ELSEVIER

ACE POLICY SYMPOSIUM

# Population-Wide Sodium Reduction: The Bumpy Road from Evidence to Policy

LAWRENCE J. APPEL, MD, MPH, SONIA Y. ANGELL, MD, MPH, LAURA K. COBB, MS, HEATHER M. LIMPER, MPH, DAVID E. NELSON, MD, MPH, JONATHAN M. SAMET, MD, MS, AND ROSS C. BROWNSON, PHD

Elevated blood pressure is a highly prevalent condition that is etiologically related to coronary heart disease and stroke, two of the leading causes of morbidity and mortality throughout the world. Excess salt (sodium chloride) intake is a major determinant of elevated blood pressure. In this article, we discuss the scientific rationale for population-wide salt reduction, the types and strength of available evidence, policy-making on dietary salt intake in the United States and other countries, and the role and impact of key stakeholders. We highlight a number of lessons learned, many of which are germane to policy development in other domains.
*Ann Epidemiol 2012;22:417–425.* 

KEY WORDS: Sodium, Salt, Blood Pressure, Hypertension, Cardiovascular Disease, Nutrition, Policy.

## INTRODUCTION

Many of the most common diseases in the United States and throughout the world are chronic conditions that reflect prolonged exposure to suboptimal lifestyle conditions, often nutrition-related (1). Evidence-based policies on preventative measures are critical to reduce the public health burden of these diseases, such as hypertension, atherosclerosis, and their sequelae. Policy-making related to lifestyle factors, particularly dietary factors, is complex and often depends on epidemiologic evidence, including ecologic studies and longitudinal observational studies. Clinical trials, particularly those with well-established surrogate outcomes, have a valuable role as well. In contrast, trials of lifestyle factors with hard outcomes such as stroke, myocardial infarction, and death are uncommon in the general population and therefore are rarely available to guide policy.

The purpose of this article is to provide insights related to policy-making on dietary salt (sodium chloride) intake. Specifically, we will cover the scientific rationale for population-wide salt reduction, the types and strength of available evidence, the history of policy-making on dietary salt in the United States and other countries, and the role and impact of key stakeholders.

## CONTEXT

### Scientific Overview

Worldwide, blood pressure (BP)-related diseases are leading causes of morbidity and mortality (2). There is a direct relationship between BP and heart disease, stroke, and end-stage renal disease (3). The relationships between BP and its sequelae have been characterized as strong, consistent, continuous, independent, and etiologically relevant (4). Notably, the risk of BP-related diseases increases progressively throughout the range of BP, including both hypertensive and nonhypertensive ranges (3). Globally, an estimated 47% of coronary heart disease events and 54% of strokes can be attributed to elevated BP (2). A cardinal feature of the elevated BP epidemic is the age-related rise in BP in both children and adults (5, 6).

From the Welch Center for Prevention, Epidemiology and Clinical Research, Johns Hopkins University, Baltimore, MD (L.J.A.); Department of Medicine, Johns Hopkins University School of Medicine, Baltimore, MD (L.J.A.); Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD (L.J.A., L.K.C); Center for Global Health, Centers for Disease Prevention and Control, Atlanta, GA (S.Y.A.); Department of Medicine, University of Chicago, Chicago, IL (H.M.L.); National Cancer Institute, Bethesda, MD (D.E.N.); Department of Preventive Medicine, Keck School of Medicine, University of Southern California, Los Angeles, CA (J.M.S.); and Division of Public Health Sciences and Alvin J. Siteman Cancer Center, Washington University School of Medicine, Washington University in St. Louis, St. Louis, MO (R.C.B.).

Address correspondence to: Lawrence J. Appel, MD, MPH, Welch Center for Prevention, Epidemiology and International Health, 2024 East Monument Street, Suite 2-642, Baltimore, MD. 21287. Tel.: 410-955-4156. E-mail: lappel@jhmi.edu.

In this article, the terms sodium and salt (sodium chloride) are used interchangeably, largely because greater than 90% of sodium intake comes from salt, which is sodium chloride. To convert grams of salt to milligrams of sodium, multiply grams of salt by 393. To convert milligrams of sodium to grams of salt, divide milligrams of sodium by 393.

Received April 1, 2012. Accepted April 8, 2012.


360 Park Avenue South, New York, NY 10010

1047-2797/$ - see front matter
doi:10.1016/j.annepidem.2012.04.003

AEP Vol. 22, No. 6
June 2012: 417–425

**Selected Abbreviations and Acronyms**

BP = blood pressure
FDA = Food and Drug Administration
GRAS = generally recognized as safe
NCD = noncommunicable disease
NGO = nongovernmental organization
NHBPEP = National High Blood Pressure Education Program
NHLBI = National Heart Lung and Blood Institute
NSRI = National Salt Reduction Initiative
WHO = World Health Organization

## Types and Strength of Existing Evidence Related to Health Effects of Sodium

Excess sodium intake has a prominent and likely predominant role in the pathogenesis of elevated BP (7, 8). Other lifestyle factors that increase BP include excess weight, insufficient potassium intake, high alcohol consumption, suboptimal dietary pattern, and physical inactivity. Supportive evidence on the adverse effects of excess sodium intake on BP comes from animal studies, migration studies, ecologic studies, longitudinal observational studies, clinical trials, and meta-analyses of trials. The best available evidence strongly supports a direct relationship between sodium intake and elevated BP—on average, as salt (sodium chloride) intake increases, so does BP (9).

Nonetheless, the evidence base does have some limitations. First, the measurement of sodium intake in humans is methodologically challenging (10). Both random and systematic errors in the measurement of dietary sodium intake can occur. The gold standard is urinary excretion of sodium from urine collected during a 24-hour period, but even these estimates can be inaccurate because of incomplete urine collections. Furthermore, because of large day-to-day variation in individual sodium consumption, repeat measurements on multiple days are needed to enhance precision when the intent is to link individual intake to subsequent events, such as cardiovascular disease or death. Such methodological issues have led to inconsistent (11, 12) and occasionally paradoxical (13, 14) findings.

A second issue relates to the types and perceived strength of available evidence. The randomized clinical trial is considered the strongest type of evidence for medical research, and trials of medical therapies with major clinical events, such as heart attack and stroke, are commonplace in high-risk populations. For sodium, more than 50 trials of sodium reduction with blood pressure as an outcome have been conducted, but none has been designed to test the effects of sodium reduction on major clinical events in general populations. Such a trial might not be feasible given the nature of the exposure, specifically, a chronic, lifelong exposure that is largely not under individual control. Furthermore, a trial with sufficient statistical power to detect reductions in outcome measures such as heart attacks and strokes in the general population would require a prohibitively large sample size and budget (15). The absence of trials with hard clinical outcomes is not an unusual situation. Public policy designed to reduce chronic disease risk in the general population often does not lend itself to same study methodologies used to evaluate medical treatments in high risk populations.

In the case of sodium, the body of evidence linking excess intake with elevated BP has been sufficiently compelling for numerous scientific bodies and policy-makers to recommend population-wide sodium reduction. The 2010 U.S. Dietary Guidelines recommend no more than 1500 mg of sodium/day for black patients, those age 51 years and older, and individuals with chronic kidney disease, diabetes, or hypertension and 2300 mg of sodium/day in all other adults (16). Concomitantly, the American Heart Association recommends an upper limit of no more than 1500 mg of sodium/day (17). Average intake levels greatly exceed recommended limits and are estimated to be more than 3400 mg of sodium/day in most age groups of men, women, and children (18). This assessment comes from food intake surveys that demonstrate persistently high levels of sodium consumption during the past 40 years (19). More than three-fourths of the sodium consumed by Americans comes from processed packaged and restaurant foods and is already in the products at the time of purchase (20). A much smaller proportion, just more than 10%, comes from salt added at the table or during cooking. The remaining dietary sodium is found naturally in foods. These observations highlight the need for changes to the food supply to accomplish population-wide reductions in sodium intake.

## Evolution of Salt Policy in the United States

Elevated lifetime sodium intake and its association with the development of hypertension received high-level attention as early as 1969 at the White House Conference on Food Nutrition and Health (21). This event marked the start of salt reduction efforts in the United States. The conference proceedings recommended that food processors reduce the amount of salt they add to their foods as a means to reduce population levels of intake. The report also identified a number of key elements needed to improve general nutrition, many of which would become relevant to U.S. sodium reduction policy approaches that followed. For example, it called upon the federal Food and Drug Administration (FDA) to review the list of foods and ingredients that the FDA considered "generally recognized as safe"(GRAS), a categorical listing under which salt also falls and which allows it to be added to processed foods without limitation. The report also recognized the increasing contribution of processed food to total daily intake, noting the "concomitant loss of consumer control over the nutritional quality

of foods purchased". (18) It recommended that the FDA produce guidelines for food manufacturers that would include a set of recommended minimum and maximum levels of nutrients in their foods.

Early U.S. policies approached the task of population-wide sodium reduction by emphasizing consumer education with the intent of stimulating individual behavior change. A second approach, pursued more intensely in recent years, is an effort to change behavior by changing the context of consumer decision-making. In this case, the intent is to create a food environment that supports reduced sodium intake by making lower sodium foods the norm. This approach should be more effective with respect to sodium reduction given that the majority of salt consumed is already in processed food at the time of purchase (20).

Major consumer education efforts started in 1972, when the National Heart Lung and Blood Institute (NHLBI) of the National Institutes of Health launched the National High Blood Pressure Education Program (NHBPEP) (22). Central to this effort were broad-reaching education programs that targeted the general public, patients, and health professionals and included information on the relationship of salt intake with hypertension. Supporting materials, tools, and scientific reviews and recommendations followed. In 1980, the U.S. Dietary Guidelines for Americans made its first formal recommendation that most Americans should avoid consuming too much sodium (23). In 1981, the FDA launched a public education initiative and encouraged manufactures to provide sodium content information on packaged food labels. By 1993, sodium was formally included in the list of nutrients that would be mandatory on packaged food labels. When target levels were set, a daily value of 2400 mg was established. That same year, the FDA introduced sodium requirements into the criteria used to determine whether a healthy food claim would be allowed on a food label. In recent years, the required disclosure of sodium on packaged foods has been extended to chain restaurant foods, first through local and state regulatory initiatives and subsequently through congressional mandates requiring specific nutrition information, including sodium content, be provided upon request (24).

Food labeling and claims regulation not only provide information for consumer decision-making but also create incentives for industry to formulate products differently. Companies may intentionally meet specific food claims criteria to make the product more attractive to the consumer upon review of the nutrition facts panel. Other policies that affect sodium intake through changing the types of foods available include institutional and government food procurement policies, and federal food commodity and food program standards that set nutritional criteria for sodium. For example, in 1995, the United States Department of Agriculture set sodium standards for food commodity categories that affected school meals. The most recent update in January 2012 includes attention to reducing sodium content further (25). Nutrition procurement policy examples exist at the city, state, and federal government level, as well as in hospitals, workplaces, and other private institutions (26). Vending machine policies that include restrictions on the sodium content of offered products have also been introduced in schools and other government and workplace settings (24).

Voluntary efforts by industry to lower the sodium content of the processed food supply, as called for by the 1969 White House Conference, have also been pursued. In 1980, the U.S. Department of Health and Human Services set as a national objective that sodium in processed foods should be reduced by 20% by 1990 (27). The American Public Health Association (28) and American Medical Association (29) have both appealed to industry to reduce the sodium content of their foods. These calls for action have not included implemented monitoring and accountability plans. Thus, we can only speculate as to their impact.

The National Salt Reduction Initiative (NSRI), which was launched in 2008, is pursuing voluntary commitments from industry to meet specific targets for more than 80 packaged and restaurant food categories (30). The NSRI is a partnership of more than 80 local and state health authorities and organizations. Sodium reduction targets have been set for 2012 and 2014. To date, 28 food companies have committed to select NSRI targets, including some of the nations' largest food manufacturers and restaurant chains, such as Kraft, Campbell's, Subway, and Starbucks (31). The NSRI emphasizes monitoring and evaluation and has developed packaged food and restaurant databases to assess changes in the food supply. In addition, New York City conducted a baseline 24-hour urinary sodium study in 2010 to measure the impact of the NSRI on population sodium intake. A follow-up study will be conducted in 2014.

Regulating the amount of sodium allowed in processed foods is another potential policy approach to change the food environment. In 1982, the FDA rejected consumer petitions requesting reclassification of salt from GRAS status to being a "food additive," a move that would have resulted in regulating the amount of sodium added to food. However, in 2010, modification of salt's GRAS status and regulation of sodium limits by food category were the primary recommendations of an Institute of Medicine Committee tasked with identifying the best approach to reduce sodium intake in the United States (19). The FDA responded in 2011 with the release of a public request for information related to sodium reduction approaches (32).

### Global Initiatives

Worldwide, there has been increased attention to salt reduction. In 2003, the World Health Organization (WHO) recommended that adults consume no more than 5 g of salt per day (equivalent to ~2000 mg of sodium) (33). Regionally, the European Union developed a salt reduction framework in 2008 that aims for a 16% reduction of salt levels in processed foods over 4 years (34). In 2009, the Pan American Health Organization convened an expert committee with the aim of reaching either the WHO or national salt intake targets by 2020 (35). In 2010, WHO held two multistakeholder information exchange forums and key technical meetings aimed at providing guidance for national sodium reduction efforts. The first focused on creating an enabling environment for salt reduction, the second on evaluating and monitoring. In September 2011, the United Nations held a high level meeting on global noncommunicable diseases (NCDs). The meeting's Political Declaration that was adopted by all member states prominently noted the link between unhealthy diet, including high salt intake, and NCDs (36). The United Nations called upon private industry to reduce sodium in foods and upon nations to implement salt reduction strategies and recommendations that would reduce the marketing of unhealthy foods to children, including those high in sodium. On the basis of cost effectiveness and implementation feasibility, WHO recognized salt reduction as one of a limited number of recommended "best buy" interventions to reduce NCDs (37).

Webster and colleagues (34) identified 32 countries with salt reduction strategies in place, of which 28 were led by governments. All but two either had or planned to promote food reformulation; Portugal and Argentina were the only countries that planned to use a regulatory rather than voluntary approach at that time. A few countries have subsequently demonstrated the effectiveness of their strategies: the United Kingdom, Finland, Japan, France, and Ireland.

**United Kingdom.** The UK Food Standards Agency salt campaign is noteworthy because of its demonstrated success in reducing salt intake, voluntary collaboration with the food industry, and use of surveillance data. Launched in 2003, the campaign aims to reduce salt intake from 9.5 to 6 grams per day (equivalent to a reduction in sodium intake from ~3700 to 2400 mg per day) through packaged food reformulation, consumer awareness campaigns, and improved front-of-pack nutrition labeling (35). In 2006, the Food Standards Agency proposed voluntary 2010 and 2012 salt-reduction targets for 80 categories of food on the basis of both average salt levels and stakeholder input. The United Kingdom has published company commitments and progress on their website and tracks changes in processed food sodium content. Intake estimated by population-level urinary sodium analysis studies conducted in 2001 and 2008 documented a reduction from 3800 milligrams in 2001 to 3400 milligrams in 2008 (38).

The UK experience also highlights the importance of nongovernment organizations (NGOs) in policy-making. The Consensus Action on Salt and Health, an NGO made up of scientific experts, was formed in 1996 to raise awareness of the dangers of excess salt intake after the government failed to recommend a 6 g per day salt intake limit (equivalent to 2400 mg of sodium per day) in 1994 (39). Their efforts have been instrumental in convincing both the UK government and the food industry to pursue salt reduction (39). The success of the UK model has inspired others to follow its example, including but not limited to the NSRI described earlier.

**Finland.** Experience from Finland illustrates the impact of policy on salt intake and the uses of epidemiologic surveillance data in setting priorities and tracking progress. The North Karelia Project, begun in 1972, is a community-based intervention program designed to reduce cardiovascular disease risk factors. The 80% decrease in coronary mortality from 1972 to 2007 is credited mainly to risk factor reduction from policies and programs implemented by this project (40). During this time period, the greatest changes in risk behaviors were related to diet (41).

A major aspect of Finland's dietary strategy was salt intake reduction, achieved through national legislation on labeling, surveillance of sodium intake and excretion, public education, and collaboration with the food industry to develop reduced salt products (42). Through these programs and policies, between 1979 and 2002, average urinary sodium excretion decreased from more than 5000 mg to less than 3900 mg/day among men, and from more than 4100 to less than 3000 mg/day among women (43).

## STAKEHOLDERS

A variety of stakeholder groups, crossing many disciplines, have contributed to increased awareness about sodium-related policies. This section briefly summarizes the roles of several stakeholders, particularly those influencing U.S. policy.

### Professional Health-Related Organizations

Numerous professional organizations advocate population-wide sodium reduction including, but not limited to the American Medical Association (29), the American Public Health Association (28), and the American Heart Association (44). More recently, the American Society of Hypertension has issued guidelines advocating a reduction in sodium intake, as well as public health efforts to achieve this goal (45). Each of these organizations has a broad policy agenda of which sodium reduction is just one component.

Hence, the effort expended by these organizations on sodium reduction is quite variable.

### Scientists

A broad spectrum of scientists, including epidemiologists, clinical researchers, and bench scientists, as well as practicing physicians and public health officials, view excess sodium intake as etiologically related to vascular disease and thus a major public health problem (46). Still, some scientists have concluded otherwise (47).

As with any area of research that has the potential to impact private industry, conflict of interest is a concern (48). Just as the pharmaceutical industry often funds drug studies, the food industry also funds nutrition studies. Furthermore, some scientists are, or have been, consultants to institutions that have financial interests related to levels of population sodium intake, such as the Salt Institute, a trade association of salt manufacturers (48). The challenge for policy makers, government officials, and the general public is to understand the merit of arguments made by those with potential conflicts of interest and the relevance and quality of evidence they present (49).

### Government

The effects of sodium intake on health have been a major concern of numerous government bodies. At the federal level, the United States Department of Agriculture and U.S. Department of Health and Human Services issue dietary guidelines every 5 years, and reduced sodium intake has been a consistent recommendation since 1980. The U.S. government's 10-year objectives for improving the health of all Americans, Healthy People 2020, include two related to reducing sodium intake (50). In 2011, the Food and Drug Administration released a docket seeking public comment on approaches to reducing sodium in the food supply (32).

The NHLBI has been a principal source of funding for basic, clinical, and epidemiologic research on the health effects of sodium intake. As discussed previously, the NHBPEP of the NHLBI was involved in developing guidelines for the prevention and treatment of hypertension and in informing a coalition of professional and government organizations with the goal of improving BP control. As part of its efforts, NHBPEP promoted sodium reduction. With recent organizational changes at NHLBI, hypertension and sodium efforts continue but have become part of educational initiatives with broader goals, namely, control of all of the major cardiovascular risk factors.

The Centers for Disease Control and Prevention has developed a substantial interest in the prevention of cardiovascular disease and is supporting several sodium reduction initiatives. Through the National Center for Health Statistics-supported National Health and Nutrition Examination Surveys, the federal government conducts surveillance of sodium intake through 24-hour dietary recall and is exploring efforts to measure 24-hour urinary sodium excretion. In 2010, the Centers for Disease Control and Prevention launched the Sodium Reduction in Communities Program to reduce sodium intake by helping create healthier food environments at the local level (51). Building on existing community policies to improve nutrition and lower blood pressure, each funded project supports implementation of at least one major sodium reduction policy strategy as well as media and evaluation activities.

State and local governments are also developing initiatives to lower sodium intake in the population. As discussed previously, the NSRI is a partnership of more than 80 state and local health authorities and national health organizations. The New York City Department of Health coordinates these efforts.

### Commercial Interests

Commercial interests include a wide spectrum of industries that manufacture, prepare, and sell food, as well as trade associations, such as the National Restaurant Association, the Grocery Manufacturers Association, the Chamber of Commerce, and the Salt Institute. Some companies and organizations have opposed salt reduction policies, including voluntary initiatives. In contrast, a number of companies have taken progressive stances and have agreed to reduce the sodium content of the products they sell or produce, independently or as part of announced efforts such as the NSRI or the First Lady's "Let's Move" campaign.

### Other Interest Groups

One of the more vocal opponents of salt reduction in the United States has been the Center for Consumer Freedom, an organization that describes itself as a "non-profit organization devoted to promoting personal responsibility and protecting consumer choices" (52). Center for Consumer Freedom writes and places ads in newspapers, radio, and television, calling efforts to reduce sodium in processed foods a "nanny state" policy.

A strong proponent of sodium reduction is World Action on Salt and Health, an NGO established in 2005 (53). World Action on Salt and Health was founded with the aim of achieving a gradual reduction in salt intake worldwide by encouraging multinational food companies and national governments to take action on salt reduction. Most members are scientists and public health experts. It is a single-issue advocacy group that focuses exclusively on salt. A multi-issue NGO, the Center for Science in the Public Interest, has had a long-standing interest in reduced

AEP Vol. 22, No. 6
June 2012: 417–425

sodium intake. Center for Science in the Public Interest has developed reports, such as "Salt, the Forgotten Killer" and has been a strong proponent of a regulatory approach to reducing sodium intake (54).

## LESSONS LEARNED

The previous sections provide the scientific rationale for sodium reduction, a review of the types and strength of existing evidence, a summary of policy-making in the United States, sodium reduction efforts in other countries, and the context for decision-making, with a focus on major stakeholders. The next section provides insights gleaned from policy-making efforts related to sodium-reduction.

### Epidemiologists Have a Crucial Role in Evaluating and Synthesizing Evidence

The array of evidence to be considered in policy-making is typically heterogeneous in design, volume, and quality. For sodium, there are also methodological issues, particularly related to measurement of dietary intake, that are inadequately recognized by many scientists. Policy makers need the assistance of epidemiologists to make sense of the vast body of evidence, including studies with flawed methods or uninformative results that create confusion and perpetuate controversy.

### Evidence-Based Medicine, Although Applicable to Many Medical Therapies, Creates Unrealistic Expectations for Evaluating Prevention Strategies

The most rigorous design for hypothesis testing is the randomized trial. For sodium, numerous trials have tested the effects of sodium reduction on BP, a well-accepted surrogate outcome for risk of vascular disease. To date, no trial has specifically tested the effects of sodium reduction on heart attacks, strokes, or mortality in the general population. As discussed earlier, such a trial may not be feasible, particularly in the United States, given the nature of the exposure and the sample size needed. Some may question if such a study would be ethical given the existing body of evidence. Still, some individuals have questioned the evidence base for public policy related to dietary salt intake (and more broadly nutrition policy) and have called for large-scale trials (55). In this context, epidemiologists and other scientists can assist policy-makers in understanding not just the strengths and limitations of available evidence but also the types of evidence that can be available in the future.

### Multidisciplinary Research Is Required

Prevention and control of elevated BP are complex problems that need to be addressed at multiple levels and among many different disciplines, not just epidemiology and the medical sciences. These areas include agriculture, food sciences, marketing, transportation, and education. Multidisciplinary research provides valuable opportunities to collaborate on interventions aimed at improving the health and wellbeing of both individuals and communities. For example, tobacco research efforts have been successful in facilitating cooperation among advertising, policy, business, economics, medical science, and behavioral science groups to bridge scientific discovery and research translation by engaging a wide range of stakeholders. A multidisciplinary approach has also shown some evidence of effectiveness in obesity prevention, and should be pursued by researchers interested in addressing sodium reduction.

### Modeling, Particularly Cost-Effectiveness Analyses, Often Has a Valuable Role in Policy-Making

Modeling is often used to quantify disease burden and to project the impact of various intervention strategies on health outcomes and costs. Cost-effectiveness modeling can conceptualize seemingly intangible evidence into terms of lives and money saved. For example, one study estimated that reduction of dietary salt intake by 3 g per day (approximately 1200 mg of sodium) would save 194,000 to 392,000 quality-adjusted life-years and $10 to $24 billion in health care costs annually, while reducing the annual number of deaths by 44,000 to 92,000 (56). This approach transforms preventative efforts into tangible monetary savings, which allow policy makers and the public to prioritize public health interventions.

### Understanding All Sides of the Argument Is Critical to Effective Policy-Making

Scientists who contribute to policy-making often focus on the set of scientific issues that provide the rationale for public policy. The scientific community that supports population-wide sodium reduction has largely focused on the adverse effects of high sodium intake on BP and vascular disease. Opponents to sodium reduction policies have a much broader set of arguments, only some of which are related to the effects of sodium intake on BP. Such arguments include (1) tangential scientific issues (e.g., acute effects of extreme sodium restriction on biomarkers of uncertain clinical relevance (57), heterogeneity of BP response to sodium intake), (2) hypothetical issues with little or no supporting evidence (e.g., volume depletion in setting of severe, acute illness, or extreme temperatures and activity), and (3) competing health issues (e.g., the potential adverse effects of reduced consumption of iodized salt and food safety issues related to reduced use of sodium preservatives). It is important that members of scientific review bodies carefully consider the full range of potential

health consequences, such as those described previously. Such comprehensive analyses have allowed policy makers to quickly respond to arguments on both sides in an evidence-informed manner (9). Still, the review is never complete. Policy is well-served when scientists diversify their understanding of a topic by carefully considering the many scientific arguments, for and against policy-making.

In addition to scientific arguments, public policy may challenge philosophical positions. For example, some have argued that policies leading to a reduction in the sodium content of foods impede an individual's freedom to make decisions related to food because it changes what's available. This line of reasoning parallels the "free choice" arguments made about cigarette smoking. A counter argument is that the current food environment, replete in excess sodium, makes it difficult for individuals to exercise their freedom to decide how much sodium they consume, be it high or low, because it's already in the food when they buy it. A food environment with lower sodium may actually increase individual freedom by allowing individuals to control sodium content, including the option of adding it back to their foods, if so desired.

### There Is a Need for Continued Research

The effects of excess sodium intake on BP are indisputable. Still, monitoring and evaluation of implemented policies is critical to assess their direct and indirect impacts, such as levels and trends in sodium intake and the effects of specific policies on sodium intake, BP levels and BP-related outcomes. Expectations should be realistic. First, evidence-informed sodium reduction policy will not reduce population sodium intake abruptly; hence, reductions in population BP levels and BP-related morbidity will also be gradual. Second, research on sodium can be challenging to implement and will require public investment and planning.

### Special Training Is Useful for Epidemiologists Who Are Interested in Policy-Making

Epidemiologists receive substantial training in scientific and statistical methods, and most have the opportunity to apply this type of knowledge as part of their regular activities. In sharp contrast, they rarely have training, let alone experience, in policy-making (58). As previously mentioned, epidemiologists have a crucial role in the assessment and synthesis of evidence. Epidemiologists also may play an important role in public health policy by communicating scientific information to media representatives and elected or appointed policy makers (59, 60). The value of effective communication by scientists has been shown in policy efforts as diverse as motor vehicle safety, immunization requirements, and tobacco regulation (61). To be effective at such communication, epidemiologists as well as other scientists greatly benefit by training from experts who work in policy and media environments. Communicating with advocates, policy makers, the media, and other players involved in policy issues is challenging and inherently different from presenting information to scientific audiences (62).

### For Scientists Who Engage in Policy-Making, There Are Both Rewards and Risks

Serving on policy-making bodies, although important from a societal perspective, is typically an honorary, unpaid activity ("scientific citizenship") in which senior scientists devote considerable effort into evaluating and synthesizing scientific findings and then making and communicating recommendations. The downstream benefits might include professional development and advancement for the scientist, as well as potential research opportunities from a greater understanding of scientific issues and knowledge gaps. However, there are costs, particularly the time involved in understanding and addressing the plethora of scientific, practical, and political issues that influence sound policy-making. The subsequent strains, both personal and professional, may not be trivial.

## SUMMARY

It has long been known that public health policy has a profound impact on our daily lives and on population-level indicators of health status, including the risk of cardiovascular disease. Many policy interventions are underway to reduce salt intake at the population level. This paper has summarized progress in this field and offers lessons for practitioners, policy makers, and researchers as they seek to translate epidemiologic and other scientific findings into policy.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention and the National Cancer Institute.

## REFERENCES

1. Danaei G, Ding EL, Mozaffarian D, Taylor B, Rehm J, Murray CJL, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. PLoS Med. 2009;6:e1000058.
2. Lawes CM, Vander Hoorn S, Rodgers A, International Society of Hypertension. Global burden of blood-pressure-related disease, 2001. Lancet. 2008;371:1513–1518.
3. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R, Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet. 2002;360:1903–1913.
4. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, et al. Seventh report of the Joint National Committee on Prevention,

Detection, Evaluation, and Treatment of High Blood Pressure. Hypertension. 2003;42:1206–1252.

5. Burt VL, Whelton P, Roccella EJ, Brown C, Cutler JA, Higgins M, et al. Prevalence of hypertension in the US adult population. Results from the Third National Health and Nutrition Examination Survey, 1988–1991. Hypertension. 1995;25:305–313.
6. Appel LJ. At the tipping point: accomplishing population-wide sodium reduction in the United States. J Clin Hypertens (Greenwich). 2008;10:7–11.
7. Appel LJ, Brands MW, Daniels SR, et al. Dietary approaches to prevent and treat hypertension: a scientific statement from the American Heart Association. Hypertension. 2006;47:296–308.
8. He FJ, Macgregor GA. A comprehensive review on salt and health and current experience of worldwide salt reduction programmes. J Hum Hypertens. 2008;23:363–384.
9. Institute of Medicine. Dietary Reference Intakes: Water, Potassium, Sodium Chloride, and Sulfate. 1st ed. Washington, DC: National Academy Press; 2004.
10. Appel LJ. The case for population-wide salt reduction gets stronger. BMJ. 2009;339:b4980.
11. Cohen HW, Hailpern SM, Alderman MH. Sodium intake and mortality follow-up in the Third National Health and Nutrition Examination Survey (NHANES III). J Gen Intern Med. 2008;23:1297–1302.
12. Yang Q, Liu T, Kuklina EV, 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;171:1183–1191.
13. Stolarz-Skrzypek K, Kuznetsova T, Thijs L, et al. Fatal and nonfatal outcomes, incidence of hypertension, and blood pressure changes in relation to urinary sodium excretion. JAMA. 2011;305:1777–1785.
14. O'Donnell MJ, Yusuf S, Mente A, et al. Urinary sodium and potassium excretion and risk of cardiovascular events. JAMA. 2011;306:2229–2238.
15. He FJ, Appel LJ, Cappuccio FP, de Wardener HE, MacGregor GA. Does reducing salt intake increase cardiovascular mortality? Kidney Int. 2011;80:696–698.
16. United States Department of Agriculture, Center for Nutrition Policy and Promotion. United States Dietary Guidelines for Americans, 2010. Available at: http://www.dietaryguidelines.gov/DietaryGuidelines.htm.
17. Lloyd-Jones D, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, et al. Defining and setting national goals for cardiovacular health promotion and disease reduction. The American Heart Association's strategic impact goal through 2020 and beyond. Circulation. 2010;121:586–613.
18. Appel LJ, Anderson CA. Compelling evidence for public health action to reduce salt intake. N Engl J Med. 2010;362:650–652.
19. Institute of Medicine. Strategies to Reduce Sodium Intake in the United States. Washington, D.C.: National Academy Press; 2010.
20. Mattes RD, Donnelly D. Relative contributions of dietary sodium sources. J Am Coll Nutr. 1991;10:383–393.
21. Establishing Guidelines for the Nutrition of Vulnerable Groups (With Special Reference to the Poor). Available at: http://www.nns.nih.gov/1969/full_report/White_House_Report2_S2.pdf.
22. National High Blood Pressure Educational Program. Available at: http://www.nhlbi.nih.gov/about/nhbpep/nhbp_pd.htm.
23. Nutrition and Your Health, Dietary Guidelines for American. Available at: http://www.cnpp.usda.gov/Publications/DietaryGuidelines/1980/DG1980pub.pdf.
24. New Menu and Vending Machines Labeling Requirements. Available at: http://www.fda.gov/food/labelingnutrition/ucm217762.htm.
25. United States Department of Agriculure, Food and Nutrition Service. USDA Unveils Historic Improvemnets to meals Served in America's Schools: New Standards Will Improve the Health and Wellbeing of 32 Million Kids Nationwide. Available at: http://www.fns.usda.gov/cga/PressReleases/2012/0023.htm.
26. Centers for Disease Control and Prevention. Improving the food environment through nutrition standards: a guide for government procurement. U.S. Department of Health and Human Services, Centers for Disease Control, National Center for Chronic Disease Prevention and Health Promotion, Division for Heart Disease and Stroke Prevention; February 2011. Available from: http://www.cdc.gov/salt/pdfs/dhdsp_procurement_guide.pdf.
27. Public Health Service. Promoting Health/Preventing Disease: Objectives for the Nation. Washington, DC: U.S. Department of Health and Human Services, Public Health Service; 1980.
28. Havas S, Roccella EJ, Lenfant C. Reducing the public health burden from elevated blood pressure levels in the United States by lowering intake of dietary sodium. Am J Public Health. 2004;94:19–22.
29. Dickinson BD, Havas S, Council on Science and Public Health, American Medical Association. Reducing the population burden of cardiovascular disease by reducing sodium intake: a report of the Council on Science and Public Health. Arch Intern Med. 2007;167:1460–1468.
30. New York City Department of Health and Mental Hygiene. Cut the salt. Get the facts. The National Salt Reduction Initiative. Available at: http://www.nyc.gov/html/doh/downloads/pdf/cardio/cardio-salt-nsri-faq.pdf.
31. New York City Department of Health and Mental Hygiene. National Salt Reduction Initiative—Statement of commitment by health organizations and public agencies. Available at: http://www.nyc.gov/html/doh/html/cardio/cardio-salt-coalition.shtml.
32. Department of Health and Human Services, Food and Drug Administration, Department of Agriculture, Food Safety and Inspection Service. Approaches to reducing sodium consumption; establishment of dockets; request for comments, data, and information. Federal Register. Washington, DC: United States Government Printing Office; September 15, 2011 76:57050–57054.
33. World Health Organization. Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases: Report of a Joint WHO/FAO Expert Consultation. Geneva: WHO; 2002.
34. Webster JL, Dunford EK, Hawkes C, Neal BC. Salt reduction initiatives around the world. J Hypertens. 2011;29:1043–1050.
35. World Health Organization. Creating an Enabling Environment for Population-Based Salt Reduction Strategies, Report of a Joint Technical Meeting Held by the WHO and the Food Standards Agency, United Kingdom. United Kingdom: World Health Organization; 2010.
36. Political Declaration of the High-level Meeting of the General Assembly on the Prevention and Control of Non-communicable Diseases. Available at: http://www.who.int/nmh/events/un_ncd_summit2011/political_declaration_en.pdf.
37. World Economic Forum, Harvard School of Public Health. From Burden to "Best Buys": Reducing the Economic Impact of Non-Communicable Diseases in Low-and Middle-Income Countries. Available at: http://www.who.int/nmh/publications/best_buys_summary.pdf.
38. Food Standards Agency. Dietary Sodium Levels Surveys. Available at: http://www.food.gov.uk/science/dietarysurveys/urinary.
39. He FJ, MacGregor GA. A comprehensive review on salt and health and current experience of worldwide salt reduction programmes. J Hum Hypertens. 2009;23:363–384.
40. Vartiainen E, Laatikainen T, Peltonen M, et al. Thirty-five-year trends in cardiovascular risk factors in Finland. Int J Epidemiol. 2010;39:504–518.
41. Pietinen P, Vartiainen E, Seppanen R, Aro A, Puska P. Changes in diet in Finland from 1972 to 1992: impact on coronary heart disease risk. Prev Med. 1996;25:243–250.
42. Pietinen P, Valsta LM, Hirvonen T, Sinkko H. Labelling the salt content in foods: a useful tool in reducing sodium intake in Finland. Public Health Nutr. 2008;11:335–340.

43. Laatikainen T, Pietinen P, Valsta L, Sundvall J, Reinivuo H, Tuomilehto J. Sodium in the Finnish diet: 20-year trends in urinary sodium excretion among the adult population. Eur J Clin Nutr. 2006;60:965–970.
44. Sacks G, Rayner M, Swinburn B. Impact of front-of-pack 'traffic-light' nutrition labelling on consumer food purchases in the UK. Health Promot Int. 2009;24:344–352.
45. Appel LJ, Giles TD, Black HR, Izzo JL Jr, Materson BJ, Oparil S, et al. ASH position paper: dietary approaches to lower blood pressure. J Am Soc Hypertens. 2010;4:79–89.
46. Appel LJ, Frohlich ED, Hall JE, et al. The importance of population-wide sodium reduction as a means to prevent cardiovascular disease and stroke: a call to action from the American Heart Association. Circulation. 2011;123:1138–1143.
47. Alderman MH. Reducing dietary sodium: the case for caution. JAMA. 2010;303:448–449.
48. McCarron DA, Drueke TB, Stricker EM. Science trumps politics: urinary sodium data challenge US dietary sodium guideline. Am J Clin Nutr. 2010;92:1005–1006.
49. Michaels D. Doubt is their Product: How Industry's Assault on Science Threatens Your Health. New York, New York: Oxford University Press; 2008.
50. Healthy People 2020. Available at: http://healthypeople.gov/2020/topicsobjectives2020/objectiveslist.aspx?topicId=29.
51. Division for Heart Disease and Stroke Prevention. Sodium Reduction in Communities Program. Available at: http://www.cdc.gov/dhdsp/programs/sodium_reduction.htm.
52. The Center for Consumer Freedom. The Center for Consumer Freedom: About Us. Available at: http://consumerfreedom.com/about.cfm.
53. He FJ, Jenner KH, Macgregor GA. WASH-world action on salt and health. Kidney Int. 2010;78:745–753.
54. Jacobson MF, ed. Salt the Forgotten Killer. Washington, DC: Center for Science in the Public Interest; 2005.
55. Marantz PR, Bird ED, Alderman MH. A call for higher standards of evidence for dietary guidelines. Am J Prev Med. 2008;34:234–240.
56. 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;362:590–599.
57. 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.
58. Brownson RC, Royer C, Ewing R, McBride TD. Researchers and policymakers: travelers in parallel universes. Am J Prev Med. 2006;30:164–172.
59. Savitz DA, Poole C, Miller WC. Reassessing the role of epidemiology in public health. Am J Public Health. 1999;89:1158–1161.
60. Friis RH, Sellers T. Epidemiology for Public Health Practice. 4th ed. Sudbury (MA): Jones and Barlette Learning; 2010.
61. Ward JW, Warren C. Silent Victories: The History and Practice of Public Health in Twentieth-Century Americ. New York (NY): Oxford University Press; 2010.
62. Nelson DE, Hesse BW, Croyle RT. Making Data Talk: Communicating Public Health Data to the Public, Policy Makers, and the Press. New York (NY): Oxford University Press; 2009.