Financial Analysis; Nutrition

Potential Health Benefits and Medical Cost Savings From Calorie, Sodium, and Saturated Fat Reductions in the American Diet

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Abstract

Purpose. *Model the potential national health benefits and medical savings from reduced daily intake of calories, sodium, and saturated fat among the U.S. adult population.*

Design. *Simulation based on secondary data analysis; quantitative research. Measures include the prevalence of overweight/obesity, uncontrolled hypertension, elevated cholesterol, and related chronic conditions under various hypothetical dietary changes.*

Setting. *United States.*

Subjects. *Two hundred twenty-four million adults.*

Measures. *Findings come from a Nutrition Impact Model that combines information from national surveys, peer-reviewed studies, and government reports.*

Analysis. *The simulation model predicts disease prevalence and medical expenditures under hypothetical dietary change scenarios.*

Results. *We estimate that permanent 100-kcal reductions in daily intake would eliminate approximately 71.2 million cases of overweight/obesity and save $58 billion annually. Long-term sodium intake reductions of 400 mg/d in those with uncontrolled hypertension would eliminate about 1.5 million cases, saving $2.3 billion annually. Decreasing 5 g/d of saturated fat intake in those with elevated cholesterol would eliminate 3.9 million cases, saving $2.0 billion annually.*

Conclusions. *Modest to aggressive changes in diet can improve health and reduce annual national medical expenditures by $60 billion to $120 billion. One use of the model is to estimate the impact of dietary change related to setting public health priorities for dietary guidance. The findings here argue that emphasis on reduction in caloric intake should be the highest priority. (Am J Health Promot 2009;23[6]:412–422.)*

Key Words: Diet, Obesity, Uncontrolled Hypertension, High Cholesterol, Health Promotion, Chronic Conditions, Cost of Illness, Prevention Research. Manuscript format: research; Research purpose: intervention testing/program evaluation; Study design: nonexperimental; Outcome measure: overweight/obesity, hypertension, cholesterol, disease, medical costs; Setting: United States; Health focus: obesity, uncontrolled hypertension, high cholesterol; Strategy: improved diet; Target population: adults; Target population circumstances: overweight, uncontrolled hypertension, high cholesterol

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This manuscript was submitted September 30, 2008; revisions were requested December 18, 2008 and February 12, 2009; the manuscript was accepted for publication February 16, 2009.

0890-1171/09/$5.00 + 0

INTRODUCTION

It is well documented that excess body weight, hypertension, and hyperlipidemia are major contributors to the nation's skyrocketing medical costs.[1–15] It is also well established that these conditions can be modified or prevented by dietary changes.[16–19] What has not been previously documented is the impact that dietary changes would have on reducing or eliminating these conditions and on the magnitude of their contribution to the national health care burden.

Although clinical trials have demonstrated the beneficial effects of improved diet on overweight, high blood pressure, and elevated cholesterol levels, studies of sufficient size and duration to properly assess the medical savings the nation would achieve have not been done. Such a prospective study may never be feasible because of the high cost and study design complexities. The U.S. medical research database does, however, encompass invaluable resources that have defined the risk of selected common medical disorders based on dietary intake as well as the yearly per patient costs for treating each of these conditions. We utilized these resources to generate a best estimate of the individual cost savings for these three conditions as well as the total savings that would be realized.

METHODS

Conceptual Model

We developed the Nutrition Impact Model to estimate the potential health benefits of weight loss for obese and overweight adults, of reduced blood pressure for hypertensive adults, and of decreased low density lipoprotein cholesterol (LDL-C) for adults with elevated blood cholesterol. To establish a baseline, we used data from the 1999 to 2004 National Health and Nutrition Examination Survey (NHANES; N = 17,061).[20] The adult population was divided into 480 unique risk groups across five dimensions: age (18–44, 45–54, 55–64, 65–74, 75+); gender; four weight categories defined[19] using body mass index (BMI)—normal weight ($18.5 < \text{BMI} < 25$), overweight ($25 \leq \text{BMI} < 30$), obese class I ($30 \leq \text{BMI} < 35$), and obese classes II and III ($\text{BMI} \geq 35$); three blood pressure categories defined[16] using systolic (SBP) and diastolic (DBP) blood pressure—normal pressure (SBP < 120 mm Hg and DBP < 80 mm Hg), prehypertension ($120 \leq \text{SBP} < 140$ and $80 \leq \text{DBP} < 90$), and hypertension ($\text{SBP} \geq 140$ or $\text{DBP} \geq 90$); and four cholesterol levels defined[21] using LDL-C level—optimal (LDL-C < 100 mg/dL), near optimal ($100 \leq \text{LDL-C} < 130$), borderline high ($130 \leq \text{LDL-C} < 160$), and high ($\text{LDL-C} \geq 160$). Using data from NHANES and the 2000 to 2004 Medical Expenditure Panel Survey (MEPS),[22] we estimated the prevalence rates for an array of chronic conditions (see Appendix for diagnosis codes used to identify these conditions) to establish the health risk profile for each unique risk group at baseline.

Authoritative scientific reports and peer-reviewed literature (described below) were used to quantify the relationships between dietary change and BMI, SBP/DBP, and LDL-C and between these same factors and disease risk.[18,23–27] We model alternate hypothetical scenarios associated with improved nutritional intake. Each hypothetical scenario produces a new health equilibrium for the population, suggesting what the healthcare utilization would be for the population with lower rates of overweight/obesity, hypertension, and high LDL-C.

The model does not indicate how long it would take for the nation to reach a new health equilibrium; to be conservative we choose to model the long-term health benefits of improved nutritional intake. Intentional weight loss can improve or prevent many cardiovascular risks (e.g., type 2 diabetes, dyslipidemia, hypertension, and inflammation). Moreover, these metabolic benefits are often found quickly after only modest weight loss (about 5% of initial weight) and continue to improve in a monotonic fashion with increasing weight loss.[26,28,29] Lifestyle dietary and activity modifications, which resulted in modest (5%) weight loss, decreased the 4- to 6-year cumulative incidence of diabetes by as much as 50% in both men and women who were overweight or obese and had impaired glucose tolerance.[30] Weight loss decreases serum LDL-C and triglyceride concentrations,[26] with greatest relative improvements reportedly occurring within the first 2 months of weight loss.[31] Within only 1 year of weight loss, diabetes patients participating in clinical trails witnessed significant improvement in hemoglobin A1c (HbA1c), SBP, DBP, triglycerides, and high density lipoprotein cholesterol.[32] Numerous clinical trials have reported that weight loss (mostly through diet and exercise) is accompanied by reduction in both SBP and DBP in a dose-response fashion.[33]

Despite the clear dose-response relationship between weight loss and reduction in cardiovascular risks, to our best knowledge, there is no consensus from prospective studies to date on whether intentional weight loss increases or decreases all-cause or cardiovascular mortality.[34–36]

Ultimately, the change in disease cases that would occur with a defined dietary change was quantified by modeling the proportional change in baseline disease prevalence rates for each unique risk group associated with collective change in body weight, blood pressure, and cholesterol levels. The annual cost per disease case was estimated by multivariate regression analysis using MEPS (See Appendix for ordinary least squares regression specification and results used to estimate annual medical cost by condition and age group). The resulting disease rates and costs were extrapolated to the 2007 U.S. population by demographic group, and converted to 2007 dollars using the consumer price index medical component.[37]

Assumptions

The parameters for the Nutrition Impact Model were based on authoritative peer-reviewed studies and analysis of widely used national databases. To our knowledge, there are no empirical studies that document a change in national medical costs resulting from a change in dietary habits among the general population. Our model is based entirely on studies that show an association between change in diet and change in risk factors (body weight, blood pressure, and LDL-C), studies and original analysis that show an association between change in these factors and risk of chronic disease, and original analysis that shows the association between presence of chronic disease and annual medical expenditures.

Caloric intake and body weight. Using estimates published in 2005 by the Institute of Medicine (IOM), the impact of a sustained reduction in daily caloric intake until a new weight equilibrium is reached was modeled.[18] The IOM report contains equations describing the estimated energy requirement (EER) for men and women of a given age, weight, height, and physical activity level (PAL) developed from data on total daily energy expenditure measured by the doubly labeled water technique.[38]

For male adults:

$$\text{EER} = 662 - \left(9.53 \times \text{age}_{\text{y}}\right) + \text{PAL} \times \left(15.91 \times \text{weight}_{\text{kg}} + 539.6 \times \text{height}_{\text{m}}\right)$$

For female adults:

$$\text{EER} = 354 - \left(6.91 \times \text{age}_{\text{y}}\right) + \text{PAL} \times \left(9.36 \times \text{weight}_{\text{kg}} + 726 \times \text{height}_{\text{m}}\right)$$

Reduced daily caloric intake below the EER results in weight loss, until a new equilibrium is reached in which

Table 1

For male adults	$\text{Total Weight Reduction}_{kg} = \dfrac{\text{Sustained Reduction in Daily Caloric Intake}_{kcal}}{\text{PAL} \times 15.91}$	(1.1)
For female adults	$\text{Total Weight Reduction}_{kg} = \dfrac{\text{Sustained Reduction in Daily Caloric Intake}_{kcal}}{\text{PAL} \times 9.36}$	(1.2)
	$\Delta \text{LDL}_{(mg/dl)} = \beta_{FL} \times \Delta \text{Fat}_{(\%energy)} = 1.5 \times \left(\dfrac{9.25_{kcal/g} \times \Delta \text{Fat}_g}{\text{EER}_{(age,gender,height,weight)}} \right),$	(1.3)

EER equals the new daily caloric intake. Dividing caloric intake reduction by the product of corresponding PAL and weight coefficients (15.91 for men and 9.36 for women) from the EER equations yields total weight loss from diet modification. (Equations 1.1-1.2; see Table 1). (see Appendix for the mathematical derivation of this relationship and examples of associated weight loss from reduced caloric intake.)

The IOM PAL coefficients (1.25 for male and 1.27 for female) associated with moderate physical activity were utilized. These coefficients produce more conservative estimates of weight loss than would be obtained using low-activity (1.11 for male and 1.12 for female) or sedentary lifestyle (1.0 for both genders) physical activity parameters.

Sodium intake and blood pressure. The relationship between sodium intake and blood pressure used was 3.3/1.6 mm Hg SBP/DBP reduction resulting from a 100-mmol sodium reduction.[23] For comparison, a sensitivity analysis was conducted using DASH diet study estimates of a blood pressure reduction of 9.0/6.0 mm Hg for the population aged 44 and under and 8.0/3.8 mmHg for the population aged 45 and over associated with a 100 mmol sodium reduction.[24]

Saturated fat intake and LDL-C level. The reduction in saturated fat intake was measured by the reduction in energy content from fat intake (9.25 kcal/g) as a percentage of total baseline energy intake. Averaging the results from three studies produces the response curve[18] (Equation 1.3; see Table 1).

where β_{FL} represents the impact of change in saturated fat intake on LDL-C. NHANES data on observed height, ideal weight (weight driven to a BMI of 18–24.9 kg/m^2), age, and gender to predict total energy intake for each population group using the EER equation from the IOM report were used. In this model, the simulated benefit of reduced saturated fat intake assumed a constant calorie intake and BMI while reducing LDL-C to below 100 mg/dL.

Analysis

To model the change in prevalence of chronic conditions associated with overweight and obesity, we synthesized the peer-reviewed literature to estimate the increased risk of comorbidities associated with overweight and obesity. Using average body weight and the disease relative risk ratios for each weight category, we calculated percentage reduction in disease risk per gram reduction in body weight. Using the above assumptions, the model attributes a reduction of 0.68/0.34 mm Hg and a 0.02 mmol/L (0.78 mg/dL) decrease in LDL-C for each kilogram of weight loss.[26,27]

We used findings reported by the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure from a meta-analysis using mortality data to estimate the decline in disease risk associated with improved blood pressure.[16,39] To model the change in cardiovascular disease risk associated with lower LDL-C, we used a relative risk reduction in coronary heart disease of about 30% for every 30 mg/dL reduction in LDL-C greater than 100 mg/dL.[17] We based the response relationship between LDL-C and stroke on Law's reported 20% reduction of stroke cases for each 1 mmol/L (39 mg/dL) reduction in LDL-C caused by statin medication.[40] We also used Law's relationship to model changes in LDL-C on peripheral artery disease, because its prevalence rate attributable to LDL-C change is limited.

We used multivariate regression analysis (ordinary least squares) with data from the 2000 to 2004 MEPS to estimate the average annual increase in medical expenditures per case of chronic conditions associated with excess weight, hypertension, and high LDL-C. (See Appendix for regression specification and results.) Annual medical expenditures across all major health care delivery settings (excluding nursing home care) comprise the dependent variable; the explanatory variables include age (in years), gender, and dichotomous indicator variables (1 = yes, 0 = no) indicating the presence of a health care visit during the previous year with a diagnosis code for a relevant chronic condition. We estimated separate regressions for each age group. We interpreted the regression coefficients for the chronic condition variables as the additional annual medical cost associated with having that comorbidity, controlling for other medical conditions.

RESULTS

National Costs of Overweight and Obesity, Uncontrolled Hypertension, and Elevated LDL-C

From the NHANES data we estimated that of the 225 million adults in the United States in 2007, 74.7 million (33%) were overweight, 37.8 million

Table 2

Comorbidity Cases and Medical Costs Associated With Preventable Risk Factors

	Total Cases in the United States (1000)	Average Annual Cost per Case ($)	Cases Attributed to Risk Factor (1000)			Total Attributed Medical Cost ($1,000,000)
			Excess Weight	Uncontrolled Hypertension	High Cholesterol	
Adult population modeled	224,669					
Overweight	74,700	N/A	74,700			N/A*
Obese I	37,782	N/A	37,782			N/A*
Obese II and III	26,724	N/A	26,724			N/A*
High cholesterol	36,713	N/A	14,685			N/A*
Uncontrolled hypertension	42,080	922	16,832	42,080		38,798
Comorbidity						
Arthritis	5797	5211	740			3855
Asthma	4597	2491	818			2037
Cancer	12,862	10,170	2299			23,384
Cerebrovascular disease	4224	9137	1309	1159	315	11,963
Congestive heart failure	6555	4226	1520	1318		6421
Coronary heart disease	11,893	10,338	4376	2091	1310	45,241
Diabetes	14,472	4326	4867			21,055
Esophagus/stomach disease	2921	2439	599			1461
Gallbladder disease	1088	9467	453			4292
Gynecological conditions	1896	454	412			187
Kidney, other urinary disease	1198	2084	117			243
Other cardiovascular disease†	5149	10,350	2128	741	487	22,027
Sleep apnea	5761	4330	2609			11,299
Overall medical costs						
Total ($1,000,000)			168,985	84,241	21,472	192,263
Individuals at risk (1000)			139,206	42,080	36,713	
Medical cost per person at risk, $			1214	2002	585	

NOTE: Estimates are rounded for presentation and might not add to totals. Some comorbidity cases are jointly attributed to multiple risk factors. Consequently, total potential savings from eliminating all cases of excess weight, uncontrolled hypertension, and high cholesterol is less than the sum of total medical costs associated with each individual risk factor. N/A indicates not available.

* Medical costs associated with obesity and high cholesterol are captured through the comorbidity estimates.

† Category includes disease of pulmonary circulation, peripheral vascular disease, and other forms of heart disease.

(17%) were obese I, and 26.7 million (12%) were obese II or III (Table 2). Using the Nutrition Impact Model, we estimated that annual medical expenditures associated with eliminating overweight and obesity among adults would be $169 billion, which is equivalent to approximately 9% of total national health care expenditures. Other studies have found that obesity alone is responsible for 3% to 9% of national health expenditures.[3,5,13,41] Approximately 53% and 47% of the savings are attributed to reduced medical costs among the currently obese and the currently overweight, respectively. One-quarter of the medical savings comes from reducing prevalence of coronary heart disease by 37%.

Applying NHANES sample data to the U.S. population, 42 million adults have uncontrolled hypertension. The potential saving associated with its elimination is $84.2 billion. Approximately half of the savings come from reduced use of health care services directly associated with hypertension, with the remainder from reduced prevalence of cardiovascular complications attributed to hypertension.

NHANES prevalence rates applied to the U.S. population indicate that approximately 36.7 million adults in the U.S. have high LDL-C levels, and that an additional 30.8 million adults have borderline high LDL-C. Savings of $21.5 billion could be achieved by eliminating all cases of elevated LDL-C, thereby reducing the prevalence of cerebrovascular disease, coronary heart disease, and other cardiovascular diseases.[42]

Although it is helpful to understand the total cost of these conditions, improved diet alone cannot eliminate the three risk factors modeled. Thus, we simulated potential medical savings potentially achievable via modest dietary changes and also simulated more aggressive dietary change that would move the population closer to current authoritative dietary recommendations.[16–19]

Potential National Health Benefits and Medical Cost Savings of Calorie Intake Reduction

We modeled a reduction in daily caloric intake of 100 to 500 kcal below current estimated energy requirements (Table 3). If all adults with above normal weight permanently reduced daily caloric intake by 100 kcal, then over a period of about 4 years the prevalence of overweight and obesity would decline until a new

Table 3

Potential Cases (Thousands) Averted Through Healthier Diet

Comorbidity Group	Current Total Cases in the United States	Cases Averted by Reducing Daily Intake by:					
		Calories		Sodium		Saturated Fat*	
		500 kcal	100 kcal	1100 mg	400 mg	12 g	4 g
Adult population modeled	224,669						
Overweight	74,700	74,700	36,870	—	—	—	—
Obese I	37,782	37,782	21,816	—	—	—	—
Obese II and III	26,724	26,664	12,532	—	—	—	—
Uncontrolled hypertension	42,080	11,248	6030	3376	1547	—	—
High cholesterol	36,713	13,323	7101	—	—	11,023	3892
Comorbidity							
Arthritis	5797	539	167	—	—	—	—
Asthma	4597	544	217	—	—	—	—
Cancer	12,862	1546	613	—	—	—	—
Cerebrovascular disease	4224	977	477	55	20	73	27
Congestive heart failure	6555	1101	524	59	21	—	—
Coronary heart disease	11,893	2700	1749	92	33	273	98
Diabetes	14,472	2872	1454	—	—	—	—
Esophagus/stomach disease	2921	380	180	—	—	—	—
Gallbladder disease	1088	303	145	—	—	—	—
Gynecological conditions	1896	292	125	—	—	—	—
Kidney, other urinary disease	1198	80	31	—	—	—	—
Other cardiovascular disease†	5149	1488	794	41	15	96	35
Sleep apnea	5761	1649	731	—	—	—	—
Premature deaths	—	134	62	22	10	—	—

NOTE: Estimates are rounded for presentation and might not add to totals. Some comorbidity cases are jointly attributed to multiple risk factors. Consequently, total potential savings from eliminating all cases of excess weight, uncontrolled hypertension, and high cholesterol is less than the sum of total medical costs associated with each individual risk factor.

* Scenario assumes substitution of saturated fat calories with nonfat calories.

† Category includes disease of pulmonary circulation, peripheral vascular disease, and other forms of heart disease.

national weight equilibrium was achieved. With the 100-kcal reduction, for example, the number of obese adults would decline by more than 34 million. Many obese adults would move into the overweight category, with a net decrease of overweight adults of close to 37 million. With the 500-kcal reduction, almost the entire adult population would move to the normal weight category. The 100-kcal reduction would eventually reduce the incidence of new cases of coronary heart disease, such that in the future the nation would have more than 1.7 million fewer cases in a given year than would occur under the status quo. Likewise, future prevalence of type 2 diabetes would be lowered by 1.5 million cases. The prevalence of chronic conditions associated with excess weight would decline such that national medical expenditures would be approximately $58 billion (Figure 1) lower than current spending levels (in 2007 dollars and assuming the same population base). The potential savings associated with a more aggressive 500-kcal reduction in daily caloric intake would eliminate most cases of overweight and obesity—with potential savings of $111 billion. The marginal national gains from reducing caloric intake diminish as the kilocalorie reduction becomes more aggressive, because there are fewer and fewer people in the obese category who benefit from the more aggressive kilocalorie reduction (because once people reach normal weight we assume no further benefits from weight loss).

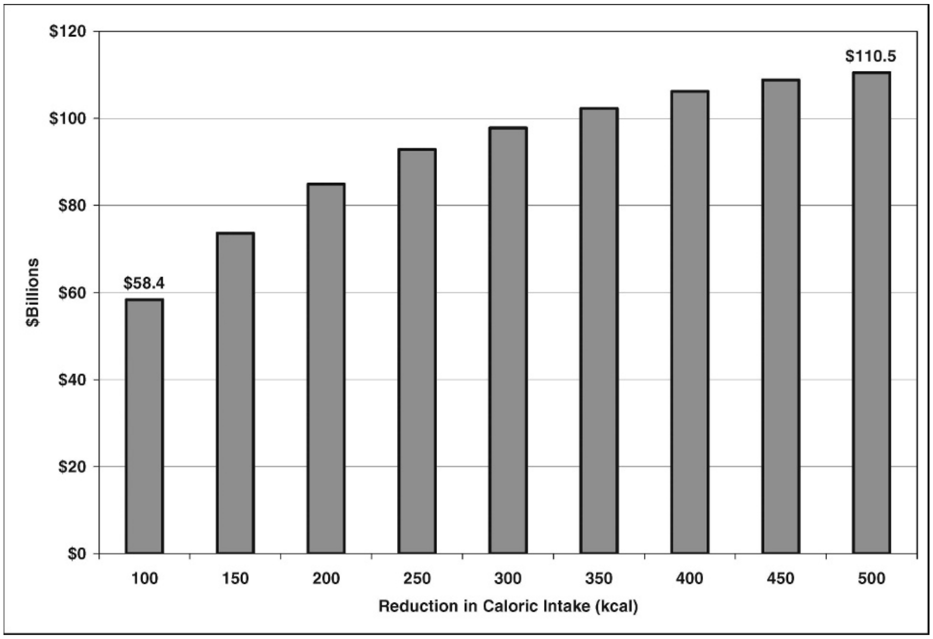
Potential National Health Benefits and Medical Cost Savings of Sodium Intake Reduction

Simulation of the impact on uncontrolled hypertension of a reduction in daily sodium intake of 400 mg per day resulted in approximately 1.5 million fewer cases of hypertension, associated with potential annual savings of $2.3 billion, rising to $5.5 billion if the daily reduction were 1100 mg sodium (Figure 2). The sensitivity analysis showed that if we modeled the larger impact of sodium on blood pressure observed in the DASH-Sodium study,[24] the societal cost savings would be approximately three times higher.

Potential National Health Benefits and Medical Cost Savings of Reduced Saturated Fat Intake

If adults with LDL-C $>$ 100 mg/dL removed 4 g of saturated fat from their daily diet (holding total calorie intake constant by substituting saturated fat calories with nonfat calories), 3.9 million cases of elevated cholesterol could be potentially eliminated and the simulated annual potential savings could be $1.6 billion (Figure 3). Potential savings with a more aggressive 12-g reduction would

Figure 1
Potential Annual Medical Savings by Reducing Daily Caloric Intake



Note: Nutrition Impact Model simulation for the estimated 139 million overweight or obese adults in 2007.

eliminate approximately 30% of elevated LDL-C cases and result in a potential savings of $4.3 billion.

DISCUSSION

The potential annual medical savings from eliminating overweight and obesity is $169 billion, from eliminating uncontrolled hypertension $84.2 billion, and from eliminating elevated LDL-C $21.5 billion. The expected medical cost savings benefit from modest and aggressive dietary change alone was estimated at $58 billion and $111 billion for overweight/obesity (34% and 66% of the total national cost associated with excess weight), $2.3 billion and $5.5 billion for hypertension (2.7% and 6.5% of the total national cost associated with uncontrolled hypertension), and $1.6 billion and $4.3 billion for elevated LDL-C (7.1% and 20% of the total national cost associated with high cholesterol).

Because of the interrelatedness of risk factors and conditions—for example, both obesity and hypertension affect heart disease—potential savings from the combination of these dietary interventions is less than the sum of the individual savings that were modeled herein. That said, the sum of the modest and aggressive dietary interventions totals $61.9 and $120.8 billion, respectively, representing 3.4% to 6.7% of the nation's $1.8 trillion in current total health care expenditures.

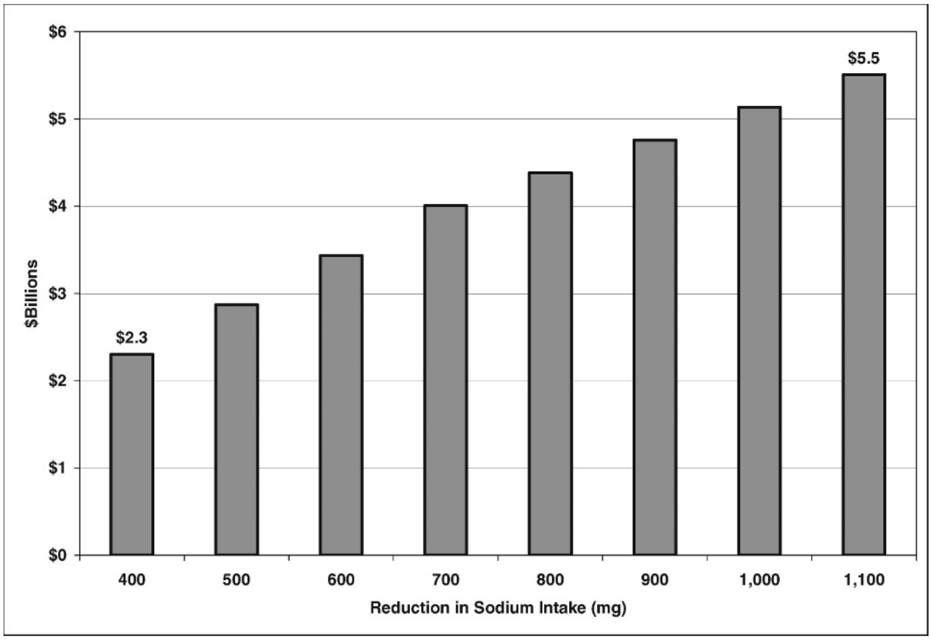
Study Limitations

This study attempted to reduce the complex relationships between diet, clinical health measures, disease prevalence, and health care use and cost into a manageable set of relationships that can be quantified and analyzed to estimate the potential national benefits of modest changes in diet. The parameters for the Nutrition Impact Model were based on authoritative peer-reviewed studies and analysis of widely used national databases. We identified no studies in the literature that document changes in national medical expenditures associated with dietary changes among the general population. Our model is based on studies that show an association between dietary change and change in BMI, SBP/DBP, and LDL-C; studies that show an association between these clinical measures and disease risk; and original analysis that shows an association between disease presence and annual medical expenditures.

Although simulation models are powerful tools for understanding complex sets of relationships and also for informing policy decisions, one must understand the limitations of modeling and interpret the results accordingly.

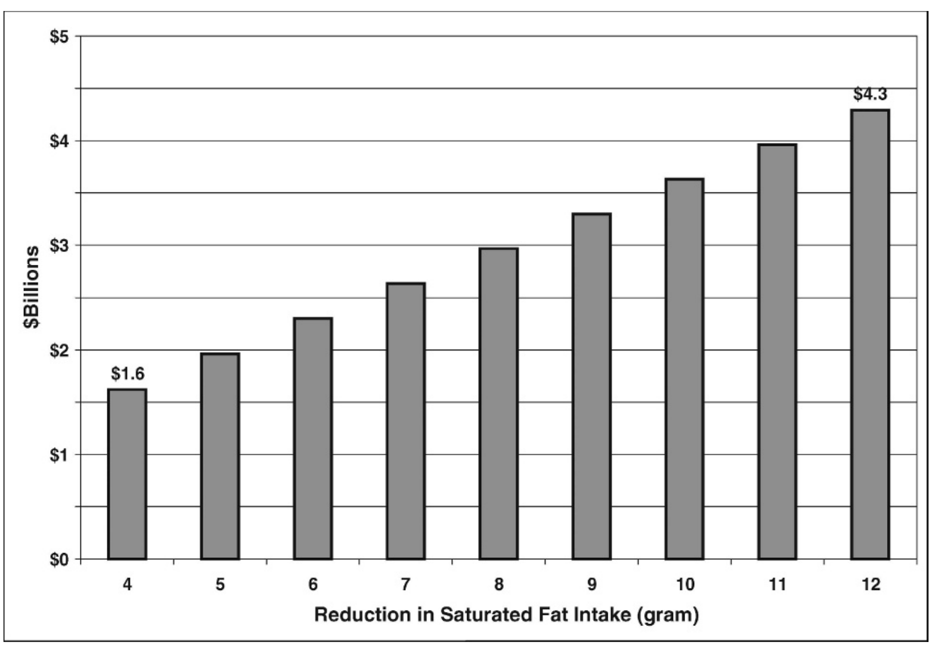
- This simulation model estimates potential benefits by comparing estimates of current medical expenditures to hypothetical equilibriums. The model provides information on health and expenditures under these different equilibriums, but does not tell us how long it will take before these annual potential savings are realized.
- This modeled cost represents only medical expenses. This study excludes intangible costs—e.g., negative perception of appearance, pain and suffering of people with chronic health problems, and reduced

Figure 2
Potential Annual Medical Savings by Reducing Daily Sodium Intake



Note: Nutrition Impact Model simulation for adults with uncontrolled hypertension and borderline hypertension in 2007.

Figure 3
Potential Annual Medical Savings by Reducing Daily Saturated Fat Intake



Note: Nutrition Impact Model simulation for adults with LDL-C > 130 in 2007.

quality of life both for people with chronic conditions and for their families and friends. A companion article presents estimates of the national productivity loss associated with obesity and hypertension, and of the potential for productivity gains through improved diet.[43]

- Parameter estimates from one study might not be generalizable to populations different from the study population.
- Because data used in the analysis come from multiple sources, including original research and model parameters obtained from the literature, standard errors cannot be calculated for the cost/savings estimates. Consequently, we model multiple scenarios to show the impact of key parameters (daily nutritional intake) and findings from the literature. An extreme scenario modeled—reducing caloric intake to the point that overweight and obesity are eliminated—provides an estimate of the current national cost of overweight and obesity. The estimate is consistent with published estimates of the national cost of obesity.
- Conservative assumptions were used throughout the analysis, so the reported potential benefits of improved diet are likely understated. For example, the estimate for uncontrolled hypertension prevalence in this model is approximately half that of national estimates, which typically include individuals whose blood pressure is under control through the use of medication.[44,45] Additionally, we modeled more modest and presumably more feasible sodium reductions than the 100-mmol (2300-mg) sodium reduction described in the DASH study and the Graudal review.[23,24] Decreasing 100 mmol from the average adults' dietary intake (NHANES 1999–2004 average U.S. sodium intake for adults 19 and over is 3464 ± 25 mg) would result in average sodium intake of about only 1164 mg/d.
- The saturated fat parameters used in this model are based on clinical trials that isolate the impact of reduced saturated fat intake holding constant total daily intake of calories. The LDL-C cost estimate is conservative because it excludes the impact of reduced cholesterol on general medical conditions not included in this study.[44,46–50] Similarly, the estimated prevalence of elevated LDL-C in this study is lower than national estimates that include people whose LDL-C is below 160 but who are taking cholesterol-lowering medications.[6]

Policy and Research Implications

Although simulation modeling is not as rigorous as a well-designed clinical trial, there are several benefits to using simulation models in health research: (1) simulation modeling can combine the best available information from the medical, public health, and economic literature to model complex relationships that are more comprehensive than those observed in individual studies; (2) modeling the complete set of relationships allows one to better identify the major cost drivers; and (3) specific policies and recommendations can be modeled, and the short-term and long-term implications better understood. Perhaps of greatest value, such simulation modeling can provide reliable estimates of long-term health care cost savings that are unlikely to be attainable through clinical trials, given the prohibitive costs and complex logistics that such a national study would require.

The dramatically greater impact of reduced calorie intake, as compared with the impact of reduced intake of sodium and saturated fats, identified here is particularly noteworthy. Whereas the smallest reduction in calorie intake in our model, 100 kcal, could potentially produce annual cost savings of $58 billion, savings from the largest and combined reductions for sodium (1100 mg) and fat (12 g) intake was only $9.8 billion. At both the highest and the lowest change levels for all three nutrients, the economic impact of reduced calorie intake was at least 90% greater than that of reduced sodium and fat intake combined. These data should help guide future priorities for dietary recommendations, namely, that a modest reduction in calories (as little as 100 kcal per day) results in the largest health care cost savings.

Areas for future research include exploring the interaction of diet change and exercise to improve

SO WHAT? Implications for Health Promotion Practitioners and Researchers

To our knowledge, this is the first attempt to merge information from a number of robust databases that would generate reasonably accurate estimates of the medical savings that would accrue from modest reduction of calories, sodium, and saturated fat in the American diet. Although reduced sodium and saturated fat intake are important, the data presented here argue that emphasis on a modest reduction in daily caloric intake has the highest potential for improving health outcomes and reducing medical costs. If this assertion holds true, one key implication for practitioners, researchers, and policy makers is that nutrition advice should emphasize sustained, modest caloric deficits for overweight and obese Americans to achieve significant health benefits.

The health-promoting changes modeled here can be achieved by improvements in the dietary habits of consumers and by changes in the nutritional content of food products by suppliers and preparers. Making the case for improving nutritional intake requires a comparison of expected benefits to expected costs. Examples of pecuniary costs to improve nutrition include expenses to motivate, educate, and enable consumers; expenses associated with environmental changes to support dietary change; and expenses for food innovation research to meet consumer demand. The intangible cost associated with improving nutritional intake is any perceived decline in consumer well-being by reducing consumption of calories, sodium, and saturated fats. This study seems to indicate that modest changes in the nation's diet have the potential to reduce national medical expenditures by tens of billions of dollars.

health, modeling the potential short-term and long-term benefits of improved diet among children and adolescents, and modeling the potential benefits of other changes in diet—particularly those that would ensure the adequate intake of a number of nutritional factors thought to be linked to disease prevention (e.g., daily intake of fiber, calcium, antioxidants, vitamins, and minerals). Longitudinal studies are needed to better understand how quickly medical savings can be achieved from improvements in diet.

Acknowledgments

The authors would like to acknowledge the contribution of Robert P. Heaney, MD; David McCarron, MD; Gary Foster, PhD; and Robert Rubin, MD, who provided expert review and comment during development of the Nutrition Impact Model and this manuscript. We would also like to thank Molly Reusser for her assistance in editing the manuscript. Funding for this study was provided by ConAgra Foods, Inc.

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Appendix

Relative Risk for Comorbidity by Body Weight Status (Relative to Normal Weight)

Comorbidity	ICD-9	Male			Female		
		Overweight	Obese I	Obese II and III	Overweight	Obese I	Obese II and III
Arthritis	71500, 71504, 71509–71518, 71520–71528, 71530–71538, 71580, 71589–71598, V134	0.96	1.59	3.19	1.18	1.31	1.87
Asthma	493	1.20	1.50	2.00	1.20	1.50	2.00
Cancers							
Breast cancer	174 (female)				1.34	1.63	1.82
Cancer of the corpus and uterus	179, 1820–1828 (female)				1.50	2.53	3.52
Cervical cancer	180 (female)				1.38	1.23	3.20
Colorectal cancer	1530–1538	1.20	1.47	1.84	1.10	1.33	1.49
Esophageal cancer	150	1.15	1.28	1.63	1.15	1.28	1.63
Gallbladder cancer	156	1.34	1.76	1.76	1.12	2.13	2.13
Kidney cancer	189	1.18	1.36	1.7	1.33	1.66	2.55
Leukemia	204–208	1.14	1.37	1.7	1.14	1.37	1.70
Liver cancer	155	1.13	1.9	4.52	1.02	1.40	1.68
Multiple myeloma	203	1.18	1.44	1.71	1.12	1.47	1.47
Non-Hodgkin's lymphoma	202	1.08	1.56	1.56	1.22	1.20	1.95
Ovarian cancer	183 (female)				1.15	1.16	1.51
Pancreatic cancer	157	1.43	1.76	1.76	1.22	1.70	1.70
Prostate cancer	185 (male)	1.08	1.20	1.34			
Stomach cancer	151	1.01	1.20	1.94	1.01	1.20	1.20
Cerebrovascular diseases							
Hemorrhagic stroke	430–432	1.20	1.30	1.40	1.40	1.90	1.90
Ischemic stroke	434–436	1.20	1.30	1.40	1.40	1.90	1.90
Other cerebrovascular disease*	433, 437, 438	1.20	1.30	1.40	1.40	1.90	1.90
Congestive heart failure	39891, 4280, 4281, 42820–42823, 42830, 42831–42833, 42840–42843, 4289	1.24	2.04	2.04	1.09	2.00	2.00
Coronary heart disease	410, 411, 412, 413, 4141, 4148, 4292	1.59	3.3	3.37	3.07	4.78	5.68
Diabetes mellitus	250	1.34	1.97	2.65	2.27	3.04	6.29
Gallbladder diseases							
Cholelithiasis	574	2.00	3.50	3.50	5.65	11.95	15.28
Gallstones and gallbladder diseases	575, 56031	0.29	0.74	2.21	4.37	8.73	10.08
Gastroeshophageal reflux disease	53081	1.35	1.53	1.65	1.35	1.53	1.65
Gynecological conditions							
Gynecological abnormalities	6260, 6262, 6263, 6270				1.34	2.11	2.11
Infertility	606 (male), 628 (female)				1.83	2.46	2.46
Hypertension	401–405	1.01	2.16	2.50	1.80	2.49	2.74
Other heart disease	415–417, 420–427, 429, 443	1.71	6.94	6.94	1.71	6.94	6.94
Sleep apnea	78051, 78053, 78057	2.50	5.00	7.50	2.50	5.00	7.50
Urinary stress incontinence	78832 (male), 6256 (female), 78833 (mix)	1.12	1.12	1.79	1.12	1.12	1.79

NOTE: The full appendix is available from the authors upon request. Relative risk ratios are based on a meta-analysis and work by Dall et al.[25]
* The *other cerebrovascular disease* category was not modeled because prevalence information is unavailable from the Medical Expenditure Panel Survey and the National Health and Nutrition Examination Survey.