The burden of smoking-related diseases in Brazil: mortality, morbidity and costs

Estimativa da carga do tabagismo no Brasil: mortalidade, morbidade e custos

Estimación de la carga de enfermedad atribuible al tabaquismo en Brasil: mortalidad, morbilidad y costos

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Abstract

Advances in tobacco control in Brazil can be reflected in the decrease in prevalence over the past two decades. Death statistics and the occurrence of events and direct costs attributable to tobacco-related diseases have not been frequently estimated in the country. The goal of this article is to estimate the burden of smoking in 2011 regarding mortality, morbidity and medical care costs of the main tobacco-related diseases. A probabilistic microsimulation health economic model was built. The model incorporates the natural history, costs and quality of life of all the tobacco-related adult-specific diseases. Smoking was accountable for 147,072 deaths, 2.69 million years of life lost, 157,126 acute myocardial infarctions, 75,663 strokes, and 63,753 cancer diagnoses. The direct cost for the health system was of BRL 23.37 billion. The monitoring of tobacco-related burden is an important strategy to guide decision-makers and to strenghten health public policies.

Cost of Illness; Smoking; Potential Years of Life Lost; Mortality

Resumo

Os avanços no controle do tabagismo no Brasil podem ser verificados na redução da prevalência nas últimas duas décadas. As estatísticas de óbitos, ocorrência de eventos e custos diretos atribuíveis às doenças tabaco-relacionadas não são estimadas com frequência no país. O objetivo deste artigo foi estimar a carga do tabagismo em 2011, em termos de mortalidade, morbidade e custos da assistência médica das principais doenças tabaco-relacionadas. Desenvolveu-se um modelo econômico baseado em uma microssimulação probabilística de milhares de indivíduos através de coortes hipotéticas que considerou a história natural, os custos diretos em saúde e a qualidade de vida desses indivíduos. O tabagismo foi responsável por 147.072 óbitos, 2,69 milhões anos de vida perdidos, 157.126 infartos agudos do miocárdio, 75.663 acidentes vasculares cerebrais e 63.753 diagnósticos de câncer. O custo para o sistema de saúde foi de R$ 23,37 bilhões. O monitoramento da carga do tabagismo é uma importante estratégica para informar aos tomadores de decisão e fortalecer a política pública de saúde.

Carga da Doença; Tabagismo; Anos Potencias de Vida Perdidos; Mortalidade

Introduction

Smoking is one of the main risk factors for non-communicable chronic diseases [1,2] and the main global cause of preventable morbidity and mortality, accounting for some 6 million deaths a year. Estimates indicate that in 2020 there will be 7.5 million deaths by smoking, or 10% of all deaths worldwide [1].

The epidemiological evidence points to a causative relationship between smoking and some 50 diseases, including cardiovascular and respiratory conditions, and cancer. Studies indicate that 45% of the deaths by coronary artery disease (acute myocardial infarction – AMI), 85% by chronic obstructive pulmonary disease (COPD), 25% by cerebrovascular disorders, and 30% by cancer could be attributed to the use of tobacco-related products [3,4,5]. Second-hand smoke is also a serious public health hazard, as 40% of the children, 35% of the women, and 33% of men who do not smoke are exposed to the smoke of tobacco products. This scenario is made worse by the estimate of 603,000 deaths a year among persons exposed to tobacco smoke, of which 47% are women, 28% are children, and 26% are men [6].

The magnitude of tobacco-related costs imposes a significant burden for individuals and health systems. Conservative estimates indicate that health costs attributable to tobacco-related diseases reach some US$ 500 billion a year globally, from loss of productivity, illnesses and premature deaths [4]. These costs may range from 0.1% to 1.5% of the Gross Domestic Product (GDP) in high-income countries. Furthermore, these costs range from 6% to 15% of national health expenditures [7]. In countries with a less developed economy, such information is more scarcely available, but it is estimated that health care costs are as high as in those countries with industrialized economies [8].

In Brazil, Monteiro et al. [9] concluded there was a decrease in the prevalence of smoking, from 34.8% in 1989 to 22.4% in 2003. Results from a national survey indicate that in 2008 prevalence was 18.5%, showing a significant reduction when compared with the 1989 data [10]. Advances in tobacco control in Brazil seen over the last decades are positive, but it is observed that prevalence among young women is growing more than among men of the same age [11], mortality is still high [12,13] and the costs are underestimated [14]. In this scenario, calculation of the tobacco-related disease burden is not often made in the country.

It is worth mentioning that this investigation is part of a collaborative effort of researchers and health system managers of seven Latin-American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Mexico and Peru). Its main purpose was the development of a methodological framework, and the design of a common economic model to estimate the burden of tobacco-related diseases. Thus, the current study intended to estimate the burden of tobacco for Brazil in 2011 in terms of mortality, morbidity and direct costs for the health system from the proposed economic model.

Materials and methods

Description of the model

This economic model used a first-order Monte Carlo (probabilistic microsimulation of individual subjects) that includes the natural history, medical care costs and quality of life loss associated with the main tobacco-related disease. The selected diseases were: ischemic heart diseases, unstable angina, other heart diseases, COPD (including chronic bronchitis and pulmonary emphysema), pneumonia and influenza, stroke, and the following types of cancer: lung, oral cavity and pharinx, oesophagus, stomach, pancreas, kidney and renal pelvis, larynx, bladder, cervical cancer, and myeloid leukemia. Further details of the methodological development of the model and coding of the disease according to the 10th revision of the International Classification of Diseases (ICD-10) may be found in Pichon-Riviere et al. [15,16].

The subjects were followed in hypothetical cohorts during annual cycles until the end of their lives. For each cycle, the individual risk for the occurrence of outcomes was calculated, which included disease-related events, its progression, and death, and the costs of medical care. From the calculation of the individual risk, aggregated results for the outcomes were obtained. The likelihood of occurrence was based on demographic data (sex and age) (Instituto Brasileiro de Geografia e Estatística. Contagem da população 2007. http://www.ibge.gov.br/home/estatistica/populacao/contagem2007/, accessed on 10/Oct/2011), life tables (Instituto Brasileiro de Geografia e Estatística. Tábuas completas de mortalidade, 2010. http://www.ibge.gov.br/home/estatistica/populacao/tabuadevida/2010/, accessed on 10/Nov/2011), status of the subject in regards to smoking (smoker, former smoker, non-smoker) [10], medical status, and risk equations. Figure 1 presents acute events, chronic conditions and cause of death used in the model, as well as the equations for the calculation of their likelihood of occurrence.

Figure 1

Acute events, chronic conditions, causes of death and calculation of likelihood.

A. Acute events	B. Chronic conditions	C. Causes of death
AMI	Patient with coronary artery disease	AMI
CAD (except AMI)		CAD (except AMI)
Stroke	Post-stroke	Stroke
COPD diagnosis	COPD stage	Pneumonia/Influenza
COPD progression	Lung cancer	Cardiovascular (non ischemic) death
Pneumonia/Influenza	Bladder cancer	COPD
Cancer diagnosis: lung, bladder, kidney, lip/oral/pharynx, larynx, stomach, esophagus, pancreas, cervix uteri, and leukemia	Kidney cancer	Lung cancer
Tobacco-related events	Lip/oral/pharyngeal cancer	Bladder cancer
Success in smoking-cessation	Laryngeal cancer	Kidney cancer
Relapse after a successful attempt to quit smoking	Esophageal cancer	Lip/oral/pharyngeal cancer
	Pancreatic cancer	Laryngeal cancer
	Cervix uteri cancer	Esophageal cancer
	Leukemia	Pancreatic cancer
		Cervix uteri cancer
		Leukemia
		Mortality for all other causes
Calculation of likelihood		**Calculation of likelihood**
Disease-related event:		Death from acute events:
Baseline risk in nonsmokers		Likelihood of the event x lethality (specific per age and sex)
(per age and sex) x smoking status RR	Smoking status:	Non-ischemic cardiovascular death:
CODP progression:	Smoker	Baseline risk in nonsmokers (specific per age and sex) x smoking status RR
Baseline risk in nonsmokers (specific per sex and years lived with former smoker x smoking status RR	Former smoker	COPD:
	Nonsmoker (never smoked)	Stage-specific mortality (specific per sex)
		Cancer:
		Cancer-specific mortality within five years after diagnosis (except lung cancer: 10 years)
		Mortality for all other causes:
		Populational mortality minus mortality from diseases included in the model (specific per age and sex)

AMI: acute myocardial infarction; CAD: coronary artery disease; COPD: chronic obstructive pulmonary disease; RR: relative risk.

The model captured the frequency of outcomes considering that a subject could present none, one, or multiple events, as acute events (such as AMI) and chronic medical conditions (like cancer) were not mutually exclusive. The likelihood of occurrence of acute events in each annual cycle, and of the chronic conditions that last a lifetime were calculated. In addition, the use of health resources and quality-adjusted life-year (QALY) were also calculated throughout life.

Risk calculation of acute events was estimated from a specific individual risk per age and sex in non-smokers (baseline incidence) per annual cycle. This risk was multiplied by the relative risk

(RR) of the disease in smokers, calculated with the tool *Smoking-Attributable Mortality, Morbidity, and Economic Costs* (SAMMEC. Department of Health and Human Services, Centres for Disease Control and Prevention, Atlanta, U.S.A.). For COPD, the risk of becoming ill and disease progression to more advanced stages according to smoking were considered [10]. Cancer incidence was estimated from the risk per age and sex in non-smokers multiplied by smoking-related RR of each type of cancer [15,16].

The risk of death was also calculated per individual per time cycle and was associated with the events and medical conditions they could experience over this cycle. Overall mortality of the population per age and sex was incorporated in the death risk estimates presented in Figure 1. Data on deaths were obtained from Mortality Information System, Brazilian Unified National Health System (SIM-SUS) (Departamento de Informática do SUS; http://www.datasus.gov.br).

The model was programmed in Excel (Microsoft Corp., U.S.A.), with Visual Basic macros (Microsoft Corp., U.S.A.), and a software to randomly generate numbers was used.

Methods for the selection of data sources and incorporation of parameters

Baseline risks for each medical condition in non-smokers were estimated from the incidence of each disease in the population, calculated from mortality data. Due to the lack of good quality information on the incidence in the population of the diseases included in the model, a SIM-SUS-supported methodology was established. The selection of this methodology, relating incidente to mortality data is common adopted in economic and epidemiological models [17,18,19,20,21,22]. Thus, there are different perspectives for the estimation of risks of acute events or chronic conditions. For each acute event, the absolute risk per age and sex was calculated against its mortality rate and lethality, given by:

$$R_{pop.event} = \frac{R_{death}}{L} \qquad \text{Equation 1}$$

Where R_{death} is the specific mortality per age and sex, and L is lethality. Once this absolute risk was obtained, the risk in non-smoking individuals was calculated from the specific prevalence of the habit of smoking, per age and sex [10]. Specific smoking RR from each disease was calculated by the following equation:

$$R_{nonsmk} = \frac{R_{pop.event}}{RR_{smk} \text{ x } F_{smk} + (RR_{frsmk} \text{ x } f_{frsmk}) + f_{nonsmk}} \qquad \text{Equation 2}$$

Where R_{nonsmk} is the annual incidence of the event of reference in non-smokers, $R_{pop.event}$ is obtained from Equation 1, and RR_{smk} and RR_{frsmk} are the RRs of the event to occur in smokers and former smokers, compared to non-smokers. The f_{smk}, f_{frsmk} and f_{nonsmk} parameters are the specific proportions per age and sex of smokers, former smokers and non-smokers [10].

In the case of lung cancer, estimates of diagnosis likelihood per age and sex were obtained from the annual mortality rate provided by SIM-SUS, and the annual estimated survival rate from the moment of diagnosis [22,23]. The specific risk of diagnosis per age and sex was given by:

$$Rdxi = \sum_{n=0}^{10} Rm_{i+n} \text{ x } P_n \text{ x } 1/|1\text{-}S10 \qquad \text{Equation 3}$$

Where Rdxi is the risk of being diagnosed with the disease at age i; Rm_{i+n} is the risk of death of the overall population by the disease at age i+n; P_n is the conditional likelihood of an individual dying in a given year n after diagnosis within a 10-year period; and S10 is the proportion of individuals who survive after 10 years. It was assumed that individuals who survive 10 years after diagnosis return to present the same risk of death of the overall population. From the results obtained through the calculation of risks, a transition model between health conditions (Markov model), with the purpose of adjusting such estimates. Next, Equation 2 was applied for the calculation of baseline risk in non-smokers. For the other types of cancer it was decided that Globocan's specific incidence and prognostic data was to be used [22,23,24]. Globocan data was selected for it provides information on types of cancer in Brazil, and because it is a common source of data for all countries participating in the project.

It is acknowledged internationally that national statistics underestimated COPD mortality [25,26], thus, the risk, incidence and progression of the disease were based on international literature [25,27,28].

It is known that the etiology of pneumonia originates from infection, for smokers and non-smokers alike, and smoking is not its cause. The inclusion of pneumonia is justified by evidence in the literature about the increased risk of smokers presenting severe exacerbation episodes, and the higher mortality among them compared to non-smokers.

Second-hand smoke and the main smoking-related perinatal causes (low weight or low size at birth, respiratory distress syndrome, and sudden infant death syndrome) were included in the analysis, but were not assessed by the model in a direct manner. A literature-based approximation was used to calculate mortality, years of life lost

(YLL) and costs [29]. The additional burden considered for these causes was 13.6% in men and 12% in women.

- **Model calibration and validation process**

The criteria suggested by the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) [30] for the development of models and their presentation in research studies and reports were adopted.

- **Internal validation**

The model was reviewed and tested after its completion to identify possible errors related to the inclusion of data and the programming syntax of the software used. It was thus ensured that all mathematical calculations were correct and consistent with all specifications established by the model.

- **Calibration**

The specific mortality rates for each disease predicted by the model were compared with national statistics from the SIM-SUS. Sixteen parameters were selected [16], with the exclusion of COPD mortality, as this is underestimated in national statistics, as previously mentioned. The results for age and sex were also compared with the rates collected from original sources of information, and the assessment of the deviations was performed. The mean rates of events simulated by the model that were 10% above or below the mean rate of reference events (statistics and national bases) were considered acceptable. In the case of major deviations, the risk equation of this specific event was modified (lethality and survival rates varied from 15% above to 15% below) to provide a better adjustment of results. Only when the rates were within the expected 10% limit the adjustment was finalized.

The process to calculate basal risk parameters and the variation allowed during calibration are presented in Pichon-Riviere et al. [16].

To ensure that the results simulated by the model were within the established variation limits, charts with the total number and the incidence of events of each parameter were designed. The resulting curves of observed (statistics and databases) and expected (model) data indicated whether or not the adjustment was adequate. The squared linear correlation coefficient (R^2) was also used to check for this adequacy.

- **External validation**

For the external validation process the model-generated results were validated through comparison with epidemioligic and medical studies [23,31,32,33,34,35,36] that not use the same sources of information for the estimation of equations.

Estimation of the smoking-related disease burden

An assessment of the differences in the occurrence of events, deaths and direct costs associated with an hypothetical cohort of non-smokers and former smokers compared to a cohort in which the prevalence of smokers and former smokers was included. Considering that one of the aims of the study was to assess smoking-related YLL on a populational level, two components were estimated: potential years of life lost due to premature death (PYLL) e potential years of life lost for living with poor quality of life (YLL-QL). PYLLs were calculated by means of standardized methodology [37], and used health status utility measures for each disease in order to estimate the YLL-QL. The sum of these components is part of the total YLL. A discount rate of 5% was applied [38].

Methodological aspects related to data collection

The epidemiological parameters used in the model match the Brazilian demographic structure and in the individual risk of death according to cause, age and sex. These data were complemented by lethality per age and sex, estimated from the ratio between deaths by the disease and hospital admissions due to this condition. The Hospital-Based Information System of the Brazilian Unified National Health System (SIH-SUS) (Departamento de Informática do SUS; http://www.datasus.gov.br) provided the number of admissions. The lethality information generated by the model for specific diseases, such as AMI, angina, and stroke, was compared with national estimates available for coronary artery disease or cerebrovascular diseases. As the cost assessment also considered the private health insurance plans, and given the lack of information on the number of annual hospital admissions, the correction proposed by Azambuja et al. [39] was made so the all hospital admissions in Brazil in 2011 could be estimated.

The information about the overall population (population per age group and sex), the disease and hospital admissions include the Brazilian population with ages between 35 and 100 years, with particulars of age and sex (Instituto Brasileiro de Geografia e Estatística. Contagem da população 2007. http://www.ibge.gov.br/home/estatistica/populacao/contagem2007/, accessed on 10/Oct/2011).

Two corrections in the SIM-SUS databank were made: (i) the application of a death coverage adjustment fator, as proposed by the World Health Organization (WHO) for Brazil, of 1.16 (World Health Organization. WHO mortality data and statistics. http://www.who.int/healthinfo/statistics/mortality/en/index3.html, accessed on 05/Jul/2011), flatly adopted for all regions of the country, and (ii) correction of death underreporting through indirect techniques (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/Jan/2012), that redistributes "garbage codes" and unspecific codes that do not allow the accurate classification of the causes of death and of ill-defined causes.

Due to lack of local data on health status utility measures, we used sources from the international literature [15] to assess the quality of life.

Calculation of costs

The perspective of the study is the health system, and it aggregates the costs for the SUS and the private health insurance plans. The direct cost of diagnosis and treatment for each disease was calculated and included in the model, which, by simulating the likelihood of occurrence of each event over the life of the individual, totalled its cost.

The costs included: medical visits, tests, hospital stay, surgical and non-surgical prodecures. To identify and quantify cost items, five specialist practitioners were consulted in the areas of oncology, cardiology, neurology, and pneumology who work in the private health insurance plans and in the SUS. These practitioners also gave information about the likelihood of each patient to use health resources. For both, the quantification of cost items and the likelihood, a value was provided for the case of reference, and minimum and maximum variation values.

To provide value to the resources the SIGTAP table (Departamento de Informática do SUS. Sistema de gerenciamento da tabela de procedimentos, medicamentos e OPM do SUS. http://sigtap.datasus.gov.br/tabela-unificada/app/sec/inicio.js, accessed on 20/Dec/2011) and the Health Price Database (Ministério da Saúde. Banco de Preços em Saúde. http://portal.saude.gov.br/portal/saude/Gestor/area.cfm?id_area=939, accessed on 20/Dec/2011) were consulted. The cost for the SUS to provide care to lung, larynx, and oesophagus cancer was obtained in the literature [14]. The costs for the private health insurance plans were obtained from companies that market health insurance and plans in selected capital cities. The cost included in the model is the mean medical care unitary cost of 2011, presented in Brazilian Reais (BRL). No adjustments for inflation or discount rates were applied.

This study was approved by the Brazilian National Ethics Research Committee (CONEP), and by the Ethics Research Committee of the Fernandes Figueira Brazilian National Institute of Women, Child and Adolescent's Health, Oswaldo Cruz Foundation (CEP IFF/Fiocruz), according to authorizations 16.457/2011 and 08/2011, respectively. The informed consent form was signed by the specialists prior to the collection of information for the cost analysis stage.

Results

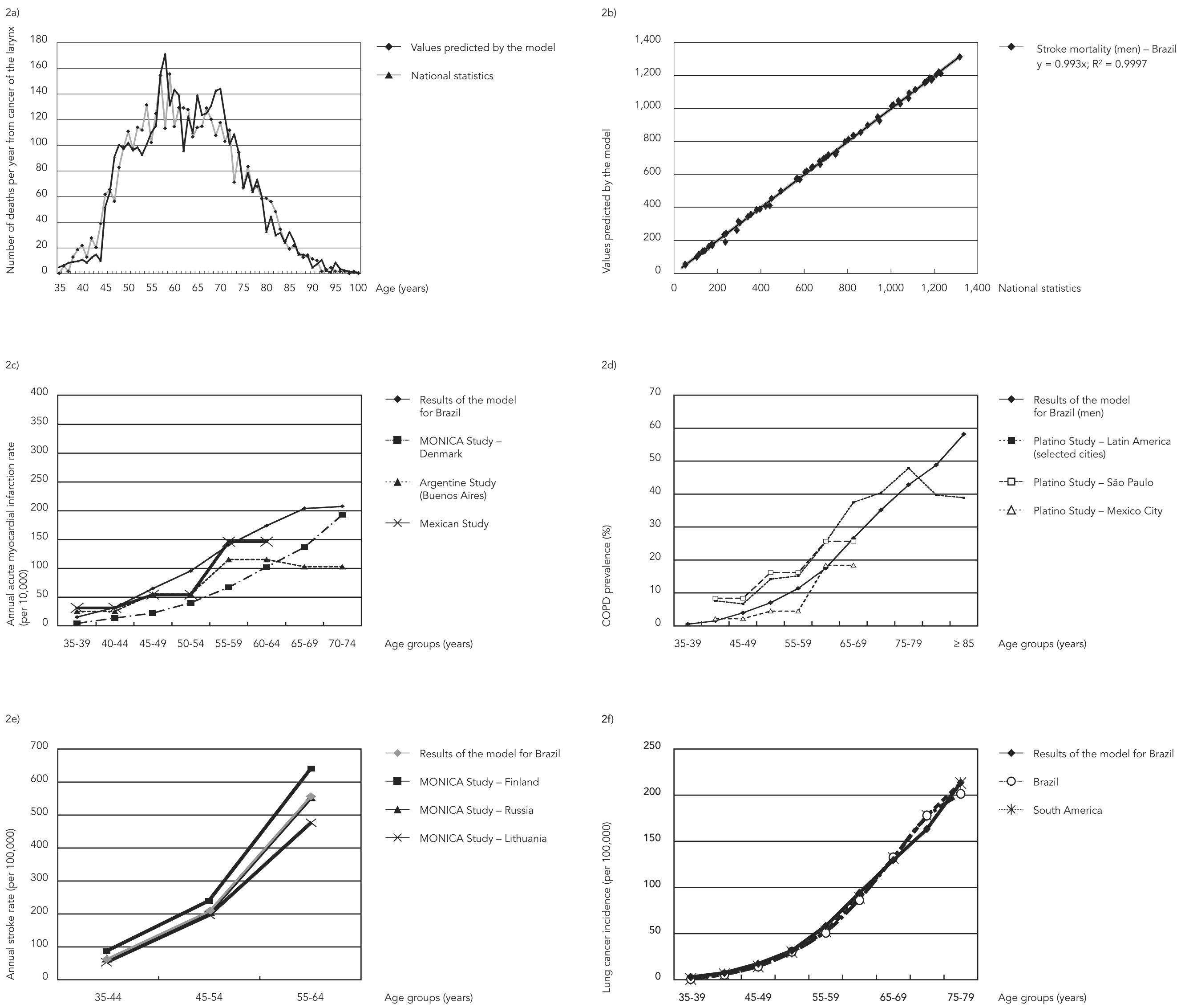
Model calibration

The set of data for the calibration process followed six hypothetical cohorts (three for males, three for females) of 8 million smokers, 8 million former smokers, and 8 million nonsmokers, followed up from age 35 years until death. This sample was estimated from a standard error of the parameter of highest variability (incidence of oral and pharyngeal cancer) due to the small incidence of events. Thus, 95% confidence intervals (95%CI) with variation +/- 2.5% for each cohort were obtained.

The incidence rates of the cohorts for each disease were transformed into absolute number of events per age and sex according to the age structure of the Brazilian population. After completion of the calibration process, the mean rate of events for each parameter was within the 10% of rates seen in national statistics, which ensured an excellent internal validation (Figure 2a). The correlation between the observed and the expected results seen in national statistics was higher for the events of higher incidence rates (AMI, stroke and lung cancer), and lower in less frequente diseases (leucemia, and oral and pharyngeal cancer). The charts generated from the observed vs. the expected data indicated the adequacy of the adjustment, and revealed that most values were close to the y=x line, which shows an almost perfect adjustment. The correlation assessment between observed and expected results reached R^2 values ranging between 0.700 and 0.999 (perfect adjustment = 1), which indicated, once more, a high degree of correlation.

Figure 2

Calibration and validation of the model.



(continues)

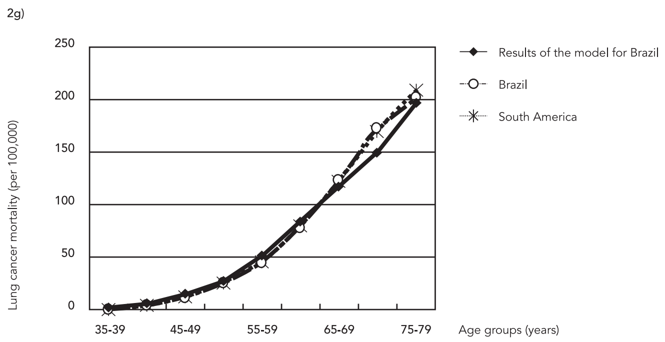
Regression lines for the 16 parameters analyzed presented gradients between 0.800 and 1.350 (Figure 2b).

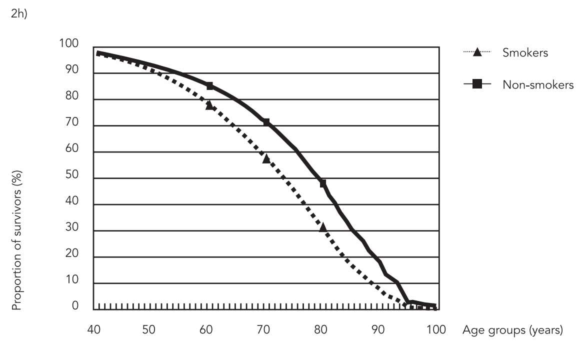
The results of external validation showed a favorable correlation between the model's predictive values and those observed in selected studies, as shown in Figures 2c, 2d, 2e, 2f and 2g.

Smoking-related deaths and events

In 2011, smoking was accountable for 147,072 preventable deaths or 403 deaths per day, which corresponded to 14.7% of the total deaths in Brazil (1,000,490 deaths). Deaths due to lung cancer and COPD corresponded to 81% and 78%, respectively, while 21% of deaths due to heart disease and 18% of deaths from stroke were also associated to this risk factor. Within the set of

Figure 2 (continued)





CAD: coronary artery disease; COPD: chronic obstructive pulmonary disease.
(2a) Calibration: annual number of deaths predicted by the model for each age group compared to national data (reference): larynx cancer (men);
(2b) Correlation chart between values predicted by the model versus the expected values in accordance with national statistics: stroke (men); (2c) Incidence of acute myocardial infarction predicted by the model compared with the following populational-based incidence studies: Danish WHO MONICA study register [34], incidence of acute myocardial infarction in Argentina [31,32] and in the Mexican population [49]; (2d) Prevalence of COPD predicted by the model, compared with the PLATINO study [35]; (2e) Incidence of stroke predicted by the model, compared with the WHO MONICA study in selected countries: Finland WHO MONICA (North Karelia province), Russia WHO MONICA (city of Novosibirsk), Lithuania WHO MONICA (city of Kaunas) [36]; (2f) Incidence of lung cancer predicted by the model, compared with estimates by the International Agency for Research on Cancer (IARC) [23]; (2g) Mortality rate of lung cancer predicted by the model, compared to IARC's estimates [23]; (2h) Survival from 35 years of age onwards in smokers and nonsmokers: results predicted by the model. In parenthesis, for the ages of 60, 70 and 90 years, the results are presented in comparison with the cohort of British physicians [33].

neoplasms, 31% of deaths were due to the use of tobacco-related products. Second-hand smoke and perinatal causes totaled 16,920 deaths. Smoking is associated to 1,147,037 PYLLs a year, concentrated in AMI (239,456), lung cancer (187,865), COPD (177,329), and stroke (164,618) (Table 1).

Tobacco-related diseases were accountable for 157,126 AMI and 75,663 strokes. A total of 63,753 individuals were diagnosed with a type of cancer included in the model. Among men, the number of events (569,098) was more than twice when compared to women (252,238), being concentrated in COPD (220,504), AMI (116,318), pneumonia (62,550) and stroke (41,577) (Table 1).

Smoking-related years of life lost and quality of life

Women who smoke have a life expectancy 4.47 years shorter than non-smoker women, and 1.32 year shorter compared to former smokers. Smoking men have a life expectancy 5.03 years shorter than non-smokers, and live 2.05 years less compared to former smokers. In addition to the impact in life expectancy, smoking-related diseases also interfere in the quality of life of individuals. Because of that, reduction of life expectancy is more significant when assessed in terms of QALY. For men, this difference is of 6.25 years between smokers and nonsmokers, and for women, of 5.72 years. Figure 2h shows the survival of smokers and nonsmokers compared to the results of the investigation by Doll et al. [34] for a cohort of British medical practitioners.

Smoking accounted for 2,699,246 YLL a year, for a scenario with a 5% discount. This total is the result of PYLL (64%) and YLL-QL (36%) combined. The higher impact was among men (1,877,198 YLL) compared to women (822,048 YLL). YLL due to second-hand smoke and perinatal causes totaled 310,533, with higher proportion of PYLL (64%) (Table 2).

Total costs attributable to smoking

The total cost for the health system was of BR$23,374,477,024. The highest amount went to heart diseases (BRL 7,219,651,548), followed by COPD (BRL 6,773,192,770), lung cancer (BRL 1,596,815,061), and stroke (BRL 1,557,995,266). These diseases accounted for 67% of the total cost, and were the higher costs for men and women. Second-hand smoke and perinatal con-

Table 1

Deaths, acute events and chronic conditions, and potential years of life lost due to premature death attributable to smoking, per sex, in Brazil.

		Deaths					
	Totals (A)	Attributable to smoking					
		Men (B)		Women (C)		Total (D = B + C)	% (D/A)
		n	%	n	%		
AMI	114,363	17,397	18	6,680	19	24,077	21
Coronary artery disease (except AMI)	33,391	4,212	4	1,540	4	5,752	17
Cardiovascular disease * (non ischemic)	50,536	5,439	6	1,419	4	6,858	14
Stroke	83,619	8,571	9	6,534	19	15,104	18
Lung cancer	27,024	15,543	16	6,363	18	21,906	81
Pneumonia	54,221	6,372	7	2,044	6	8,416	16
COPD	31,600	19,355	20	5,401	16	24,756	78
Oral and pharyngeal cancer	4,318	2,554	3	417	1	2,971	69
Esophageal cancer	9,633	5,457	6	1,127	3	6,584	68
Stomach cancer	17,594	3,355	4	523	2	3,878	22
Pancreatic cancer	8,857	1,137	1	777	2	1,914	22
Kidney and renal pelvis cancer	2,625	686	1	48	0	734	28
Larynx cancer	4,724	3,509	4	392	1	3,901	83
Myeloid leukemia	4,717	606	1	178	1	783	17
Bladder cancer	3,681	1,254	1	234	1	1,488	40
Cervical cancer	8,084	-	-	1,033	3	1,033	13
Passive smoking and perinatal causes	16,920	-	-	-	-	16,920	-
Total	475,906	5,445	100	34,707	100	147,072	31

		Acute events and chronic conditions					
	Totals (A)	Attributable to smoking					
		Men (B)		Women (C)		Total (D = B + C)	% (D/A)
		n	%	n	%		
AMI	567,214	116,318	20	40,808	16	157,126	28
Coronary artery disease (except AMI)	417,747	78,739	14	23,412	9	102,151	24
Cardiovasculas disease * (non ischemic)	-	-	-	-	-	-	-
Stroke	392,978	41,577	7	34,086	14	75,663	19
Lung cancer	29,125	17,192	3	6,561	3	23,753	82
Pneumonia	490,904	62,550	11	42,529	17	105,080	21
COPD	434,118	220,504	39	97,060	38	317,564	73
Oral and pharyngeal cancer	10,666	6,610	1	882	0	7,492	70
Esophageal cancer	10,340	5,858	1	1,210	0	7,068	68
Stomach cancer	26,087	5,082	1	756	0	5,838	22
Pancreatic cancer	9,011	1,169	0	785	0	1,953	22
Kidney and renal pelvis cancer	5,546	1,379	0	115	0	1,494	27
Larynx cancer	8,776	6,780	1	505	0	7,285	83
Myeloid leukemia	6,912	897	0	257	0	1,154	17
Bladder cancer	11,947	4,444	1	599	0	5,043	42
Cervical cancer	20,667	-	-	2,674	1	-	-
Passive smoking and perinatal causes	-	-	-	-	-	-	-
Total	2,442,038	569,098	100	252,238	100	821,336	34

(continues)

Table 1 (continued)

	PYLL (with a 5% discount)					
	Men		Women		Total	
	n	%	n	%	n	%
AMI	162,970	21	76,486	20	239,456	21
Coronary artery disease (except AMI)	33,876	4	15,473	4	49,349	4
Cardiovascular disease * (non ischemic)	43,405	6	15,237	4	58,642	5
Stroke	79,909	10	84,709	22	164,618	14
Lung cancer	119,276	16	68,589	18	187,865	16
Pneumonia	39,019	5	18,248	5	57,267	5
COPD	127,873	17	49,456	13	177,329	15
Oral and pharyngeal câncer	25,516	3	4,609	1	30,125	3
Esophageal cancer	47,060	6	11,161	3	58,221	5
Stomach cancer	27,420	4	5,434	1	32,854	3
Pancreatic cancer	9,624	1	7,429	2	17,053	1
Kidney and renal pelvis cancer	5,963	1	534	0	6,497	1
Larynx cancer	31,034	4	4,145	1	35,180	3
Myeloid leukemia	5,967	1	2,250	1	8,218	1
Bladder cancer	8,836	1	2,149	1	10,986	1
Cervical câncer	-	-	13,377	4	13,377	1
Passive smoking and perinatal causes	-	-	-	-	-	-
Total	767,479	100	379,288	100	1,147,037	100

AMI: acute myocardial infarction; COPD: chronic obstructive pulmonary disease; PYLL: potential years of life lost due to premature death.

* The matematic model does not include non-ischemic events, only the deaths.

Table 2

Potential years of life lost due to premature death and impairment related to smoking, per sex, in Brazil. Scenarios with and without discounts.

	Scenario without discount					
	Women		Men		Total	
	n	%	n	%	n	%
PYLL	919,539	79	1.743,804	74	2,663,343	76
YLL-QL	244,963	21	607,244	26	852,207	24
Total YLL attributable to smoking	1,164,502	100	2,351,048	100	3,515,550	100
PYLL attributable to passive smoking and perinatal causes	119,540	79	226,695	74	346,235	76
YLL-QL lost due to impairment attributable to passive smoking and perinatal causes	31,845	21	78,942	26	110,787	24
Total YLL attributable to passive smoking and perinatal causes	151,385	-	305,636	-	457,022	-
Total YLL	1,315,887	-	2,656,685	-	3,972,572	100
	Scenario with a 5% discount					
	Women		**Men**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**
PYLL	482,513	66	1,053,993	63	1,536,507	64
YLL-QL	244,963	34	607,244	37	852,208	36
Total YLL attributable to smoking	727,476	100	1,661,237	100	2,388,715	100
PYLL attributable to passive smoking and perinatal causes	62,727	66	137,019	63	199,746	64
YLL-QL lost due to impairment attributable to passive smoking and perinatal causes	31,845	34	78,942	37	110,787	36
Total YLL attributable to passive smoking and perinatal causes	94,572	100	215,961	100	310,533	-
Total YLL	822,048	-	1,877,198	-	2,699,246	100

PYLL: potential years of life lost due to premature death; YLL: years of life lost; YLL-QL: years of life lost for living with poor quality of life.

ditions generated costs of BRL 2,689,099,127, representing 11.5% of the total costs (Table 3).

Discussion

The results of this study indicate that smoking is a serious public health problem in Brazil, in terms of morbidity, mortality and costs for the health system. Brazil is signatory of WHO's Framework Convention on Tobacco Control since 2005 [40], a decision that legally strengthens the public policy for the control of the epidemics. For this purpose, information generated from researchers on the burden of smoking may contribute with policy-makers in decision-taking on the actions to be developed.

Our findings show that smoking-related mortality is high in Brazil, particularly among men, and is concentrated in heart diseases, COPD, stroke and lung cancer. Similar results were also found in a study developed in Argentina, in which smoking accounted for 926,878 YLL a year, representing 40,591 deaths a year that could have been prevented [15].

Our results also point to a significant burden of second-hand smoke in terms of death and illnesses. Costa et al. [41] observed that exposure to tobacco smoke accounts for 2,655 annual deaths and, according to the authors, these estimates are conservative.

The model calibration process showed that the same results from the sources of data through which the parameters were obtained were replicated. The model is based on individual simulations, which allows the occurrence of multiple events in the annual cycle. This feature is the main reason for its selection, and supports the justification of not adopting models that reflect health states, and possible transitions between these states, like the Markov chains.

The results of direct costs among men were about three times higher than the costs among women, which, along with other results, is evidence that the burden of smoking in concentrated in that population. Also worthy of mention is the cost of second-hand smoke and of perinatal conditions, particularly the former, that have been included in the calculation of economic burden in a number of countries [42,43]. The comparison of our findings with those of other investigations that estimated costs for the health system is limited, due to aspects that were mentioned in a previous research [44]. It is possible, however, to state that many studies lead to similar results by providing evidence the high economic burden of smoking for countries [45,46,47]. One of the parameters to measure this magnitude is the GDP. In China, the economic impact of smoking represented 0.7% of the GDP in 2008 [47]. Our results indicate that in Brazil this impact was 0.5% of the GDP in 2011. It is also to be stressed that federal tax collection from the tobacco industry reached BRL 6.3 billion in 2011, thus, the total cost was four times higher than the amount collected in taxes [48].

There are some limitations in the interpretation of results from this study. The uniform cor-

Table 3

Total direct costs for the health system attributable to smoking, per sex, in Brazil (BRL, 2011).

	Costs						Total (D = B + C) *	% (D/A)
	Men (B)			Women (C)				
	Totais (A)	Attributable to smoking		Total (A)	Attributable to smoking			
		n	%		n	%		
Heart conditions	18,277.741,703	5,529,399,893	35	9,635,358,870	1,690,251,655	7	7,219,651,548	26
Stroke	3,920,102,035	848,698,670	5	3,958,646,458	709,296,597	3	1,557,995,266	20
COPD	6,502,884,836	5,154,782,425	33	2,459,444,931	1,618,410,345	7	6,773,192,770	76
Pneumonia	292,903,047	69,545,072	0	252,897,780	47,285,283	0	116,830,355	21
Lung cancer	1,332,623,595	1,189,296,787	8	612,263,501	407,518,274	2	1,596,815,061	82
Other types of cancer	5,801,696,332	2,924,913,248	19	3,083,034,477	495,979,648	2	3,420,892,897	39
Passive smoking and other causes	-	-	-	-	-	-	2,689,099,127	-
Total	36,127,951,549	15,716,636,095	100	20,001,646,016	4,968,741,802	100	23,374,477,024	42

COPD: chronic obstructive pulmonary disease.

* Includes the cost with the passive smoking.

rection of mortality rates for the whole of Brazil may account for differences in the number of deaths for particular diseases, since, in some states, death registrations are more accurate and, in others, there might be undernotification. The correction of hospital admissions for the private health insurance plans by a single adjustment factor [38] is also a limitation. However, considering the scarcity of information, which includes insufficiency of ICD-10-based data, this was the methodological alternative to calculate lethality and costs as comprehensively as possible. The model used populational data of 2007 corrected for 2008, due to unavailability of data from the *2010 Census Survey* at the time parameters were defined. The growth of the Brazilian population between 2007 and 2009 was not, however, significant enough to affect the results.

Tobacco-control policies in Brazil have advanced significantly over the past 25 years, with positive results leading to a reduction in prevalence. There is an ample room for the intensification of actions already set in motion, such as increase in price and taxes, and the provision of smoking-cessation treatment, as long as their effectiveness may be monitored. Furthermore, protection to non-smokers by establishing smoking-free environments is a measure that should be more strenuously enforced in Brazil.

Finally, our findings indicate that the economic burden is underestimated, as costs with absenteeism, loss of productivity, and out-of-the-pocket family expenditures were not included. Considering the whole scenario, we have presented only a small fraction of the cost and, therefore, it is suggested that the calculation of the impact from smoking be expanded, so that the actual magnitude of this risk factor can be known.

Resumen

Los avances en el control del tabaquismo en Brasil pueden reflejarse en la reducción de la prevalencia observada en las últimas dos décadas. Las estadísticas de muertes, incidencia de eventos y costos directos atribuibles a las enfermedades, relacionadas con el tabaquismo, no han sido estimadas frecuentemente en el país. El objetivo de este estudio fue estimar la carga del tabaquismo en el año 2011, en términos de mortalidad, morbilidad y costos de asistencia médica para las patologías relacionadas con el tabaquismo. Se construyó un modelo de microsimulación probabilístico que incorpora la historia natural, los costos y la calidad de vida de los individuos. En 2011, el tabaquismo fue responsable de 147.072 muertes prematuras, 2,69 millones de años de vida perdidos, 157.126 infartos de miocardio, 75.663 accidentes cerebro-vasculares y 63.753 diagnósticos de cáncer. El costo directo fue de R$ 23,37 mil millones. El monitoreo de la carga de enfermedad atribuible al tabaquismo es una importante estrategia para informar a los responsables de las políticas públicas de salud.

Costo de Enfermedad; Tabaquismo; Años Potenciales de Vida Perdidos; Mortalidad

Contributors

M. T. Pinto and A. Bardach participated in the epidemiological data and costs data collection and analysis, and in the writing of the manuscript. A. Pichon-Riviere was responsible for the development of the economic model and the calibration process, participated in the epidemiological data collection and analysis, and in the writing of the manuscript.

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