

Mortality by colon, lung, esophagus, prostate, cervix and breast cancers in Brazilian capitals, 2000 to 2015: a multilevel analysis

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Abstract

Background. In Brazil, cancer is the second most common cause of death, and the most incident types of cancer are prostate, breast, lung, colon and rectum. This study aimed to analyze the role of period, geographic and socio demographic factors in cancer-related mortality by prostate, breast, cervix, colon, lung and esophagus cancer in Brazilians capitals from 2000 to 2015. **Methods.** Data from 2005-2015 cancer mortality and resident population were collected from Information Technology Department of the Brazilian Unified Health System (DATASUS), the Brazilian Institute of Geography and Statistics (IBGE) and the Brazilian Mortality Information (SIM). State capitals were the study's analytic units. A multilevel Poisson model was used to estimate the adjusted risk of cancer mortality (prostate, breast, cervix, colon, lung and esophageal cancers). The adjusted models included the following variables as fixed effects: age, Gross Domestic Product, region, year squared and year of death. **Results.** A statistically significant difference was found between mortality rates by gender for colon, lung and esophageal cancers. The highest mortality rates were observed in the older age group, especially for prostate and lung cancers, which values were higher than 100 deaths per 100,000. Comparing with those aged 40-59 years, men older than 59 years showed 47 times higher mortality risk for prostate cancer, 8-9 times higher for lung or colon cancers and four times higher for esophageal cancer. Compared with those aged 40-59 years, women older than 59 years old showed 5-7 times higher mortality risk for esophageal, lung or colon cancers and 2-3 times higher for breast or cervix cancers. **Conclusions.** Colon cancer mortality rate increased from 2000 to 2015 for both genders, while breast and lung cancers mortality increased over the period only for women. In both genders, the highest mortality risk for lung and esophageal cancers was observed in Southern capitals. Northern capitals had a lower risk of death by prostate and breast cancer and a higher risk of death by cervix cancer.

Background

There were about 9.6 million deaths by cancer worldwide in 2018. One in eight men and one in eleven women die from cancer. Several factors, like aging, changes in the prevalence of cancer causes and population growth contribute to increased cancer deaths [1]. Varying levels of cancer mortality may be associated with the distribution of risk factors in different countries [2].

Although the highest mortality rates are observed in developed countries, it is expected that cancer will become the leading cause of morbidity and mortality, even in developing countries over time [3]. Cancer is the second most common cause of death in Brazil, and approximately 395,000 new cancer cases were recorded in 2014 [4]. Around 600,000 new cases of cancer per year are estimated for 2018–2019 in Brazil. The most incident types of cancer in Brazil are prostate, breast, lung, colon and rectum, and cervix, stomach and esophageal cancers also show high incidence rates [5].

This study aimed to analyze the role of period, geographic and socio demographic factors in cancer-related mortality by prostate, breast, cervix, colon, lung and esophagus cancer in Brazilians capitals from 2000 to 2015.

Methods

This is an ecological study using public access data collected from Information Technology Department of Brazilian Unified Health System (DATASUS), the Brazilian Institute of Geography and Statistics (IBGE) and the Brazilian Mortality Information (SIM). State capitals were the study's analytic units. In Brazil has 27 states with their respective capitals.

For each capital, we collected mortality cases by gender from 2000 to 2015 in the population older than 19 years of age. We only collected mortality cases classified in International Classification of Diseases (10th revision) with codes C15, C18, C34, C50, C53 and C61, corresponding to deaths by esophagus, colon, lung, breast, cervix and prostate cancers, respectively. We assessed the annual Gross Domestic Product per capita per 1,000 USD (GDP), which was adjusted by deflation over time.

Statistical analysis

All analyses were performed separately by type of cancer and gender. We used chi-square tests to evaluate the association between cancer mortality and the following factors: age group, GDP, region of the capital and period.

A multilevel Poisson model was used to estimate the adjusted risk of cancer mortality (prostate, breast, cervix, colon, lung and esophageal cancers). The adjusted models included the following variables as fixed effects: age, GDP, region, year squared and year of death. Also, we included an offset with the logarithm of the population of the capital. The variables included as random effects were capital (intercept), year squared (slope) and year of death (slope).

We used R-Project (version 3.5.3) software to perform data analysis.

Results

From 2000 to 2015, 45,595 deaths by colon cancer, 95,555 deaths by lung cancer and 32,885 deaths by esophageal cancer were recorded in Brazilians capitals. The annual average number of deaths was 2,787.19, 5,972.19 and 2,055.31 deaths per year for colon, lung and esophageal cancers, respectively. Crude mortality rates per 100,000 over the period were 12.57, 40.24 and 9.84 for colon, lung and esophageal cancers, respectively. Age-period standard rates per 100,000 were 11.87, 39.96 and 9.41 for colon, lung and esophageal cancers, respectively.

Women (2000–2015) recorded 23,655 deaths by cervix cancer, 65,291 by breast cancer, 24,613 by colon cancer, 37,200 by lung cancer and 5,138 by esophageal cancer in Brazilians capitals. Crude female mortality rates per 100,000 over the period were 17.07, 31.46, 11.76, 24.78 and 3.45 for cervix, breast,

colon, lung and esophageal cancers, respectively. Age-period standard rates per 100,000 were 16.32, 30.15, 11.34, 23.53 and 3.32 for cervix, breast, colon, lung and esophageal cancers, respectively.

Men (2000–2015) recorded 46,623 deaths by prostate cancer, 19,982 by colon cancer, 58,355 by lung cancer and 27,747 by esophageal cancer in Brazilians capitals. Crude male mortality rates per 100,000 were 56.06, 13.40, 55.90 and 16.23 per 100,000 for prostate, colon, lung and esophageal cancers, respectively. Age-period standard rates per 100,000 were 49.51, 12.39, 50.38 and 15.50 for prostate, colon, lung and esophageal cancers, respectively.

Colon, lung and esophageal cancers showed a statistically significant difference between mortality rates by gender. Men evidenced the highest mortality rates of colon, lung and esophageal cancers. Compared to women, the mortality rate in men was around twice higher for lung cancer and around four times higher for esophageal cancer. Among the cancers investigated over the period, prostate and lung cancer showed the highest rate in men (56/100,000), while breast cancer showed the highest rate in women (31/100,000) (Table 1).

All cancers investigated showed a statistically significant difference between age group and mortality rates. Regarding the 40–59 age group, rates ranged from 3.33/100,000 to 26.39/100,000 for breast and prostate cancer, respectively. The highest mortality rates were observed in the older age group, especially for prostate and lung cancers, whose values were higher than 100 deaths per 100,000 (Table 1).

In most cancers, the higher mortality rates occurred in capitals with a GDP higher than 10,000 USD. However, regarding cervix cancer, the higher mortality rates occurred in capitals with GDP lower than 10,000 USD (Table 1).

In most cancers, a significant difference was identified between the mortality rate and the capital region. The highest mortality rate of breast, colon, lung and esophageal cancers was observed in capitals from the South region. Regarding cervix cancer, the highest mortality rate was observed in Northern capitals (Table 1).

There was a significant difference between mortality by colon cancer over the period. Rates ranged from 10.46 in the 2000–2003 period to 14.04 in the 2012–2015 period (Table 1).

Comparing with those aged 40–59 years, men aged 20–39 years showed 97–99% lower mortality risk for prostate or lung cancers, 90% lower for colon cancer and 8% lower for esophageal cancer, while men older than 59 years showed 47 times higher mortality risk for prostate cancer, 8–9 times higher for lung or colon cancers and four times higher for esophageal cancer (Table 2).

Comparing with those aged 40–59 years, women aged 20–39 years showed 95–96% lower mortality risk for esophageal or lung cancers, 88–90% lower for colon or breast cancers and 79% lower for cervix cancer, while women older than 59 years showed 5–7 times higher mortality risk for esophageal, lung or colon cancers and 2–3 times higher for breast or cervix cancers (Table 3).

Except for colon and lung cancers, the death year was not associated with the mortality risk in the male group. The adjusted risk indicated that recent years showed a higher mortality risk for colon cancer and lower mortality risk for lung cancer in males (Table 2).

Except for cervix cancer mortality, the death year was not associated with the mortality risk in the female group. The adjusted risk indicated that recent years showed a higher mortality risk for breast, colon and lung cancers and lower mortality risk for esophageal cancer in females (Table 3).

Male and female cancers showed different mortality risk according by region of the capital. In both genders, the highest mortality risk for lung and esophageal cancers was observed in Southern capitals. Southern, Southeastern and Midwestern capitals showed the highest mortality risk for colon cancer for males and females (Tables 2 and 3).

Midwestern and Northeastern capitals showed the highest mortality risk for prostate cancer. Comparing to Southern capitals: esophageal mortality cancer in males was 69–73% lower in Northern and Northeastern capitals and 38–47% lower in Southeastern and Midwestern capitals; lung mortality cancer in males was around 30–38% lower in Northern, Northeastern, Southeastern and Midwestern capitals; colon mortality cancer in males was 61% lower in Northern capitals and 29% lower in Northeastern capitals; and prostate mortality cancer was 20–23% higher in Midwestern or Northeastern capitals (Table 2).

The highest mortality risk for breast was observed in Southern capitals, while Northern capitals showed the highest mortality risk for cervix cancer. Compared with Southern capitals, esophageal mortality cancer in females was around 42–52% lower in Northern and Northeastern capitals and 30% lower in Southeastern capitals; lung mortality cancer in females was 24–30% lower in Northeastern, Southeastern or Midwestern capitals; colon mortality cancer in females was 54% lower in Northern capitals and 27% lower in Northeastern capitals; breast mortality cancer was 29% lower in Northern capitals; and cervix mortality cancer was around two times higher in Northern capitals (Table 3).

After adjustment of the models, there was a significant reduction of residual deviance and standard deviation of random effects. The capital (intercept) random effect showed the highest standard deviation (Tables 4 and Table 5).

Discussion

Colon, esophageal and lung cancers mortality rates are consistently higher in men than in women [6–8]. Our results also pointed statistical difference in mortality by gender for colon, lung and esophageal cancers.

From 2000 to 2015, we detected a high lung cancer mortality rate in Brazilians capitals: 60/100,000 and 25/100,000 for males and females, respectively. As in many other countries, lung cancer is the leading cause of cancer death in Brazil [9]. In the U.S., the mortality rates by lung cancer are around 72/100,000 and

40/100,000 for men and women, respectively. From 1995 to 2003, lung mortality rates in the United States showed a decrease for males and increase for females [10]. From 1979 to 2004, Brazilian mortality by lung cancer increased by 78.4% in men and 8.2% in women [11].

The main risk factor for lung cancer is tobacco consumption, which is higher for males [12]. Tobacco consumption has been decreasing gradually in Brazil from 1980 to 2013 [13], and this decline could explain the lower levels of mortality risk in men over time.

In the same period, we detected a colon cancer mortality rate in Brazilians capitals around 12/100,000 for people older than 19 years old. Colon cancer is one of the three leading cancer death causes in Brazil. From 1996 to 2015, Brazilian mortality by colon cancer increased by around 7% in both genders [14]. From 1997 to 2007, mortality by colon cancer in the European Union fell from 19.7/100,000 to 17.4/100,000 for men and 12.5/100,000 to 10.5/100,000 for women [15]. Our findings pointed to a 3–4% annual increase in colon cancer mortality rates. Dutra et al., 2018, also reported a significant increasing trend of colon cancer mortality in both genders from 1996 to 2015, which are higher for men than for women [14].

The main risk factor for colon cancer is the high consumption of red meat [16]. However, others factors like sedentary lifestyle, tobacco and alcohol use have also been associated with colon cancer [17]. Regarding sedentary lifestyle, the 2015 data pointed out that men are less sedentary than women and the older the population, the higher the sedentary lifestyle [18]. Regarding red meat intake, from 2007 to 2014, red meat consumption remained stable in Brazil [19]. The average meat intake among Brazilians from Campinas, São Paulo, in 2008–2009 was 182.3 g. Women and the population older than 49 years showed the lowest intake [20].

In the 2000–2015 period, our results showed that the esophageal cancer mortality rate in Brazilians capitals was around 9/100,000. In the 2012–2016 period, the U.S. showed a rate of 4/100,000 for esophageal mortality cancer [21]. Studies evidenced a growing increase of esophageal cancer mortality in the Southern and Southeastern Brazilian regions, where the rates are similar to highly industrialized countries [7]. In 2011, the esophageal cancer mortality rate in Hebei Province (China) was 25/100,000 (males, 31/100,000, and females, 18/100,000), ranking third in deaths among all cancers. However, data showed a 42% decrease in mortality rates by esophageal cancer from 1973–1975 (49/100,000) to 2004–2005 (28/100,000) [22].

Concerning esophageal cancer, the main risk factors are the high intake of hot drinks [23], alcoholic beverages and tobacco, low ingestion of fruit and vegetable and exposure to occupational agents like benzene, silica and asbestos [24]. There is current scientific evidence about the diet's role in preventing and controlling non-transmissible chronic diseases morbidity. Dietary behavior can determine the development of chronic diseases, including cancer [25]. Around half of the Brazilian population eat fruit daily, and less than one-third eat vegetables every day [26].

Breast cancer mortality rates over the study period were around 30/100,000 for women older than 19 years. Breast cancer is the most common malignancy worldwide [27]. From 2002 to 2004, mortality by breast cancer in Porto Alegre (South of Brazil) in the age group of 40–49-years was 26/100,000 [28]. Breast cancer mortality increased from 1991 to 2010. The significant elevation occurred in the Northeastern region (106%) [29]. In Europe, breast cancer age-standardized mortality rates decreased from 1989 (60/100,000) to 2016 (34/100,000).

Among primary breast cancer risk factors is family history of breast cancer [30]. However, other risk factors for this type of cancer can be listed, namely, getting older, genetic mutations, reproductive history, having dense breasts, personal history of breast cancer or some non-cancerous breast diseases, previous treatment using radiation therapy, sedentary lifestyle, overweight or obesity after menopause, alcohol intake, taking hormones, having used certain oral contraceptives or other specific drugs [31]. In the U.S., in 1999–2000, the hormonal reposition therapy was used by 38% of women aged 50–59 years, while in 2009–2010, it was only used by 7% [32]. The declining use of hormonal reposition therapy has extended to other countries; however, it was not necessarily proportional to the reduction of breast cancer mortality rates, as many other factors are also involved. In Brazilian capitals, we identified an annual increase of 2% in mortality rates by breast cancer.

Our findings indicated that cervix mortality rates from 2000 to 2015 were around 16/100,000 for women older than 19 years. Cervix cancer is the third leading cause of death among women worldwide [33]. In Brazil, this is the fourth most common type of cancer [34]. Correcting and redistributing all the deaths classified as “malignant neoplasm of uterus, part unspecified” for “deaths due to cancer of cervix uteri and corpus uteri”, it can become the second leading cause of death in the Brazilian female population [35]. Some Brazilian capitals recorded declining trend in cervix cancer mortality. In Pernambuco (Northeast of Brazil), the mortality rate by cervix cancer fell from 7.6/100,000 in 2000 to 6.8/100,000 in 2012 [36]. In the U.S., in 2017, the highest mortality rates by cervix cancer are found in Oklahoma, Mississippi and Louisiana, 3.6–4.1/100,000 [37]. Age-standardized mortality rates in the U.S. for black and white women were 10.1/100,000 and 4.7/100,000, respectively. Black women aged 85 years or older had the highest mortality rate, namely, 37.2 deaths/100,000. A trend analysis showed that white women's rates decreased 0.8% yearly, whereas the annual decrease for black women was 3.6% [38].

Cervix cancer risk factors are associated with the risk of Human Papillomavirus (HPV) infection. A high number of pregnancies and no regular preventive colposcopy are pointed out as risk factors to cervix cancer [39]. Brazilian research detected that around 7% of females have never submitted to cervical cancer screening, around 11% have done so late (over 36 months) and 19% do not have any guidance about the need of regular cervical cancer screening [40].

Prostate cancer mortality rates over the study period were around 50/100,000 for men older than 19 years. This type of cancer is the sixth leading cause of death worldwide [41]. Brazil and Latin America have a special position regarding the incidence and mortality of prostate cancer. In Brazil, prostate cancer is the second male mortality cause. Central America has the highest mortality rate in the Americas [42]. From 1980 to 2010, there was an annual increase of 2.8% in prostate mortality rates in Brazil [43]. In England, age-standardized mortality rate per 100,000 ranged from 27 to 24 from 1995–97 to 2007–09 [44].

The main risk factors associated with this type of cancer are age, ethnicity, family history [45], besides lifestyle and dietary habits [46]. As for other types of cancer, the diet is pointed as one crucial risk factor for the differences found in prostate cancer rates among the several countries. A plant-based diet, which can include vegetables, fruit, legumes, nuts, seeds, whole grains and also lean protein, is associated with a lower risk of prostate cancer [47].

Many cancer risk factors are related to development. While morbidity and mortality of some cancers are higher in more developed countries, for other types, like cervical cancer, the rates are higher in developing countries [2]. Corroborating these findings, in this study, the highest rate of cervix cancer was detected in Northern capitals, which show one of the lowest Human Developing Index of Brazil.

The results found in this study must be interpreted with caution, as our findings are derived from secondary data. Problems like underreporting and data coverage can differ by capital and region and can conceal the actual number of cancer mortality cases. These problems are more significant in the Northern and Northeastern Brazilian regions.

Conclusion

Colon mortality rate increased from 2000 to 2015 for both genders, while breast and lung cancers mortality increased over the period only for women. Male and female cancers showed different mortality risk by region of the capital. In both genders, the highest mortality risk for lung and esophageal cancers was observed in Southern capitals, while both Southern, Southeastern and Midwestern capitals showed high mortality risk for colon cancer. North capitals had the lowest risk of death by prostate and breast cancer and the highest risk of death by cervix cancer.

Abbreviations

DATASUS: Information Technology Department of Brazilian Unified Health System; IBGE: Brazilian Institute of Geography and Statistics; SIM: Brazilian Mortality Information; GDP: Gross Domestic Product per capita per 1,000 USD; USD: United States Dollar.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

Data analyzed in this study is publicly available in Brazilian Mortality Information System.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

NCPR made substantial contributions to the design of the work, data acquisition, analysis and interpretation. She drafted the paper. GO, MKNA, DLMM, INR, VCF, AG, RPR and VTSL substantively revised the paper. All authors have approved the submitted version and have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Tables

Table 1. Distribution of the incidence rate of cancer in Brazilian capitals

	Prostate cancer		Breast cancer		Cervix cancer		Colon cancer		Lung cancer		Esophageal cancer	
	Rate/100,000		Rate/100,000		Rate/100,000		Rate/100,000		Rate/100,000		Rate/100,000	
	Mean (SD)	P-v	Mean (SD)	P-v	Mean (SD)	P-v	Mean (SD)	P-v	Mean (SD)	P-v	Mean (SD)	P-v
Gender												
Female			31.46 (29.98)		17.07 (19.01)		11.76 (16.96)	*	24.58 (30.82)	***	3.45 (6.28)	***
Male	56.06 (80.16)						13.40 (20.71)		55.90 (72.84)		16.23 (15.98)	
Age												
20-39	0.05 (0.21)	***	2.96 (1.58)	***	3.03 (2.14)	***	0.49 (0.60)	***	0.63 (0.77)	***	3.51 (4.65)	***
40-59	3.33 (2.36)		26.39 (8.37)		14.73 (9.06)		4.45 (3.17)		13.74 (7.33)		4.67 (5.12)	
≥60	164.80 (39.00)		65.03 (25.64)		33.45 (22.96)		32.78 (21.11)		106.35 (58.47)		21.33 (17.83)	
GDP												
<10,000	56.80 (81.72)	NS	29.31 (28.53)	***	18.08 (19.28)	*	10.41 (16.47)	***	39.09 (57.38)	NS	9.22 (13.61)	**
≥ 10,000	54.56 (76.99)		35.81 (32.31)		15.01 (18.30)		16.95 (22.53)		42.63 (59.38)		11.09 (13.86)	
Region												
Midwest	58.60 (82.42)	NS	32.71 (28.90)	***	14.50 (13.08)	***	15.53 (19.24)	***	39.31 (53.55)	***	11.45 (14.49)	***
North	55.60 (82.04)		21.67 (23.22)		27.01 (28.18)		6.20 (11.58)		39.56 (58.28)		7.05 (12.97)	
Northeast	58.61 (83.00)		32.00 (27.87)		15.92 (14.81)		9.42 (12.73)		35.36 (48.49)		8.35 (19.95)	
South	50.22 (72.15)		41.48 (38.55)		10.50 (8.82)		22.92 (28.53)		57.26 (82.51)		15.04 (18.26)	
Southeast	52.97 (73.98)		38.61 (33.89)		9.78 (8.05)		20.12 (24.64)		40.56 (56.85)		12.54 (14.10)	
Period												
2000-2003	55.00 (79.50)	NS	29.27 (29.09)	NS	17.25 (17.50)	NS	10.46 (17.52)	**	39.29 (60.34)	NS	10.42 (15.62)	NS
2004-2007	57.41 (82.93)		29.85 (29.07)		17.26 (18.75)		12.26 (18.64)		41.74 (59.94)		9.85 (13.69)	
2008-2011	56.61 (80.34)		32.37 (30.53)		16.53 (18.66)		13.53 (20.13)		40.28 (57.30)		9.41 (12.78)	
2012-2015	55.22 (78.16)		34.35 (31.03)		17.24 (21.04)		14.04 (19.21)		39.64 (54.60)		9.66 (12.57)	

GDP (Gross Domestic Product) = GDP/1000USD (GDP was calculated in USD using the currency exchange rate on July 1st of each year); P-v = P-value; NS = not significant.

P-value significance codes: *** : < 0.001; ** : < 0.01; * : < 0.05; NS : > 0.05

Table 2. Unadjusted and adjusted rate ratio for a set of factors associated with cancer mortality in men.

	Prostate cancer		Colon cancer		Lung cancer		Esophageal cancer		Adjusted	RR	P-v	RR	P-v	RR	P-v	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted								
Fixed effect																
Age																
20-39	0.01	***	0.01	***	0.10	***	0.10	***	0.03	***	0.03	***	0.92	***	0.0	
40-59	1		1				1				1				1	
≥60	46.57	***	46.59	***	8.51	***	8.50	***	8.64	***	8.64	***	3.78	***	3.0	
GDP	1.00	NS	1.00	NS	1.04	NS	0.99	NS	1.02	NS	1.00	NS	1.05	**	1.0	
Year	1.02	***	1.00	NS	1.05	***	1.04	***	1.01	NS	0.99	**	1.01	**	1.0	
Year2	1.00	NS	0.999	**	1.00	NS	0.998	***	1.00	NS	0.999	***	1.00	NS	1.0	
Region																
South	1		1		1		1		1		1		1		1	
Southeast	1.05	NS	1.06	NS	0.87	NS	1.00	NS	0.65	**	0.65	***	0.60	***	0.0	
Midwest	0.98	NS	1.23	*	0.58	**	1.07	NS	0.59	***	0.70	**	0.46	***	0.0	
Northeast	0.92	NS	1.20	*	0.33	***	0.71	**	0.48	***	0.62	***	0.27	***	0.0	
North	0.69	**	1.14	NS	0.18	***	0.39	***	0.40	***	0.64	***	0.23	***	0.0	

RR = Rate Ratio; P-v = P-value; ref = reference; GDP (Gross Domestic Product) = GDP/1000USD (GDP was calculated in USD using the currency exchange rate on July 1st of each year); P-value significance codes: *** : < 0.001; ** : < 0.01; * : < 0.05; NS : > 0.05.

We used Poisson multilevel modeling, with the following random effects: capital (intercept), year squared (slope) and year of the death (slope). The response variables of the unadjusted and adjusted models were mortality by prostate cancer, colon cancer, lung cancer and esophageal cancer. The adjusted models were adjusted with the following fixed effects: age and GDP, region, year squared and year of death. Also, we included an offset with the logarithm of the population of the capital.

Table 3. Unadjusted and adjusted rate ratio for a set of factors associated with cancer mortality in women

	Breast cancer		Cervix cancer		Colon cancer		Lung cancer		Adjusted	RR	P-v	RR	P-v	RR	P-v	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted								
Fixed effect																
Age																
20-39	0.12	***	0.12	***	0.21	***	0.21	***	0.10	***	0.10	***	0.05	***	0.0	
40-59	1		1	***	1		1				1				1	
≥60	2.64	***	2.64	***	2.05	***	2.05	***	6.76	***	6.75	***	5.31	***	5.0	
GDP	0.99	NS	0.99	NS	0.98	NS	1.01	NS	1.03	NS	0.98	NS	1.02	*	1.0	
Year	1.03	***	1.02	***	1.00	NS	0.99	NS	1.03	***	1.03	***	1.03	***	1.0	
Year2	1.00	NS	1.00	NS	1.00	NS	1.00	NS	1.00	NS	1.00	NS	1.00	NS	0.0	
Region																
South	1		1		1		1		1		1		1		1	
Southeast	0.98	NS	1.00	NS	0.93	NS	0.89	NS	0.98	NS	1.10	NS	0.76	NS	0.0	
Midwest	0.83	NS	0.93	NS	1.12	NS	1.26	NS	0.55	*	1.02	NS	0.60	**	0.0	
Northeast	0.84	NS	0.92	NS	1.23	NS	1.42	NS	0.35	***	0.73	*	0.57	***	0.0	
North	0.54	***	0.71	**	1.71	**	2.27	***	0.16	***	0.46	***	0.47	***	0.0	

RR = Rate Ratio; P-v = P-value; ref = reference; GDP (Gross Domestic Product) = GDP/1000USD (GDP was calculated in USD using the currency exchange rate on July 1st of each year); P-value significance codes: *** : < 0.001; ** : < 0.01; * : < 0.05; NS : > 0.05.

We used Poisson multilevel modeling, with the following random effects: capital (intercept), year squared (slope) and year of the death (slope). The response variables of the unadjusted and adjusted models were mortality by breast cancer, cervix cancer, colon cancer, lung cancer and esophageal cancer. The adjusted models were adjusted with the following fixed effects: age and GDP, region, year squared and year of death. Also, we included an offset with the logarithm of the population of the capital.

Table 4. Random effects of cancer mortality risk estimation models for men

	Standard Deviation		Deviance	
	Null model	Adjusted model	Null model	Adjusted model
Prostate			172,502	5,106
Capital (intercept)	0.29	0.11		
Year (inclination)	0.02	0.01		
Year2 (inclination)	0.00	0.00		
Colon			48,344	5,089
Capital (intercept)	1.49	0.32		
Year (inclination)	0.06	0.02		
Year2 (inclination)	0.00	0.01		
Lung			147,960	6,970
Capital (intercept)	0.36	0.16		
Year (inclination)	0.02	0.02		
Year2 (inclination)	0.00	0.00		
Esophagus			17,308	7,041
Capital (intercept)	0.53	0.28		
Year (inclination)	0.02	0.01		
Year2 (inclination)	0.00	0.00		

We used Poisson multilevel modeling, with the following random effects: capital (intercept), year squared (slope) and year of death (slope). The response variables of the unadjusted and adjusted models were mortality by prostate cancer, colon cancer, lung cancer and esophageal cancer. The adjusted models were adjusted with the following fixed effects: age and GDP, region, year squared and year of death. Also, we included an offset with the logarithm of the population of the capital.

Table 5. Random effects of cancer mortality risk estimation models for women

	Standard Deviation		Deviance	
	Null model	Adjusted model	Null model	Adjusted model
Breast			77,248	7,657
Capital (intercept)	0.70	0.17		
Year (inclination)	0.04	0.02		
Year2 (inclination)	0.00	0.00		
Cervix			24,069	7,273
Capital (intercept)	0.33	0.24		
Year (inclination)	0.02	0.02		
Year2 (inclination)	0.00	0.00		
Colon			48,344	5,396
Capital (intercept)	1.49	0.38		
Year (inclination)	0.06	0.02		
Year2 (inclination)	0.00	0.00		
Lung			73,348	6,636
Capital (intercept)	0.33	0.16		
Year (inclination)	0.04	0.02		
Year2 (inclination)	0.00	0.00		
Esophagus			13,349	3,507
Capital (intercept)	0.46	0.26		
Year (inclination)	0.01	0.01		
Year2 (inclination)	0.00	0.00		

We used Poisson multilevel modeling, with the following random effects: capital (intercept), year squared (slope) and year of the death (slope). The response variables of the unadjusted and adjusted models were mortality by breast cancer, cervix cancer, colon cancer, lung cancer and esophageal cancer. The adjusted models were adjusted with the following fixed effects: age and GDP, region, year squared and year of death. Also, we included an offset with the logarithm of the population of the capital.

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