Financial Analysis/Nutrition

Potential Societal Savings From Reduced Sodium Consumption in the U.S. Adult Population

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Abstract

Purpose. *Policies that address the food environment at the population level may help prevent chronic disease, but their value to society is still uncertain. Dietary sodium is linked to increased prevalence of hypertension, a primary risk factor for cardiovascular and renal diseases. This study calculates the potential societal savings of reducing hypertension and related cardiovascular disease via a reduction in population-level sodium intake. On average, U.S. adults consume almost twice the recommended maximum of dietary sodium, most of it from processed foods.*

Design. *This study modeled sodium-reduction scenarios by using a cross-sectional simulation approach. The model used population-level data on blood pressure, antihypertensive medication use, and sodium intake from the National Health and Nutrition Examination Survey (1999–2004). This data was then combined with parameters from the literature on sodium effects, disease outcomes, costs, and quality of life to yield model outcomes.*

Measures. *This study calculated the following outcome measures: hypertension prevalence, direct health care costs, and quality-adjusted life years for noninstitutionalized U.S. adults.*

Analysis. *The simulation was conducted with STATA 9.2 and Microsoft Excel. Survey weights were used to calculate population averages.*

Results. *Reducing average population sodium intake to 2300 mg per day, the recommended maximum for adults, may reduce cases of hypertension by 11 million, save $18 billion health care dollars, and gain 312,000 QALYs that are worth $32 billion annually. Greater reductions in population sodium consumption bring even greater savings to society.*

Conclusions. *Large benefits to society may result from efforts to lower sodium consumption on a population level by modest amounts over time. Although savings in direct health care costs are likely to be quite high, they could easily be matched or exceeded by the value of quality-of-life improvements. (Am J Health Promot 2009;24[1]:49–57.)*

Key Words: Sodium, Cardiovascular Diseases, Hypertension, Prevention and Control, Costs and Cost Analysis. Manuscript format: research; Research purpose: modeling; Study design: quasi-experimental; Outcome measure: other financial/economic and morbidity; Setting: national; Health focus: nutrition; Strategy: policy; Target population age: adults; Target population circumstances: N/A

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PURPOSE

Although age-adjusted mortality rates from cardiovascular disease (CVD) and stroke have decreased by 50% since 1970, evidence suggests that these conditions have simply been made less lethal, rather than prevented, because of improved medical care.[1–3] In fact, key risk factors for CVD and stroke have increased throughout this time period. In particular, hypertension rates have increased in the United States since 1991[4] despite targets set by Healthy People 2010 to significantly decrease population blood pressures.[5]

The high burden of hypertension in the United States has serious cost implications. A recent study found that hypertension cost the United States $55 billion in medical expenditures in 2001, based on the assumption that 17% of ambulatory patients were hypertensive in that year.[6] The National Center for Health Statistics estimated that 26% of adults were hypertensive in 2001, however, so actual expenditures are likely to be even higher.[3]

Options for reducing high blood pressure include drug treatment as well as lifestyle modification, such as changes in diet and exercise. Improved drug therapy for hypertension could add substantial societal value by effectively decreasing the risk of CVD and stroke. Indeed, treatment strategies have received considerable attention in the clinical setting, and recent evidence suggests that the societal benefits of antihypertensive drugs are likely to exceed their costs.[7] However, far less is known about the benefits and costs of specific strategies for the prevention of hypertension, especially for population-based approaches. This lack of information and analysis about the costs and benefits of population-level hypertension prevention strategies reduce their attractiveness and policy relevance, even if their societal benefits may in theory exceed those of additional treatment.

In this paper, we calculated the societal benefits for one particular approach to hypertension prevention:

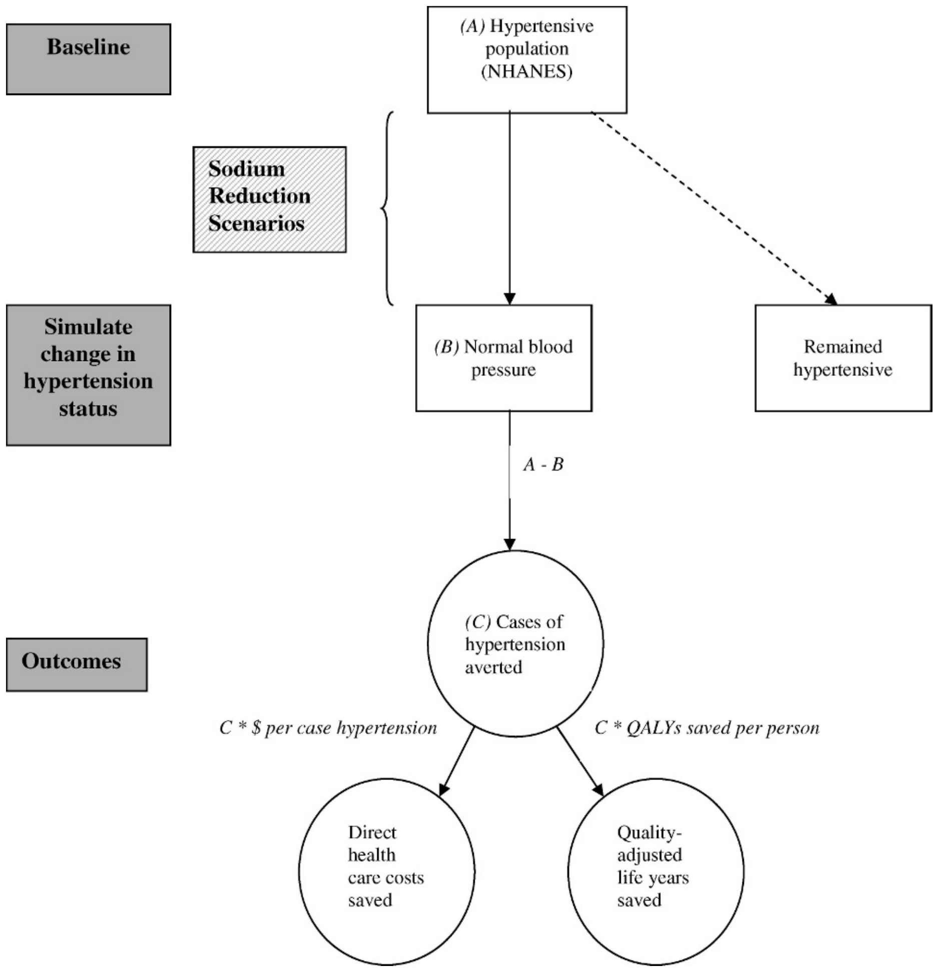
the reduction of dietary sodium. The health effects of dietary sodium have been extensively studied; although individual responses vary, higher sodium consumption at the population level raises average blood pressure levels and hypertension rates.[8] Several public health and medical associations have issued summaries and guidelines recommending reductions in dietary sodium and have advocated for population-level strategies to accompany clinical approaches to hypertension control.[9–12] Furthermore, the Institute of Medicine (IOM) recommends that adults consume no more than 2300 mg sodium per day, with lower maximums for older adults, black patients, and hypertensive patients, whereas the objective of Healthy People 2010 is for 65% of the population to consume less than 2400 mg of sodium per day. By using data from the National Health and Nutrition Examination Survey (NHANES; 1999–2004), we estimated that American adults consume roughly 3400 mg of sodium per day and that only 30% of the population consumes less than 2400 mg of sodium per day. Clearly, to achieve stated public health targets, substantial changes are necessary.

Our objective was to quantify the potential benefits of reducing sodium consumption at the population level to levels recommended by public health guidelines by considering both savings in health care costs and increases in quality of life. We took a cost-of-illness approach: how would medical expenditures decrease and how would quality-adjusted life years (QALYs) increase with a reduction in dietary sodium, assuming that treatment patterns stay the same?

This analysis provides key inputs for evaluating sodium-reduction policy options, such as package labeling or changing the regulatory status of salt. In the United Kingdom, for example, the Food Standards Agency has encouraged companies to use a traffic-light, front-of-package labeling system that identifies food products as low (i.e., green), medium (i.e., yellow), and high (i.e., red) in sodium. In 2003, the Food Standards Agency also started an aggressive advertising campaign to lower sodium consumption.[13] In the United States, the U.S. Food and Drug Administration recently opened proceedings to reevaluate the regulatory status of salt and sodium, which has been unchanged for more than 40 years.[14] Although specific strategies that the U.S. Food and Drug Administration may consider were not analyzed in this study, our calculations are intended to inform future analyses that compare strategies and include evidence of their effectiveness. Thus, this study calculates the potential benefits of achieving certain levels of reduction in population-level sodium consumption, regardless of the mechanism used to achieve these reductions.

Figure 1

Simulation Approach



METHODS

Design

This analysis calculated the change in health care costs and quality of life expected from a reduction in population-level sodium consumption and driven by simulated changes in the prevalence of hypertension. A cross-sectional simulation model was used as the basis for the analysis (Figure 1).

Measures

Blood Pressure and Sodium Inputs. The distributions of blood pressure and sodium consumption were estimated for adults (i.e., 18 years or older) from the NHANES (1999–2004). NHANES is a nationally representative, cross-sectional survey of health and nutrition of the U.S. noninstitutionalized population, and it includes direct blood pressure measurement. To make the most accurate measurements, certified examiners received special training

Table 1

Dose-Response Estimate of Sodium Reduction on Blood Pressure Among Hypertensive Patients*

Blood Pressure Measurement	Blood Pressure Reduction, mm Hg†	95% CI
Systolic	7.2	8.8 to 5.6
Diastolic	3.8	4.7 to 2.8

* Data from He and MacGregor, 2004.[8]
† Reported per 100-mmol reduction in sodium intake.

and took three to four readings of both systolic and diastolic blood pressure from each participant. The survey also included interview data on daily sodium consumption, caloric consumption, medication use, and demographic characteristics. Survey weights were available to make nationally representative estimates from the data.

Estimates for the dose-response relationship between sodium and blood pressure reduction came from a meta-analysis of long-run trials (4 weeks or longer) of modest to substantial sodium reduction (average reduction, 1800 mg) published by the Cochrane Database of Systematic Reviews (Table 1).[8] This meta-analysis included 31 randomized, controlled trials of sodium reduction alone (without concomitant interventions) in a total of 3022 adult participants. Other meta-analyses exist but include trials with either extreme or short-term drops in sodium consumption, making them less applicable to current public health recommendations for sodium reduction over time.[8,15–17]

Use of antihypertensive medication was identified in NHANES by using detailed prescription drug data obtained when interview participants were asked to list all the prescription drugs they were taking for any condition. NHANES researchers then broke down each of these drugs into their effective components and organized them into therapeutic classes. In our study, use of antihypertensive medication was defined as the use of one or more drugs in the following therapeutic classes: β blockers; calcium channel blockers (CCBs); diuretics; angiotensin-converting enzyme (ACE) inhibitors; angiotensin-receptor blockers (ARBs); and other antihypertensive agents, which included α_1 blockers, central α_2 blockers, direct vasodilators, and other centrally acting drugs.

The definition of clinical hypertension used in this analysis was the same as that used by the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: patients with blood pressure equal to or exceeding 140 mm Hg systolic or 90 mm Hg diastolic, or patients taking antihypertensive medications.[18]

Cost Inputs. The annual cost per case of hypertension used in our analysis was $1598 (for the year 2005). This figure is based on a published estimate from a recent study on health care expenditures attributable to chronic conditions in the United States, including hypertension.[19] The authors of the expenditure study used econometric analysis of data from the Medical Expenditure Panel Survey (2000–2003) to obtain hypertension cost estimates. This survey is a nationally representative survey of the civilian, noninstitutionalized, U.S. population. Because hypertension is both a condition in itself and a major risk factor for CVD, the attributable cost includes a portion of the costs for CVD, and analysis of the data is controlled for demographics, comorbidities, and other risk factors.

Quality-of-Life Inputs. The full benefits of prevention include gains in quality of life. In this study, we measured savings in quality-adjusted life years (QALYs), which is the preferred measure of quality of life for cost-effectiveness analysis.[20] The quality-of-life weight for hypertension was based on a recent study that developed a catalog of nationally representative, U.S. community–based utility weights for chronic conditions in adults (i.e., 18 years or older), including CVDs.[21] These weights were based on index scores from the EQ-5D, a preference-based instrument developed by the EuroQol Group for capturing health-related quality of life; the reliability and validity of this instrument has been reported favorably in the literature.[22]

The attributable risk percent (AR%) of heart attack (i.e., acute myocardial infraction), stroke, and heart failure as a result of hypertension, as well as the prevalence of these conditions among hypertensive patients, was calculated by using estimates from the epidemiological literature.[23–25] The AR% was then multiplied by the prevalence of these conditions among hypertensive patients to capture the percentage of disease among hypertensive patients that would be averted as a result of a decrease in hypertension. The utility weight for hypertension was then calculated by adding the published marginal utilities for hypertension alone with those for AMI, stroke and heart failure scaled down by this percentage (Table 2).

Published estimates of risk for AMI and stroke applied to hypertensive patients older than 65 years, whereas the estimate for heart failure applied to hypertensive patients older than 40 years. Therefore, the estimates of quality-of-life savings were scaled down according to the percent of hypertensive patients older than these ages estimated in NHANES. The age- and disease-specific limitations of the data, along with the annual perspective taken, imply that our QALY calculations represent only a partial indication of the potential savings in quality of life as a result of sodium reduction.

Measurement of QALYs is the primary outcome used in the cost-effectiveness analysis of health interventions; however, it is sometimes useful to express intervention outcomes in monetary terms, although this is a more speculative step and only analytically useful in cost-benefit analyses. A review of willingness-to-pay estimates for a QALY revealed a wide range of valuations, depending on the methods used: from $32,000/QALY with the human capital method to $427,000/QALY with the revealed preference method that used risky occupation

Table 2

Key Formulas Used in Analysis

Formula Name	Formula Definition
Change in number of hypertension cases (ΔHT)	% of hypertensive patients who changed status after sodium reduction* × total number of hypertensive patients in the United States†
Attributable risk percent (AR%)	$100 \times (RR_i - 1) \div (RR_i)$‡
Change in quality of life per case of hypertension reduced (ΔQoL)	$\Delta U_{hypertension} + (\Delta U_i \times AR\%_i \times P_i)$§
Direct health care costs saved annually	$ per case of hypertension × ΔHT‡
QALYs saved (annual population)‖	ΔQoL × ΔHT
Value of QALYs saved in annual population	$ per QALY × QALYs saved

* Input from simulation results.
† Italicized inputs come from the literature. Underlined inputs are outputs from previous calculations.
‡ In which RR_i is the relative risk for condition *i* among hypertensive patients.
§ In which U_i is the utility weight for condition *i* and P_i is the prevalence of condition *i* among hypertensive patients, where *i* = heart attack or stroke.
‖ QALY indicates quality-adjusted life year.

data, updated to 2005 dollars using the Consumer Price Index.[26] The dialysis standard of $50,000 (according to data in 1982) is often used as a rough cutoff of what society is willing to pay for a QALY.[27] This study used $100,000/QALY as its valuation, which is the dialysis standard updated to 2005 dollars by using the Consumer Price Index.

It is important to note that health care cost savings and QALYs are not mutually distinct measures of potential benefit; therefore, these benefits cannot be added. Rather, the value to an individual of averting the cost of illness—in this case, hypertension and related conditions—is part of well-being as measured by QALYs.

Analysis

Hypertension Prevalence Changes. We considered several scenarios of sodium reduction corresponding to public health targets, and we simulated these scenarios with Stata 9.2 (StataCorp LP, College Station, Texas). The four scenarios simulated were as follows: reduction of sodium from 3400 mg per day to (1) 2300 mg per day (i.e., IOM upper limit for adults), (2) 1700 mg (approximately 50% of estimated average daily consumption), (3) 1500 mg per day (IOM adequate intake for adults younger than 50 years and U.S. dietary guidelines upper limit for black and hypertensive patients), and (4) 1200 mg per day (IOM adequate intake for adults older than 50 years).[28,29] The percentage drop in sodium consumption was calculated for each scenario and was used to create a sodium-reduction variable for each respondent in NHANES. We then applied the dose-response relationship from Table 1 to the sodium-reduction variable and calculated the decrease in blood pressure that resulted from a decrease in sodium consumption. For each scenario, the percentage reduction in hypertension was calculated by counting the number of hypertensive patients who crossed the blood pressure threshold to less than 140/90 mm Hg. The reduction in hypertension cases this represents in the population was estimated by applying the percent who shifted status to the total number of hypertensive patients estimated in the United States as of 2007 (Table 2).[30] It is important to note that this is a very conservative approach to calculating the expected benefits from reducing sodium consumption across the population, because benefits are only calculated for those patients who cross the hypertension threshold and not for those whose blood pressure is reduced but stays higher than (or less than) 140/90 mm Hg.

To account for medication use, the simulated reduction in sodium was conducted only for hypertensive patients who did not report taking antihypertensive medication. We then assumed that the underlying distribution of blood pressure for medicated hypertensive patients was the same for those not taking medication, so that the same percentage of both groups was assumed to cross the hypertension threshold after sodium reduction. An alternate approach to account for medication use, in which the blood pressure of each medicated individual was adjusted upward by using published estimates of the effect of drug therapy, also was conducted.[31] Although a previous study relied on this latter approach to simulate the underlying distribution of blood pressure among medicated hypertensive patients, both approaches have their drawbacks.[32] Thus, the second approach is reported as part of the sensitivity analysis.

Direct Health Care Cost Savings. Savings in direct health care costs were calculated in Microsoft Excel. The attributable cost per case of hypertension was multiplied by the reduction in the number of hypertension cases obtained from the sodium-reduction simulation model (Table 2).

Quality-Adjusted Life Years Saved Annually. Annual population QALYs gained were calculated in Microsoft Excel by multiplying the reduction in cases of hypertension obtained from the sodium-reduction simulation model by a specially constructed utility weight that represented the quality of life gained from averting hypertension and hypertension-attributable CVD (Table 2).

Value of Quality-Adjusted Life Years Saved Annually. Total population QALYs gained were then multiplied by the value of a QALY to yield estimates of the dollar value of quality-of-life

Table 3

Reduction in Hypertension With Reduced Population Sodium Consumption

Average Sodium Consumption, mg/d	Average Reduction in Blood Pressure (systolic/diastolic)		Hypertension Prevalence (% of population age 18 years or older)	Reduction in Cases of Hypertension (millions)
	Systolic	Diastolic		
3400*	—	—	32.9	—
2300	3.4	1.8	28	11.1
1700	5.3	2.8	26.3	14.9
1500	5.9	3.1	25.6	16.4
1200	6.9	3.6	25.1	17.7

* Baseline amount.

savings to society from reducing sodium consumption (Table 2).

Sensitivity Analysis. To test the sensitivity of the results to different sodium-blood pressure dose-response relationships, several alternate scenarios were modeled. One set of scenarios repeated the analysis with the lower and upper bound on the 95% confidence interval of the dose-response relationship reported in the meta-analysis that was used as the basis for the sodium-reduction simulation model.[8] The other set of scenarios repeated the simulation with a nonlinear dose-response relationship that was based on outcome data from the Dietary Approaches to Stop Hypertension (DASH)-Sodium trial.[33,34] The DASH-Sodium trial was a randomized trial that compared the effects of three levels of sodium intake (1150, 2300, and 3450 mg/d) on blood pressure. Because NHANES includes observations along a continuous spectrum of blood pressure, two different methods of applying the nonlinear dose-response relationship found in the DASH trial were used. In addition, the analysis was conducted with an alternate method to account for antihypertensive medication use. In this method, the blood pressure of each medicated hypertensive patient was adjusted upward before the sodium-reduction scenarios were applied. The adjustment factor was based on published estimates of the effect of drug therapy on blood pressure, which included both monotherapy and multi-drug therapy.[31,35] Finally, the values of QALYs saved was recalculated with the upper and lower bounds of dollars per QALY that were identified in the literature.

RESULTS

Prevalence of Hypertension

The baseline prevalence of clinical hypertension calculated by using NHANES data was 32.9% among U.S. adults, which was similar to other estimates.[3,36] Differences in the specific years of data used, how incomplete data were handled, and other inclusion/exclusion criteria could account for the small variations in these estimates. An analysis of the prescription drug data revealed that 69% of people with clinical hypertension were using antihypertensive medications, an this was associated with an increasing trend between 1999 and 2004. These results are also comparable to estimates of antihypertensive medication use in the literature.[35,37]

Table 3 presents the reduction in hypertension prevalence and cases expected from a decrease in population blood pressure attributable to reduced population sodium consumption. A decrease in average population sodium consumption to the recommended daily maximum of 2300 mg/d would reduce the estimated prevalence of adult hypertension to 28% of the population. This translates to 11.1 million fewer cases of hypertension by using projections from the Census Bureau that the adult (i.e., 18 years or older) population will reach 229.5 million people in 2007.[30] Decreasing sodium consumption further to the adequate intake of 1500 mg/d would reduce the prevalence to 25.6% and would result in 16.4 million fewer cases of hypertension.

Savings in Health Care Costs

Table 4 presents the reduction in direct health care costs expected from a decrease in population blood pressure attributable to reduced population sodium consumption. A decrease in average population sodium consumption to the recommended daily maximum of 2300 mg/d may save almost $18 billion health care dollars by reducing hypertension cases by 11 million. Reducing sodium even further to 1500 mg/d may decrease health care costs by $26 billion.

Savings in Quality of Life

Table 5 presents quality-of-life savings expected from reduced population sodium consumption in terms of both QALYs and their monetary value by using the commonly cited dialysis standard of $50,000 per QALY,[27] which we updated to $100,000 per QALY in 2005 dollars for comparability with health care cost savings estimates.

A decrease in average population sodium consumption to the recommended daily maximum of 2300 mg/d may save approximately 312,000 QALYs in 1 year throughout the entire population because of quality-of-life gains from the absence of hypertension and reduced subsequent heart attack and stroke attributable to hypertension. In monetary terms, the value of these QALYs is approximately $32 billion by using the commonly cited dialysis standard for valuing a QALY. However, this standard may not necessarily be the most appropriate one,[26] and using a range of the possible values of QALY from across the literature may present a more realistic picture of possible valuations.

Table 4

Direct Health Care Costs Saved Because of Reduced Population Sodium Consumption

Average Sodium Consumption, mg/d	Direct Health Care Costs Saved in 2005 (billions of dollars)	Sensitivity Analysis (billions of dollars)			
		Dose-Response Lower Bound	Dose-Response Upper Bound	Non-Linear Dose Response	Alternate Medication Adjustment
3400*	—	—	—	—	—
2300	17.8	14.8	20.5	15.6	13.62
1700	23.8	19.9	27.4	26.1	19.19
1500	26.2	21.8	28.8	30.2	21.13
1200	28.3	23.6	31.1	35.2	23.70

* Baseline amount.

To be fully useful QALYs gained must be compared with other policies that are roughly comparable in terms of scope rather than measured by the absolute number QALYs saved by any one intervention. For instance, although saving 312,000 QALYs is a small absolute amount when compared with the size of the U.S. adult population, it compares favorably with the QALYs saved by other key public health interventions. Figure 2 illustrates how an average reduction to 2300 mg per day of sodium consumption across the adult, U.S. population may meet or exceed the quality-of-life savings from other potential population-level, public health policies, such as increasing breast cancer screening and influenza vaccine rates. Cost-effective analysis, which calculates the cost per QALY of each intervention to determine its comparative value, will be an important next step for using these data to inform policy.

Sensitivity Analysis

Alternate assumptions about the sodium–blood pressure relationship were modeled as part of the sensitivity analysis but did not drastically change the overall prevalence, cost, or quality-of-life savings. When this relationship was varied by using the upper and lower bounds of the 95% confidence interval of the dose-response relationship, as well as by using a nonlinear dose-response relationship that was based on results from the DASH-Sodium trial, the savings changed by no more than 15% higher than and lower than the point estimate reported above. The alternate approach described previously to account for use of antihypertensive medications changed the estimates by a larger amount, up to 30% less than the point estimate reported above, with smaller percentage differences for more modest sodium-reduction scenarios (Tables 4 and 5). The biggest potential differences are seen when the value per QALY is varied by using the upper and lower bounds of the large range found in the literature (Table 6),[38] which results in potential savings from $9 to $120 billion per year.

DISCUSSION

Lowering dietary sodium is likely to have substantial financial and health benefits. Considering the need to lower government expenditures for health care, it is worth noting that the projected $18 billion in annual direct health care cost savings would lead to approximately $9 billion in public sector savings, as the public sector accounts for nearly half of national health expenditures.[39] Yet, although savings in medical expenditures are large, they offer only one perspective of the potential benefits; these may be doubled easily when increased quality of life is considered. Although monetizing health improvements can be problematic, the large savings expect-

Table 5

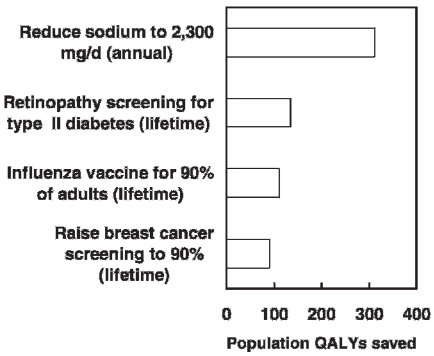
Quality-of-Life Savings Because of Reduced Population Sodium Consumption

Average Sodium Consumption, mg/d	Annual QALYs Saved	Sensitivity Analysis on QALYs Saved*			
		Dose-Response Lower Bound	Dose-Response Upper Bound	Non-Linear Dose Response	Alternate Medication Adjustment
3400†	—	—	—	—	—
2300	312,021	260,439	359,709	273,634	239,160
1700	417,464	350,132	480,235	457,383	336,887
1500	459,337	383,067	505,695	530,397	371,000
1200	496,897	414,600	546,571	618,364	415,991

* QALY indicates quality-adjusted life year.
† Baseline amount.

Figure 2

Comparison of Population Quality-Adjusted Life Years Saved From Different Health Policies*



*Data from Vijan et al., 2000,[47] and Maciosek et al., 2006.[48]

ed from even a conservative estimate of the value of QALYs gained—$32 billion—points to the potentially large impact of an effective sodium-reduction policy in the United States.

Although clinicians can educate their patients about sodium intake, it is very difficult for individuals to reduce sodium intake. Studies estimate that more than 75% of dietary salt intake in the U.S. population comes from processed foods rather than from sources added during cooking or at the table.[12,40] Restaurant foods also contain high amounts of sodium, as the sodium density of restaurant foods was estimated to be 1873 mg per 1000 calories in 1995.[41] Despite these challenges, consumers are also faced with the need to choose lower-sodium–dense foods to account for higher caloric intakes if they wish to reach overall target sodium intakes. Without more accessible information, voluntary actions by companies, or government regulation, consumers may have difficulty reducing sodium consumption on their own. When informational problems are sufficiently severe, regulation may be needed for an efficiently working market. Even voluntary efforts by food processors and restaurants to reduce sodium are difficult to sustain without better information. It is apparent that widespread changes in the food environment, in tandem with continued efforts by clinicians to give appropriate individual advice on sodium intake, are needed to make any progress toward the Health People 2010 objectives. This requirement echoes recent calls for the federal government to address nonmedical determinants of health, which would include the food environment, as it moves towards better public health policy.[42]

A common argument is that population prevention strategies are ineffective, or too costly, or both. Although the medical system has been very effective in reducing the mortality from CVD, it is not clear that increased treatment is a more effective or less costly way to achieve the same benefits as prevention. Despite huge costs and initiatives by both the federal government and private health care delivery systems to improve care, American patients receive about half of recommended medical care processes.[43] Arguably, one the most emphasized targets in clinical settings is blood pressure control, but many patients fail to meet widely accepted goals. In 12 communities, only 57% of hypertensive patients received optimal care, and only 42% had controlled hypertension.[44] Younger patients without cardiac risk factors are at the greatest risk for poor care. To match the decrease in blood pressure from reduced sodium consumption, treatment would have to increase and improve dramatically. In addition, the costs of lowering sodium consumption may be relatively low, considering that the reductions could be accomplished through consumer use of information on labels and at restaurants, by companies voluntarily lowering sodium levels in their products, and/or by government mandates to lower sodium levels in various categories of foods. Future studies should address the costs of specific reduction strategies.

This study is a first step towards quantifying the benefits of sodium reduction, and it should be emphasized that it needs to be combined with evidence on the effectiveness, costs, and benefits of specific strategies for sodium reduction in order to yield concrete, policy-relevant results. In addition, we acknowledge several key limitations of this preliminary study. First, this analysis is based on a cross-sectional model that does not take into account health effects, including quality-of-life effects, over time. A longitudinal model would be much more realistic to simulate the probable impact of any sodium-reduction strategy, both because policies will not start to work instantaneously and because the benefits of lowering blood pressure will

Table 6

Value of QALYs Saved Because of Reduced Population Sodium Consumption*

Average Sodium Consumption, mg/d	Value of Annual QALYs Saved in 2005 (billions of dollars) ($100,000/QALY)	Sensitivity Analysis on Value of QALYs Saved (billions of dollars)	
		Lower Bound ($32,000/QALY)	Upper Bound ($427,000/QALY)
3400†	—	—	—
2300	31.6	8.8	119.0
1700	42.2	11.8	159.3
1500	46.5	13.0	175.2
1200	50.3	14.1	189.6

* QALY indicates quality-adjusted life year.
† Baseline amount.

accrue over the lifetime of individuals. Although the limited scope of this study is less realistic, it nevertheless serves to place a lower bound on the possible benefits of population-level sodium-reduction policies and, thus, should be taken as a conservative and initial approach to explore a gap in the current knowledge. A second drawback in this model was that costs were linked only to changed hypertensive status rather than to any reduction in blood pressure for individuals. In fact, there is a continuous (and nonlinear) relationship between blood pressure and health outcomes, with implications for costs. However, because the published data linking costs and quality-of-life weights to blood pressure only report these parameters for hypertension categories, we conducted the analysis by using the hypertension dichotomy, and we acknowledge its limitations. A third drawback is that there are limitations to some of the measurements in NHANES. The estimates of sodium consumption in NHANES are based on self-reported intake data, which tends to underestimate actual intake. Furthermore, sodium content can vary by producer in the same foods.[45] Although this study estimated average daily intake as 3400 mg, the actual figure may be 4000 mg or greater.[10] In addition, blood pressure measurements can fluctuate within an individual over time on the basis of both internal and external circumstances. Because NHANES measurements were taken in one sitting, it is possible that the hypertension statuses of some people were misclassified. A fourth drawback is that, although the association between sodium intake and blood pressure is well established, the relationship is complex and nuanced depending on biological, health status, behavioral, and demographic characteristics. Our model utilized average relationships between sodium intake and blood pressure and, therefore, may not capture the nuances in this association for some groups or individuals. A fifth drawback is that our model only includes hypertension-related effects of sodium reduction, and this excludes any effects of sodium on costs or health-related quality of life that are not mediated by blood pressure.[46] The sixth drawback is that, because of data restrictions and the lack of a longitudinal model, the measurement of QALYs is very preliminary and is likely to underestimate true quality-of-life benefits. Finally, a multivariate sensitivity analysis to include more of the potential sources of uncertainty in the simulation would be an additional contribution to enhance this study. In particular, given that Medicare did not cover prescription drugs during the study time-frame, the attributable cost figure used in the simulation is likely to be an underestimate.

SO WHAT? Implications for Health Promotion Practitioners and Researchers

Combined with other research, this study provides preliminary support for the assertion that large benefits to society could result from efforts to lower sodium consumption at the population level by modest amounts over time. If these assertions hold true, both researchers and practitioners may find it useful to combine evidence from this study with cost and effectiveness data to answer key policy questions about the value of sodium reduction to society.

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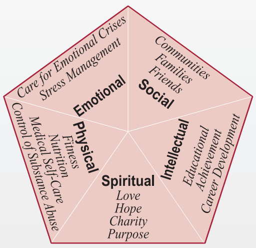

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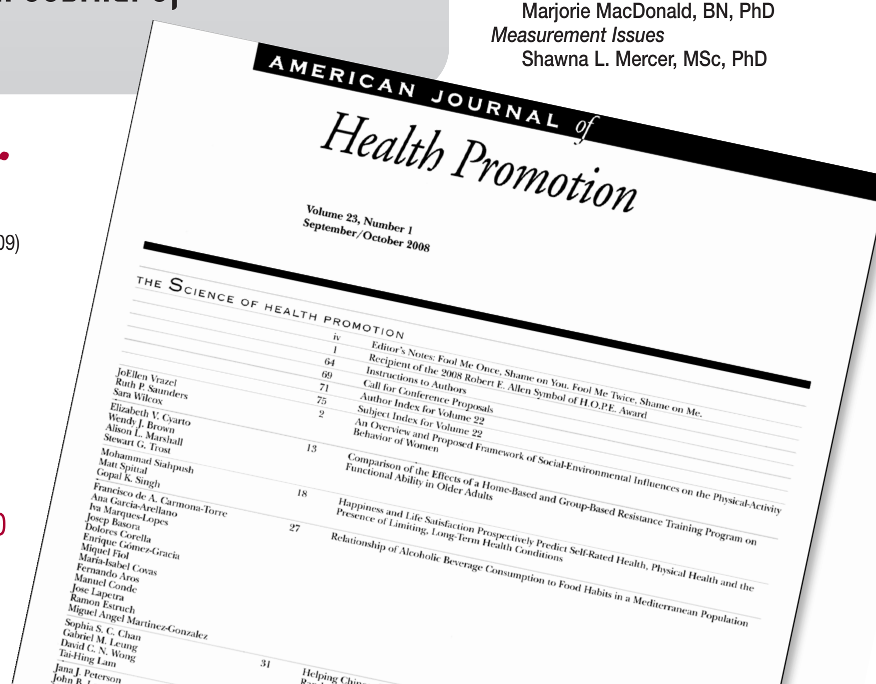
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