relationship between sodium intake and blood pressure. Intervention studies tend to be more powerful than observational studies;

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however, observational studies may also provide valuable insights on the relationship between sodium intake and health outcomes.

To date, more than 50 randomized, dose-response trials have evaluated the effect of sodium reduction on blood pressure in adults. In general, the results suggest a direct dose-response relationship between sodium intake and blood pressure (systolic or SBP and diastolic or DBP), with the effect being more pronounced for individuals with prehypertension and hypertension.[12-14]

McGregor et al. (1989) reported a linear dose response to a decrease in sodium intake over a range of 50 – 200 mmol/day (1150-4598 mg/day) for adults with mild hypertension (mean SBP/DBP of 164/101 mmHg).[12] Johnson et al. (2001) reported a linear relationship between sodium intake (50 – 300 mmol/day) and blood pressure for participants (≥60 years of age), regardless of blood pressure state.[13] The effect was more pronounced for individuals with isolated systolic hypertension (ISH, SBP/DBP ≥160/<90 mmHg) than systolic-diastolic hypertension (DBP ≥90 mmHg), and more pronounced for ISH compared to normotensive (SBP/DBP of <160/<90 mmHg) individuals.

In another study, Sacks et al. (2001) studied the impact of sodium intake (target 50, 100 and 150 mmol/day) and diet type (Control versus Dietary Approaches to Stop Hypertension or DASH) on the blood pressure of adult having blood pressure >120/80 mm Hg.[14] Reducing sodium intake significantly reduced SBP and DBP for both control and DASH diets. The effects were greater for participants with hypertension than those without. Compared to the control diet, individuals on the DASH diet had significantly lower SPB at all three sodium levels and significantly lower DBP at the high and intermediate levels.

He and McGregor (2002) conducted a meta-analysis of randomized salt reduction trials (≥4 weeks duration and modest sodium reductions) and reported a dose-response effect of changes in sodium intake (24-h UnaV) and blood pressure in hypertensive and normotensive participants.[15] Pooled estimates of blood pressure drops were 4.96/2.73 and 2.03/.97 mmHg for hypertensive and normotensive individuals, respectively. Using weighted linear regression analysis, the predictive drop in blood pressure (SBP/DBP) was 7.11/3.88 mmHg and 3.57/1.66 mmHg for hypertensive and normotensive participants, respectively, per 100 mmol/day reduction in salt.

Recent observational studies have challenged the conventional wisdom of the relationship between sodium intake and health outcomes. Mente et al. (2014) examined the effect of sodium and potassium intake (24-h UNaV and 24-h UKV) on blood pressure of adult participants.[16] The results suggest a nonlinear relationship between sodium excretion and SBP, with the greatest association for those with a sodium intake >5 g per day (slope = 2.58 mm Hg), a modest association with 3-5 g/day (slope = 1.74 mm Hg) and no significant association for <3 g/day (slope = 0.74 mm Hg). There was a greater impact of sodium intake on blood pressure for participates with hypertension, higher age and obesity. There was an inverse relationship between potassium excretion and SBP, with greater impact for individuals with hypertension and increased age. These results align with the International Study of Electrolyte Excretion and Blood Pressure (INTERSALT) studies where there was a reported positive correlation between 24-h UNaV and blood pressure.[17] However, the PURE results had a steeper slope of association by comparison with differences due to the inclusion of more elderly individuals and larger Chinese population in the PURE study.

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O'Donnell et al. (2014) examined the association between estimated 24-h UNaV (morning fasting urine) on mortality and cardiovascular events of >100,000 individuals in 17 countries.[18] Results suggesting a J-shape association between estimated 24-h UNaV and cardiovascular events and mortality in individuals with hypertension. Both higher (≥7 g/day) and lower (<3 g/day) sodium excretion levels were significantly associated with an increased risk compared to an intermediate level (3–6 g/day). Adjusting for blood pressure, only the participants with high blood pressure had a significant association at high sodium excretion, suggesting sodium intake may mediate the effect. For individuals without hypertension and lower sodium excretion (<3 g/day), there was a significant increased risk of cardiovascular events and mortality. There was no association for those normotensive individuals with higher level of sodium excretion. Adjusting for blood pressure did not alter the outcome of the results, suggesting other mechanisms may be contributing to the increased risk. Considering potassium, the data suggests an association between higher estimated 24-h UKV and reduced risk of the composite of major cardiovascular events and death.

Combining data from four large international prospective studies, Mente et al. (2016) studied the sodium intake (24-h UNaV) and composite death and major cardiovascular events for individuals with and without hypertension.[19] For individuals with hypertension and a sodium excretion of ≥7 g/day and for those with <3 g/day, there was an increased risk of cardiovascular disease and death compared to individuals with hypertension and sodium excretion of 4-6 g/day. For individuals without hypertension and compared to those with 4-5 g/day sodium excretion, only the group with <3 g/day had a significant increased risk of cardiovascular disease and death. Results suggests that sodium reduction for individuals with hypertension and high sodium intake (approximately 10% of the population) may benefit from a reduction in sodium intake.

Graudal et al. (2017) performed a meta-analysis of randomized controlled trials that included analysis of other surrogate markers for cardiovascular mortality and morbidity. In addition to blood pressure, other surrogate markers included hormones (renin, aldosterone, adrenaline and noradrenaline) and lipids (cholesterol, low-density lipoproteins, high-density lipoproteins and triacylglycerides).[20] The drop in blood pressure (SBP/DBP) for individuals (Caucasian population) with hypertension (-5.5/-2.88 mmHg) was greater than those without hypertension (-1.09/0.03 mmHg). Similar results were observed with black (hypertensive -6.64/-2.91 mHg, normotensive -4.02/-2.01 mmHg) and Asian (hypertensive -7.72/-2.68 mHg, normotensive -0.72/-1.63 mmHg) participants. The authors suggests that the small difference between low and high sodium intake for the normotensive Caucasian participants may be explained by the significant increase in renin and aldosterone, and lesser degree with adrenalin and noradrenalin. However, the researchers suggests that the increase in cholesterol (2.5%) and triglycerides (7%) may offset the benefits of the decrease in blood pressure (<1%).[20]

As the science evolves and new evidence is published, ad hoc committees will form to assess the historical and current science-based evidence for any nutrient. In 2013, the United States Institute of Medicine (IOM, currently the National Academy of Medicine or NAM) conducted a review of the latest scientific evidence on the dietary sodium intake and health outcomes.[23] The IOM concluded a positive relationship between sodium intake ≥2.3 g/day and risk of cardiovascular disease. However, the committee found the evidence to be inconsistent for lowering sodium intake to 1.5 g/day for the general public. In addition, data on health outcomes for subgroups (e.g., individuals with chronic kidney disease) were too limited to support treatments different than the general population.

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Recently, the Agency for Healthcare Research and Quality (AHRQ) published their report on the effect of dietary sodium reduction and increased potassium intake on high blood pressure and risk for cardiovascular diseases and renal disease.[24] The results suggests a benefit for reduced sodium and increased dietary potassium (including potassium containing salt substitutes) on blood pressure, especially for those with hypertension. Findings from the AHRQ report will be leveraged during the upcoming review of the Dietary Reference Intake for sodium and potassium.[25]

Salt/Sodium Reduction Initiatives

The United Nations' Global Action Plan for the Prevention and Control of Noncommunicable Diseases (NCD) identified sodium reduction as one of nine voluntary targets to help reduce premature mortality from cardiovascular disease.[26] In 2013, WHO Member States adopted the global target of 30% reduction in mean population salt intake by 2025, as part of a broader set of strategies to reduce premature mortality NCD by 25% in 2025.[26]

Globally, many countries have implemented governmental sodium reduction initiative. Trieu et al., (2015) conducted a global review of these initiatives and reported 75 countries with national salt reduction strategies in the WHO regions of Africa, Americas, Eastern Mediterranean, Europe, Eastern Asia and Western Pacific.[4] The target dietary salt intake for these initiatives varies from 5-8 g/day (2-4. g sodium/day). Strategies include food reformulation (industry engagement), consumer education, front of package labelling (FoPL), interventions in public institution settings and taxation.

By 2015, 36 countries had implemented voluntary sodium target guidelines for foods and 9 countries have mandated maximum sodium content limits. [4,5] Targeted food categories varied by country, however all of the initiatives listed a sodium target for bread. Two countries (South Africa and Argentina) had mandatory targets for a broad range of foods and two countries (Bulgaria and Greece) had up to four product categories.[4] Consumer education on sodium intake is part of the most strategies (71 countries) and generally used in conjunction with targeted public settings, such as schools and public hospitals. FoPL, voluntary or mandatory, were identified in 31 countries and may include mandatory schemes, logos and symbols (e.g. traffic light[27], salt shaker[28]), and percentage daily intake. Intervention initiatives are reported in 43 countries and three countries (Fiji, Hungary, Portugal) implemented a sodium specific or general tax (prepackaged foods with high salt content) tax.

Sodium Reduction Progress in the Food Supply

Many of the global government and non-government sodium reduction initiatives have monitoring programs to help determine the overall impact on the food supply over time.[5] Programs include industry self-reporting, food label surveys, branded good composition databases and chemical analysis. Results from various monitoring programs suggest progress is being made towards removing sodium from foods.[29-31]

In 2012, Health Canada published a three-phased, voluntary sodium reduction program to help reduce sodium in 94 food categories by 2016.[29] The approach allowed for gradual reduction to better acclimate consumers to any perceived taste differences. Evaluation of industry progress concluded in 2017 and it was reported that 52% of the products made progress towards meeting the 2016 target, with 14%, 10% and 28% of the products meeting Phase III (2016), Phase II and Phase I targets, respectively.

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Since 2003, the Food Safety Authority of Ireland (FSAI) has been monitoring the sodium and potassium levels across 10 categories of processed foods.[30] The main sources of salt (sodium) in the population are meat and fish (30%), and bread (22%). There have been significant sodium reductions in breads and breakfast cereals between 2003-2015, while progress in processed meats has lagged behind FSAI's expectations. Reported sodium reduction in breads range between 0 (brown) and 42% (specialty breads). Rashers (bacon) have decreased by 27%, whereas no significant difference was reported for puddings.

The United Kingdom's voluntary sodium reduction program began following the Scientific Advisory Committee on Nutrition recommended salt intake of 6 g salt/day (2.4 g sodium/day) for adults.[31,32] Sodium targets (step-wise approach) were set for various food categories that contribute the most sodium to the diet. Eyles et al. (2013) used household consumer panel data (>18,000) and nutrition information panels of products to determine the effect of the UK voluntary program on sodium content of packaged foods between 2006 and 2011 (>47,000 products).[33] The mean sodium reduction and sales-weighted reduction was 7% and 6%, respectively. There was a slight increase in reduction for products that were both commercially available in both 2006 and 2011 (9%). Greatest sales-weighted reductions occurred in dairy (27%), cereal and cereal products (19%) and sauces and spreads (16%).

In a Brazilian survey, over 3,000 food products were monitored for sodium content between 2011-2017 using nutrition label information.[34] The products evaluated were predominantly bakery items (bread, cookies, crackers, cakes), but also included cereals, chip snacks, mayonnaise and dairy spreads, pasta, cheese and condiments. The results indicate that over half of the food categories met the 2017 general sodium target set by Pan American Health Organization.[35] With the exception of one food subcategory (corn chips), 85% of the surveyed foods met the target. For over 50% of the products, there was a significant reduction in sodium for the 2017 samples compared to the baseline (2011), with ranges between 8% (bouillon cubes) and 34% (dairy spreads).

South Africa was one of the first countries to mandate the sodium content of certain food products.[36] Swanepoel et al. (2017) measured the sodium content of 110 food products (chemical analysis) representing 13 food categories identified for mandatory regulation.[37] Of the 13 categories, 72% of the products were in compliance with the 2016 sodium targets. Those not meeting the target included flavored potato crisps (including salt and vinegar) and flavored ready-to-eat snack. Compared to the 2019 target, 46% of the products met the sodium target. Categories meeting both 2016 and 2019 targets include bread, processed meat (uncured), raw-processed meat sausages, all fat and buttered spreads, breakfast cereals and savory snacks (excluding salt and vinegar).

Impact of Sodium Reduction Initiatives on Population Dietary Intake

Although there is evidence that the industry is removing sodium from the food supply, there is a lag in time before the observed effect on population sodium intake due to the time it takes to gather, analyze and report data. In addition, sodium intake accuracy will improve as methodologies improve (e.g. UNaV versus dietary recall).

In the systematic review by Trieu et al., 12 countries reported a decrease in population sodium intake, ranging from 4.9% (France) to 36% (Finland) over a period range between 4 (Denmark, 7%) and 29 (Finland) years.[4] Strength of the monitoring program will depend on the method used to determine sodium intake. Only three countries solely used 24-h UNaV, the most predictive estimate of sodium intake (Slovania, Turkey, United Kingdom). Finland used a

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combination of 24-h UNaV and dietary survey, the weakest predictor. The remainder used spot urine (Denmark) or dietary survey (China, France, Iceland, Ireland, Japan, Korea and Lithuania).

The UK has been very active and productive with their initiatives to reduce sodium in the food supply and populations. Results from population surveys for England, Northern Ireland and Scotland report mean salt intakes (24 h UNaV) of 8 (3.2 g sodium), 8.6 (3.44 g sodium) and 7.1 (2.84 g sodium) g/day, respectively.[38,39,40] In 2001, the reported mean salt intake (24 h UNaV) in the adult UK population was 9.5 g/day, with men having a higher (11.0 g/day) intake than women (8.1 g/day).[41]

Conclusions

Sodium is an essential mineral required to maintain health. Research suggests that high levels of sodium intake can lead to an increase in hypertension, a risk factor for cardiovascular disease. Meta-analysis studies of sodium intake suggests that most individuals consume more sodium than what is recommended by WHO. Results from intervention studies suggests a benefit from reducing sodium intake to decrease blood pressure for individuals with hypertension. However, observational studies suggest that lower sodium intake may increase cardiovascular events and mortality for normotensive individuals. As a result, there are differences of opinions on the recommended sodium intake for the general adult population. These observational studies suggests the need for additional research to better understand the relationship between sodium intake and risk of cardiovascular events and mortality. In addition to blood pressure, identification of other suitable cardiovascular disease biomarkers will increase understanding of the overall effect of sodium intake on health outcomes. Continued improvement of measurement methodologies, such as estimate of sodium intake (UNaV versus dietary recall), will also enhance the quality of the research.

Many geographies have implemented voluntary or mandatory initiatives to reduce the sodium content in foods. Monitoring surveys suggests a decrease in overall sodium content across the food supply, which are contributing to a positive effect on decreasing sodium intake. However, continued efforts to improve the accuracy of methods to monitor changes in sodium content of food products (e.g., chemical analysis vs. nutrition fact labels) will provide better insights on the impact these changes have on population sodium intakes.

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