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ARTICLE

Burden of smoking in Brazil and potential benefit of increasing taxes on cigarettes for the economy and for reducing morbidity and mortality

Carga do tabagismo no Brasil e benefício potencial do aumento de impostos sobre os cigarros para a economia e para a redução de mortes e adoecimento

Carga del tabaquismo en Brasil y beneficio potencial del aumento de impuestos sobre el tabaco para la economía y para la reducción de muertes por enfermedad

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Abstract

The prevalence of smoking in Brazil has decreased considerably in recent decades, but the country still has a high burden of disease associated with this risk factor. The study aimed to estimate the burden of mortality, morbidity, and costs for society associated with smoking in 2015 and the potential impact on health outcomes and the economy based on price increases for cigarettes through taxes. Two models were developed: the first is a mathematical model based on a probabilistic microsimulation of thousands of individuals using hypothetical cohorts that considered the natural history, costs, and quality of life of these individuals. The second is a tax model applied to estimate the economic benefit and health outcomes in different price increase scenarios in 10 years. Smoking was responsible for 156,337 deaths, 4.2 million years of potential life lost, 229,071 acute myocardial infarctions, 59,509 strokes, and 77,500 cancer diagnoses. The total cost was BRL 56.9 billion (USD 14.7 billion), with 70% corresponding to the direct cost associated with healthcare and the rest to indirect cost due to lost productivity from premature death and disability. A 50% increase in cigarette prices would avoid 136,482 deaths, 507,451 cases of cardiovascular diseases, 64,382 cases of cancer, and 100,365 cases of stroke. The estimated economic benefit would be BRL 97.9 billion (USD 25.5 billion). In conclusion, the burden of disease and economic losses associated with smoking is high in Brazil, and tax increases are capable of averting deaths, illness, and costs to society.

Tobacco Use Disorder; Cost of Ilness; Costs and Cost Analysis

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Introduction

There are 1.1 billion smokers in the world, and four out of five live in low- and middle-income countries [1]. Smoking is the leading risk factor for death from chronic noncommunicable diseases, accounting for 6 million deaths a year [2]. A total of 603 thousand deaths a year are attributable to passive smoking, 28% of which in children [3]. This risk factor is associated 75% of cases of chronic obstructive pulmonary disease (COPD) and 22% and 10% of deaths in adults from cancer and cardiovascular diseases, respectively [2]. Recent epidemiological evidence also indicates that other diseases such as breast and prostate cancer and vascular disorders of the gastrointestinal tract are partly attributable to smoking [4].

The total global cost reaches USD 1.4 trillion per year, or 1.8% of the global Gross Domestic Product (GDP) [5]. Approximately 40% of these losses occur in low- and middle-income countries. Four of the five BRICS countries – Brazil, Russia, India, and China –, account for 25% of the global cost attributable to smoking [5]. From the health sector's perspective, the cost of care represents 15% of total expenditures in some countries, and in seven Latin American countries alone it is the equivalent of 8.3% [6].

Smoking is the third leading risk factor for death and quality-adjusted years of life lost in South American countries [7]. It is associated with a reduction in productivity and heavy expenses for families, factors that contribute to the exacerbation of poverty. The loss of productivity is the result of premature death, which occurs before the individual retires, and also indirectly, with the reduction in productivity due to the chronic diseases associated with smoking [8].

Brazil has an outstanding position in the global scenario with its National Tobacco Control Policy, which incorporates the guidelines of the World Health Organization Framework Convention on Tobacco Control (WHO-FCTC), ratified by Brazil more than 10 years ago (*Decree n. 5,658* of 2006). Although Brazil was one of the world leaders in the number of smokers, from 1990 to 2015 it was also one of the countries that showed a significant reduction in smoking prevalence among both men and women (56.5% and 55.8%, respectively) [9]. These strides are important, but data from 2011 showed that the burden of disease associated with smoking is still high, with some 147 thousand deaths and 2.69 million years of life potential lost per year, in addition to generating an annual cost to the health system of BRL 23.37 billion (USD 6.1 billion) [10].

The objectives of this study were to estimate the burden of disease and economic burden associated with smoking in Brazil in 2015 and to predict the economic and health benefits from increasing excise taxes on cigarettes in a 10-year scenario.

Materials and methods

The study used two models: (i) a model of the burden of disease associated with smoking, which allowed estimating the impact in terms of morbidity, mortality, and cost to society and (ii) an excise tax model to measure how price increases would avoid deaths, illness, and costs to society based on different scenarios of cigarette price increases in 10 years. We also estimated the government's increase in tax revenue resulting from the excise tax increases.

Model of burden of disease associated with smoking

This is a mathematical model with first-order Monte Carlo microsimulation using a probabilistic simulation of each individual to incorporate the natural history, direct and indirect costs, and loss of quality of life associated with the main tobacco-related diseases. The model has been validated in various countries, as shown by previous studies [10,11,12]. The selected diseases were: ischemic and non-ischemic cardiac diseases, COPD, pneumonia and influenza, stroke, and the following types of cancer: lung, mouth and pharynx, esophagus, stomach, pancreas, kidneys and renal pelvis, larynx, uterine cervix, and myeloid leukemia. The model's methodological development and coding of the diseases by the 10th revision of the International Classification of Diseases (ICD-10) have been presented in detail in previous studies [10,13]. The model was programmed in Excel (https://products.office.com/) with macros in *visual basic*.

Initially, for each individual from a hypothetical cohort of non-smokers, we calculated, by age and sex, the baseline risk of occurrence of acute and chronic events that could be related to the disease, its progression or death, and the direct costs (healthcare) and indirect costs (productivity lost to premature death and disability). Individuals were followed in six hypothetical cohorts in which we estimated, in annual cycles, each event's risk of occurrence, according to demographic characteristics and smoking status (non-smoker, smoker, or former smoker), clinical conditions, and risk equations [10,11,13].

Due to the lack of information of good quality on the population incidence of the target diseases, a method was determined backed by data from the Brazilian Mortality Information System (SIM. http://datasus.gov.br) for 2015. This option has been adopted in economic and epidemiological models [14,15,16,17,18,19] and allows estimating the absolute risks by age and sex for acute or chronic events. It is acknowledged internationally that national statistics underestimate mortality from COPD [20,21], so the estimates for COPD risk, incidence, and progression were taken from the international literature [20,22]. Case-fatality was estimated from hospitalizations in the Brazilian Hospital Information System of the Brazilian Unified National Health System (SIH/SUS. http://www.datasus.gov.br). Although the etiology of pneumonia and influenza is infectious, the inclusion of both is justified by evidence of increased risk in smokers suffering severe episodes of exacerbation and higher mortality when compared to non-smokers.

The model captured the outcomes' frequency to the extent that each individual could present no events or multiple events, since acute events and chronic conditions were not mutually exclusive. We also calculated years of potential life lost (YPLL), with two components – YPLL due to premature morality (YPLL-PM) and YPLL due to reduced quality of life (YLL-QL), the direct and indirect costs associated with tobacco-related diseases. Since the model did not include a direct estimate of the effects of passive smoking and perinatal diseases (low birthweight, low birth stature, respiratory distress syndrome, and sudden infant death syndrome), we used an approximation based on the literature to calculate mortality. The additional burden from these causes was 13.6% in males and 12% in females [23].

Calibration, internal consistency, and validation of the model of burden of disease associated with smoking

The following methodological steps were performed: internal consistency to identify errors related to the incorporation of data and the model's programming syntax in the software; calibration to ensure reproducibility of the results in relation to the incidence and mortality indicators; and external validation, in which the model's results were validated via comparison with epidemiological and clinical studies that did not use the same data sources to estimate the risk equations. This process allowed verifying the model's reliability. For calibration specifically, we selected all the mortality rates except for mortality from COPD, since it is underestimated in national statistics. The results by age and sex were compared to rates presented in national statistics, and we proceeded to the analysis of deviations. The mean rates of events simulated by the model that were within +/- 10% of the mean reference rate of events (national statistics and databases) were considered acceptable. In case of larger deviations, the risk equation for this specific event was modified (the case-fatality and survival values varied in the +/- 15% range) to provide for a better fit in the results.

Data collection

The parameters used in the model were backed by Brazil's demographic structure and by the individual risk of death by cause, age, and sex, and the prevalence of smoking based on smoking status [24]. The demographic data were obtained via projection of the population to 2015 by the Brazilian Institute of Geography and Statistics (IBGE. Projeção da população brasileira por sexo e idade: 2000-2060. https://www.ibge.gov.br/estatisticas-novoportal/sociais/populacao/9109-projecao-da-populacao.html?=&t=o-que-e, accessed on 20/Apr/2016), considering each individual in the cohorts by sex and age from 35 to 100 years. Overall population mortality and disease-, age-, and sex-specific mortality were incorporated into the estimated risk of death [10,13]. The following adjustments were made to the data from the SIM: (i) correction of the under-recording of deaths by application of the adjustment factor for coverage of deaths [25]; (ii) imputation of missing values for age and sex, replaced respectively by median age and the most frequent sex calculated by considering the records with the same underlying cause; and (iii) redistribution of garbage codes and ill-defined causes that did not allow the precise classification of cause of death for the diseases included in the model (Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz. Projeto Carga de Doença. http://www4.ensp.fiocruz.br/projetos/carga/downloads1.htm, accessed on 05/Apr/2017).

The relative risks of developing each disease in smokers and former smokers compared to non-smokers were obtained from the *Cancer Prevention Study II* (CPS-II) [26]. Case-fatality was calculated by the model for certain conditions such as acute myocardial infarction (AMI), angina pectoris, and stroke and compared to the available national statistics for ischemic coronary disease or cerebrovascular diseases. By dividing the data on deaths grouped according to ICD-10 codes by the Brazilian population, it was possible to obtain the absolute mortality risk by cause, sex, and age. For the cancer case-fatality rates, we obtained data on specific prognoses by type of cancer, age, and sex using Globocan [19,27]. Due to the unavailability of hospitalizations by sex, age, and ICD-10 in Brazil's supplementary health system (private plans), a correction was performed in the data from the SIH/SUS in order to include all hospitalizations in 2015 in the country [28].

Estimated burden of disease associated with smoking

The burden was estimated by analysis of differences in the occurrence of acute and chronic events, deaths, and costs between the results predicted by the model, according to current data on smoking prevalence [24], and the results predicted for a cohort of non-smokers. Estimated burden of disease was expressed in YPLL in population terms, through two components: YPLL-PM and YPLL-QL. YPLL-PM were calculated via a standardized methodology [29] and measures of state-of-health utility were used for each disease to estimate the YPLL-QL.

Cost calculation

We adopted society's perspective, including the direct cost of care and the indirect cost associated with loss of productivity due to premature death and disability. Costs are shown in Brazilian Reais (BRL) for 2015, with no adjustment for inflation.

A 5% annual discount rate was applied for all the health outcomes and for the costs [30]. The discount was necessary in order for these results estimated over the years to express present values.

Direct cost

We estimated the mean unit cost per disease to the SUS (public) and the supplementary health sector (private) through the micro-costing and cost-per-procedure technique. This cost was incorporated into the model, which simulated the likelihood of occurrence of the events over the individual's life to estimate the total cost of care. The Delphi technique was used, consulting specialists in oncology, cardiology, pulmonology, and neurology to identify and quantify the health resources. The costs items included: medical consultations, tests, hospitalizations, and surgical and non-surgical procedures.

To assess the resources for the SUS, we consulted: (i) Management System for Table of Procedures, Medicines, and Orthoses, Prostheses, and Special Materials (SIGTAP. http://sigtap.datasus.gov.br/tabela-unificada/app/sec/inicio.jsp, accessed on 20/Sep/2017); (ii) Database on Prices in Health (BPS. http://aplicacao.saude.gov.br/bps/login.jsf, accessed on 22/Sep/2016); and (iii) Chamber for Regulation of the Pharmaceuticals Market (CMED. http://portal.anvisa.gov.br/cmed, accessed on 25/Sep/2016). We also reviewed the reports on approval of incorporation of technologies by the SUS by the National Committee for Health Technology Incorporation since 2011 (CONITEC. http://conitec.gov.br/, accessed on 04/Oct/2016). The cost of cancer of the larynx and cancer of the esophagus for the SUS was obtained in the literature [31]. The procedures tables for the national health insurance market and the Brazilian Hierarchical Classification of Medical Procedures published by the Brazilian Medical Association (CBHPM. https://amb.org.br/cbhpm/, accessed on 30/Sep/2017) were consulted to calculate the costs to the supplementary health system.

- **Indirect cost**

The theory of human capital was used to estimate the cost from premature death and disability [32,33]. We assumed that the value for society of the loss of productivity can be measured as the current values of the individuals' lost work time, according to their market wages, and to which was assigned a productivity equal to a worker's marginal productivity in a perfectly competitive market [34].

Presenteeism was used to estimate the disability's cost, a concept that refers to the decrease in work productivity when an individual is reincorporated into work after the disease. The decrease in productivity as a consequence of the illness can be expressed as a shorter workday and lower level of production per hour of work, or both [35].

The current value of a person's future income depends on their life expectancy, participation in the labor market, and income from work. The human capital value of an individual of a given sex and age is the current value of this income in the future, according to the actuarial formula of the value of a statistical life (VSL):

$$VSL=\sum_{j=i}^{E(x)} prob(alive) * Wages * \left(\frac{1+g}{1+r}\right)^{E(x)-i} \quad \text{(Equation 1)}$$

In which *prob(alive)* is the probability that an individual will be alive the next year (Instituto Brasileiro de Geografia e Estatística. Projeção da população brasileira por sexo e idade: 2000-2060. https://www.ibge.gov.br/estatisticas-novoportal/sociais/populacao/9109-projecao-da-populacao.html?=&t=o-que-e, accessed on 20/Apr/2016); *wages* is an estimate of the individual's annual income from work [36]; and the last term considers two parameters assumed as constants: a growth rate over time in income from work (parameter *g*), the premise of which is that this growth is equal to the mean annual growth rate for Brazil's per capita GDP, or 2.25% per annum, from 1960 to 2015 (World Bank. http://data.worldbank.org/indicator/), and a 5% discount factor for future income (parameter *r*). Calculation of the VSL associated with an individual of a given sex and age is the sum of the products for each age.

It was necessary to adopt alternative models for the reduction of work productivity [35,37,38] using an indirect estimation criterion: it was assumed that individuals' work productivity decreased due to smoking at the same proportion as the reduction of quality of life attributed to it [16]. We also estimated the probability of an individual surviving from year *t* to year *t + 1* according to the life table by age and sex in 2015, published by the IBGE (http:www.ibge.gov.br, accessed on 18/Mar/2017).

The Mincer [39,40] equation was applied to estimate mean annual income (referring to the term *wages* in Equation 1) by sex and age based on maximum schooling attainment, labor market experience (approximated by age and age-squared), and geographic location:

$$\ln''(wage) = \alpha+\beta_{age}+\gamma_{age^2}+\delta_{levelschooling1}+\cdots+\theta_{levelschooling8}+\varphi_{urban}+\varepsilon \quad \text{(Equation 2)}$$

In which *ln(wages)* is the natural logarithm of the wages received for the individual's principal work activity, *age* and age^2 seek to approximate work experience, *level schooling 1,... level schooling 8* represent the different levels of schooling attained, *urban* is the variable that indicates whether the individual lives in an urban or rural area, and ε represents the model's error term, which assumes meeting the classical assumptions. To calculate the equation, the ordinary least squares method was applied and the data were obtained from the *Brazilian National Household Sample Survey* (PNAD 2015) [36]. The analyses were performed with Stata, version 14.1 (https://www.stata.com).

Excise tax model

This model was based on the application of percentage increases in cigarette prices. Prevalence of smoking obtained with this increase was calculated as:

$$Prevalence_{post} = Prevalence_{pre} + (E_d * \Delta\%P * Ip * Prevalence_{pre}) \quad \text{(Equation 3)}$$

In which: $Prevalence_{post}$ is the prevalence of smoking after the price increase; $Prevalence_{pre}$ is the prevalence of smoking before the price increase; E_d is the price elasticity of demand [41]; Δ%P is the percentage variation of price; and I_p is the proportion of variation in tobacco consumption that impacts the prevalence of smokers.

We calculated the expected impact on health outcomes, drawing on the Brazilian national context to define three price increase scenarios: short-, medium-, and long-term. The basi case for comparison was estimated by the unification of the three scenarios, and the results were accumulated for 10 years. We assumed linear evolution from the short-term scenario to the medium-term scenario in a five-year period, and then to the long-term scenario, from year 6 to year 10 [12]. Based on these estimates of change in the prevalence and redistribution involved in the proportion of smokers, former smokers, and non-smokers in the population, we focused on the estimate of the expected burden of tobacco-related diseases in the country based on these new conditions, according to the same method adopted to estimate the underlying burden of disease. The impact on health outcomes was calculated as the observed difference between the two estimates of deaths, occurrence of events, years of potential life lost, disability, and direct and indirect costs.

Impact on tax revenue

The expected variation in revenue in the different scenarios of cigarette sales price increases was estimated by [42]:

$$\Delta\%R = \Delta\%consumption * (\Delta\%price/\%tax) \qquad \text{(Equation 4)}$$

In which: Δ%R is the percentage variation in revenue; Δ% consumption is the expected percentage variation in consumption from the increase in sales price; Δ% price represents the percentage variation in the consumer sales price; and %tax is the proportion of the consumer sales price corresponding to the tax.

Impact on health outcomes and the economy

Three scenarios of price increases for cigarettes, through taxes, were proposed (25%, 50%, and 75%) over the course of 10 years. Impacts on health outcomes are expressed as the decrease in prevalence and thus in deaths, cases of tobacco-related diseases, and averted costs. Impacts on the economy are expressed as the total economic benefit calculated by the sum of the averted direct and indirect costs and the additional tax revenue due to the price increase. The results are presented in BRL for 2015.

Results

Calibration and validation

The mean event rate for each parameter was within plus-or-minus 10% of the rates found in the national statistics, which guaranteed excellent internal validation. Assessment of the correlation between the observed and expected results produced R^2 values between 0.700 and 0.999 (perfect fit = 1), indicating high correlation. External validation was performed by comparison of the model's results with published epidemiological studies (that were not used as data sources in this study). A favorable correlation was observed between the model's predicted values and those observed in the selected references (Figure 1).

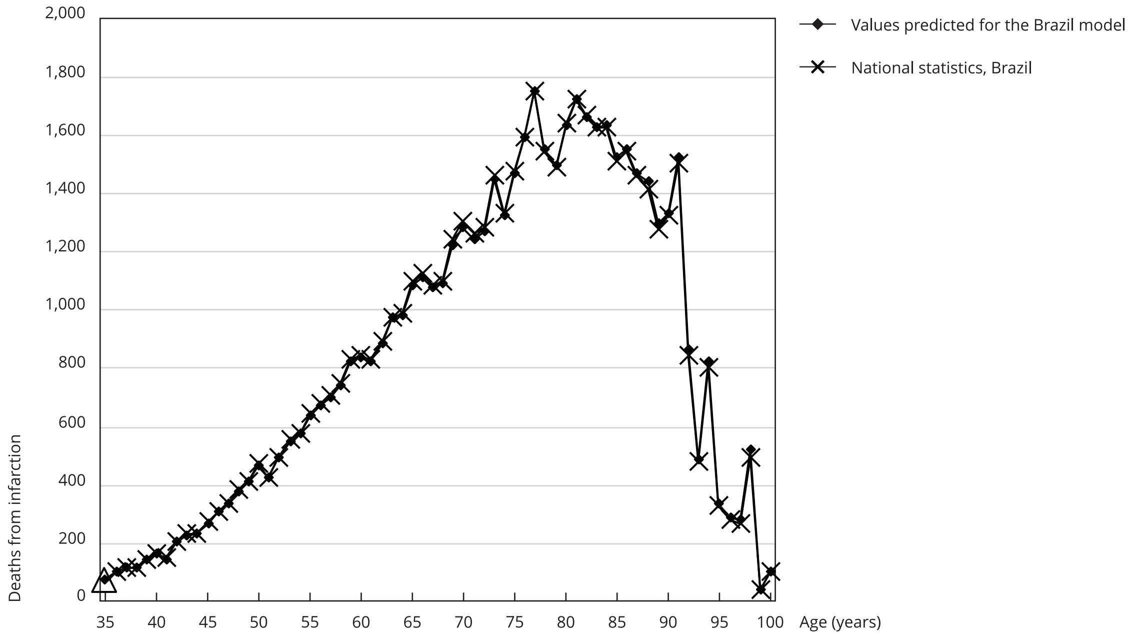
Deaths and events attributable to smoking

The model estimated 558,789 deaths in 2015, of which 156,337 (28%) were attributable to smoking and which corresponded to 12.6% of total deaths in the country (1,239,810). The proportion of attributable deaths was highest for COPD (74%) and lung cancer (78%). Cerebrovascular accident

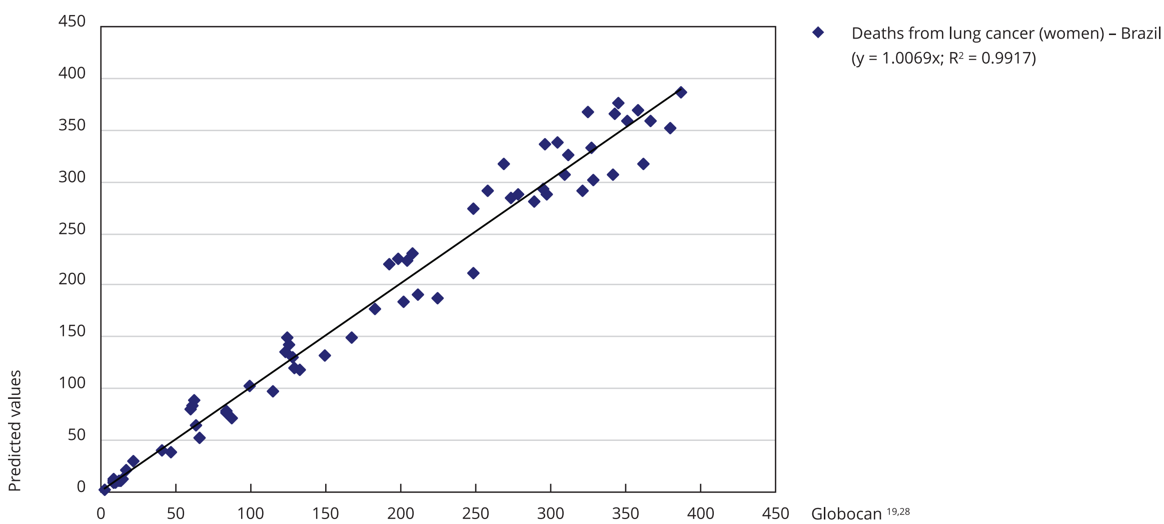
Figure 1

Internal validation, calibration, and external validation of the burden-of-disease model associated with smoking. Brazil, 2015.

1a) Calibration: number of deaths predicted by the model compared to national statistics



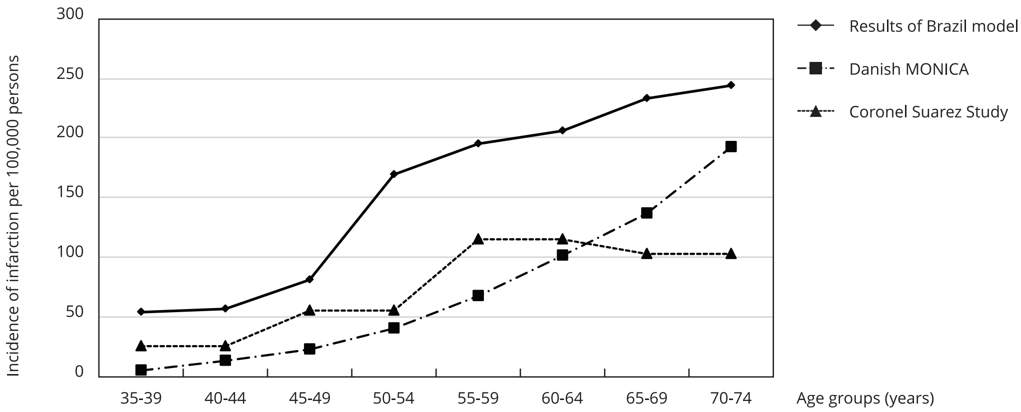
1b) Graph of correlation between values predicted by the model versus expected values according to national statistics



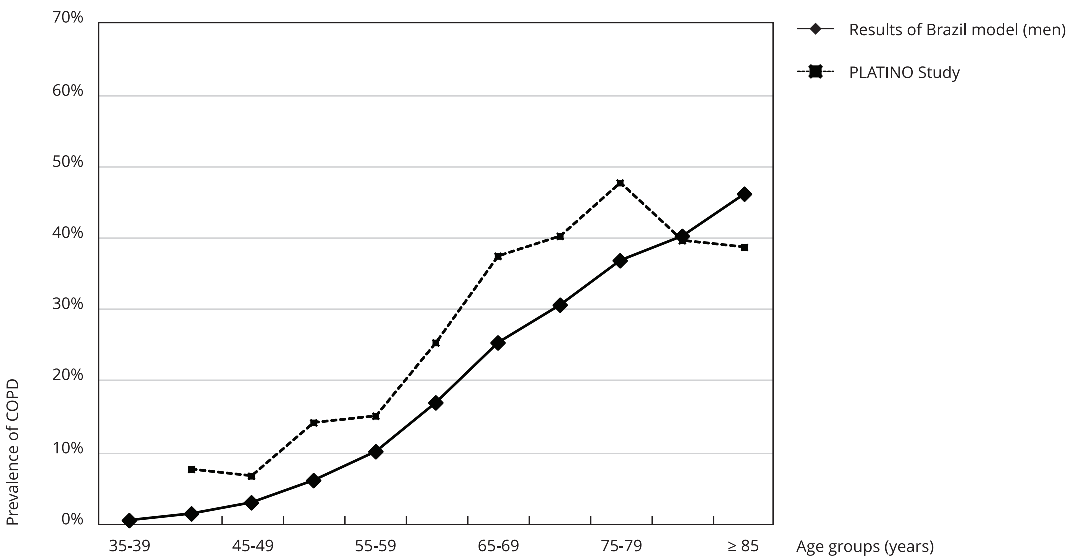
(continues)

Figure 1 (continued)

1c) Incidence of infarction predicted by the model, compared to the following population-based incidence studies: Danish WHO MONICA study register [55], AMI incidence in Argentina (province of Coronel Suarez) [56]



1d) Prevalence of COPD predicted by the model compared to the PLATINO study [57]



(continues)

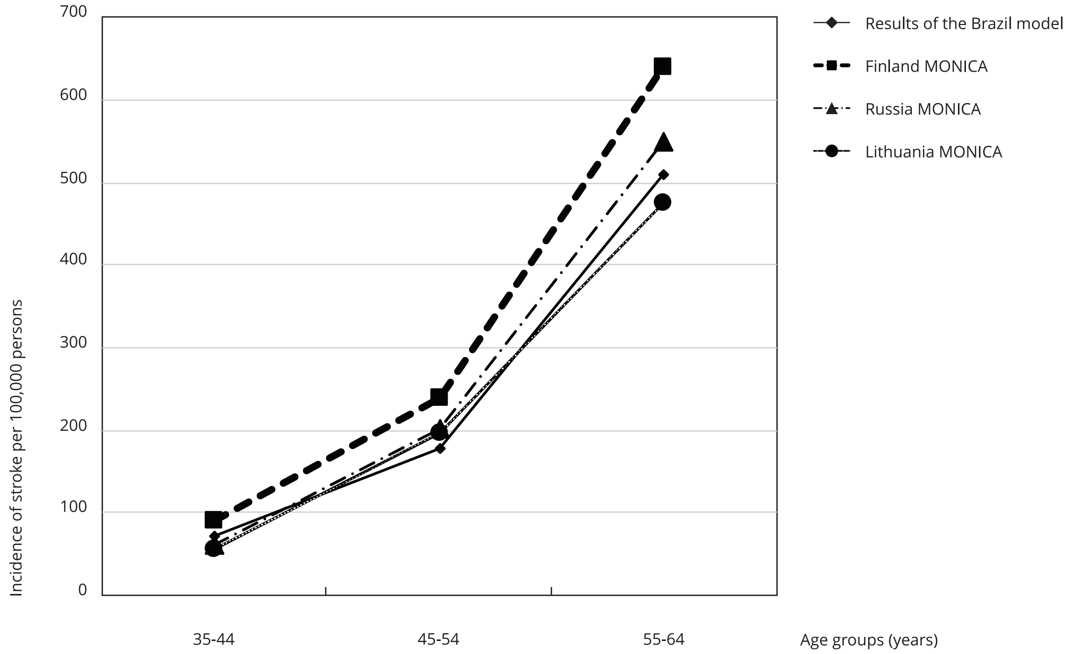
(stroke) and AMI corresponded to 13% and 18% of the total, respectively. Passive smoking and perinatal causes totaled 18,093 deaths per year. A total of 77,500 cases of cancer were diagnosed, of which 26,850 were lung cancer. There were 1,103,423 acute and chronic events, of which 378,594 (34%) cases of COPD, 229,071 (21%) of AMI, and 59,509 (5%) of stroke (Table 1).

Years of potential life lost

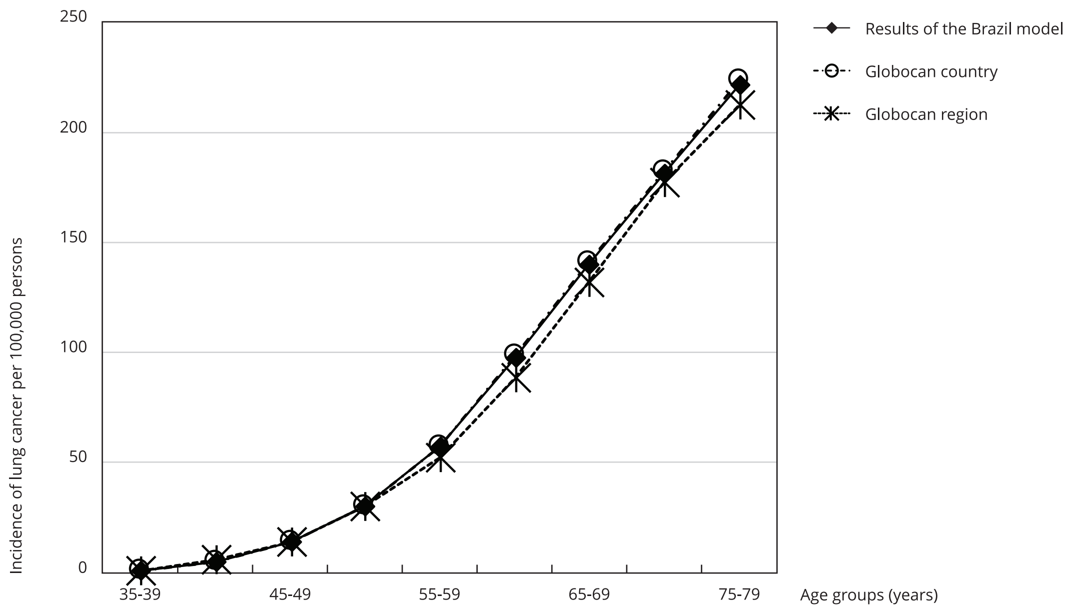
The years of life lost, expressed as YPLL, totaled 4,203,389, resulting from 71.7% of YPLL-PM for both sexes. Of this total, 64% of YPLL-PM occurred in males. Most of the YPLL-PM were attributed to ischemic cardiovascular diseases (27.1%), COPD (20%), and lung cancer (16%). Life expectancy in female smokers is 6.71 years shorter than for non-smokers, while the difference between former

Figure 1 (continued)

1e) Incidence of stroke predicted by the model compared to the WHO MONICA Study in selected countries: Finland WHO MONICA (province of de North Karelia), Russia WHO MONICA (city of Novosibirsk), Lithuania WHO MONICA (municipality of Kaunas) [55]



1f) Incidence of lung cancer predicted by model compared to IARC estimates for Brazil and regions [19,27]



COPD: chronic obstructive pulmonary disease; IARC: International Agency for Research on Cancer; MONICA: Multinational MONItoring of trends and determinants in CArdiovascular disease; PLATINO: Latin American Project for the Investigation of Obstructive Lung Disease.

Table 1

Deaths, acute and chronic events, and years of potential life lost due to premature deaths attributable to smoking. Brazil, 2015.

Disease	Total of deaths (A) *	Deaths attributable to smoking					
		Men (B)		Women (C)		Total (D = B + C)	% (D/A)
	n	n	%	n	%	n	
Total	558,789	106,729	100	49,608	100	156,337	28
AMI	130,312	16,791	16	6,397	13	23,188	18
Ischemic heart disease (except AMI)	32,293	3,545	3	1,462	3	5,007	16
Cardiovascular disease (non-ischemic causes)	59,944	5,182	5	1,622	3	6,804	11
Stroke	80,857	6,493	6	4,319	9	10,812	13
Cancer of lung	30,519	16,077	15	7,686	15	23,763	78
Pneumonia	85,442	7,954	7	2,946	6	10,900	13
COPD	41,924	17,891	17	13,229	27	31,120	74
Cancer of mouth and pharynx	10,269	3,845	4	2,036	4	5,881	57
Cancer of esophagus	10,597	5,695	5	1,195	2	6,890	65
Cancer of stomach	16,770	2,846	3	533	1	3,379	20
Cancer de pancreas	10,846	1,149	1	1,058	2	2,207	20
Cancer of kidneys and renal pelvis	3,295	754	1	53	0	807	24
Cancer of larynx	4,796	3,433	3	397	1	3,830	80
Myeloid leukemia	11,116	1,237	1	325	1	1,562	14
Cancer of bladder	3,720	1,060	1	296	1	1,356	36
Cancer of uterine cervix	7,996	-	-	739	1	739	9
Passive smoking and other causes	18,092	12,777	12	5,315	11	18,093	100
Disease	**Total of deaths (A) ***	**Acute and chronic events attributable to smoking**					
		Men (B)		**Women (C)**		**Total (D = B + C)**	**% (D/A)**
	n	**n**	**%**	**n**	**%**	**n**	
Total	3,825,406	706,321	-	397,102	-	1,103,423	29
AMI	905,532	169,439	30	59,632	18	229,071	25
Ischemic heart disease (except AMI)	1,102,307	154,317	26	87,279	18	241,595	22
Cardiovascular disease (non-ischemic causes)	59,944	5,182	5	1,622	3	6,804	11
Stroke	385,523	35,641	18	23,869	13	59,509	15
Cancer of lung	34,313	18,702	87	8,148	64	26,850	78
Pneumonia	705,548	78,483	20	42,669	13	121,152	17
COPD	557,944	214,351	73	164,243	63	378,594	68
Cancer of mouth and pharynx	24,813	10,279	73	4,347	41	14,626	59
Cancer of esophagus	12,260	6,496	70	1,418	48	7,914	65
Cancer of stomach	23,611	3,968	26	770	9	5,738	20
Cancer de pancreas	11,199	1,189	23	1,097	19	2,287	20
Cancer of kidneys and renal pelvis	6,914	1,552	37	108	4	1,660	24
Cancer of larynx	8,591	6,290	82	581	67	6,871	80
Myeloid leukemia	16,458	1,878	21	480	6	2,358	14
Cancer of bladder	11,896	3,736	44	778	23	4,513	38
Cancer of uterine cervix	18,496	-	-	1,683	9	1,683	100
Passive smoking and other causes	-	-	-	-	-	-	-

(continues)

Table 1 (continued)

Disease	Years of potential life lost due to premature deaths attributable to smoking **			
	Men	Women	Total	
	n	n	n	%
Total	1,046,516	542,074	1,588,590	100
AMI	204,654	80,864	285,318	18
Ischemic heart disease (except AMI)	40,177	17,312	57,489	9
Cardiovascular disease (non-ischemic causes)	56,994	19,063	76,057	4
Stroke	80,642	61,945	142,587	5
Cancer of lung	172,761	94,978	267,739	6
Pneumonia	71,454	30,578	102,032	21
COPD	181,735	152,742	334,477	17
Cancer of mouth and pharynx	48,513	26,683	75,196	5
Cancer of esophagus	68,194	14,290	82,484	5
Cancer of stomach	31,485	6,511	37,966	2
Cancer de pancreas	13,756	12,949	26,705	2
Cancer of kidneys and renal pelvis	9,104	718	9,822	1
Cancer of larynx	41,129	4,963	46,092	3
Myeloid leukemia	15,132	4,332	19,464	1
Cancer of bladder	10,786	3,457	14,243	1
Cancer of uterine cervix	-	10,689	10,689	1
Passive smoking and other causes	-	-	-	-

AMI: acute myocardial infection; COPD: chronic obstrutive pulmonary disease.
* Totals are not attributable to smoking;
** With application of 5% discount.

smokers and non-smokers is 2.45 years. Male smokers and former smokers lose 6.12 and 2.66 years of life, respectively, when compared to non-smokers.

Costs

The direct cost of healthcare for diseases not attributed to smoking was BRL 96,724,046,812. The cost (from society's perspective) attributable to smoking totaled BRL 56,898,155,567, and the direct cost accounted for 70% (BRL 39,404,319,965). COPD (BRL 15.990.182.776), cardiac diseases (BRL 10,264.380,964), lung cancer (BRL 2,285,584,843), and stroke (BRL 2,174,230,523) accounted for 78% of this cost. The costs of passive smoking and perinatal causes totaled BRL 4,542,046,307 (Table 2). The indirect cost was BRL 19,744,770,789, of which BRL 9,751,467,172 due to premature death and BRL 9,993,303,617 due to disability (Table 3).

Expected effects of cigarette sales price increases by increasing taxes

In 10 years, the impact produced by increases in cigarette prices expressed in economic benefits would vary from BRL 55.1 billion (price increase of 25%) to BRL 128.8 billion (increase of 75%). With a 50% price increase, the number of averted deaths would vary from 68,241 to 204,723. Averted cardiac diseases and strokes would total 507,451 and 100,365 cases, respectively. For cancer, the projection would be 64,382 averted cases (Table 4).

Table 2

Total direct costs and costs attributed to smoking, by sex, for Brazilian Unified National Health System (SUS) and supplementary health, in Brazilian Reais (BRL). Brazil, 2015.

Diseases	**Cost**				
	Men		**Women**		**Total attributable to smoking (men + women)**
	Total *	**Attributable to smoking**	**Total ***	**Attributable to smoking**	
Cardiac deseases	26,710,814,513	7,099,459,424	19,139,483,274	3,164,921,540	10,264,380,964
Stroke	6,567,735,100	1,251,024,227	6,432,148,992	923,206,296	2,174,230,523
COPD	11,991,177,002	9,170,718,873	10,481,665,204	6,819,463,903	15,990,182,776
Pneumonia	466,538,203	94,626,804	384,141,825	51,445,899	146,072,702
Cancer of lung	1,877,966,347	1,630,924,926	1,023,252,825	654,659,917	2,285,584,843
Other types of cancer	6,902,454,354	3,164,087,473	4,746,669,814	837,734,377	4,001,821,850
Passive smoking and other causes	-	3,047,874,475	-	1,494,171,832	4,542,046,307
Total	54,516,685,354	25,458,716,202	42,207,361,277	13,945,603,762	39,404,319,956

COPD: chronic obstrutive pulmonary disease.
* Total cost of diseases estimated by the model.

Table 3

Indirect cost attributable to smoking, by sex, in Brazilian Reais (BRL). Brazil, 2015.

Indirect cost	**Men**	**Women**	**Total ***	**%**
Premature death	8,318,500,168	1,432,967,004	9,751,467,172	49
Disability	7,617,250,799	2,376,052,818	9,993,303,617	51
Total	15,935,750,967	3,809,019,822	19,744,770,789	100

* Without discount.

Table 4

Total benefit in averted health outcomes, averted costs to society, and additional tax revenue based on cigarette price increase scenarios in 10 years, Brazil.

	Scenarios *		
	25%	**50%**	**75%**
Health outcomes			
Averted deaths	68,241	136,482	204,723
Averted cardiac diseases	253,725	507,451	761,176
Averted stroke	50,182	100,365	150,547
Averted cancer cases	32,192	64,382	96,575
Averted costs to society			
Direct (BRL billion) – A	16.3	32.5	48.8
Averted losses in productivity (BRL billion) – B	10.0	20.0	30.0
Tax revenue			
Increase in excise tax revenue (BRL billion) – C	28.8	45.4	50
Total economic benefit (A+B+C)	55.1	97.9	128.8

* Amounts represent the percentage increase in retail cigarette sales prices due to excise tax increases.

Discussion

This study expanded the results published in 2011 [10] by estimating indirect costs and developing a cigarette excise tax model. There were 156,337 deaths in 2015, or 6.3% more than in 2011 [10]. Factors that could explain this increase would be a difference in smoking prevalence between age groups and the 11% population growth from 2007 to 2015, the year of the first and current estimates, respectively (IBGE. http://www.ibge.gov.br, accessed on 15/Mar/2017).

Cardiac diseases, COPD, lung cancer, and stroke accounted for 65% of the deaths, maintaining the same tendency as in 2011 [10]. However, deaths from AMI and stroke were reduced by some 4% and 40%, respectively, also in comparison to 2011, which corroborates the downward trend in mortality from cardiovascular diseases in Brazil [43]. The burden of disease was concentrated in males, with 68% of all deaths and 64% of all events. However, our results showed a reduction in the burden among men when compared to 2011, with a decline of 12% and 8% in deaths and events, respectively [10]. Prevalence of smoking dropped considerably from 2008 to 2013 in both sexes, and although Brazilian men smoke more than Brazilian women [44], the reduction in prevalence and thus in the burden in men indicates an important convergence of these two indicators.

Measures to reduce exposure to second-hand smoke are a reality in Brazil (*Law n. 12,546* of 2011), but before 2011 there was an increase in deaths and in the direct cost related to passive smoking and perinatal diseases (7% and 69%, respectively) [10]. In newborns, the consequences of second-hand smoke include reduction in weight, stature, and head circumference [45]. Thus, protective measures for non-smokers must be enforced routinely in all environments.

In recent years, Brazil has adopted a policy of increasing excise taxes on cigarettes. In 2011, an *ad valorem* tax rate entered into force for cigarettes, currently set at 66.7%, besides a policy of minimum prices per pack [46,47]. Our results demonstrate the benefits generated for tax revenue (an increase of up to BRL 50 billion in 10 years). It is an effective measure, as demonstrated in Brazilian and international studies [41,48], contributing to the expansion of fiscal space and favoring public investments. The success with the price and excise tax policy in avoiding costs, mortality, and morbidity also assumes the joint involvement of government areas in health, the economy, and law enforcement due to the volume of the illegal cigarette market in Brazil.

The cost of disease not attributed to smoking was significant, reaching BRL 96.7 billion per year. The estimates of burden and costs of chronic diseases at the national level in adults are scarce, and the current study is intended to support policymakers and researchers in chronic diseases by providing data on the problem's magnitude in Brazil. The direct cost attributable to smoking increased by 70% from 2011 to 2015, which could be explained by the incorporation of new technologies both in the SUS (CONITEC. http://conitec.gov.br/decisões-sobre-incorporacoes, accessed on 11/Sep/2016) and in the private supplementary health system (ANS. http://ans.gov.br, accessed on 11/Sep/2016). The indirect cost accounted for 30% of the total cost. Since this was the first such estimate in Brazil, we suggest that indirect costs should be incorporated into future studies, given their magnitude, as already observed in other countries [23,49,50,51].

Due to methodological issues, comparison of the findings with other studies is limited. Still, the results in other countries are similar to ours, presenting a heavy burden for the economy. In Europe, smoking compromises 2.5% of the annual GDP, reaching 0.55% in China [52]. In the USA and Canada, smoking accounts for losses of 3% in the GDP, compared to 1% in the other countries of the Americas [2]. In Brazil, the loss was 0.7% of the GDP, and tax revenue from the tobacco industry reached BRL 13 billion in 2015 [46], that is, 23% of the total cost of BRL 56.89 billion. On this point, article 19 of the WHO-FCTC which deals with criminal and civil liability, raises the possibility of compensation for damages, which has already been enforced through court action in the United States [53].

The results proved robust, based on the process of calibration and validation, guaranteeing the reproducibility of the model's results. But some limitations should be addressed. The literature points to friction cost [54], the Washington panel approach [33], and the theory of human capital [35,36] as the principal methods for calculating indirect cost. The theory of human capital may overestimate costs, especially when compared to friction costs, whose calculation is more complex [34]. However, this approach was applied due to the availability of local data, the concepts' simplicity and that of the associated calculations, and because it is also the preferred method in the guidelines for economic evaluation in Brazil [30]. Another limitation was the correction of hospitalizations for the supplementary health system (private) based on a single adjustment factor [28], which was necessary given the insufficiency of data based on the ICD-10. This was the solution adopted in order for calculations of case-fatality and direct cost to be performed comprehensively. Finally, the results may be underestimated, since an association with smoking has been established for a broader set of diseases than those included in the current burden-of-disease model [4].

Cost-effective measures should be intensified in order to avoid deaths and illness from smoking, and in consequence, generating benefits for Brazilian society. The costs for society reflect an important opportunity cost, and compensation for damages is a timely topic for the debate on the tobacco control agenda. The resulting resources can be invested in the full implementation of the Framework Convention on Tobacco Control, but they should not be limited only to this purpose, since other public policies can also benefit from this compensation.

Contributors

M. Pinto participated in the collection and analysis of epidemiological data and cost data and writing and final approval of the article. A. Bardach, A. Palacios and A. Pichon-Riviere contributed in the collection and analysis of epidemiological data and cost data, development of the models, and writing and final approval of the article. A. Biz participated in the collection and analysis of epidemiological data and cost data and writing and final approval of the article. A. Alcaraz, B. Rodriguez and F. Augustovski contributed in the collection and analysis of epidemiological data and cost data, development of the models, and writing and final approval of the article.

Additional informations

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Resumo

A prevalência do tabagismo no Brasil reduziu sobremaneira nas últimas décadas, mas o país ainda tem uma elevada carga de doença associada a este fator de risco. O objetivo deste trabalho foi estimar a carga de mortalidade, morbidade e custos para a sociedade associada ao tabagismo em 2015 e o potencial impacto gerado em desfechos de saúde e para a economia a partir do aumento de preços dos cigarros por meio de impostos. Foram desenvolvidos dois modelos: o primeiro é um modelo matemático baseado em uma microssimulação probabilística de milhares de indivíduos usando-se coortes hipotéticas que considerou a história natural, custos e a qualidade de vida destes indivíduos. O segundo é um modelo de impostos aplicado para estimar o benefício econômico e em desfechos de saúde de diferentes cenários de aumento de preços em 10 anos. O tabagismo foi responsável por 156.337 mortes, 4,2 milhões de anos de vida perdidos, 229.071 infartos agudos do miocárdio, 59.509 acidentes vasculares cerebrais e 77.500 diagnósticos de câncer. O custo total foi de BRL 56,9 bilhões, dos quais 70% corresponderam ao custo direto associado à assistência à saúde e o restante ao custo indireto devido à perda de produtividade por morte prematura e incapacidade. Um aumento de 50% do preço do cigarro evitaria 136.482 mortes, 507.451 casos de doenças cardiovasculares, 64.382 de casos de câncer e 100.365 acidentes vasculares cerebrais. O benefício econômico estimado seria de BRL 97,9 bilhões. Concluiu-se que a carga da doença e econômica associada ao tabagismo é elevada no Brasil e o aumento de impostos é capaz de evitar mortes, adoecimento e custos para a sociedade.

Tabagismo; Efeitos Psicossociais da Doença; Custos e Análise de Custo

Resumen

La prevalencia del tabaquismo en Brasil se redujo sobremanera en las últimas décadas, pero el país todavía cuenta con una elevada carga de enfermedad asociada a este factor de riesgo. El objetivo de este trabajo fue estimar la carga de mortalidad, morbilidad y costes para la sociedad, asociada al tabaquismo en 2015, y el impacto potencial generado en los desenlaces de salud y para la economía a partir del aumento de precios del tabaco a través de impuestos. Se desarrollaron dos modelos: el primero es un modelo matemático, basado en una microsimulación probabilística de millares de individuos, a través de cohortes hipotéticas, que consideró la historia natural, costes y calidad de vida de esos individuos. El segundo se trata de un modelo de impuestos aplicado para estimar el beneficio económico y en desenlaces de salud de diferentes escenarios con el aumento de precios durante 10 años. El tabaquismo fue responsable de 156.337 muertes, 4,2 millones de años de vida perdidos, 229.071 infartos agudos de miocardio, 59.509 accidentes vasculares cerebrales y 77.500 diagnósticos de cáncer. El coste total fue de BRL 56,9 billones (USD 14,7 billones), de los cuales un 70% correspondieron al coste directo asociado a la asistencia a la salud y lo restante al coste indirecto, debido a la pérdida de productividad por muerte prematura e incapacidad. Un aumento de un 50% del precio del tabaco evitaría 136.482 muertes, 507.451 casos de enfermedades cardiovasculares, 64.382 de casos de cáncer y 100.365 accidentes vasculares cerebrales. El beneficio económico estimado sería de R$ 97,9 billones (USD 25,5 billones). Se concluyó que la carga de la enfermedad y económica asociada al tabaquismo es elevada en Brasil y el aumento de impuestos es capaz de evitar muertes, enfermedad y costes para la sociedad.

Tabaquismo; Costo de Enfermedad; Costos y Análisis de Costo

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