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Proportion of cancer cases and deaths attributable to lifestyle risk factors in Brazil

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ABSTRACT

Background: Lifestyle risk factors (tobacco smoking, alcohol consumption, overweight and obesity, unhealthy diet, and lack of physical activity) have been associated with increased risk of at least 20 types of cancer. We estimated the proportion of cancer cases and deaths that could be potentially avoided by eliminating or reducing lifestyle risk factors in Brazil.

Methods: We obtained the distribution of lifestyle risk factors by sex and age groups from recent representative health surveys in Brazil; relative risks from pooled analyses of prospective studies and meta-analyses; and cancer cases and deaths in 2012 from GLOBOCAN.

Results: We found that 26.5% (114,497 cases) of all cancer cases and 33.6% (63,371 deaths) of all cancer deaths could be potentially avoided by eliminating lifestyle risk factors in Brazil. Plausible reductions in these exposures based on policy targets and cancer prevention recommendations could have potentially avoided 4.5% (19,731 cases) and 6.1% (11,480 deaths) of all cancer cases and deaths, respectively. Tobacco smoking accounted for most of the preventable cancer cases and deaths, followed by high body mass index and alcohol consumption. Larynx, lung, oropharynx, esophagus and colorectum cancer cases and deaths could be at least halved by eliminating these lifestyle risk factors.

Conclusion: Findings from this study may be useful to inform strategies for cancer prevention and control across Brazil.

1. Introduction

Cancer is the second leading cause of death in Brazil [1]. In 2012, 224,000 cancer deaths occurred and 437,000 new cancer cases were diagnosed [2]. By 2025, the burden of cancer is projected to increase by 50% due to population growth and aging [2]. Besides changes in the population structure, the increasing prevalence of lifestyle risk factors may pose additional challenges to cancer control [3–6]. Lifestyle risk factors (tobacco smoking, alcohol consumption, overweight and obesity, unhealthy diet, and lack of physical activity) have been associated with increased risk of at least 20 types of cancer [7–17]. Therefore, cancer prevention through lifestyle modification is one of the most attractive and realistic approaches for cancer control in Brazil.

Quantitative estimation of proportion of cancer that could be potentially avoided by eliminating or reducing lifestyle risk factors is useful to inform cancer prevention strategies [18]. In Brazil, previous studies on preventability of cancer have focused on single risk factors [6,19], cancer incidence or mortality [6,19], historical exposure profile [20], or single exposure estimate for all age groups [19,20].

Herein, we estimated the proportion and number of cancer cases

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Table 1
Lifestyle risk factors associated with cancer incidence and mortality considered in this study.

Exposure	Distribution and theoretical minimum risk exposure level (in bold and italic)	Cancer sites-related (ICD-10)
Alcohol consumption (%)	***Abstainer (0 g/day)***	Lip, oral cavity, pharynx (C00-C14); Esophagus (C15; squamous cell carcinoma only); Colorectum (C18-C20); Liver (C22); Gallbladder (C23); Pancreas (C25); Larynx (C32); female Breast (C50)
	Light (1–12.5 g/day)	
	Moderate (12.6–49.9 g/day)	
	Heavy (≥50 g/day)	
High body mass index (in kg/m^2)	Mean and standard deviation ***(22 kg/m2 and 1 sd)***	Esophagus (C15; adenocarcinoma only); Stomach (C16.0; cardia only); Colorectum (C18-C20); Liver (C22); Gallbladder (C23); Pancreas (C25); female Breast (C50; postmenopausal cancers only); Corpus uteri (C54-C55); Ovary (C56); Kidney, renal pelvis (C64-C66); Thyroid (C73); Multiple myeloma (C90), Prostate (C61; advanced only)
Low dietary calcium consumption (%)	***≥1000 mg/day***	Colorectum (C18-C20)
	800–999 mg/day	
	600–799 mg/day	
	400–599 mg/day	
	200–399 mg/day	
	0–199 mg/day	
Low dietary fiber consumption (%)	***≥30 g/day***	Colorectum (C18-C20)
	20–29 g/day	
	10–19 g/day	
	0–9 g/day	
Low fruits and vegetables consumption (%)	***≥400 g/day***	Oral cavity, pharynx (C00-C14); Larynx (C32)
	300–399 g/day	
	200–299 g/day	
	100–199 g/day	
	0–99 g/day	
Low fruit consumption only (%)	***≥250 g/day***	Lung, bronchus, trachea (C33-C34)
	200–249 g/day	
	150–199 g/day	
	100–149 g/day	
	50–99 g/day	
	0–49 g/day	
Red meat consumption (%)	***0–99 g/day***	Colorectum (C18-C20)
	100–199 g/day	
	200–299 g/day	
	300–399 g/day	
	≥400 g/day	
Processed meat consumption (%)	***0–49 g/day***	Colorectum (C18-C20); Stomach (C16; non-cardia only)
	50–99 g/day	
	100–149 g/day	
	150–199 g/day	
	200–249 g/day	
	≥250 g/day	
Lack of physical activity (%)	***≥8000 MET-min/week***	Colon (C18); female Breast (C50; post-menopausal cancers only)
	4000–7999 MET-min/week	
	600–3999 MET-min/week	
	< 600 MET-min/week	
Passive smoking (%)	***No***	Lung, bronchus, trachea (C33-C34)
	Yes	
Smoking (%)	***Never***	Oral cavity, pharynx (C00-C14); Esophagus (C15); Stomach (C16); Colorectum (C18-C20); Liver (C22); Pancreas (C25); Nasal cavity/paranasal sinus (C30-C31); Larynx (C32); Lung, bronchus, trachea (C33-C34); Cervix (C53); Kidney, renal pelvis, ureter (C64-C66); Urinary bladder (C67); Myeloid leukemia (C92)
	Former	
	Current	

and deaths attributable to lifestyle risk factors in Brazil in 2012. We provided estimates of preventability of cancer due to lifestyle risk factors, individually and in combination, by sex and cancer site in Brazil. We also considered two counterfactual (alternative) exposure scenarios for the lifestyle risk factors at the population level.

2. Methods

2.1. Lifestyle exposure data: current distribution and counterfactual scenarios

We included in our study lifestyle risk factors with convincing evidence for causing cancer in humans according to the International Agency for Research on Cancer (IARC), the World Cancer Research Fund (WCRF), results from recent meta-analyses, and for which exposure data were available (Table 1) [7–17,21,22]. Data on the distribution of lifestyle risk factors were calculated from the most recent nationally representative surveys conducted in Brazil. We used data from the National Health Survey 2013 (*Pesquisa Nacional de Saúde* - PNS), to estimate alcohol consumption, body mass index (BMI), fruits and vegetables consumption, physical activity, tobacco smoking, and passive smoking in Brazil [23]. The National Household Budget Survey (*Pesquisa de Orçamentos Familiares* – POF) conducted in 2008–2009 was also used to obtain the dietary consumption of fiber, calcium, red and processed meat [24]. The distribution of lifestyle risk factors was estimated by sex and age groups (20–44, 45–54, 55–64, 65–74, and ≥75 years), while accounting for the complex sample design (Supplementary file).

We calculated the preventability of cancer by comparing the burden of cancer due to the observed distribution of lifestyle risk factors (Tables S1–S2) with two counterfactual exposure scenarios:

i) Theoretical minimum risk exposure level: lifestyle risk factors eliminated in the whole population as defined in Table 1.

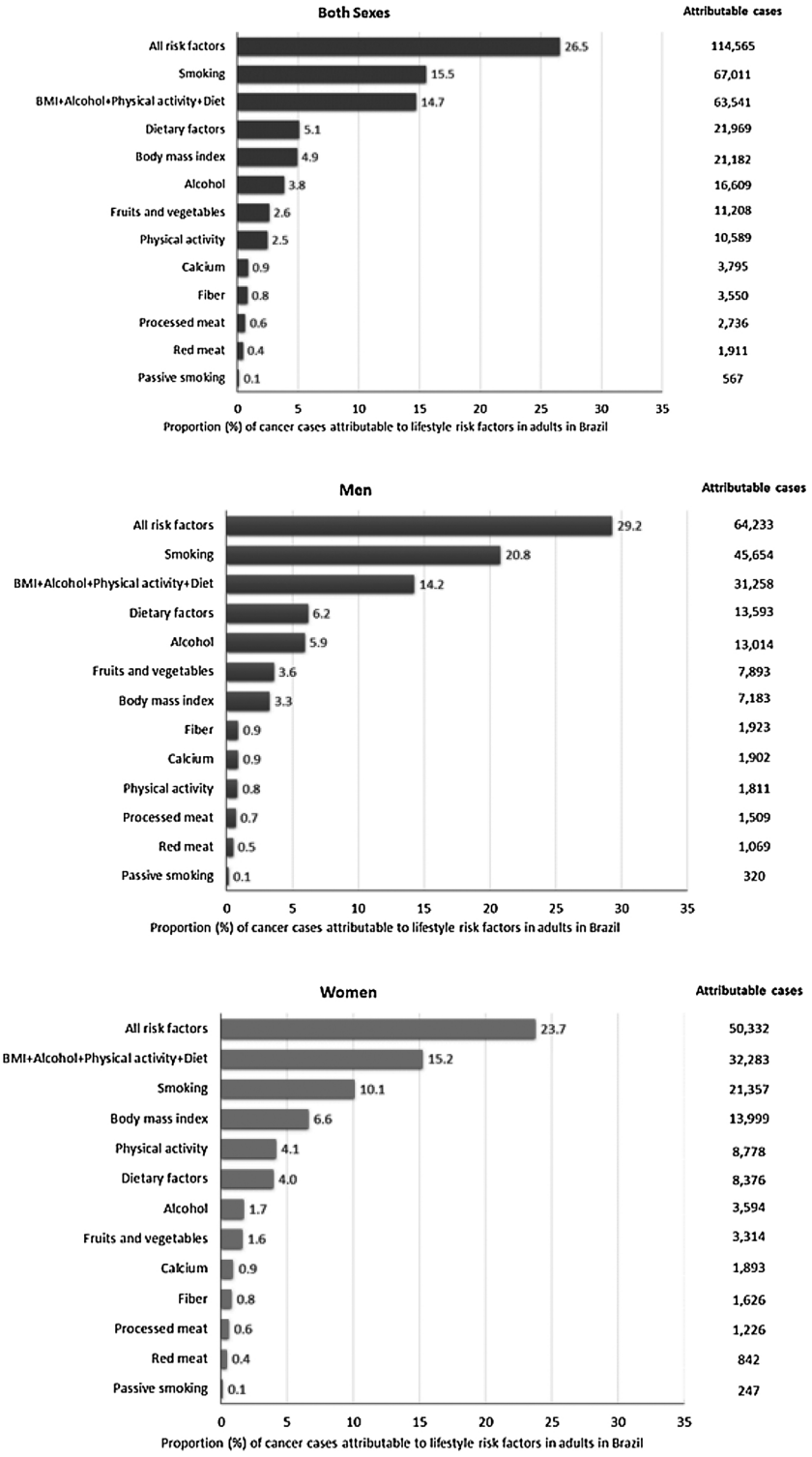

Fig. 1. Proportion and number of all cancer cases attributable to lifestyle risk factors in Brazil in 2012, by exposure.

ii) Plausible reduction in exposure level: Alternative exposure scenario was based on policy targets and cancer prevention recommendations, whenever available [12,25,26]. It included a 10% relative reduction in heavy alcohol consumption (≥50.0 g/day) [25]; 1 kg/m^2 reduction of BMI mean at the population level; dietary calcium consumption of at least 200–399 mg/day; dietary fiber consumption of at least 10–19 g/day; fruits and vegetables consumption of at least 100–199 g/day (for fruit only: at least 50–99 g/day); red meat consumption < 300 g/day [12]; processed meat consumption < 100 g/day [12]; physical activity recommendation for adults of at least 600 MET-min/week [26]; a 30% relative reduction in prevalence of current tobacco use (*i.e.*, then considered former smoker) and consequently in passive smoking among never smokers [25].

2.2. Cancer data: relative risk and estimated cancer incidence and deaths

We retrieved relative risks (RR) of exposure-cancer pairs from meta-analyses and large pooled analyses of cohort studies conducted

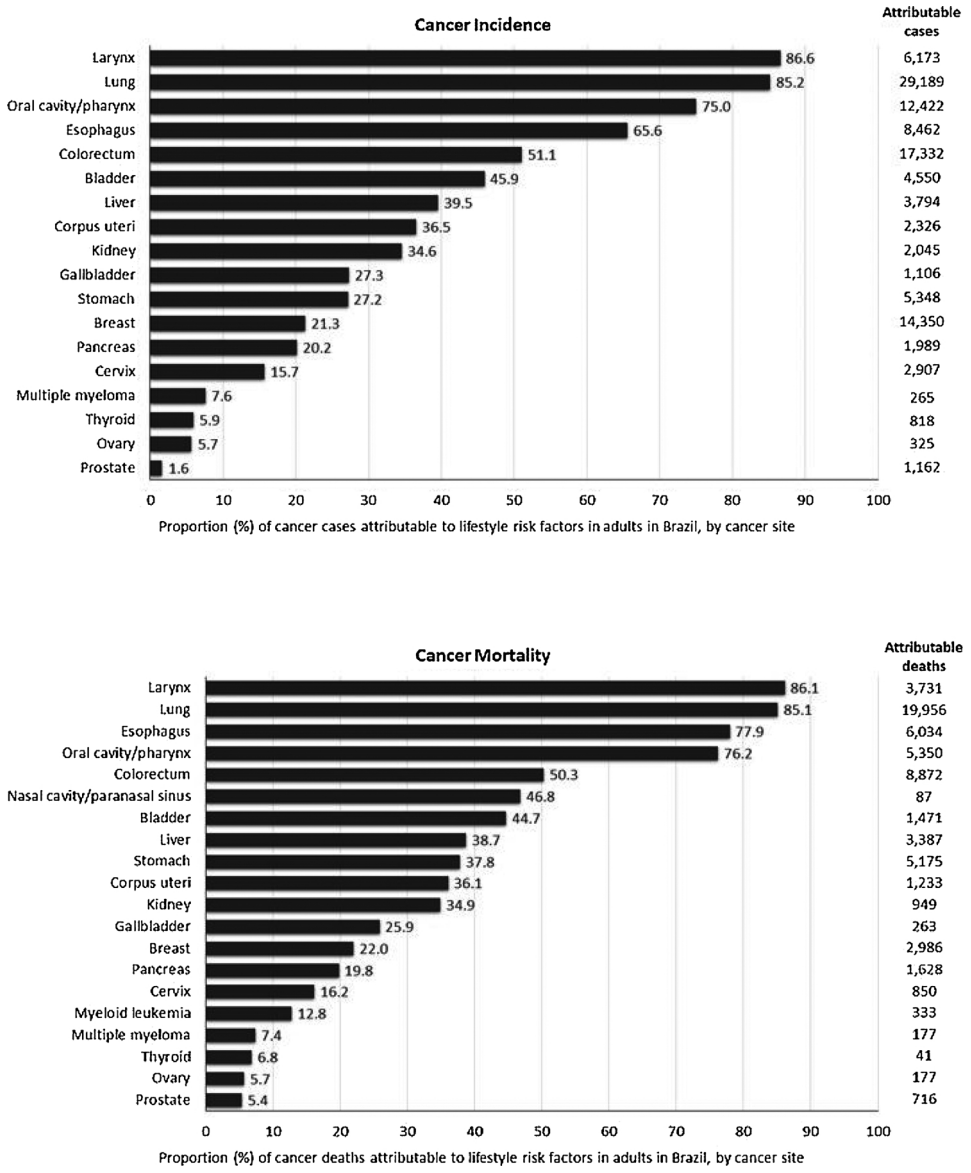

Fig. 2. Proportion and number of cancer cases and deaths attributable to lifestyle risk factors in Brazil in 2012, by cancer site.

worldwide due to lack of prospective studies to study cancer etiology in Brazil (Table S3). Estimated number of new cancer cases diagnosed in Brazil in 2012 by sex and age-group were retrieved from the GLOBOCAN project [2] (Table S4). Cancer deaths in Brazil in 2012 by sex and age-group were obtained from the Brazilian Mortality Information System [1].

2.3. Statistical analysis

Preventability of cancer cases and death by sex and age-group was estimated using the following equation for potential impact fraction (PIF) [27]:

$$PIF = \frac{\sum_{i=1}^{n} P_i\, RR_i - \sum_{i=1}^{n} P'_i\, RR_i}{\sum_{i=1}^{n} P_i\, RR_i}$$

where P_i is the proportion of the population at the level i of exposure, P'_i is the proportion of the population at the level i of exposure in the counterfactual scenario, and RR_i is the relative risk of cancer at the level i of exposure. Level i for each exposure is presented in Table 1.

For BMI, we calculated preventability of cancer using equation for continuous exposures [27]:

$$PIF = \frac{\int \mathrm{RR(x)P(x)\ dx} - \int \mathrm{RR(x)}P^{*}\mathrm{(x)dx}}{\int \mathrm{RR(x)P(x)dx}}$$

where P(x) is the population distribution of BMI (mean and standard deviation), P^{*}(x) distribution of BMI in the counterfactual scenario (Table 1), RR(x) is the relative risk of cancer per one increment unit in BMI, and dx indicates that the integration was done with respect to the BMI level. We used a log-logit function to represent each RR value across BMI units [6].

Preventability of each cancer site attributable to combined lifestyle risk factors were estimated using the joint PIF equation [27]:

$$Joint \quad PIF = 1 - \prod_{i=1}^{n} (1 - PIF_i)$$

Where PIF_i is each individual lifestyle risk factor PIF.

Number of cancer cases and deaths attributable to lifestyle risk factors were obtained by applying PIF estimates to cancer cases and cancers deaths in the corresponding cancer site or subsite, as defined in the Table 1. Then, we divided the number of attributable cases and deaths by total number of cancers in the corresponding cancer site. We summed-up the number of cancer cases and deaths attributable to

combined lifestyle risk factors across cancer sites to obtain the number of all cancer cases and deaths that could be potentially avoided. Proportion of all cancer attributable to exposures was obtained by dividing the total number of attributable cases and deaths by total number of cancer cases (excluding non-melanoma skin cancer) and deaths, respectively.

3. Results

3.1. Cancer incidence

Lifestyle risk factors accounted for 26.5% of all cancer cases (114,497 of 431,557 cases) in adults in Brazil. Tobacco smoking was the single most important risk factor in both men (20.8%; 45,654 cases) and women (10.1%; 21,357 cases). Alcohol consumption had the second highest PAF (5.9%) in men, although combined dietary factors (low consumption of fruits and vegetables, fiber, calcium, and consumption of red and processed meat) accounted for similar cancer burden (6.2%). High BMI had the second highest PAF in women (6.6%), followed by lack of physical activity (4.1%) and combined dietary factors (4.0%). The preventable cases accounted by combination of high BMI, alcohol consumption, lack of physical activity, and dietary factors was higher than cases accounted by smoking in women (15.2% *vs* 10.1%), but not in men (14.2% *vs* 20.8%) (Fig. 1).

The proportion of cancer cases accounted by all lifestyle risk factors combined ranged from 1.6% for prostate cancer to 86.6% for larynx cancer. From the 18 cancer sites considered in the cancer incidence analysis, five cancer sites (larynx, lung, oral cavity, esophagus and colorectum) had PAF > 50%. Lung (17,944 cases) and breast cancers (14,350 cases) had the highest number of cases attributable to lifestyle risk factors in men and women, respectively (Fig. 2).

Considering the plausible reduction in lifestyle risk factors, 4.6% of all cancer cases (19,850 of 431,557 cases) could be potentially avoided. Smoking had the highest PAF (2.1%), followed by high BMI (0.8%), and lack of physical activity (0.5%). Cancer sites with highest PAF were larynx (21.1%), oral cavity (16.4%), and lung (14.8%) in men, and larynx (16.3%), lung (12.7%), and colorectum (11.4%) in women (Figs. S1–S2 and Tables S5). Proportion and number of cancer cases attributable to lifestyle risk factor by sex, cancer site, and exposure are shown in Table 2.

3.2. Cancer mortality

Lifestyle risk factors accounted for 33.7% of all cancer deaths (63,417 of 188,379 deaths) in Brazil. Ranking of lifestyle risk factors was similar to those observed for cancer incidence. Tobacco smoking accounted for the greatest proportion and number of cancer deaths in both men (28.4%; 28,404 deaths) and women (13.5%; 11,907 deaths). High BMI had the second highest PAF (6.9%; 13,011 deaths), with differences between men (6.5%; 6543 deaths) and women (7.3%; 6468 deaths) less pronounced than those observed in the incidence estimates. Dietary factors and alcohol consumption accounted for 6.7% (12,692 deaths) and 4.5% (8547 deaths) of all cancer deaths, respectively (Fig. 3). Proportion and number of cancer deaths attributable to lifestyle risk factor by sex, cancer site, and exposure are shown in Table 3.

In 13 out of the 20 cancer sites included in the cancer mortality analysis, the proportion of deaths that could be potentially avoided was higher than 20% (Fig. 2). By cancer site, proportion of cancer deaths attributable to lifestyle risk factors ranged from 5.4% for prostate to 86.1% for larynx cancer. Lung cancer (19,956 deaths), colorectum cancer (8872 deaths), and esophageal cancer (6034 deaths) had the highest number of deaths due to lifestyle risk factors (Table 3).

Considering the plausible reduction in the lifestyle risk factors, 6.1% of all cancer deaths (11,561 of 188,379 deaths) could be potentially avoided, with a higher proportion in men (7.3%) than in women (4.8%). The combination of high BMI, alcohol consumption, lack of physical activity and dietary factors accounted for more cancer deaths (3.3%) than smoking (2.9%) (Figs. S2–S3 and Table S6).

4. Discussion

In this study, we found that 27% of all cancer cases and 34% of all cancer deaths were attributable to lifestyle risk factors in Brazil in 2012. Tobacco smoking was the single major cause of cancer, accounting for more than half of all preventable cancer cases and deaths. High BMI and alcohol consumption were the second most important lifestyle factors for women and men, respectively. Larynx, lung, oropharynx, esophagus and colorectum cancer cases and deaths could be at least halved by eliminating lifestyle risk factors included in our analysis.

Our results are comparable to recent studies, using similar methods, conducted in the Australia, China, United Kingdom (UK), and United States (US) [28–31] (Table 4).

Tobacco smoking was the leading factor contributing to cancer cases in all countries: 19.0% in US, 15.5% in Brazil (our study), 15.1% in UK, 14.8% in China, and 13.4% in Australia [28–31]. Smoking-related cancer cases were higher in men than women, ranging from 43% in UK to 20-fold in China [28–31]. High BMI had the second highest PAF among lifestyle factors in US (7.8%), UK (6.3%), Australia (3.4%), and Brazil (4.9%), and the third highest PAF in China (2.9%) and [28–31]. Alcohol consumption the third highest PAF in Australia (2.8%), UK (3.3%), Brazil (3.8%) and US (5.6%), and the fourth in China (2.9%) [28–31].

Our findings slightly differ from previous studies quantifying the preventability of cancer due to lifestyle risk factors in Brazil [6,19,20]. For example, compared to our study, Azevedo e Silva and colleagues [20] reported lower proportion of cancer cases due to smoking in both men (14.4% *vs* 20.8% in our study) and women (7.2% *vs* 10.1%). Tobacco smoking is constantly declining in Brazil [32], and our study used the most recent prevalence data, which would lead to lower estimates. However, our study also considered RR of cancers among former smokers, relative to never smokers, which were not considered by Azevedo e Silva and colleagues [20]. RR of lung cancer among heavy former smokers may remain at least threefold higher than never smokers after 25 years since quitting [33]. Azevedo e Silva and colleagues also reported lower PAF for all cancer cases due to high BMI (2.1% men; 3.3% women) compared to ours (3.3% men; 6.6% women). These differences could be relate to our use of continuous rather than categorical to estimates PAF, but mainly due to cancer sites considered with convincing evidence to be associated with high BMI (6 *vs* 13 cancer sites in our study) [9]. Indeed, BMI has constantly increased over the last years in Brazil [6], and anthropometrics measurements were considered five years apart (2008 *vs* 2013).

Our estimates of preventability of cancer used recent exposure profile. These estimates reflect the expected impact on cancer cases and deaths by eliminating/reducing current prevalence of lifestyle risk factors, but it does not account for cancers that have already been prevented by avoidance of ever being exposed. For instance, in Brazil, the broad framework of laws to control tobacco introduced in the late 1980s was responsible for halving the prevalence of tobacco smoking between 1989 (30%) and 2013 (15%) [32]. Therefore, current preventability of cancer due to smoking is lower than it was in the 1980s, but it does not mean cancer prevention strategies should be less vigilant about tobacco control. In fact, a full range of interventions and tools have been proposed to address the challenges of tobacco control in the 21st century [34]. For instance, regulation of flavored and candy-like tobacco products, among other youth-specific marketing strategies, is important to prevent tobacco addiction in the future generations [34].

High BMI, alcohol consumption, unhealthy diet and lack of physical activity are also important targets for cancer prevention. We found that these lifestyle factors accounted for the highest proportion of cancer cases and deaths in women, but not in men. These lifestyle risk factors may increase cancer risk through several inflammatory and hormonal

Table 2
Proportion and number of cancer cases attributable to lifestyle risk factors in Brazil in 2012, by exposure, sex, and cancer site.

	Men			Women			Both		
Exposure/ cancer site	Number of cases	PAF (%)	Attributable cases	Number of cases	PAF (%)	Attributable cases	Number of cases	PAF (%)	Attributable cases
Smoking									
Lung	20,229	86.5	17,490	14,041	76.4	10,724	34,270	82.3	28,214
Larynx	6281	78.5	4934	850	66.2	563	7,131	77.1	5496
Oral cavity/pharynx	11,901	53.1	6313	4653	39.1	1819	16,554	49.1	8132
Esophagus	9713	52.6	5106	3191	38.5	1228	12,904	49.1	6334
Bladder	7033	50.7	3566	2869	34.3	983	9,902	45.9	4550
Liver	5726	29.5	1691	3870	9.0	349	9,596	21.3	2040
Stomach	12,606	25.8	3251	7078	8.2	578	19,684	19.5	3829
Kidney	3611	24.2	873	2307	5.7	131	5,918	17.0	1004
Cervix	–	–	–	18,503	15.7	2907	18,503	15.7	2907
Pancreas	4640	9.6	444	5222	11.2	586	9862	10.4	1030
Colorectum	16,359	12.1	1986	17,579	8.5	1489	33,938	10.2	3475
High Body mass index									
Corpus uteri	–	–	–	6366	36.5	2326	6366	36.5	2,326
Kidney	3611	19.9	718	2307	22.9	529	5918	21.1	1,247
Gallbladder	1456	15.9	231	2593	20.9	542	4049	19.1	773
Liver	5726	15.0	858	3870	17.9	692	9596	16.2	1,550
Breast[a]	–	–	–	67,307	9.9	6660	67,307	9.9	6,660
Colorectum	16,359	12.2	2002	17,579	7.6	1334	33,938	9.8	3,336
Pancreas	4640	9.6	446	5222	9.1	475	9862	9.3	921
Multiple myeloma	1866	8.4	156	1642	6.6	109	3508	7.6	265
Esophagus	9713	6.4	626	3191	7.7	247	12,904	6.8	873
Thyroid	2576	12.3	316	11,210	4.5	502	13,786	5.9	818
Ovary	–	–	–	5745	5.7	325	5745	5.7	325
Stomach[a]	12,606	5.3	667	7078	3.7	259	19,684	4.7	925
Prostate[a]	72,536	1.6	1,162	–	–	–	72,536	1.6	1,162
Alcohol consumption									
Oral cavity/pharynx	11,901	46.8	5572	4653	11.5	536	16,554	36.9	6,108
Esophagus[a]	9713	34.3	3328	3191	12.0	383	12,904	28.8	3,711
Larynx	6281	26.0	1632	850	3.0	26	7131	23.3	1658
Gallbladder	1456	20.6	300	2593	4.0	105	4049	10.0	405
Liver	5726	9.6	552	3870	6.9	268	9596	8.5	820
Colorectum	16,359	9.1	1483	17,579	0.8	137	33,938	4.8	1620
Breast	–	–	–	67,307	3.1	2116	67,307	3.1	2116
Pancreas	4640	3.1	146	5222	0.5	25	9862	1.7	171
Lack of Physical activity									
Colorectum[a]	16,359	11.1	1811	17,579	11.8	2067	33,938	11.4	3878
Breast[a]	–	–	–	67,307	10.0	6712	67,307	10.0	6712
Low Fruits and vegetables consumption									
Larynx	6281	26.3	1652	850	23.9	203	7131	26.0	1855
Oral cavity/pharynx	11,901	26.5	3152	4653	24.0	1,117	16,554	25.8	4269
Lung	20,229	15.3	3089	14,041	14.2	1,995	34,270	14.8	5084
Low dietary calcium consumption									
Colorectum	16,359	11.6	1,902	17,579	10.8	1,893	33,938	11.2	3795
Low dietary fiber consumption									
Colorectum	16,359	11.8	1923	17,579	9.3	1626	33,938	10.5	3550
Processed meat consumption									
Stomach[a]	12,606	5.0	626	7078	5.6	393	19,684	5.2	1019
Colorectum	16,359	5.4	883	17,579	4.7	833	33,938	5.1	1716
Red meat consumption									
Colorectum	16,359	6.5	1069	17,579	4.8	842	33,938	5.6	1911
Passive smoking									
Lung	20,229	1.9	375	14,041	1.8	255	34,270	1.8	630

Abbreviation: PAF: population attributable fraction.

[a] Only cancer subtypes (as defined by International Classification of Diseases-10 in the Table 1) were considered to estimate the attributable cases. Number of cancer cases and PAF refer to total number of cases in the corresponding cancer site.

pathways, some of which are likely causal for cancer in women only (*e.g.*, estrogen and breast and endometrial cancer). [17] As opposed to smoking, the prevalence of these lifestyle risk factors is constantly increasing in Brazil [3–5]. For instance, the caloric share of ultra-processed food and products increased from 20.8% in 2002/2003 to 25.4% in 2008/2009 [4]. In the same period, consumption of vegetables, red and processed meat remained stable, dairy products decreased, and fruit intake slightly increased. High consumption of ultra-processed products is associated with an overall unhealthy dietary profile characterized by high consumption of free sugars and fat and low dietary fiber consumption [35]. Moreover, ultra-processed food intake has been recently linked with higher BMI, waist circumference and cancer risk [36,37]. Public health actions aiming to reduce the intake of these products (*e.g.*, taxation, food labeling) are necessary for obesity and cancer prevention. Further regulations in regard to alcohol sales and marketing (*i.e.*, it is currently prohibited to advertise alcoholic beverages on the radio and television between 6:00 AM to 9:00 PM; sell alcohol for people under 18 years of age; to drink and drive) would also be highly beneficial for cancer prevention, especially for men. Rising prices of alcohol have shown to be an effective measure to reduce drinking. [38] Finally, despite modest increase in leisure-time physical activity over the past few years, commuting activities have steeply

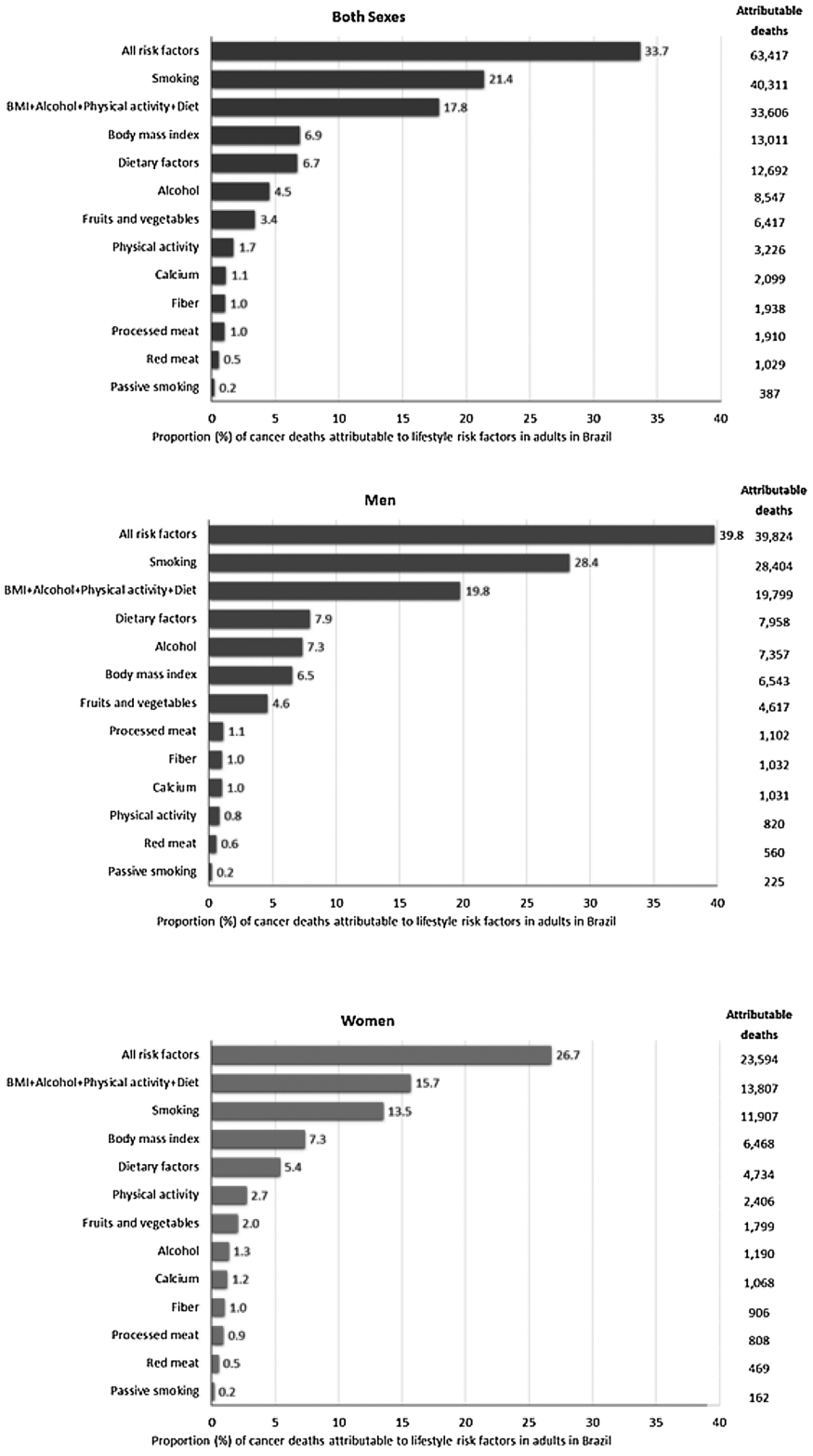

Fig. 3. Proportion and number of total cancer deaths attributable to lifestyle risk factors in Brazil in 2012, by exposure and sex.

declined, and the prevalence of physical inactivity remains high [5]. Expansion of physical activity programs in the Brazilian primary health care system and improvement of built environment of public spaces (*e.g.*, schools, bike paths, parks, sidewalks) towards active modes of living are key to increase population levels of physical activity. [39]

Our study has some limitations that should be considered while interpreting the results. We used RR from meta-analyses and large pooled data from cohort studies conducted worldwide. The RR might not be applicable to the Brazilian population if the exposure, latency of the disease, or prevalence of effect modifiers are different between populations [40]. For instance, the effect of high BMI on cancer risk may differ by smoking status due to residual confounding and reverse causation [41]. Lean non-smokers tend to be different than lean smokers in terms of visceral adiposity and metabolic profiles [41]. In

Table 3
Proportion and number of cancer deaths attributable to lifestyle risk factors in Brazil in 2012, by exposure, sex, and cancer site.

	Men			Women			Both		
Exposure/cancer site	Cancer deaths	PAF (%)	Attributable deaths	Cancer deaths	PAF (%)	Attributable deaths	Cancer deaths	PAF (%)	Attributable deaths
Smoking									
Lung	14,246	86.3	12,295	9208	75.9	6991	23,454	82.2	19,286
Larynx	3780	78.4	2962	552	64.9	358	4332	76.6	3320
Oral cavity/pharynx	5510	53.1	2924	1512	39.4	596	7022	50.1	3520
Esophagus	5983	52.9	3164	1760	38.3	674	7743	49.6	3838
Nasal cavity/paranasal sinus	115	51.4	59	71	39.3	28	186	46.8	87
Bladder	2231	50.5	1127	1061	32.4	344	3292	44.7	1471
Liver	4986	29.5	1469	3761	8.8	331	8747	20.6	1801
Stomach	8708	25.7	2235	4984	7.8	390	13,692	19.2	2625
Kidney	1694	24.8	421	1028	5.6	58	2722	17.6	479
Cervix	–	–	–	5258	16.2	850	5258	16.2	850
Myeloid leukemia	1333	22.3	298	1277	2.8	35	2610	12.8	333
Colorectum	8533	12.6	1076	9112	8.7	793	17,645	10.6	1869
Pancreas	4014	9.3	374	4201	10.9	459	8,215	10.1	833
High body mass index									
Corpus uteri	–	–	–	3416	36.1	1233	3,416	36.1	1,233
Esophagus[a]	5983	33.9	2028	1760	35.1	617	7,743	34.2	2645
Kidney	1694	19.7	333	1028	22.8	234	2,722	20.8	567
Gallbladder	233	15.8	37	784	20.8	163	1,017	19.7	200
Stomach[a]	8708	15.8	1380	4984	19.1	950	13,692	17.0	2330
Liver	4986	14.9	741	3761	17.8	670	8747	16.1	1411
Breast	–	–	–	13,587	10.3	1400	13,587	10.3	1400
Pancreas	4014	9.5	382	4201	9.0	380	8215	9.3	762
Colorectum[a]	8533	9.4	806	9112	6.0	547	17,645	7.7	1352
Multiple myeloma	1212	8.1	99	1190	6.6	78	2402	7.4	177
Thyroid	176	11.9	21	423	4.6	20	599	6.8	41
Ovary	–	–	–	3106	5.7	177	3,106	5.7	177
Prostate[a]	13,344	5.4	716	–	–	–	13,344	5.4	716
Alcohol consumption									
Oral cavity/pharynx	5510	45.8	2522	1512	11.1	168	7022	38.3	2690
Esophagus[a]	5983	41.5	2483	1760	15.3	270	7743	35.6	2753
Larynx	3780	25.4	958	552	2.8	16	4332	22.5	974
Liver	4986	9.4	467	3761	6.5	245	8747	8.1	712
Gallbladder	233	20.1	47	784	3.8	30	1017	7.6	77
Colorectum	8533	8.9	759	9112	0.7	67	17,645	4.7	826
Breast	–	–	–	13,587	2.8	377	13,587	2.8	377
Pancreas	4014	3.0	121	4201	0.4	19	8215	1.7	139
Lack of physical activity									
Breast[a]	–	–	–	13,587	10.6	1,444	13,587	10.6	1444
Colorectum[a]	8533	9.6	820	9112	10.6	963	17,645	10.1	1782
Low fruits and vegetables consumption									
Larynx	3780	26.3	992	552	23.8	132	4332	25.9	1124
Oral cavity/pharynx	5510	26.4	1453	1512	24.0	362	7022	25.9	1815
Lung	14,246	15.2	2172	9208	14.2	1305	23,454	14.8	3477
Low dietary calcium consumption									
Colorectum	8533	12.1	1031	9,112	11.7	1068	17,645	11.9	2099
Low dietary fiber consumption									
Colorectum	8533	12.1	1032	9,112	9.9	906	17,645	11.0	1938
Processed meat consumption									
Stomach[a]	8708	7.3	639	4984	6.9	343	13,692	7.2	982
Colorectum	8533	5.4	464	9112	5.1	465	17,645	5.3	928
Red meat consumption									
Colorectum	8533	6.6	560	9112	5.1	469	17,645	5.8	1029
Passive smoking									
Lung	14,246	1.9	264	9208	1.8	167	23,454	1.8	431

Abbreviation: PAF: population attributable fraction.

[a] Only cancer subtypes (as defined by International Classification of Diseases-10 in the Table 1) were considered to estimate the attributable deaths. Number of cancer deaths and PAF refer to total number of deaths in the corresponding cancer site.

addition, lean smokers also tend to have more preclinical malignancies and other chronic illnesses than lean non-smokers [41]. Differences in the prevalence of current smokers between populations where RR were estimated and the Brazilian population may have biased our results. Future prospective studies on cancer etiology in Brazil are desired.

We opted to estimate the preventability of cancer using the most recent exposure data in Brazil, which may not have properly accounted for the latency between exposures and cancer. This approach has been used in the literature due to uncertainty and variation in regard to latency of lifestyle exposures to cancer occurrence and deaths [29]. We used data from POF 2008/09 and PNS 2013 in order to estimate the prevalence of lifestyle risk factors, although cancer cases and deaths were estimated for 2012. Depending on trends of cancer incidence and risk factors over time, this may have underestimated or overestimated our estimates.

We limited our estimates to associations supported by convincing evidence according to the IARC and the WCRF, and results from recent meta-analyses [7–17,21,22]. Our results might be underestimated, especially for lifestyle exposures with recent promise findings in regard to cancer prevention [42]. For instance, a recent pooled analysis found

Table 4
Comparison of population attributable fraction for cancer cases and deaths associated with lifestyle risk factors in Brazil, China, Australia, USA, and UK.

	Brazil (our study)		China		Australia		US		UK	
	PAF cases	PAF deaths	PAF cases	PAF deaths	PAF cases	PAF deaths	PAF cases	PAF deaths	PAF cases	PAF deaths
Alcohol consumption	3.8	4.5	2.9	3.1	2.8	–	5.6	4.0	3.3	–
High BMI	4.9	6.9	2.9	3.5	3.4	–	7.8	6.5	6.3	–
Lack of physical activity	2.5	1.7	0.9	1.2	1.6	–	2.9	2.2	0.5	–
Low dietary calcium consumption	0.9	1.1	–	–	–	–	0.4	0.5	–	–
Low dietary fiber consumption	0.8	1.0	–	–	2.2	–	0.9	0.9	3.3	–
Low fruits and vegetables consumption	2.6	3.4	5.7	6.9	0.3 and 1.3[b]	–	1.9	2.7	–	–
Passive smoking	0.1	0.2	1.9	2.4	–	–	0.4	0.7	–	–
Processed meat consumption	0.6	1.0	–	–	2.2[a]	–	0.8	0.8	1.5	–
Red meat consumption	0.4	0.5	–	–	2.2[a]	–	0.5	0.5	–	–
Smoking	15.5	21.4	14.8	18.1	13.4	–	19.0	28.8	15.1	–

Abbreviation: US: United States of America; UK: United Kingdom; PAF = population attributable fraction expressed as a percentage; BMI: body mass index.
[a] PAF of red and processed meat combined.
[b] PAF = 0.3% for low fruits consumption and 1.3% for low vegetables consumption.

that physical activity was associated with lower risk of 13 types of cancer [42]. If these associations are causal, our estimates preventability of cancer due to physical activity are underestimated. Regarding the dietary factors, calcium was the only nutrient considered in our analysis. The WCRF report assessed the association between consumption of dairy products as well as calcium supplements as probable protective against colorectal cancer [12]. One potential interpretation is that both results on dairy products and calcium supplements supports calcium as the key protective component. In fact, a meta-analysis of prospective studies found that calcium supplements and non-dairy products fortified with calcium may play a role in colorectal cancer prevention [43]. In our study, we considered exposure as total dietary calcium consumption only.

PAF estimates did not either account for interaction between lifestyle risk factors nor exposures at earlier stages of life, which may also have underestimated the actual preventability of cancer in Brazil. Finally, this study focused on lifestyle risk factors, but reductions in other modifiable risk factors (*e.g.*, infections) may certainly play an important role in cancer prevention. These modifiable risk factors were considered in a previous study in Brazil [20], but since then its prevalences have not been updated.

Lifestyle risk factors accounted for nearly 27% of cancer cases and one-third of cancer deaths in Brazil in 2012. Preventive actions focusing on tobacco control and prevention of overweight and obesity are likely to have the greatest impact on cancer prevention. Findings from this study may be useful to inform strategies for cancer prevention and control in Brazil.

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Conflict of interest

None.

Authorship contribution statement

LFMR, DHL, MLCL, MS, EG, and JEN conceived and designed the study. LFMR, MLCL acquired and collated the data. LFMR and MLCL analyzed the data. All authors drafted and critically revised the manuscript for important intellectual content and gave final approval of the version to be published.

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Appendix A. Supplementary data

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