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Developing and applying a costing tool for hypertension and related cardiovascular disease: Attributable costs to salt/sodium consumption

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Abstract

This paper proposes a costing tool for hypertension and cardiovascular disease by adapting cost-of-illness methodologies to estimate the attributable burden of excessive salt intake on cardiovascular disease. The methodology estimates the changes in blood pressure that result from each gram change in salt intake and links diet to the direct and indirect costs of cardiovascular diseases (CVD), such as coronary heart disease, stroke, hypertensive disease, aortic aneurysm, heart failure, pulmonary embolism, and rheumatic heart, using the relative risks of disease and the prevalence of salt consumption in the population. The methodology includes (a) identifying major diseases and conditions related to excessive salt intake and relevant economic cost data available, (b) quantifying the relationship between the prevalence of excessive salt intake and the associated risk of disease morbidity and mortality using population attributable risks (PAR), (c) using PARs to estimate the share of total costs directly attributed to excessive salt intake, and (d) undertaking a sensitivity analysis of key epidemiological and economic parameters. The costing tool has estimated that, in 2013, US$ 102.0 million (95% uncertainty interval—UI: US$ 96.2-107.8 million) in public hospitalizations could be saved if the average salt intake of Brazilians were reduced to 5 g/d, corresponding to 9.4% (95% UI: 8.9%-9.9%) of the total hospital costs by CVDs. This methodology of cost of illness associated with salt consumption can be adapted to estimate the burden of other dietary risk factors and support prevention and control policies in Brazil and in other countries.

1 | INTRODUCTION

Recently, many national, regional, and global studies and methodologies have evaluated risk factors for many diseases and produced estimates of attributable deaths and costs. Particularly in the case of non-communicable diseases (NCDs), the main causes of morbimortality in most countries, these methodologies can improve policy cost-effectiveness and reduce the deaths and costs to health systems and to societies.[1,2]

In recent decades, several modeling methodologies involving macro- and microsimulations have incorporated ex ante evaluations of policies (ie, prior to implementation[3]) and counterfactual scenarios (ie, comparative scenarios to a given baseline, changing one or more inputs, such as health risk factors), especially for NCDs, such as obesity and cardiovascular diseases (CVD).[4] Most initial health impact methodologies modeled preventable or postponed deaths, and gradually incorporated economic analyses, such as direct and indirect costs of disease and the cost-benefit, cost-utility, and cost-effectiveness analysis of policies and interventions.[5-7]

The choice of a methodology for impact modeling depends on many factors, such as the urgency of results, budget availability, quality of national or local data, the data processing capacity, and the possibility of comparing results to other studies or settings.[4]

For example, the Preventable Risk Integrated ModEl (PRIME), developed by the University of Oxford, is a static macrosimulation methodology for modeling scenarios for NCD risk factors and preventable deaths, which has adapted methodologies from the Global Burden of Disease (GBD) project. This methodology allows the comparison of counterfactual scenarios with a baseline, modeling the changes in risk factors for NCDs, such as dietary factors (including sodium/salt intake), physical activity, alcohol consumption, and smoking.[8]

In Brazil, cost-of-illness methodologies have been applied to obesity[9] and diabetes,[10] using the attributable risk fraction of these diseases for several comorbidities, although no national studies have evaluated the costs of NCD risk factors, such as diet.

Brazilians have experienced gradual changes in their dietary patterns, partly reflected in the consumption of critical nutrients linked to NCDs, such as sodium, sugars, and fats, and in the increase of diet-related NCDs.[11] A recent GBD study estimated that excessive sodium consumption is the risk factor associated with the highest loss of disability-adjusted life years (DALYs) in Brazil and globally.[12]

Despite recent studies that have questioned the optimum levels of salt/sodium consumption recommended to populations,[13,14] experts and international institutions have supported that these controversial studies are biased by inaccurate methodologies and that current salt intake recommendations (consumption of less than 5 g/d of salt) are based on robust scientific evidence and are important to improve health conditions across the world.[15-18]

The evaluations on smoking and its consequences to health and to the economy are a successful example of applying health economics to policy making; therefore, national food policies could benefit from adapting these analyses to estimate the costs of inadequate diets in Brazil and in other low- and middle-income countries (LMIC). This is especially useful in the context of budgetary restraints and economic crisis and may help reducing the resistance engaged by the productive sector to regulatory and fiscal measures for public health, despite the overall acknowledgment of their cost-effectiveness.[19]

There is scarce evidence on the economic impact of cardiovascular diseases and low-and medium-income countries, although studies are increasingly being published in Brazil and in Latin America.[7] Recent studies have shown that CVDs are the main cause of years lost to premature death and have a large economic impact on society (estimated at 9.5% of the Gross National Product), considering direct health costs and indirect costs, such as premature retirements and productivity losses.[20,21]

Meanwhile, the populations of over 90% of the countries in the world consume excessive salt, which is a major risk factor to most cardiovascular diseases mediated by increased blood pressure. Consequently, sodium reduction policies are global priorities[22,23] that may benefit from methodologies for estimating their impacts on deaths and costs.

The Brazilian population consumes, on average, 9.34 g/d (CI 95%: 9.27-9.41 g/d) of salt per capita, almost twice the 5 g maximum recommendation by the World Health Organization—WHO.[24] Therefore, estimating the costs associated with excessive salt/sodium and the economic impact of interventions, based on an analysis of health policy and salt intake scenarios, can support more cost-effective public policies for salt reduction.

This work aims to propose a methodologic adaptation of the cost-of-illness methodology to estimate the attributable burden of dietary factors, such as salt/sodium intake, in different scenarios for the consumption of critical nutrients.

2 | METHODS

2.1 | Overview and data parameters

This paper presents an adaptation of a scenario modeling of NCD-related deaths, as developed by the Preventable Risk Integrated ModEl (PRIME)[8] to cost-of-illness methodologies already used in Brazil[25] in order to build a costing tool for salt consumption. The methodology links changes in salt consumption to the risk of cardiovascular diseases (CVD), mediated by changes in systolic blood pressure, and estimates the attributable fractions that can be applied to the direct and indirect costs of disease, as detailed in the Appendix S1.[26]

This economic burden of excessive salt intake represents an estimate of costs that could potentially be avoided by comparing a baseline scenario (current salt intake) to an alternative salt consumption scenario. This costing tool for cardiovascular diseases associated with salt intake uses a prevalence-based approach by estimating the costs in a given period of time (ie, 1 year) that are attributable to salt intake in different consumption scenarios for specific age and sex groups.

The economic burden estimates are based on population attributable risk (PAR), which uses both the relative risk of cardiovascular disease due to exposure and the distribution of salt intake (the risk factor) in a specific population to estimate the fraction of disease cases that would not occur should the exposure be eliminated or changed for the entire population. The PAR values are then multiplied by the overall economic costs associated with cardiovascular diseases to determine the estimated economic burden attributable to excessive salt intake.

This adaptation of the cost-of-illness methodology is based on a top-down approach, using aggregate national data or data from other sources. The tool relies on available data from countries, such as health system costs, the relative risks of disease from the literature, and the prevalence of salt intake (preferably from national surveys). However, other sources for input data can also be used, including estimates from the Global Burden of Disease Project or WHO.

This paper presents a stepwise explanation of the application of a costing tool for salt/sodium costs, using the hospitalization costs for CVD in adults over 30 years of age in Brazil and estimating the cardiovascular disease hospitalization costs that could be saved if the average salt consumption in Brazil were reduced to 5 g/d. The same approach can be used to model the known or estimated impacts of different policies on salt reduction and compare the effects.

2.2 | Data inputs

The first step of the methodology is to obtain the costs of CVDs, identified by the International Code of Disease (ICD) and, preferably, disaggregated by age and sex. Relative risks, disaggregated by age and sex, are obtained from the scientific literature, preferably from robust estimates as meta-analyses.

As an example of the application of the costing tool, the results presented are based on the costs of hospitalizations for CVD causes (coronary heart disease, stroke, hypertensive disease, heart failure, pulmonary embolism, aortic aneurysm, and rheumatic heart disease) to the Brazilian National Health System in 2013. The Brazilian National Health System (SUS, *Sistema Único de Saúde*) has many open databases with identification of ICD codes and sex and age-groups, such as the Hospital Information System (*Sistema de Informação Hospitalar*, SIH/SUS). All costs in Brazilian Reals (R$) were converted to US dollars based on the exchange rate on December 31, 2013 (US$ 1.00 = R$ 2.357).

Costs can be estimated for different time periods, but, in general, cost-of-illness methodologies, such as this one, are based on annual costs. These costs can also be calculated for a longer time span, considering the evolution of annual costs, if there are available data on annual costs for the time period, and if changes in salt consumption are known or are assumed in the model.

This methodology can be applied to all direct costs of CVD outcomes, including the costs of treatment, such as medical consultations, medical procedures, and drugs, as well as to the indirect societal and economic impacts of CVDs, such as absenteeism, losses of productivity, and costs of disease to the families and communities.

In Brazil, the National Health Survey 2013 included spot urine collection for the direct estimation of salt intake.[24] The mean salt intake was estimated at 9.34 g/d (95% CI: 9.27-9.41 g/d), from a representative national sample of 8083 adults. As a result of the salt estimation methodology and the sample size of the survey, salt consumption was grouped into four intervals: <5 g/d, 5-8 g/d, 8-12 g/d, and 12 g/d or more, for the various sex and age-groups (18-29 years, 30-44 years, 45-59 years, and 60 years or more).

The relative risks (RR) of salt consumption and changes in systolic blood pressure (SBP),[27] as well as the RR of increased SBP and cardiovascular outcomes,[28] used in this methodology are based on the results of robust meta-analyses of epidemiologic studies with data from cohorts.[29] The main inputs to the model are summarized in Table 1.

2.3 | Population attributable risks

Population attributable risk (PAR) approaches are commonly used to estimate the proportion of disease outcomes attributable to risk factors by quantifying the relationship between the prevalence of the risk factor, including diet, and the associated risk of disease morbidity and mortality.

First, changes in systolic blood pressure (SBP), for each gram of salt added to the diet, are calculated. The consumption bands can be larger than 1 g and the estimated change in SBP is calculated for the midpoint of the band, as was done in the validation test presented in this paper.

The following step consists of calculating the differential relative risk associated with the increase of SBP for each disease, considering age-groups and sex, for each interval of salt intake. It is possible to incorporate the relative risks of SBP to coronary heart disease (CHD), stroke, hypertensive disease, heart failure, pulmonary embolism, rheumatic heart disease, and aortic aneurysm.[29]

Then, the population attributable risk (PAR), by sex, age-group, and salt consumption, is calculated, using the formula:

$$PARi = P(RRi - 1)/[P(RRi - 1) + 1]$$

where,

P = the prevalence of salt intake in the interval and strata (age and sex group), and RRi = the relative risk for each interval of salt intake to the CVD outcome.

Finally, the attributable costs are estimated by multiplying the costs in the stratum by its PAR, by disease, and by sex and age-group.

2.4 | Sensitivity analysis

The results can be presented through a deterministic (confidence intervals, CI) or probabilistic (uncertainty intervals, UI) approach. In the case of a deterministic analysis, the CI (confidence intervals) are normally calculated using the distribution for the relative risks used in the model, as reported in the accompanying literature.[28,29]

Considering the uncertainty of outcomes in the model, performing a probabilistic sensitivity analysis is recommended in order to explore the potential effects of reducing salt consumption on the risk factors for CVDs. In this paper, simulations were performed using the Monte Carlo methodology, which allows a stochastic (random) variation of the model parameters (salt intake, costs, and relative risks) based on the sizes of the effects obtained from the literature. By using this technique, the model results were recalculated iteratively and uncertainty intervals of 95% (95% UI) were generated for the median using the bootstrap percentile method. The model

TABLE 1 Summary of the key model inputs and sources for the salt/sodium costing tool

Model inputs	Value	Source
Baseline characteristics		
Salt consumption	9.34 g (9.27-9.41)	National Health Survey (IBGE) 2013[24]
Hospitalization costs		SIH-SUS 2013[27]
Effect of salt consumption on systolic blood pressure	−5.80 (−2.50, 9.20)	He & MacGregor, 2013[28]
Relative risk of systolic blood pressure	Unit of change: 20 mm Hg SBP decrease	Lewington el al, 2002[29]
Coronary heart disease	<49 y: 0.49 (0.45-0.53) 50-59 y: 0.50 (0.49-0.52) 60-69 y: 0.54 (0.53-0.55) 70-79 y: 0.60 (0.58-0.61) Over 79 y: 0.67 (0.64-0.70)	
Stroke	<49 y: 0.36 (0.32-0.40) 50-59 y: 0.38 (0.35-0.40) 60-69 y: 0.43 (0.41-0.45) 70-79 y: 0.50 (0.48-0.52) Over 79 y: 0.67 (0.63-0.71)	
Hypertensive disease	0.22 (0.20-0.25)	
Heart failure	0.53 (0.48-0.59)	
Pulmonary embolism	0.72 (0.60-0.87)	
Rheumatic heart disease	0.74 (0.61-0.89)	
Aortic aneurysm	0.55 (0.49-0.62)	

TABLE 2 Cardiovascular disease hospitalization costs (US$ 1000) saved to the National Health System if the average salt intake of Brazilians were reduced to 5 g/d, 2013

	Hospitalization costs in US$ thousands due to excessive salt consumption (95% UI)		
Disease	Men	Women	Total
Cardiovascular disease	62 642 (59 062-66 240)	39 361 (37 155-41 577)	102 003 (96 217-107 817)
Coronary heart disease	34 669 (33 077-36 274)	16 456 (15 701-17 218)	51 125 (48 777-53 492)
Stroke	13 647 (13 223-14 072)	12 024 (11 650-12 398)	25 671 (24 873-26 470)
Hypertensive disease	2078 (1962-2199)	2167 (2046-2293)	4245 (4007-4492)
Heart failure	7500 (6793-8208)	6071 (5498-6643)	13571 (12 291-14 851)
Pulmonary embolism	102 (84-120)	135 (111-159)	237 (195-278)
Aortic aneurysm	3733 (3111-4355)	1471 (1225-1716)	5204 (4336-6071)
Rheumatic heart disease	913 (813-1013)	1037 (924-1150)	1950 (1737-2163)

simulation was implemented using MS Excel with the addition of the Ersatz package and running 10 000 iterations (draws) from specified probabilistic distributions for the model input variables.[30]

3 | RESULTS

According to the National Health Survey (2013), only 2.4% (95% CI: 2.0%-2.8%) of Brazilian adults consumed less than the recommended 5 g of salt per day, which means that 97.6% of adult Brazilians consume excessive salt.[24]

Considering the hospitalization costs of the Brazilian National Health System in 2013, US$ 102.0 million (95% UI: 92.7-103.8 million) could be saved if the average salt intake of Brazilians were reduced to 5 g/d in adults over 30 years of age. Most costs attributable to excessive salt intake were among men (US$ 62.6 million, 95% UI: US$ 59.1-66.2 million), and, considering the disease burden for both sexes, 50.8% (US$ 51.1 million, 95% UI: US$ 48.4-53.5 million) of the attributable hospitalization costs were related to coronary heart disease, 25.2% (US$ 25.7 million, 95% UI: US$ 24.9-26.5 million) to stroke, and 12.6% (US$ 13.6 million, 95% UI: US$ 12.3-14.8 million) to heart failure (Table 2).

The attributable costs saved correspond to 9.4% (95% UI: 8.9%-9.9%) of the total hospitalizations by cardiovascular diseases (CVDs). Considering the most prevalent CVDs, the savings are responsible for 8.2% of the costs for coronary heart disease hospitalizations (95% UI: 7.8%-8.5%) and 15.6% of the costs for stroke hospitalizations (95% UI: 15.1%-16.1%). In total, 73.2% (95% UI: 69.2%-77.2%) of the CVD hospitalization costs that could be saved were among adults aged 30-69 years (Table 3) and represented 75.1% (95% UI: 71.0%-79.3%) of the costs among men and 70.0% (95% UI: 66.3%-73.8%) of the costs among women.

4 | DISCUSSION

Economic studies have increasing importance to public policies, by subsidizing interventions and policy decisions and completing impact analysis based on morbidity and mortality. These studies can also improve treatment and prevention strategies and, when necessary, target policies for specific population groups, with different needs and realities.[31]

Despite the importance of regional and global studies on more cost-effective interventions for NCD prevention and control, these do not replace national studies based on specific data from each country. National health and economic data can play a key role in supporting advocacy and improving the design of national policies, as well as subsidizing regulatory and fiscal measures that are necessary for reshaping food systems, improving diets, and reducing dietary risk factors.

The application of this tool to Brazil, as a proof of concept, shows the potential use of the tool to estimate the burden of excessive salt consumption in the country. Solely considering hospitalization costs by cardiovascular diseases to the Brazilian National Health System, the annual costs that could be saved in 2013 if the average salt intake were reduced to 5 g/d reached US$ 102.0 million (9.4% of the total public hospitalization costs).

The counterfactual scenarios of salt consumption could also include the impact of salt reduction policies (before or after implementation, that is, ex ante and ex post evaluations), in order to subsidize policy makers and decision-makers in formulating and implementing more effective policies.

Cost-effectiveness analyses can incorporate comparisons between policies and interventions, by assessing different counterfactual scenarios and strengthening evidence for decision-making and optimizing health impacts while minimizing costs to health systems and to society.

TABLE 3 Cardiovascular disease hospitalization costs saved if the average salt intake of Brazilians were reduced to 5 g/d, according to age and sex groups (Brazil, 2013)

	Cardiovascular disease costs		
	Attributable costs (US$)	UI 95%	
Men			
30-34 y	926 524.71	866 757.96	986 506.71
35-39 y	1 532 489.39	1 443 380.34	1 621 975.83
40-44 y	2 695 386.85	2 544 821.02	2 846 663.60
45-49 y	4 572 480.30	4 325 101.80	4 821 137.53
50-54 y	7 477 830.03	7 084 476.00	7 873 356.12
55-59 y	10 085 520.49	9 542 096.68	10 631 917.08
60-64 y	10 112 561.08	9 552 915.82	10 675 141.78
65-69 y	9 662 184.68	9 109 940.29	10 217 132.16
70-74 y	6 854 915.86	6 436 904.18	7 274 711.27
75-79 y	4 962 814.79	4 650 974.47	5 275 866.58
≥80 y	3 759 606.97	3 504 428.19	4 015 707.22
Women			
30-34 y	677 265.71	636 339.45	718 381.35
35-39 y	1 190 035.99	1 122 616.43	1 257 738.73
40-44 y	1 965 032.73	1 859 957.41	2 070 609.15
45-49 y	3 049 478.16	2 890 969.02	3 208 719.24
50-54 y	4 153 881.62	3 939 953.03	4 368 840.92
55-59 y	5 506 480.91	5 216 189.40	5 798 243.10
60-64 y	5 432 920.80	5 139 015.35	5 728 359.41
65-69 y	5 587 895.61	5 280 835.90	5 896 464.76
70-74 y	4 418 052.53	4 157 486.29	4 679 861.68
75-79 y	3 710 485.90	3 489 773.16	3 932 172.70
≥80 y	3 669 279.91	3 421 681.71	3 917 980.02
Total	102 003 125.02	96 216 613.87	107 817 486.95

The adaptation of the cost-of-illness methodologies to assess the impact of dietary risk factors allows the analysis of the potential impact of planned interventions. These analyses can also incorporate equity lenses as differences related to other variables, such as education, income, and race.

This costing tool is reasonably straightforward to use in many different settings, as the data requirements to parametrize the model are not demanding and are largely based on population-level estimates of current risk factor distributions and disease costs. However, a drawback of this simplicity is that the health outcomes estimated by the model are crude and do not allow for temporal considerations of the health impact; therefore, the model cannot be used to estimate the effect of risk factor scenarios on a larger time span or to measure indicators, such as health-related quality of life. The costing tool does not take account of the interaction between behavioral risk factors for NCDs and is unable to incorporate the effect of time lag between exposure and disease outcome. This tool also does not consider lifetime exposure to risk factors when calculating PARs and was not designed to predict the future but rather to estimate the difference between two possible future scenarios. This kind of study also assumes that the relative risks used in the models are the same for all populations, as a proxy in the absence of specific relative risks for the countries or for different populations.

The strengths of this model include the use of robust international evidence for estimating the association of risk factors, such as salt intake, and their impact on cardiovascular outcomes mediated by blood pressure. This method allows the use of national, aggregated data commonly available from health and other administrative information systems; thus, it is applicable in national settings and for comparing countries and regions. The methodology also generates conservative estimates, as they do not account for all possible attributable costs and for synergies with other risk factors.

As open policy information from other sources is expanded, as in Brazil and other countries, future analysis can be completed and more comprehensive in terms of the direct and indirect costs of NCDs, addressing the costs of premature deaths, losses of productivity, and other societal impacts.

Considering the increasing epidemiological and economic impact of NCDs, health systems and governments need to produce a larger body of evidence on cost-effective policies. In the future, cost-of-illness studies could similarly incorporate other negative dietary factors (such as sugar and fat intake), as well as positive variables (such as fruit, vegetable, and fiber intake), in order to analyze diets in a broader perspective and subsidize more comprehensive food system–driven policies.

5 | CONCLUSIONS

Cost-of-illness methodologies can be adapted to the analysis of dietary risk factors, such as salt intake, and to different scenarios of data availability, such as in Latin American countries. The use of these methods can improve policies for NCD prevention and control, by comparing the costs of interventions with the economic savings for health systems and for society.

Economic methodologies and analyses are very useful tools for health and can be used to strengthen effective interventions on NCD risk factors, including inadequate diets, and thereby prevent avoidable deaths and diseases, as well as their costs.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Eduardo A.F. Nilson conceived and designed the methodology and the study. Eduardo A.F. Nilson interpreted the analysis of the data and prepared the original draft manuscript. Everton N. da Silva and Patricia C. Jaime contributed to comments and revised the draft manuscript. Eduardo A.F. Nilson conducted the statistical analysis.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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