ORIGINAL ARTICLE

Projected Effect of Dietary Salt Reductions on Future Cardiovascular Disease

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ABSTRACT

BACKGROUND

The U.S. diet is high in salt, with the majority coming from processed foods. Reducing dietary salt is a potentially important target for the improvement of public health.

METHODS

We used the Coronary Heart Disease (CHD) Policy Model to quantify the benefits of potentially achievable, population-wide reductions in dietary salt of up to 3 g per day (1200 mg of sodium per day). We estimated the rates and costs of cardiovascular disease in subgroups defined by age, sex, and race; compared the effects of salt reduction with those of other interventions intended to reduce the risk of cardiovascular disease; and determined the cost-effectiveness of salt reduction as compared with the treatment of hypertension with medications.

RESULTS

Reducing dietary salt by 3 g per day is projected to reduce the annual number of new cases of CHD by 60,000 to 120,000, stroke by 32,000 to 66,000, and myocardial infarction by 54,000 to 99,000 and to reduce the annual number of deaths from any cause by 44,000 to 92,000. All segments of the population would benefit, with blacks benefiting proportionately more, women benefiting particularly from stroke reduction, older adults from reductions in CHD events, and younger adults from lower mortality rates. The cardiovascular benefits of reduced salt intake are on par with the benefits of population-wide reductions in tobacco use, obesity, and cholesterol levels. A regulatory intervention designed to achieve a reduction in salt intake of 3 g per day would save 194,000 to 392,000 quality-adjusted life-years and $10 billion to $24 billion in health care costs annually. Such an intervention would be cost-saving even if only a modest reduction of 1 g per day were achieved gradually between 2010 and 2019 and would be more cost-effective than using medications to lower blood pressure in all persons with hypertension.

CONCLUSIONS

Modest reductions in dietary salt could substantially reduce cardiovascular events and medical costs and should be a public health target.

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The U.S. diet is high in salt. The Departments of Agriculture and Health and Human Services recommend daily intake of less than 5.8 g of salt (2300 mg of sodium), with a lower target of 3.7 g of salt per day for most adults (persons over 40 years of age, blacks, and persons with hypertension).[1] Despite these guidelines, during the period from 2005 through 2006, the average man in the United States is estimated to have consumed 10.4 g of salt per day and the average woman 7.3 g per day — amounts that exceed those in preceding years.[2]

Reducing dietary salt lowers blood pressure and the risk of cardiovascular disease.[3,4] Accomplishing this reduction is challenging, however, in part because 75 to 80% of the salt in the U.S. diet comes from processed foods, not from salt added during food preparation or consumption.[5,6] Many countries, including Japan, the United Kingdom, Finland, and Portugal, have reduced population-wide salt intake through a combination of regulations on the salt content in processed foods, labeling of processed and prepared foods, public education, and collaboration with the food industry.[7] To explore the potential impact of a modest reduction in dietary salt on population health, we used the Coronary Heart Disease (CHD) Policy Model, a computer simulation of heart disease in U.S. adults 35 to 84 years old, and an extension of the model that is used to assess stroke. We estimated the effects in different segments of the U.S. population, compared these projections with the health benefits expected from a range of other public health and clinical interventions aimed at reducing cardiovascular disease, and analyzed the relative cost-effectiveness of salt reduction as compared with treatment of hypertension with medication.

METHODS

STRUCTURE OF THE MODEL

The CHD Policy Model is a computer-simulation, state-transition (Markov cohort) model of the incidence and prevalence of CHD and of the mortality and costs associated with CHD in U.S. residents 35 years of age or older. The model has been used to describe trends in CHD and the effects of interventions intended to reduce the risk of CHD.[8,9] (For an overview of the model, see the Supplementary Appendix, available with the full text of this article at NEJM.org.) The model has three submodels: demographic–epidemiologic, bridge, and disease-history. The demographic–epidemiologic submodel predicts the incidence of CHD and the rates of death due to causes other than CHD among persons without a history of CHD. The risk of CHD is categorized according to age, sex, and the following six factors: systolic blood pressure, use or nonuse of antihypertensive medications, smoking status, level of high-density lipoprotein (HDL) cholesterol, level of low-density lipoprotein (LDL) cholesterol, and presence or absence of diabetes mellitus. For persons in whom CHD develops, the bridge submodel characterizes the initial CHD event and its sequelae for 30 days. The disease-history submodel then predicts the rate of subsequent CHD events and rates of death from CHD and of deaths not related to CHD among simulated subjects with CHD, with each category stratified according to age, sex, and history of events. The data in the CHD Policy Model are derived from national data sets and calibrated to national event-rate estimates.

In addition to using the standard CHD Policy Model of the entire U.S. population, we created race-specific versions of the model for the black and nonblack populations. We derived the race-specific distribution of risk factors for CHD from the National Health and Nutrition Examination Survey. Beta coefficients derived from the Framingham Heart Study and the Framingham Offspring Study were applied to all three population groups, but the overall age-specific incidence rates of CHD were specific to each population.[10] The average incidence rates for the black and nonblack subpopulations were validated with national data.[11] In sensitivity analyses we also examined beta coefficients specific to the black population.[12] We did not assign a coefficient to use of antihypertensive medications; rather, we used systolic blood pressure or treatment with antihypertensive medications to define the population of persons with hypertension, who might have a greater response to a reduction in dietary salt. Finally, we extended the model to estimate the incidence of stroke using beta coefficients derived from the Framingham Heart Study and the Framingham Offspring Study and published rates on the incidence of stroke.[13,14]

Modeling Approach and Underlying Assumptions

We assumed that the effect of salt reduction on blood pressure reduction was linear over the range of 0 to 3 g per day.[15] We used a lower estimate for the effect of salt reduction on systolic blood pressure on the basis of the findings of a large meta-analysis[3,16] and used a higher estimate for this effect on the basis of data from clinical trials.[17,18] We modeled an accentuated response to salt reduction among blacks, persons with hypertension, and persons 65 years of age or older (Table 1).[17,19-22] We compared the effects of a salt-restricted diet on numbers of CHD events with the effects of other interventions aimed at reducing cardiovascular risk by modeling a 50% reduction in smoking and environmental tobacco exposure,[23] a 5% reduction in body-mass index among obese adults,[8] treatment of persons at low or intermediate risk with statins in accordance with the guidelines in the Adult Treatment Panel III of the National Cholesterol Education Program,[9] and treatment of hypertension as described in the Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial (ALLHAT; ClinicalTrials.gov number, NCT00000542).[24,25]

We conducted simulations for the entire U.S. population and for black and nonblack subgroups and estimated annual reductions in the incidence of CHD, new and recurrent myocardial infarctions, the incidence of stroke, and death from any cause as a result of reductions in dietary salt for the entire population and for subgroups defined according to age, sex, and race. We projected annual cost savings in health care and annual gains in quality-adjusted life years (QALYs) that would result from an intervention to reduce salt for the entire U.S. population and for Medicare enrollees, on the basis of the World Health Organization estimate that the cost of such a national effort would be $1 per person annually.[26] We made the same projections for population-wide treatment of hypertension with antihypertensive medications.[25] We also report the cumulative costs and effectiveness for a gradual introduction of the intervention over the decade from 2010 through 2019.

Sensitivity Analyses

We used Monte Carlo simulations to estimate the uncertainty of our projections for both the high and low estimates of the effects of salt reduction on systolic blood pressure. Beta coefficients for the association of systolic blood pressure, LDL and HDL cholesterol, and diabetes with both CHD events and deaths not associated with CHD were assumed to have a normal probability distribution, with standard errors derived from the fitted regression. We generated covariance matrixes for each of these beta coefficients. On the basis of the evidence of minimal correlation between factors, we assumed that the effects were independent. For each simulation, we report the mean

Table 1. Estimated Changes in Systolic Blood Pressure Associated with Reductions in Dietary Salt.*

Group	Salt Reduction, 1 g/day		Salt Reduction, 3 g/day		Reference No.
	Low Estimate of SBP Decrease	High Estimate of SBP Decrease	Low Estimate of SBP Decrease	High Estimate of SBP Decrease	
	mm Hg				
Entire U.S. population					
Persons with hypertension†	1.20	1.87	3.60	5.61	3, 15
Persons ≥65 yr old	1.20	1.87	3.60	5.61	17, 19–22
All others	0.60	1.17	1.80	3.51	3, 15
Black subpopulation					
Persons with hypertension†	1.80	3.03	5.40	9.10	3, 17, 19–22
Persons ≥65 yr old	1.20	1.87	3.60	5.61	17, 19–22
All others	1.20	1.87	3.60	5.61	17, 19–22

* SBP denotes systolic blood pressure.
† Hypertension was defined as a systolic blood pressure of 140 mm Hg or higher, a diastolic blood pressure of 90 mm Hg or higher, or use of an antihypertensive medication.

(±SE) for 1000 simulations. We conducted sensitivity analyses in which we varied the effect of salt reduction on changes in cardiovascular risk on the basis of estimates suggesting that the risk of cardiovascular disease associated with blood pressures lowered by means of salt reduction or medication is not as low as the risk associated with similar, naturally occurring blood pressures.[27,28]

RESULTS

A population-wide reduction in dietary salt of 3 g per day (1200 mg of sodium per day) is projected to reduce the annual number of new cases of CHD by 60,000 to 120,000, stroke by 32,000 to 66,000, and myocardial infarction by 54,000 to 99,000 and to reduce the annual number of deaths from any cause by 44,000 to 92,000. Since the relationship between reductions in salt and the projected declines in event rates is linear over the range examined, even a more modest reduction of 1 g of salt per day is projected to result in large declines in annual rates of cardiovascular events and deaths (with new cases of CHD declining by 20,000 to 40,000, new and recurrent cases of myocardial infarction by 18,000 to 35,000, new cases of stroke by 11,000 to 23,000, and deaths from any cause by 15,000 to 32,000).

All adult age groups, both sexes, and blacks and nonblacks would be expected to benefit from reductions in salt intake (Fig. 1). The anticipated relative benefits among blacks would be greater

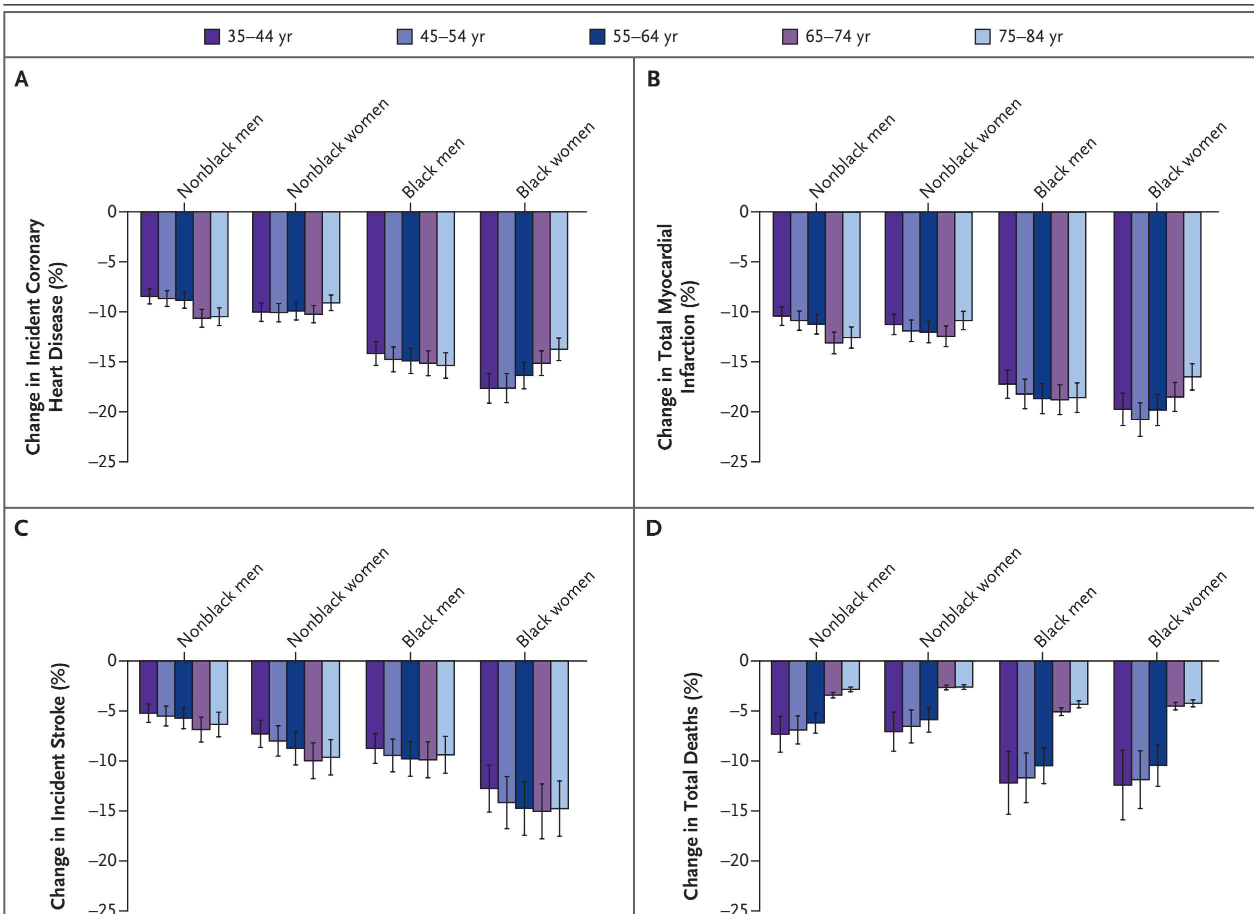

Figure 1. Projected Annual Reductions in Cardiovascular Events Given a Dietary Salt Reduction of 3 g per Day in Black Men, Black Women, Nonblack Men, and Nonblack Women, According to Age Group.

Panel A shows changes in the incidence of coronary heart disease, Panel B changes in the rates of new and recurrent myocardial infarctions, Panel C changes in the incidence of stroke, and Panel D changes in the rate of death from any cause. The projections are based on a reduction in dietary salt of 3 g per day and on the high estimate for the effect of salt reduction on systolic blood pressure. Total myocardial infarction includes new and recurrent myocardial infarctions. I bars indicate standard errors of the Monte Carlo simulation.

than those among nonblacks across all age groups and both sexes. The projected reductions in stroke would be greater among women than among men, with rates decreasing by 9 to 15% among black women and by 5 to 9% among nonblack women. All age groups would be expected to benefit, with middle-aged and older populations projected to have larger relative reductions in the incidence of CHD and in rates of new and recurrent myocardial infarction and stroke. A large relative reduction in mortality is projected for young and middle-aged adults, with mortality rates among blacks between 35 and 64 years of age reduced by 7 to 11% and those among nonblacks in this age range reduced by 3 to 6%.

SENSITIVITY ANALYSES

If a lower blood pressure achieved through reduced salt intake is not as advantageous as the same blood pressure without such intervention, the expected health benefit of salt reduction will be decreased (Table 2). If persons 65 years of age or older have the same degree of salt sensitivity as those younger than 65 years of age, the total estimated benefits of salt reduction would also be somewhat decreased. If blacks have no greater salt sensitivity than nonblacks, the magnitude of the anticipated effects on blacks will be reduced, but there will still be greater reductions in cardiovascular events and deaths among blacks because they have a higher prevalence of hypertension.

COMPARISON WITH OTHER INTERVENTIONS

In a projection assuming a reduction in dietary salt of 3 g per day calculated using the high estimate for the effects of salt reduction on systolic blood pressure, the expected reductions in cardiovascular events would be similar in magnitude to

Table 2. Projected Estimates of Annual Reductions in Rates of Cardiovascular Disease with a Dietary Salt Reduction of 3 g per Day, in the Main Simulation and According to Various Assumptions about Differential Salt Sensitivity in the Sensitivity Analyses.*

Group	Incidence of CHD		Total MI†		Incidence of Stroke		Death from Any Cause	
	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
	reduction in rate per 10,000 persons (%)‡							
Main simulation								
U.S. population	4.7±0.4 (6.1)	8.3±0.8) (10.7)	3.7±0.3 (7.7)	6.2±0.6 (12.8)	2.4±0.3 (5.2)	3.9±0.5 (8.2)	3.3±0.5 (2.7)	5.4±0.8 (4.4)
Nonblack population subgroup	4.3±0.4 (6.1)	7.0±0.6 (9.8)	3.4±0.3 (7.7)	5.3±0.4 (12.0)	2.2±0.3 (5.1)	3.4±0.5 (8.0)	3.1±0.4 (2.7)	4.9±0.7 (4.3)
Black population subgroup	7.9±0.7 (9.8)	12.6±1.0 (15.8)	5.8±0.5 (11.8)	9.3±0.7 (18.7)	4.2±0.5 (7.7)	6.7±0.9 (12.4)	5.3±0.7 (4.4)	8.5±1.2 (7.0)
Sensitivity analyses								
U.S. population								
Diminished risk reduction with blood-pressure lowering§	2.8±0.3 (4.1)	4.6±0.4 (6.6)	2.5±0.2 (5.2)	4.0±0.3 (8.3)	1.6±0.2 (3.5)	2.6±0.3 (5.5)	2.3±0.3 (1.8)	3.6±0.5 (2.9)
No increased salt sensitivity with advanced age	4.5±0.4 (5.9)	7.3±0.6 (9.6)	3.5±0.3 (7.2)	5.6±0.5 (11.5)	2.2±0.3 (4.7)	3.6±0.5 (7.6)	3.2±0.4 (2.5)	5.2±0.7 (4.1)
Black subpopulation								
No increased salt sensitivity	5.2±0.5 (6.5)	8.2±0.7 (10.3)	4.0±0.3 (8.0)	6.1±0.5 (12.4)	2.8±0.4 (5.2)	4.4±0.6 (8.1)	3.5±0.5 (2.9)	5.5±0.8 (4.6)
Black race–specific beta coefficients¶	6.4±2.8 (8.0)	10.0±4.2 (12.5)	4.6±2.0 (9.0)	7.0±2.9 (13.9)	4.2±0.6 (7.7)	6.8±0.9 (12.5)	4.7±1.2 (3.8)	7.4±1.8 (6.1)

* Plus–minus values are means ±SE from the Monte Carlo simulations. CHD denotes coronary heart disease, and MI myocardial infarction. Results based on a dietary salt reduction of 1 g per day are available with the full text of this article at NEJM.org.
† Total myocardial infarction includes new and recurrent myocardial infarctions.
‡ Rates for the nonblack and black populations were adjusted in accordance with the age of the U.S. population.
§ The cardiovascular benefit for a person with blood pressure that was lowered by reducing dietary salt was assumed to be equivalent to two thirds of the benefit for a person whose natural blood pressure was at that level.[27,28]
¶ The black race–specific beta coefficients used for all CHD risk factors are based on a published analysis from the Atherosclerosis Risk in Communities study.[12]

or greater than those projected for interventions targeting tobacco, obesity, primary prevention with statins, and pharmacologic treatment of hypertension, based on simulations for the same time frame and overall population (Table 3). For example, a reduction in dietary salt of 3 g per day would have approximately the same effect on rates of CHD events as a 50% reduction in tobacco use, a 5% reduction in body-mass index among obese adults, or the use of statins to treat persons at low or intermediate risk for CHD events. Salt reduction would have a much greater benefit with respect to stroke prevention than these other interventions. A population-wide reduction of salt intake of 3 g per day is expected to result in the same reduction in death rates as the use of medical treatment to control hypertension in all persons with the condition.

COST-EFFECTIVENESS

A national effort to decrease salt consumption by 3 g per day would result in an estimated annual gain of 194,000 to 392,000 QALYs and estimated savings of $10 billion to $24 billion in health care costs. Even if salt targets were achieved gradually over the years 2010 through 2019 (Table 4) and a reduction in dietary salt of only 1 g were achieved only by the end of the decade, such an intervention is expected to result in cost savings. A salt-reduction strategy is projected to compare favorably with the provision of antihypertensive therapy for all persons with hypertension — a strategy that would result in more QALYs gained but at a cost of $6,000 to $26,000 for each additional QALY. Even if the federal government were to bear the entire cost of a regulatory program designed to reduce salt consumption, the government would still be expected to realize cost savings for Medicare, saving $6 to $12 in health care expenditures for each dollar spent on the regulatory program. The strategy of providing antihypertensive medications for all persons with hypertension would still be cost-effective if it were added to a successful program of population-wide

Table 3. Projected Estimates of Comparative Effect of Various Population Interventions on Annual Reductions in Cardiovascular Events.*

Intervention	Incidence of CHD	Total MI†	Incidence of Stroke	Death from Any Cause
	reduction in absolute number of events (% change from expected)			
Salt reduction				
1 g/day				
Low estimate	22,000±2000 (2.0)	20,000±1800 (2.6)	13,000±1800 (1.7)	17,000±2400 (0.9)
High estimate	37,000±3300 (3.3)	32,000±2900 (4.2)	20,000±2900 (2.7)	28,000±3800 (1.4)
2 g/day				
Low estimate	44,000±4000 (4.0)	39,000±3500 (5.1)	25,000±3500 (3.4)	34,000±4600 (1.7)
High estimate	71,500±6300 (6.4)	62,500±5400 (8.1)	40,000±5400 (5.3)	55,000±7500 (2.8)
3 g/day				
Low estimate	66,000±5800 (5.9)	58,000±5100 (7.6)	37,000±5100 (5.0)	51,000±7100 (2.6)
High estimate	110,000±9200 (9.6)	92,000±7800 (12.0)	59,000±8100 (7.8)	81,000±11,000 (4.1)
Smoking cessation‡	41,000±10,000 (3.7)	92,000±14,000 (11.9)	32,000±13,000 (4.4)	84,000±9300 (4.3)
Weight loss§	59,000±3500 (5.3)	61,000±3200 (8.0)	5600±600 (0.7)	36,000±2000 (2.0)
Statin therapy for primary prevention¶	52,000±5600 (5.3)	17,000±1800 (2.9)	6600±200 (0.9)	5400±540 (0.3)
Pharmacologic treatment of hypertension‖	100,000±11,000 (9.3)	100,000±9700 (13.1)	69,000±11,000 (9.3)	80,000±10,000 (4.1)

* Plus–minus values are means ±SE from the Monte Carlo simulations. CHD denotes coronary heart disease, and MI myocardial infarction.
† Total myocardial infarction includes new and recurrent myocardial infarctions.
‡ Smoking cessation was defined as elimination of 50% of use of or exposure to tobacco.
§ Weight loss was defined as a 5% reduction in body-mass index in an obese adult.
¶ Cholesterol treatment for primary prevention was defined according to the National Cholesterol Education Program Adult Treatment Panel III guidelines as treatment with statins in persons with a 10-year risk of CHD of less than 20%.
‖ Pharmacologic treatment of hypertension was defined on the basis of treatment of all persons with hypertension to the degree described in the Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial.[24]

Table 4. Projected Estimates of the Cost and Effectiveness of Salt Reduction and Hypertension Treatment Annually and Cumulatively, 2010–2019.*

Intervention	U.S. Population					Medicare Population				
	Cost of Intervention (billions of dollars)	Reduction in Health Care Costs (billions of dollars)†	Gain in QALYs (thousands)	Cost per QALY Gained (dollars)‡	Cost Saved per Dollar Spent on Intervention (dollars)‡	Cost of Intervention (billions of dollars)	Reduction in Health Care Costs (billions of dollars)†	Gain in QALYs (thousands)	Cost per QALY Gained (dollars)‡	Cost Saved per Dollar Spent on Intervention (dollars)‡
Reduction in dietary salt										
1 g/day										
Low estimate	0.3§	4.1±0.8	75±9	Cost savings	15.4±3.0	0.3	0.7±0.1	46±4	Cost savings	2.5±0.2
High estimate	0.3§	7.0±1.4	120±15	Cost savings	26.1±5.2	0.3	1.0±0.1	72±6	Cost savings	3.8±0.4
3 g/day										
Low estimate	0.3§	12.1±2.4	220±26	Cost savings	45.2±9.1	0.3	2.0±0.2	135.0±12	Cost savings	7.3±0.7
High estimate	0.3§	20.4±4.1	350±42	Cost savings	76.0±15.4	0.3	3.0±0.3	208.3±19	Cost savings	11.1±1.1
Hypertension treatment¶	19.5±0.1	14.2±2.7	360±42	15,800±9,900	0.7±0.1	9.3±0.03	3.4±0.3	260±24	23,300±3,600	0.4±0.04
Gradual reduction in dietary salt, 2010–2019‖										
1 g/day										
Low estimate	2.7§	18.9±3.8	220±27	Cost savings	7.0±1.4	2.7	4.3±0.4	220±20	Cost savings	1.6±0.2
High estimate	2.7§	31.6±6.5	350±43	Cost savings	11.8±2.4	2.7	6.1±0.6	240±21	Cost savings	2.3±0.2
3 g/day										
Low estimate	2.7§	56.9±11.5	650±78	Cost savings	21.2±4.3	2.7	12.1±1.2	420±37	Cost savings	4.5±0.5
High estimate	2.7§	95.6±19.6	1000±127	Cost savings	35.6±7.3	2.7	18.5±1.9	665±58	Cost savings	6.9±0.7

* Plus–minus values are means ±SE from the Monte Carlo simulations. QALY denotes quality-adjusted life years.

† The reduction in health care costs is for the U.S. population of persons 35 years of age or older. Costs were discounted at 3% over the course of the decade.

‡ These values represent the ratio of the cost of the intervention in dollars to the number of QALYs gained as a result of the intervention. In some cases this calculation results in a negative number because the savings in health care costs as a result of the intervention are greater than the total cost of the intervention itself. In these cases, the intervention is described as cost saving. The column "Cost saved per dollar spent on the intervention" provides an estimate of the magnitude of these savings.

§ The cost of a population-wide regulatory approach to salt reduction is estimated at $1 per person per year, discounted at 3% over the course of the decade, according to the World Health Organization, and the total U.S. population was 306,913,687 persons as of July 2009, according to the U.S. Census.

¶ Hypertension treatment was defined on the basis of treatment of all persons with hypertension to the degree described in the Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial[24]; the cost-effectiveness analysis was also based on the results of this trial.[25]

‖ The gradual reduction from 2010 to 2019 represents a cumulative effect, with one third of the total reduction achieved in 2012, another third in 2015, and the final third in 2019.

dietary salt reduction, but the number of persons requiring treatment with such medications would be markedly reduced; the number of women with hypertension would be reduced by 16 to 24%, and the number of men by 22 to 34%, with a savings of $3 billion to $6 billion annually in the cost of treating hypertension.

DISCUSSION

Despite evidence linking salt intake to hypertension and cardiovascular disease, dietary salt intake in the U.S. is on the rise. This worsening trend has led to calls for population-wide interventions to reduce salt in the U.S. diet[29] — interventions already adopted in other countries.[7] Our findings provide evidence to support these calls for action. Our postulated dietary reduction of 3 g of salt per day, which is within the range targeted by other developed countries, is projected to benefit the entire U.S. population and yield substantial reductions in morbidity, mortality, and health care costs. The population-wide benefits of salt reduction are similar in magnitude to the benefits that would accrue from other public health and clinical interventions and would reduce costs even if only a more modest reduction of 1 g of salt per day were achieved gradually over time.

Changes in behavior are notoriously difficult to achieve, and attempts to lower dietary salt intake on an individual basis have largely proved to be ineffective.[5] Nevertheless, cholesterol levels in the U.S. population fell before the widespread use of cholesterol-lowering medications, and smoking rates have fallen substantially as the result of a combination of regulatory, public health, and individual approaches to smoking cessation. The large and growing burden of hypertension, despite improved medical therapies,[30] and increased awareness that dietary salt reduction can help prevent and treat hypertension reinforce the urgent need for dietary change.

There is a considerable body of literature linking higher salt intake with higher blood pressure and increased cardiovascular risk,[16,31] and randomized trials have shown that a diet that is lower in salt reduces both blood pressure[17,32] and cardiovascular risk.[31] Despite concerns about the accurate assessment of salt intake, the difficulty of adhering to a low-salt diet, and the theoretical increase in the risks associated with diets that are very low in salt, several large meta-analyses and reports from the Institute of Medicine[3,5,16,27,34] have concluded that reducing dietary salt would lower blood pressure and reduce cardiovascular risk. Professional societies, including the American Medical Association, the American Heart Association, the American Society of Hypertension, and the World Health Organization, have endorsed population-wide efforts to reduce salt intake.

The results of our study are similar to those of other analyses[35,36] and extend the findings of these analyses in important ways. We incorporated updated information on distributions of the prevalence of cardiovascular risk factors, particularly hypertension, in the entire U.S. population and in the black and nonblack subpopulations. We considered current levels of hypertension treatment, treatment and control of other cardiovascular risk factors, and competing and ongoing risks among persons in whom death was averted. Our expectations concerning the cardiovascular benefits of salt reduction are similar to those anticipated for established public health targets such as reducing tobacco use, obesity, and levels of LDL cholesterol. Targeted interventions have very large per-person effects, but their benefits are restricted to the smaller numbers of affected persons who are at increased risk. Lowering salt in the U.S. diet would result in small but measurable reductions in blood pressure across the entire U.S. population, thereby reducing rates of cardiovascular disease among all adults at risk.

A national regulatory effort to lower dietary salt intake would be cost-saving even if only a modest salt reduction were achieved after a decade. If a population-wide approach to lowering salt intake were sponsored by the federal government, the savings in expenditures for Medicare, the major federally sponsored health care program, would be greater than the cost of the regulatory intervention itself, even without the incremental benefits for younger persons not covered by Medicare. Some costs, such as those borne by the food industry in reformulating processed foods, are not considered in these analyses. However, as salt intake is reduced, people appear to prefer food with less salt,[15] a phenomenon that is probably related to the accommodation of taste receptors over the course of weeks to months.[37] In the United Kingdom, a population-wide reduction in dietary salt of 10% was achieved in 4 years[38] without a reduction in sales of the food products included in the initial effort and without consumer complaints about taste. The magnitude of the health benefit suggests that salt should be a regulatory target of the Food and Drug Administration, which currently designates salt as a food additive that is "generally regarded as safe."[29]

We projected that similar levels of salt reduction may be of proportionately greater benefit to certain subpopulations. Blacks have high rates of hypertension and cardiovascular diseases that contribute to racial disparities in mortality[39]; the benefits of a diet lower in salt could narrow these disparities. Similarly, women would have a proportionately greater benefit than men because women have a higher lifetime risk of stroke.[11] Young and middle-aged adults could benefit because of the relative importance of blood-pressure elevations in younger adults without other major risk factors for cardiovascular disease. Blood-pressure elevations in young adulthood increase the likelihood that atherosclerosis[9] and other illnesses will develop by middle age,[40] yet younger adults with hypertension are less likely to receive treatment for it.[41] The benefits of salt reduction may be even greater than we have projected if hypertension is completely prevented or its onset delayed by lowering salt intake even earlier, during childhood and adolescence.[42]

Projections such as ours are limited by any uncertainty concerning the data entered into the model. We modeled the effects of salt reduction on blood pressure in accordance with published data and assumed that the health benefits of salt reduction were mediated through these blood-pressure reductions. We did not account fully for possible effects of salt reduction that are unrelated to control of blood pressure — for example, potential improvements in outcomes for the increasing numbers of patients with heart failure or prevention of other serious conditions, such as end-stage renal disease. Our estimates of the differential effects of salt reduction according to age and race were extrapolated from clinical-trial data, and there is uncertainty about these effects on the total population; however, sensitivity analyses suggest that our primary findings are not dependent on variations in these assumptions. We modeled only the linear effects of reduced salt intake on reductions in blood pressure. It has been suggested that these effects may be nonlinear,[17] with greater reductions in blood pressure at lower levels of salt intake; such an assumption would result in larger reductions in cardiovascular disease than we present here.

Even with these limitations, our simulations suggest that modest reductions in dietary salt would yield substantial health benefits across the U.S. population of adults by lowering rates of cardiovascular events and death and reducing medical costs. Our findings underscore the need for an urgent call to action that will make it possible to achieve these readily attainable cardiovascular benefits.

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