Public Health 229 (2024) 24–32

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Themed Paper — Original Research

Smoking-attributable mortality by sex in the 27 Brazilian federal units: 2019

B. Wanderlei-Flores [a], J. Rey-Brandariz [a, b, *], P.C. Rodrigues Pinto Corrêa [c], A. Ruano-Ravina [a, b, d], C. Guerra-Tort [a], C. Candal-Pedreira [a, b], L. Varela-Lema [a, b, d], A. Montes [a, b, d], M. Pérez-Ríos [a, b, d]

[a] Department of Preventive Medicine and Public Health, Universidade de Santiago de Compostela, Santiago de Compostela, Spain
[b] Consortium for Biomedical Research in Epidemiology and Public Health (CIBER en Epidemiología y Salud Pública/CIBERESP), Madrid, Spain
[c] Escola de Medicina, Universidade Federal de Ouro Preto (UFOP), Ouro Preto, MG, Brazil
[d] Health Research Institute of Santiago de Compostela (IDIS), Santiago de Compostela, Spain

ARTICLE INFO

Article history:
Received 23 September 2023
Received in revised form
23 December 2023
Accepted 3 January 2024
Available online 20 February 2024

Keywords:
Smoking
Attributable mortality
Brazil
Lung cancer
Cardiovascular disease
Chronic obstructive pulmonary disease

ABSTRACT

Objectives: The aim of this study was to estimate smoking-attributable mortality (SAM) in the population aged 35 years and over in Brazil's 27 federal units by sex, in 2019.
Study design: This is an attributable mortality analysis.
Methods: We applied a method dependent on the prevalence of smoking, based on the population attributable fractions. Data on mortality due to causes causally related to smoking were derived from Brazil's Death Registry, data on prevalence of smoking from a survey conducted in Brazil in 2019, and data on relative risks from five US cohorts. Crude and age-adjusted SAM rates were calculated by sex. Estimates of SAM were calculated by specific causes of death and major mortality groups for each federal unit by sex.
Results: In 2019, smoking caused 480 deaths per day in Brazil. Although the SAM varied among the federal units, the pattern is not clear, with the greatest difference being between Rio Grande do Sul (crude rate: 248.8/100,000 inhabitants) and Amazonas (106.0/100,000). When the rates were adjusted by age, the greatest differences were observed between Acre (271.1/100,000) and Distrito Federal (131.1/100,000). SAM was higher in males; however, while the main specific cause of SAM in men was ischemic heart disease, in women it was chronic obstructive pulmonary disease. The major mortality group having the greatest impact on SAM across all federal units was the cardiometabolic diseases.
Conclusions: The variability in the burden of SAM in the different regions of Brazil reaffirms the need for SAM data disaggregated at the geographic level.

Introduction

Smoking is the leading preventable cause of disease and one of the main causes of premature death worldwide, associated with more than seven million deaths per year. According to the World Health Organization (WHO), there are more than one billion smokers in the world, and approximately 80% of these live in low-to middle-income countries.[1]

After recognizing smoking as a major public health problem, Brazil set up a National Smoking Control Program in 1989. Tax increases, restrictions on availability, control of marketing and sale, heightened educational activities in schools, and implementation of laws governing smoke-free zones are some of the actions by the National Smoking Control Program that have contributed to the decrease in the prevalence of smoking in Brazil since the late 1990s.[2,3] Regarding taxes, in 2012, a minimum sale price for cigarettes was established and there are currently two tax reform bills for tobacco products under revision in the National Congress. The implementation in 2011 of the Law 12.5464 was a milestone; it

* Corresponding author. Área de Medicina Preventiva y Salud Pública, Universidade de Santiago de Compostela, Santiago de Compostela, C/ San Francisco s/n, A Coruña CP 15782, Spain. Tel.: +34 881 81 22 78.
E-mail address: juliarey.brandariz@usc.es (J. Rey-Brandariz).

https://doi.org/10.1016/j.puhe.2024.01.016

prohibits the advertising, promotion and sponsorship of tobacco products and the consumption of tobacco in closed settings. In the period 1990–2017, the prevalence of smoking in Brazil fell by 24 percentage points, sitting at 11.3% in 2017.[4] Comparing the 2013 and 2019 *Pesquisa Nacional de Saúde* (PNS) results, smoking prevalence in men in Brazil decreased by 3% and in women by 1.4%. When analyzing the results by region, the region with the largest decrease in smoking prevalence for both men and women was the Northeast region, with a decrease of 4.9% in men and 2.2% in women, followed by the North region with a decrease of 3.8% and 1.7%, respectively. The region with the smallest decrease in smoking prevalence in men was the South region with 2.1%, followed by the Southeast region with 2.4%. In women, the smallest decrease was the Center-west region with a decrease of 0.4%, followed by the South region with 0.8%. However, it should be noted that based on data furnished by the 2019 PNS, smoking prevalence is seen to vary by federal unit with the northern federal units showing decreases in smoking prevalence above the Brazilian average, while smaller decreases are recorded in the southern ones.[5] Notwithstanding this fall in prevalence, Distrito Federal was the federal unit with the lowest smoking prevalence (10.9%) and Acre with the highest (17.0%).[5]

Estimating the burden of mortality attributable to a risk factor such as tobacco consumption makes it possible to ascertain its impact on population health. This estimate is crucial for planning, implementing, and assessing the impact of smoking control programs, whether at the city, state, or country level. Since 2008, seven studies have estimated smoking-attributable mortality (SAM) in Brazil. Four of these studies estimated attributable mortality for Brazil as a whole,[6–9] one estimated it for federal units,[4] one for 16 Brazilian capitals[10] and another for a single federal unit.[11] However, the study that estimated SAM in the federal units did not perform a detailed analysis by cause of death. In addition, in 2019, a health survey making smoking prevalence at the federal unit level available was conducted. Therefore, it would be appropriate to update the SAM estimates and to have a more detailed analysis of these estimations.

Accordingly, the aim of this study was to estimate SAM in the population aged 35 years and over by sex in the Brazil's 27 federal units, in 2019.

Methods

Brazil is a country of continental dimensions, made up of five large regions, North, North-east, Center-west, South-east, and South, divided into 27 federal units. The North region (N) includes the states of Roraima, Amazonas, Acre, Rondônia, Amapá, Pará and Tocantins; the North-east (NE) includes Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe y Bahía; the Center-west (CW) Mato Grosso, Mato Grosso do Sul, Goiás, and Distrito Federal; the South-east (SE) Minas Gerais, Espírito Santo, Rio de Janeiro, and São Paulo; and the South (S) Paraná, Rio Grande do Sul, and Santa Catarina (Supplementary Fig. S1). Brazil population is estimated at 213.3 million. The three most heavily populated states lie in the South-east region of the country, with São Paulo being the first of these with 46.6 million inhabitants, accounting for 21.9% of the country's total population. It is followed by Minas Gerais with 21.4 million, and Rio de Janeiro with 17.5 million. The least populous state is Roraima, situated in the North region, with 652,713 inhabitants.[12]

Calculation procedure

We applied a method dependent on the prevalence of smoking, based on the calculation of population attributable fractions (PAFs).[13] This method estimates SAM as the product of observed mortality by PAF.

The PAF is estimated as:

$$\frac{[P_0 + P_1RR_1 + P_2RR_2] - 1}{[P_0 + P_1RR_1 + P_2RR_2]},$$

where P is the prevalence of never smokers (0), smokers (1), and ex-smokers (2); and RR is the risk posed to smokers (1) and ex-smokers (2) of dying due to smoking-related diseases, taking never smokers as the reference group.

The SAM estimates were calculated in accordance with the STREAMS-P tool guidelines.[14]

Data source

Observed mortality in the country's 27 federal units in 2019 was based on data derived from the Mortality Information System of Brazil's Unified Health System. Death data due to underlying causes codified by the 10th edition of the International Classification of Diseases (ICD-10) were available. The observed mortality figures and the smoking-related causes of death included in this analysis, along with their ICD-10 rubrics, are shown in Supplementary Tables S1 and S2. Causes of death were grouped into cardiovascular diseases and diabetes mellitus (hereinafter 'cardiometabolic diseases'), cancer, and respiratory diseases.

The prevalence of smokers, ex-smokers, and never smokers in each federal unit, with a breakdown by sex and age group (35–54; 55–64; 65–74, and 75 years and over), was obtained on the basis of microdata from Module P–Lifestyles of the 2019 National Health Survey (PNS). The PNS is a nation-wide household health survey conducted by the Ministry of Health in collaboration with the Brazilian Geography and Statistics Institute (*Instituto Brasileiro de Geografia e Estatística/IBGE*) (Supplementary Table S3).

The relative risks (RRs) applied were drawn from the follow-up of five US cohorts that included 956,756 participants: the National Institutes of Health-AARP Diet and Health Study, the American Cancer Society's CPS-II Nutrition Cohort, the Women's Health Initiative, the Nurses' Health Study, and the Health Professionals Follow-Up Study.[15] These risks are risk ratios adjusted for age, race, and educational level (Appendix 1 and Supplementary Table S4).

The population for calculating global and age-specific SAM rates was derived from the *IBGE* and was adjusted applying the WHO Standard World Population for 2000–2025.[16]

Analysis

In each of Brazil's federal units, we estimated the following: PAFs and SAM for specific causes and in the three main groups of causes of death, global and by sex; crude SAM rates by sex; age-specific rates by sex; and age-adjusted rates in men and women. In addition, sex ratios for the adjusted SAM rates were calculated in each federal unit. The age-specific SAM rates and the adjusted rates broken down by sex are shown on maps.

Estimates were calculated using the Stata 16.1 statistics software program, and spatial representation was performed using the QGIS 3.10 software package.

Results

In 2019, smoking caused 174,483 deaths in Brazil among the population aged 35 years and over, accounting for 14.5% of the country's total mortality for that year in the same population. A total of 109,161 deaths (62.6% of SAM) occurred in men, accounting for 16.9% of the total mortality in Brazil in men aged 35 years and

over. In women, tobacco consumption was associated with 65,322 deaths (37.4% of SAM), accounting for 11.6% of the total mortality in Brazil in women aged 35 years and over. In the population under 75 years of age, tobacco consumption caused 108,371 deaths (37.9% of SAM), representing 10.2% of the total mortality in Brazil in the 35–74 age group. The highest SAM burden was due to cardiometabolic diseases (72,172 deaths, 41.4% of SAM), followed by respiratory diseases (59,301 deaths, 34.0% of SAM), and cancer (43,010 deaths, 24.6% of SAM). Within the SAM due to cancer, 54.8% were due to lung cancer (23,558 deaths). The specific cause of death which accounted for the highest SAM (36,934 deaths) was chronic obstructive pulmonary disease (COPD).

In relation to federal units, federal-SAM over total-SAM ranged from 0.2% in Roraima (N) and Amapá (N) to 26.1% in São Paulo (SE). São Paulo (SE) was the federal unit with the highest SAM percentage in men (44.3%) and in women (25.5%). Regardless of federal unit or cause of death, SAM was in all cases higher in men, i.e. for each attributable death in women, there were 1.7 in men (sex ratio: 1.7:1). The highest sex ratios were observed in Mato Grosso (CW) (2.3:1), and Roraima (N) (2.2:1) (Tables 1 and 2).

In Brazil, the SAM by specific cause of death varied between sex and between federal units. Among men, the leading cause of smoking-related death was ischemic heart disease, which caused 19.5% of total SAM, with variations between federal units. Hence, ischemic heart disease accounted for 27.0% of SAM among men in Rio Grande do Norte (NE) vs. 14.2% of SAM among men in Minas Gerais (SE). COPD was the second leading cause to which most mortality was attributed in men, accounting for 19.2% of total attributable deaths in men; the SAM for COPD varied between 31.6% of SAM in Acre (N) and 11.7% in Rio Grande do Norte (NE). Influenza-pneumonia-tuberculosis was the third leading cause of death in men, accounting for 13.5% of total SAM in men, while lung cancer was the fourth leading cause, accounting for 12.8% of total SAM in men. Attention should be paid to the differences in terms of SAM burden in men due to lung cancer between Rio Grande do Sul (S), where it was associated with 19.7% of SAM, and Roraima (N), where it accounted for 8.1% (Table 1 or Fig. 1).

Among women, the leading cause of SAM was COPD, which caused 24.5% of total SAM in women, with variations between federal units. Thus, in Goiás (CW) COPD accounted for 34.5% of SAM in women and in Rio Grande do Norte (NE) it accounted for 16.3%. Ischemic heart disease was the second leading cause to which most mortality was attributed, causing 17.7% of total SAM in women. This percentage of SAM ranged from 24.4% in Rio Grande do Norte (NE) to 12.2% in Amazonas (N). Lung cancer was the third leading cause of SAM in women, causing 14.7% of total SAM. In terms of the SAM burden in women due to lung cancer, there were differences between Rio Grande do Sul (S), where it was associated with 20.0% of SAM in women, and Tocantins (N), where it accounted for 10.1% (Table 2).

The crude rate of SAM in men ranged from 139.3 deaths per 100,000 inhabitants in Amazonas (N) to 328.2 deaths in Rio Grande do Sul (S). In women, the crude SAM rate ranged from 73.1 deaths per 100,000 inhabitants in Amazonas (N) to 177.7 in Rio Grande do Sul (S) (Table 3). The age-specific SAM rate increased with age in all of Brazil's federal units, both among men and women (Fig. 2). The age-adjusted SAM ranked Acre (N) as the federal unit having the highest rate, followed by Rio Grande do Sul (S). The federal units registering the lowest age-adjusted SAM rates were Bahía (NE) and Distrito Federal (CW). The breakdown by sex showed that Acre was also the federal unit with the highest age-adjusted SAM rates for both men and women (Table 3). Furthermore, while Santa Catarina (S) and Espírito Santo (SE) were the federal units where the sex ratios were the highest (2.4:1), Tocantins (N) was the unit where the sex ratio was the lowest (1.6:1) (Fig. 3).

Discussion

In 2019, smoking caused one death every 3 minutes in Brazil. The results of this study show differences in SAM among federal units with the greatest differences between death rates in Rio Grande do Sul and Amazonas, and with the rates of the former being twice as high as those of the latter. When the rates were adjusted by age, the greatest differences were observed between Acre and Distrito Federal, with the rates of the former being twice as high as those of the latter. The group of causes which had greatest SAM burden in all federal units was that of cardiometabolic diseases, followed by respiratory diseases and cancer. The leading specific cause of smoking-related death was ischemic heart disease in men, and COPD in women. Regarding sex, despite federal unit, SAM was higher in males; however, among men ischemic heart disease was the main specific cause of SAM, while in women, it was COPD. When assessing the impact of tobacco consumption on lung cancer mortality, it should be noted that it was greater among women, accounting for 14.7% of the SAM, while in men it represented 12.8%.

To our knowledge, this is the second study to estimate SAM in Brazil's federal units using common data sources and methodology. The results yielded by this study should not be directly compared with those of the previous study,[4] since the age groups analyzed and causes included are different. That said, however, as in the previous study, our study shows that there are major differences in SAM rates among federal units. The distribution of SAM does not show a clear geographical pattern. Two states, Acre and Rio Grande do Sul, show the highest burden of SAM; and a higher burden is observed in the North-east, Center-west (except Mato Grosso) and South. The results of the study by Malta et al.[4] point to the federal units of the South (Rio Grande do Sul, Santa Catarina and Paraná) and South-east (São Paulo, Rio de Janeiro, Espírito Santo, and Minas Gerais) as being the units with highest rate of SAM. Similar results were found by our study, with Rio Grande do Sul being the federal unit with the highest crude SAM rate and the highest SAM burden due to lung cancer. Rio Grande do Sul is the federal unit with the second most aged population in Brazil, with two out of every ten persons over 60 years old.[12] Furthermore, 45% of the population reported that they smoke or smoked at some time in their lives.[17] It should be borne in mind that Brazil is the second leading tobacco-producing country in the world and the largest exporter[18] with Rio Grande do Sul being Brazil's biggest tobacco producer, responsible for 41% of total national production.[19] However, when adjusted by age, Acre was the federal unit with the highest SAM burden. This could be related with its geographic situation, in that it lies in an area bordering Peru and Bolivia, which gives Acre access to cheaper cigarettes through cross-border trading or smuggling.

We should be cautious when analyzing the impact of tobacco consumption on the major groups of causes of mortality such as cancer, cardiovascular or respiratory diseases. The concurrence of competing risks or socioeconomic differences could partly explain the results obtained. The population living in less developed areas has less access to health services, which could translate into higher mortality from causes such as cardiovascular or respiratory diseases or into poorer diagnostic capacity for cancer. The former would result in higher mortality from cardiovascular and respiratory diseases, and the latter in lower mortality attributed to cancer, since it would not be coded as a cause of death because it was not diagnosed. Regarding lung cancer, studies in North America and Europe show that lung cancer is the leading cause of death from tobacco consumption in both men and women.[20,21] However, in Brazil, it is the fourth leading cause of death from tobacco use in men and the third in women. In a study analyzing the evolution of SAM in Brazil between 1996 and 2019, it was observed that the

Table 1
Smoking-attributable deaths in relation to attributable mortality in men aged ≥35 years, by cause of death, in Brazil's federal units in 2019.

Federal unit	Cancer				Cardiometabolic diseases										Respiratory diseases				Total
	Lung cancer		Other cancer		Ischemic heart disease		Other heart diseases		Cerebrovascular disease		Other vascular diseases		Diabetes mellitus		COPD		Influenza-pneumonia-tuberculosis		
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Acre	37	9.4	33	8.5	69	17.8	15	3.8	29	7.5	6	1.6	14	3.7	122	31.6	63	16.2	387
Alagoas	113	8.4	107	7.9	322	23.8	94	7.0	151	11.1	39	2.9	108	8.0	235	17.4	185	13.6	1354
Amapá	27	11.4	24	10.0	43	18.2	14	6.0	22	9.3	5	1.9	15	6.4	55	23.3	32	13.6	237
Amazonas	147	14.7	122	12.2	171	17.2	44	4.4	93	9.3	15	1.5	86	8.6	181	18.2	137	13.7	995
Bahía	572	9.8	823	14.0	1090	18.6	436	7.4	707	12.1	153	2.6	380	6.5	1074	18.3	626	10.7	5860
Ceará	560	12.8	553	12.7	967	22.1	337	7.7	409	9.4	145	3.3	142	3.2	528	12.1	730	16.7	4371
Distrito Federal	132	15.0	140	15.8	156	17.7	40	4.5	74	8.4	34	3.8	42	4.7	178	20.2	87	9.9	883
Espírito Santo	274	13.3	318	15.4	406	19.7	91	4.4	168	8.1	83	4.0	101	4.9	412	20.0	210	10.2	2063
Goiás	482	12.5	395	10.3	706	18.4	250	6.5	270	7.0	129	3.4	166	4.3	1048	27.3	394	10.3	3839
Maranhão	229	9.4	211	8.6	614	25.1	147	6.0	314	12.8	54	2.2	220	9.0	363	14.9	295	12.0	2446
Mato Grosso	167	11.8	157	11.1	254	18.0	71	5.0	108	7.6	36	2.6	74	5.3	400	28.3	146	10.3	1413
Mato Grosso do Sul	160	10.4	179	11.6	367	23.8	70	4.5	116	7.5	31	2.0	58	3.7	319	20.7	243	15.8	1543
Minas Gerais	1360	12.4	1479	13.5	1558	14.2	788	7.2	877	8.0	291	2.7	488	4.5	2531	23.1	1597	14.6	10,970
Pará	274	9.9	282	10.2	583	21.1	153	5.5	291	10.5	35	1.2	198	7.2	490	17.7	462	16.7	2767
Paraíba	206	9.9	245	11.7	502	24.1	136	6.5	173	8.3	58	2.8	139	6.6	324	15.6	303	14.5	2085
Paraná	945	14.5	888	13.6	1074	16.5	334	5.1	522	8.0	187	2.9	294	4.5	1517	23.2	765	11.7	6526
Pernambuco	468	10.7	457	10.4	1099	25.0	225	5.1	422	9.6	153	3.5	248	5.6	801	18.3	517	11.8	4389
Piauí	152	10.3	137	9.3	351	23.9	81	5.5	179	12.2	37	2.5	98	6.7	202	13.7	233	15.9	1470
Rio de Janeiro	1205	12.5	1096	11.4	2016	21.0	707	7.4	754	7.8	225	2.3	539	5.6	1405	14.6	1660	17.3	9608
Rio Grande do Norte	210	12.8	197	12.1	443	27.0	79	4.8	124	7.6	46	2.8	89	5.5	192	11.7	257	15.7	1637
Rio Grande do Sul	1807	19.7	1314	14.3	1347	14.7	375	4.1	652	7.1	243	2.6	445	4.8	2275	24.7	735	8.0	9193
Rondônia	72	11.1	87	13.5	108	16.7	45	6.9	47	7.3	14	2.1	34	5.3	171	26.4	70	10.8	648
Roraima	15	8.1	24	13.1	34	18.8	14	7.7	23	12.8	3	1.9	13	7.4	37	20.5	18	9.8	182
Santa Catarina	731	18.5	524	13.3	636	16.1	216	5.5	239	6.0	133	3.4	146	3.7	927	23.5	399	10.1	3951
São Paulo	3464	12.0	3926	13.6	6039	20.9	2030	7.0	2092	7.2	1153	4.0	1012	3.5	4839	16.7	4396	15.2	28,950
Sergipe	96	12.6	86	11.4	139	18.3	46	6.1	75	9.9	24	3.2	54	7.1	140	18.4	100	13.1	761
Tocantins	73	11.6	64	10.2	142	22.5	36	5.7	59	9.4	17	2.7	52	8.2	143	22.7	44	7.0	631
Brazil	13,974	12.8	13,868	12.7	21,238	19.5	6873	6.3	8989	8.2	3350	3.1	5255	4.8	20,911	19.2	14,703	13.5	109,161

COPD: chronic obstructive pulmonary disease.

Table 2
Smoking-attributable deaths in relation to attributable mortality in women aged ≥ 35 years, by cause of death, in Brazil's federal units in 2019.

Federal unit	Cancer				Cardiometabolic diseases										Respiratory diseases				Total
	Lung cancer		Other cancer		Ischemic heart disease		Other heart diseases		Cerebrovascular disease		Other vascular diseases		Diabetes mellitus		COPD		Influenza-pneumonia-tuberculosis		
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Acre	31	14.9	15	7.0	33	15.9	11	5.2	15	7.5	5	2.6	7	3.6	59	28.6	30	14.7	207
Alagoas	110	11.4	58	6.0	193	19.8	61	6.3	107	11.0	35	3.6	66	6.8	212	21.8	128	13.2	971
Amapá	18	12.8	12	8.8	20	14.1	7	5.2	10	7.0	1	0.8	10	7.1	42	29.7	20	14.5	140
Amazonas	86	16.4	59	11.3	64	12.2	25	4.8	45	8.5	7	1.3	36	6.9	136	25.8	68	12.9	528
Bahía	421	12.3	334	9.7	633	18.5	285	8.3	340	9.9	108	3.2	225	6.6	762	22.2	318	9.3	3427
Ceará	523	15.7	281	8.4	642	19.3	233	7.0	277	8.3	110	3.3	99	3.0	654	19.6	517	15.5	3335
Distrito Federal	107	16.2	71	10.8	91	13.8	37	5.6	55	8.3	34	5.1	21	3.2	191	28.8	54	8.2	663
Espírito Santo	153	14.4	96	9.1	205	19.4	51	4.8	89	8.4	41	3.9	43	4.0	273	25.8	109	10.3	1061
Goiás	295	12.8	166	7.2	335	14.6	169	7.3	151	6.6	78	3.4	89	3.9	794	34.5	224	9.7	2301
Maranhão	172	10.7	136	8.4	372	23.0	115	7.1	189	11.7	50	3.1	117	7.2	279	17.3	187	11.5	1617
Mato Grosso	77	12.3	44	7.1	99	15.9	40	6.4	47	7.5	17	2.8	37	5.9	202	32.4	60	9.6	623
Mato Grosso do Sul	111	12.2	64	7.0	193	21.2	50	5.5	63	7.0	22	2.4	36	4.0	246	27.1	123	13.6	909
Minas Gerais	823	13.2	544	8.7	815	13.0	601	9.6	458	7.3	184	2.9	262	4.2	1754	28.1	810	13.0	6250
Pará	165	12.2	112	8.3	224	16.6	75	5.6	114	8.5	20	1.5	78	5.8	352	26.1	207	15.3	1347
Paraíba	169	11.6	112	7.7	322	22.1	114	7.8	127	8.7	38	2.6	75	5.2	301	20.6	198	13.6	1458
Paraná	629	17.0	310	8.4	499	13.5	225	6.1	247	6.7	94	2.5	152	4.1	1216	32.9	327	8.8	3699
Pernambuco	351	12.0	224	7.7	669	22.9	161	5.5	246	8.4	121	4.1	149	5.1	706	24.2	296	10.1	2922
Piauí	121	11.9	83	8.2	203	19.9	63	6.2	124	12.2	28	2.8	56	5.5	178	17.5	163	16.0	1019
Rio de Janeiro	931	15.3	522	8.6	1215	20.0	442	7.3	466	7.7	163	2.7	298	4.9	1126	18.5	914	15.0	6077
Rio Grande do Norte	173	14.9	103	8.9	284	24.4	74	6.3	83	7.1	38	3.2	67	5.7	190	16.3	152	13.0	1164
Rio Grande do Sul	1111	20.0	523	9.4	748	13.5	319	5.7	379	6.8	142	2.5	243	4.4	1715	30.8	380	6.8	5560
Rondônia	55	16.9	25	7.9	44	13.7	23	7.2	20	6.3	5	1.4	16	5.0	101	31.3	33	10.4	324
Roraima	13	15.9	9	10.7	12	14.8	4	5.2	6	7.1	3	4.0	6	6.9	18	22.6	10	12.7	81
Santa Catarina	373	17.5	183	8.6	300	14.1	159	7.5	140	6.6	79	3.7	72	3.4	622	29.2	200	9.4	2128
São Paulo	2461	14.8	1430	8.6	3190	19.2	1465	8.8	1103	6.6	800	4.8	495	3.0	3657	22.0	2042	12.3	16,645
Sergipe	65	13.5	40	8.4	76	15.8	29	6.0	42	8.7	15	3.2	29	6.0	124	25.8	61	12.6	482
Tocantins	39	10.1	26	6.8	69	17.8	24	6.3	42	10.9	18	4.6	24	6.2	111	28.7	33	8.5	386
Brazil	9584	14.7	5584	8.5	11,552	17.7	4863	7.4	4984	7.6	2258	3.5	2809	4.3	16,023	24.5	7664	11.7	65,322

COPD: chronic obstructive pulmonary disease.

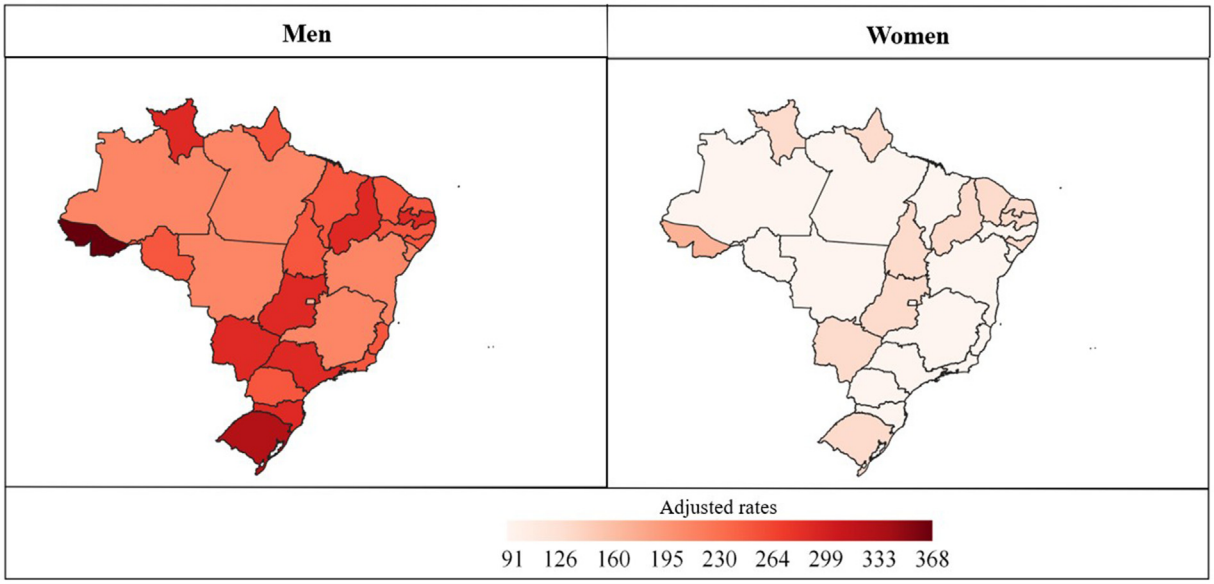

Fig. 1. Age-adjusted smoking-attributable mortality rates in men and women aged ≥35 years: rates per 100,000 population, by federal unit, in 2019.

crude rate of SAM due to lung cancer in men remained stable at around 25 deaths per 100,000 inhabitants.[22] This figure is well below than that observed in a study conducted in Spain where this rate was found throughout the period 1990–2018 to be above 100 deaths per 100,000 population.[23] In Brazilian women, an upward trend of SAM rates due to lung cancer is observed and these rates are more similar to rates observed in a study conducted in Spain.[23] This evolution of the rates of SAM due to lung cancer could be explained by the evolution of smoking prevalence in Brazil, since lung cancer is considered a marker of the tobacco epidemic. Thus, from 1996 to 2019 the prevalence of tobacco consumption in Brazil went from 29% to 15.9% in men and from 19% to 9.6% in women.[5,7] However, it should be noted that based on data furnished by the 2019 PNS, smoking prevalence is seen to vary by federal unit. While Amapá, Goiás, Rondônia, Acre, Pará, Sergipe, Rio Grande do Norte, Alagoas, Espírito Santo, Piauí, Ceará, Maranhão, Roraima, and Bahía

Table 3
Smoking-attributable mortality rates, crude and adjusted per 100,000 inhabitants in the population aged ≥35 years, by federal unit, and the sex ratio of the adjusted rates, in 2019.

Federal unit	Crude rates			Adjusted rates			Sex ratio
	Total	Men	Women	Total	Men	Women	
Acre	206.7	271.3	142.9	271.1	367.8	174.3	2.1
Alagoas	168.7	211.9	131.3	194.1	252.5	135.6	1.9
Amapá	138.3	171.9	103.9	203.3	259.4	147.2	1.8
Amazonas	106.0	139.3	73.1	148.3	199.8	96.7	2.1
Bahía	133.5	176.0	94.4	147.1	203.2	91.1	2.2
Ceará	198.6	240.9	161.5	206.2	262.8	149.6	1.8
Distrito Federal	108.7	140.3	83.7	131.1	171.0	91.2	1.9
Espírito Santo	161.2	218.7	106.7	168.4	237.8	99.0	2.4
Goiás	195.5	251.0	142.7	225.4	296.1	154.7	1.9
Maranhão	155.7	196.2	118.6	178.8	233.9	123.8	1.9
Mato Grosso	137.2	187.2	85.5	163.1	227.7	98.5	2.3
Mato Grosso do Sul	199.0	256.2	144.3	215.9	283.2	148.5	1.9
Minas Gerais	164.5	216.8	115.6	159.6	217.7	101.5	2.1
Pará	130.5	175.7	85.3	162.8	225.5	100.1	2.3
Paraíba	196.4	250.0	150.3	202.4	267.6	137.2	2.0
Paraná	183.5	245.0	127.2	182.5	248.6	116.5	2.1
Pernambuco	173.1	225.7	128.2	190.4	258.3	122.4	2.1
Piauí	179.2	226.8	137.6	200.2	265.0	135.4	2.0
Rio de Janeiro	181.4	240.1	130.9	174.6	238.6	110.7	2.2
Rio Grande do Norte	178.5	220.5	140.7	188.5	246.9	130.1	1.9
Rio Grande do Sul	248.8	328.2	177.7	223.0	305.4	140.6	2.2
Rondônia	128.3	169.2	86.4	175.8	233.1	118.5	2.0
Roraima	145.9	196.8	92.4	212.2	288.9	135.5	2.1
Santa Catarina	181.0	248.2	120.5	190.5	270.2	110.9	2.4
São Paulo	200.0	267.3	139.1	201.4	279.1	123.7	2.3
Sergipe	127.9	166.6	93.6	154.4	209.8	98.9	2.1
Tocantins	162.4	199.1	124.8	186.2	231.4	141.0	1.6
Brazil	179.0	235.1	127.9	177.6	251.2	123.5	2.0

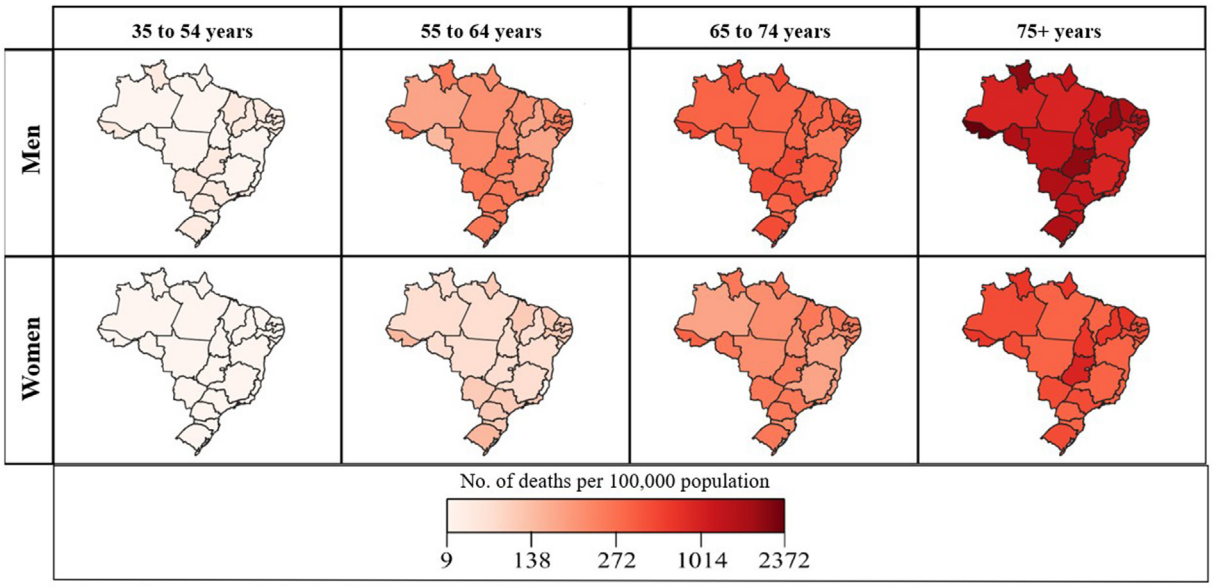

Fig. 2. Specific smoking-attributable mortality rates, by sex (men and women) and age group (35–54, 55–64, 65–74 and ≥75 years), in each federal unit in 2019: rates per 100,000 population.

display decreases above the Brazilian mean, São Paulo, Pernambuco, Minas Gerais, Rio de Janeiro, Paraná, Distrito Federal, Mato Grosso do Sul, Rio Grande do Sul, Mato Grosso, and Santa Catarina register smaller decreases.[5]

In contrast to what is observed in Europe,[20] in Brazil, COPD is the specific cause of death to which most mortality is attributed to tobacco use. This may be due to the fact that in Brazil treatment of this disease is relatively recent, since it was not until 2013 that the federal government began to guarantee cost-free distribution of drug treatment.[24] Additionally, account must be taken of the way in which socio-economic differences in the regions of Brazil are associated with COPD mortality. For instance, COPD mortality was lower in the South and South-east regions, where socioeconomic conditions are better and social inequality is less.[24,25] Furthermore, these better socio-economic conditions could be associated with a lower exposure to COPD risk factors other than smoking, such as less use of fossil fuel or biomass such as firewood, charcoal, or animal dung to heat homes and cook food.[26,27] A previous study undertaken in Brazil identified changes in risk of COPD-related death by birth cohort, though such changes show differences by sex, decreasing in men and increasing in women.[28] Goiás is the federal unit which registers the highest burden of COPD-SAM in women (34.5%) and ranks fourth in the use of energy obtained from biomass.[29] In men, the federal unit registering the highest burden of COPD-SAM was Acre (31.6%). This federal unit is situated in the North of the country, an area with less favorable conditions in terms of Mortality Information System coverage, due to its territorial isolation.[30]

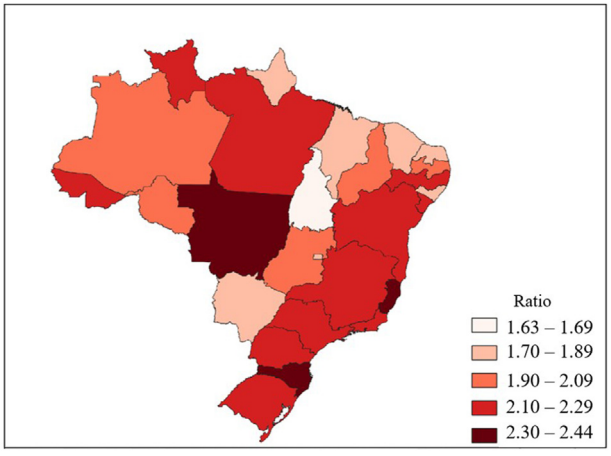

Fig. 3. Sex ratio of the age-adjusted smoking-attributable mortality rates in the Brazilian population aged ≥35 years, by federal unit: 2019.

Ischemic heart disease is responsible for a high SAM. This result also differs from what has been reported by other studies conducted in European countries such as Spain or in the USA,[20,31] where cancer causes the highest number of smoking-attributable deaths. Differences in life expectancy could partially explain the difference in the causes of death. Also, this difference may be due to the fact that Brazil is a country of continental dimensions, with marked social inequalities. Rio Grande do Norte is the federal unit in which the SAM due to ischemic heart disease is highest in both sexes; whereas the North-west region is noteworthy for the rise in ischemic heart disease mortality since 1996. The South and South-east regions, the most developed regions in Brazil, display a downward trend; and the North and Center-west regions show a stabilization.[32] The fact that wealthier regions have lower SAM due to ischemic heart disease may be due to better access to health services, which has led to improved secondary and tertiary prevention of cardiovascular disease. The presence of lower SAM associated with cardiovascular disease in wealthier regions was also observed in a study conducted in Portugal.[33] In Portugal, mortality from cardiovascular disease was reduced by approximately 40% due to improvements in treatment and speed of diagnosis.[34]

In Brazil, as in most countries, men register higher smoking-related mortality rates. This is related to a higher prevalence of smokers in men than in women.[4] Although in comparison with European countries such as Spain, the difference in smoking prevalence between men and women in Brazil is smaller. This is also to be seen from the male/female SAM rates ratio, which in Brazil rises to a peak of 2.4 in the federal units of Santa Catarina and Espirito Santo, as compared to Spain where the maximum of 12.1 is observed in

Extremadura (a region located in the west of Spain).[13] Comparison of these results with those derived from studies analyzing prevalence or SAM at the regional level in South America would be of value; however, detailed regional analyses are scarce.[35]

This study has limitations, including those specific to the method of estimation used. It should be borne in mind that the RRs were drawn from cohort studies conducted on the US population, where the evolution of the smoking epidemic is different from that in Brazil. Even so, these risks are the best evidence available when assessing excess risk of death associated with smoking, by virtue of the fact that they derive from the follow-up of five cohorts which included 956,756 participants.[15] In this study, the PAF was used to calculate the attributed mortality. However, there are some problems in the definition and interpretation of the PAF that should be considered when interpreting the results. This is because different definitions of PAF have been used in the literature that include three different concepts. These three concepts are the excess fraction, the etiological fraction, and the incidence-density fraction. Therefore, some authors indicate that the term PAF requires the separation of these three concepts.[36] Due to the lack of data, no account was taken of the length of smoking among smokers or the time elapsed since ex-smokers had quit smoking. Regarding observed mortality, the quality and coverage of the death registry must be taken into consideration. The quality of Brazil's Death Registry has improved in recent years:[6,37] death registry coverage is estimated to have risen from 83.2% in the period 1980–1991 to 89.7% in the period 2000–2010.[38] Moreover, it is estimated that the percentage of deaths in the population aged ≥35 years, classified as 'Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified' went from 16.4% in 1996 to 5.6% in 2017.[6]

On the other hand, this study has strengths. The most important one is the use of prevalence data representative at a federal-unit level to estimate SAM. Moreover, our study used the same calculation procedure and the same data-sources to estimate SAM in the federal units. The STREAMS-P tool[14] was applied to enhance the reliability of the results.

Conclusions

In 2019, smoking caused 14.5% of total mortality in the Brazilian population aged 35 years and over. The SAM varied between sex, such that six of every ten attributable deaths occurred in men. SAM also varied between federal units, so that the crude mortality rate was highest in Rio Grande do Sul and the age-adjusted rate was highest in Acre. In all federal units, regardless of sex, the group of causes that had the greatest impact on SAM was cardiometabolic diseases. That said, the specific cause that had the greatest impact was COPD in women and ischemic heart disease in men.

The variability in the burden of SAM in the different federal units of Brazil reaffirms the need for SAM data disaggregated at the geographic level. This is especially relevant in countries, such as Brazil, with important demographic, social or economic differences between the geographic areas that compose it. The results of this study should be the basis for other analyses that assess the evolution of SAM at the regional level in Brazil and in other South American countries. Having detailed information on the burden of attributable mortality to a risk factor makes possible advances in health policies aimed at specific groups or geographic areas. Identified inequalities indicates the need for intensification of the Unified Health System's principle of equity, which is directly related with the concepts of equality and social justice, and the need to focus attention on the reinforcement of public policies in the regions most affected.

Author statements

Acknowledgments

None.

Ethical approval

Not applicable.

Funding

This study has been funded by Instituto de Salud Carlos III (ISCIII) through the project 'PI19/00288' and co-funded by the European Union.

Competing interests

None declared.

Consent for publication

No applicable.

Availability of data and material

No applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2024.01.016.

References

1. World Health Organization. *Report on the global tobacco epidemic: protect people from tobacco smoke*. 2023. https://www.who.int/publications/i/item/9789240077164. [Accessed 19 August 2003].
2. Monteiro CA, Cavalcante TM, Moura EC, Claro RM, Szwarcwald CL. Population-based evidence of a strong decline in the prevalence of smokers in Brazil (1989–2003). *Bull World Health Organ* 2007;**85**(7):527–34. https://doi.org/10.2471/blt.06.039073.
3. da Silva ST, Martins MC, de Faria FR, Cotta RMM. Combate ao tabagismo no Brasil: a importância estratégica das ações governamentais. *Cien Saude Colet* 2014;**19**(2):539–52. https://doi.org/10.1590/1413-81232014192.19802012.
4. Malta DC, Flor LS, MacHado ÍE, Felisbino-Mendes MS, Brant LCC, Ribeiro ALP, et al. Trends in prevalence and mortality burden attributable to smoking, Brazil and federated units, 1990 and 2017. *Popul Health Metr* 2020;**18**(Suppl. 1):24. https://doi.org/10.1186/s12963-020-00215-2.
5. Pesquisa Nacional de Saúde. *Painel de Indicadores – PNS*. 2023. https://www.pns.icict.fiocruz.br/painel-de-indicadores-mobile-desktop/. [Accessed 14 March 2023].
6. Giraldo-Osorio A, Moreira RS, Neto PA, Santiago-Pérez MI, Rey J, Mourino N, et al. Mortality attributed to Tobacco consumption in Brazil, 2016. *Rev Bras Epidemiol* 2020;**24**:e210007. https://doi.org/10.1590/1980-549720210007.
7. Levy D, de Almeida LM, Szklo A. The Brazil SimSmoke policy simulation model: the effect of strong tobacco control policies on smoking prevalence and smoking-attributable deaths in a middle income nation. *PLoS Med* 2012;**9**(11):e1001336. https://doi.org/10.1371/journal.pmed.1001336.
8. Acosta LD, Molinatti F, Peláez E. Comparison of mortality attributable to tobacco in selected Latin American countries. *Poblac Salud Mesoam* 2019;**16**(2):154–74. https://doi.org/10.15517/psm.v0i0.34484.
9. Pinto MT, Pichon-Riviere A, Bardach A. The burden of smoking-related diseases in Brazil: mortality, morbidity and costs. *Cad Saúde Públ* 2015;**31**(6):1283–97. https://doi.org/10.1590/0102-311X00192013.

10. Corra PC, Barreto SM, Passos VM. Smoking-attributable mortality and years of potential life lost in 16 Brazilian capitals, 2003: a prevalence-based study. *BMC Publ Health* 2009;**9**:206. https://doi.org/10.1186/1471-2458-9-206.
11. Ferreira Oliveira A, Gonçalves Valente J, Leite IC. Clinical science the disease burden attributable to smoking in the State of Rio de Janeiro, Brazil in 2000. *Clinics* 2008;**63**(2):215–22. https://doi.org/10.1590/s1807-59322008000200010.
12. Ministerio de Saúde DATASUS. Propulação residente, https://datasus.saude.gov.br/populacao-residente/; [accessed 23 April 2023].
13. Rey J, Pérez-Ríos M, Santiago-Pérez MI, Galán I, Schiaffino A, Varela-Lema L, et al. Smoking-attributable mortality in the autonomous communities of Spain, 2017. *Rev Esp Cardiol* 2022;**75**(2):150–8. https://doi.org/10.1016/j.rec.2020.10.023.
14. Pérez-Ríos M, Rey-Brandariz J, Galán I, Fernández E, Montes A, Santiago-Pérez MI, et al. Methodological guidelines for the estimation of attributable mortality using a prevalence-based method: the STREAMS-P tool. *J Clin Epidemiol* 2022;**147**:101–10. https://doi.org/10.1016/j.jclinepi.2022.03.016.
15. Thun MJ, Carter BD, Feskanich D, Freedman ND, Prentice R, Lopez AD, et al. 50-Year trends in smoking-related mortality in the United States. *N Engl J Med* 2013;**368**(4):351–64. https://doi.org/10.1056/NEJMsa1211127.
16. Ahmad OB, Boschi-Pinto C, Lopez Christopher AD, Murray JL, Lozano R, Inoue M. *Age standardization of rates: a new WHO standard*. https://cdn.who.int/media/docs/default-source/gho-documents/global-health-estimates/gpe_discussion_paper_series_paper31_2001_age_standardization_rates.pdf, 2001. [Accessed 21 December 2023].
17. da Silva PA, Meucci RD, Luzini R, Paiva LA. Tobacco smoking prevalence and associated factors among the elderly in the rural area of Rio Grande/RS, Brazil. *Rural Rem Health* 2019;**19**(4):4982. https://doi.org/10.22605/RRH4982.
18. Santos CE. *Anuário Brasileiro do Tabaco. Santa Cruz do Sul*. https://www.editoragazeta.com.br/sitewp/wp-content/uploads/2021/01/TABACO_2020_DUPLAS.pdf, 2020. [Accessed 21 December 2023].
19. Grupo Amanhã. *Quem são os maiores produtores de tabaco no Brasil*. https://amanha.com.br/categoria/agronegocio/quem-sao-os-maiores-produtores-de-tabaco-no-brasil, 2023. [Accessed 11 July 2023].
20. Pérez-Ríos M, Schiaffino A, Montes A, Fernández E, López MJ, Martínez-Sánchez JM, et al. Smoking-attributable mortality in Spain in 2016. *Arch Bronconeumol* 2020;**56**(9):559–63. https://doi.org/10.1016/j.arbr.2020.07.005.
21. Rostron B. Smoking-attributable mortality by cause in the United States: revising the CDC's data and estimates. *Nicotine Tob Res* 2013;**15**(1):238–46. https://doi.org/10.1093/ntr/nts120.
22. Wanderley-Flores B, Pérez-Ríos M, Montes A, Santiago-Pérez MI, Varela-Lema L, Candal-Pedreira C, et al. Attributable mortality to tobacco consumption in Brazil, 1996–2019. *Gac Sanit* 2023;**37**:102297. https://doi.org/10.1016/j.gaceta.2023.102297.
23. Rey-Brandariz J, Pérez-Ríos M, Santiago-Pérez MI, Galán I, Schiaffino A, Varela-Lema L, et al. Trends in smoking-attributable mortality in Spain: 1990–2018. *Eur J Public Health* 2022;**32**(6):919–25. https://doi.org/10.1093/eurpub/ckac165.
24. Gonçalves-Macedo L, Lacerda EM, Markman-Filho B, Lundgren FLC, Luna CF. Trends in morbidity and mortality from COPD in Brazil, 2000 to 2016. *J Bras Pneumol* 2019;**45**(6):e20180402. https://doi.org/10.1590/1806-3713/e20180402.
25. Instituto Brasileiro de Geografia e Estatística (IBGE). *Síntese de Indicadores Sociais. Uma análise das Condições de Vida da População Brasileira*. https://biblioteca.ibge.gov.br/visualizacao/livros/liv101979.pdf, 2022. [Accessed 21 December 2023].
26. Moreira MAC, Barbosa MA, Jardim JR, Queiroz MCC, Lu Inácio. Doença pulmonar obstrutiva crônica em mulheres expostas à fumaça de fogão à lenha. *Rev Assoc Med Bras* 2013;**59**(6):607–13. https://doi.org/10.1016/j.ramb.2013.09.001.
27. Salvi SS, Barnes PJ. Chronic obstructive pulmonary disease in non-smokers. *Lancet* 2009;**374**(9691):733–43. https://doi.org/10.1016/S0140-6736(09)61303-9.
28. Torres KDP, Cunha GM, Valente JG. Tendências de mortalidade por doença pulmonar obstrutiva crônica no Rio de Janeiro e em Porto Alegre, 1980–2014. *Epidemiol Serv Saude* 2018;**27**(3):e2017139. https://doi.org/10.5123/S1679-49742018000300013.
29. *Geração das usinas a biomassa bate recorde em julho – canal Bioenergia*. https://www.canalbioenergia.com.br/geracao-das-usinas-biomassa-bate-recorde-em-julho/, 2018. [Accessed 19 April 2023].
30. Área de vigilância do óbito da GCIAE/MS. Qualidade da informação sobre óbitos em municípios do Brasil: reconhecimento das diferenças e áreas com maior precariedade. https://svs.aids.gov.br/daent/centrais-de-conteudos/eventos/2020/IVideoVO/qualidade-informacao-mortalidade-Brasil.pdf [accessed 20 May 2023].
31. Jacobs EJ, Newton CC, Carter BD, Feskanich D, Freedman ND, Prentice RL, et al. What proportion of cancer deaths in the contemporary United States is attributable to cigarette smoking? *Ann Epidemiol* 2015;**25**(3):179–82. https://doi.org/10.1016/j.annepidem.2014.11.008.
32. Da Silva Pinheiro D, Veiga Jardim PCB. Mortality due to ischemic heart disease in Brazil – Northeast disparities. *Arq Bras Cardiol* 2021;**117**(1):61–2. https://doi.org/10.36660/abc.20210419.
33. Rey-Brandariz J, Ravara S, López-Vizcaíno E, Santiago-Pérez MI, Ruano-Ravina A, Candal-Pedreira C, et al. Smoking-attributable mortality in Portugal and its regions in 2019. *Pulmonology* 2023. https://doi.org/10.1016/j.pulmoe.2023.09.006.
34. De Almeida J, Gonçalo S, Augusto F, Fronteira I, Hernández-Quevedo C. Portugal: health system review. *Health Syst Transit* 2017;**19**(2):1–184.
35. Bardach A, Perdomo HA, Gándara RA, Ciapponi A. Niveles de ingreso y prevalencia de tabaquismo en América Latina: revisión sistemática y metaanálisis. *Rev Panam Salud Publ* 2016;**40**(4):263–71.
36. Greenland S, Robins JM. Conceptual problems in the definition and interpretation of attributable fractions. *Am J Epidemiol* 1988;**128**(6):1185–97. https://doi.org/10.1093/oxfordjournals.aje.a115073.
37. Queiroz BL, De Araujo FreireI FHM, Gonzaga MR, De Lima EEC. Estimativas do grau de cobertura e da mortalidade adulta (45q15) para as unidades da federação no Brasil entre 1980–2010. *Rev Bras Epidemiol* 2017;**20**:21–33. https://doi.org/10.1590/1980-5497201700050003.
38. Antunes Paes N. Avaliação da cobertura dos registros de óbitos dos Estados brasileiros em 2000. *Rev Bras Epidemiol* 2005;**39**(6):882–90. https://doi.org/10.1590/S0034-89102005000600003.