Cancer Epidemiology 86 (2023) 102438

Contents lists available at ScienceDirect

Cancer Epidemiology

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

The economic impact of cancer mortality among working-age individuals in Brazil from 2001 to 2030

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ARTICLE INFO

Keywords:
Productivity loss
Human capital approach
Cancer mortality
Cancer
Indirect costs

ABSTRACT

Background: About half of cancer deaths in Brazil occur among individuals of working-age (under 65 years for men, under 60 for women), resulting in a substantial economic impact for the country. We aimed to estimate the years of potential productive life lost (YPPLL) and value the productivity lost due to premature deaths from cancer between 2001 and 2015 and the projected to 2030.

Methods: We used the Human Capital Approach to estimate the productivity losses corresponding to YPPLL for cancer deaths in working age people (15–64 years). Mortality data were obtained from the Mortality Information System from 2001 to 2015 and projected between 2016 and 2030. Economic data were obtained from the Continuous National Household Sample Survey and forecasted to 2030. Productivity lost was calculated as the monetary value arising from YPPLL in Int$(2016).

Results: Between 2001 and 2030, a total of 2.3 million premature deaths from all cancers combined were observed and forecasted in Brazil (57% men, 43% women), corresponding to 32 million YPPLL and Int$141.3 billion in productivity losses (men: Int$102.5 billion, women: Int$38.8 billion). Between 2001 and 2030, among men, lung (Int$ 12.6 billion), stomach (Int$ 10.6 billion) and colorectal (Int$ 9.4 billion) cancers were expected to contribute to the greatest productivity losses; and among women, it will be for breast (Int$ 10.0 billion), cervical (Int$ 6.4 billion) and colorectal (Int$ 3.2 billion) cancers.

Conclusions: Many preventable cancers result in high lost productivity, suggesting measure to reduce smoking prevalence, alcohol consumption, physical inactivity and inadequate diet, improving screening programs and increasing vaccination coverage for human papillomavirus and hepatitis B would have a positive impact on the economy, as well as reducing morbidity and mortality from cancer.

Abbreviations: ASR, age-standardized rates; DATASUS, Department of Informatics of the Unified Health System; GDP, Gross Domestic Product; HCA, Human Capital Approach; ICD-10, of the International Classification of Diseases - 10th edition; Int$, International Dollars; LAC, Latin America and Caribbean; OECD, Organization for Economic Cooperation and Development; PNAD, National Household Sample Survey; PPP, Purchasing Power Parity; SIM, Mortality Information System; YPPLL, Years of Potential Productive Life Lost.

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https://doi.org/10.1016/j.canep.2023.102438
Received 25 April 2023; Received in revised form 2 August 2023; Accepted 5 August 2023
Available online 12 August 2023

Table 1
Observed (2001–2015), projected (2016–2030) and total (2001–2030) cancer–related productivity losses due to premature mortality (15–65) among men by overall and cancer type in Brazil. Base-case scenario.

Cancer site (ICD-10)	Periods	Absolute number of deaths	YPPLL	Average YPPLL per death	Productivity losses (Int$)	
					Total	Average Per death
All cancer types (C00-C99)	2001–2015	591,641	7313,528	12	36,185,611,264	60,987
	2016–2030	737,207	8229,404	11	66,321,893,376	89,637
	2001–2030	1328,848	15,542,932	12	102,507,504,640	77,140
Lips, oral cavity and pharynx (C00–14)	2001–2015	55,795	638,453	11	3672,286,208	65,697
	2016–2030	66,891	716,093	11	6382,169,216	95,150
	2001–2030	122,686	1354,546	11	10,054,455,424	81,953
Oesophagus (C15)	2001–2015	55,493	575,533	10	3503,805,824	62,992
	2016–2030	63,690	592,835	9	5820,508,800	91,263
	2001–2030	119,183	1168,368	10	9324,314,624	78,235
Stomach (C16)	2001–2015	64,645	711,783	11	3955,089,408	61,116
	2016–2030	71,015	766,483	11	6629,843,584	92,855
	2001–2030	135,660	1478,266	11	10,584,932,992	78,025
Colorectum (C18–21)	2001–2015	44,578	537,700	12	2795,527,104	62,399
	2016–2030	73,031	761,218	10	6596,367,744	89,736
	2001–2030	117,609	1298,918	11	9391,894,848	79,857
Liver (C22)	2001–2015	35,365	391,148	11	2148,867,200	60,577
	2016–2030	49,424	468,805	9	4295,712,384	86,590
	2001–2030	84,789	859,953	10	6444,579,584	76,007
Gallbladder (C23–24)	2001–2015	6171	64,743	11	371,507,136	59,942
	2016–2030	8999	83,823	9	796,828,608	87,964
	2001–2030	15,170	148,566	10	1168,335,744	77,016
Pancreas (C25)	2001–2015	26,355	270,608	10	1581,639,328	59,758
	2016–2030	39,595	345,648	9	3388,547,904	85,235
	2001–2030	65,950	616,256	9	4970,187,232	75,363
Larynx (C32)	2001–2015	30,350	305,265	10	1895,082,016	62,268
	2016–2030	38,210	348,185	9	3463,204,928	90,397
	2001–2030	68,560	653,450	10	5358,286,944	78,155
Lung with trachea (C33–34)	2001–2015	89,013	821,023	9	4965,582,336	55,702
	2016–2030	92,593	799,158	9	7622,368,512	82,431
	2001–2030	181,606	1620,181	9	12,587,950,848	69,315
Skin melanoma (C43)	2001–2015	7107	103,938	15	486,278,368	68,442
	2016–2030	7368	96,330	13	717,823,072	97,590
	2001–2030	14,475	200,268	14	1204,101,440	83,185
Prostate (C61)	2001–2015	23,613	147,003	6	1006,574,528	42,301
	2016–2030	29,966	181,910	6	2109,576,128	69,842
	2001–2030	53,579	328,913	6	3116,150,656	58,160
Testis (C62)	2001–2015	4229	133,693	32	297,961,080	69,954
	2016–2030	6681	197,388	30	709,363,856	105,255
	2001–2030	10,910	331,081	30	1007,324,936	92,330
Kidney (C64–66)	2001–2015	11,549	130,598	11	706,783,600	61,044
	2016–2030	17,175	168,768	10	1521,973,184	88,203
	2001–2030	28,724	299,366	10	2228,756,784	77,592
Bladder (C67)	2001–2015	7860	67,605	9	414,530,008	52,498
	2016–2030	10,674	92,470	9	893,434,128	82,973
	2001–2030	18,534	160,075	9	1307,964,136	70,571
Brain and central nervous system (C70–72)	2001–2015	38,823	672,743	17	2610,134,720	67,044
	2016–2030	51,604	776,615	15	5004,492,288	96,585
	2001–2030	90,427	1449,358	16	7614,627,008	84,207
Thyroid (C73)	2001–2015	1422	16,895	12	88,466,440	62,026
	2016–2030	1796	18,650	10	160,053,108	88,888
	2001–2030	3218	35,545	11	248,519,548	77,228
Hodgkin Lymphoma (C81)	2001–2015	3384	86,450	26	227,602,100	67,044
	2016–2030	4751	125,858	27	474,875,160	99,057
	2001–2030	8135	212,308	26	702,477,260	86,352
Non-Hodgkin Lymphoma (C82–85, C96)	2001–2015	19,077	343,983	18	1246,733,312	65,228
	2016–2030	22,392	358,125	16	2163,564,800	96,336
	2001–2030	41,469	702,108	17	3410,298,112	82,237
Multiple myeloma (C88, C90)	2001–2015	8179	79,383	10	480,415,312	58,517
	2016–2030	11,598	105,900	9	1017,968,256	87,306
	2001–2030	19,777	185,283	9	1498,383,568	75,764
Leukemia (C91–95)	2001–2015	26,115	610,973	23	1649,048,576	63,051
	2016–2030	28,411	594,598	21	2616,749,952	92,024
	2001–2030	54,526	1205,571	22	4265,798,528	78,234

ICD: International Classification of Disease;
YPPLL: years of potential productive life lost

1. Background

Cancer is the second leading cause of death from non-communicable chronic diseases in Brazil [1] and forty percent of cancer cases in Latin America and the Caribbean (LAC) region occur in Brazil as well as 36% of deaths [2]. About 257,000 cancer deaths occurred in 2020 and an increase of 80% is estimated by 2040 [2]. This increasing trend is attributed to population aging, westernization of lifestyle and changes in

distribution of sociodemographic determinants [3].

Forty-four percent of cancer deaths in Brazil occur among individuals of working age (between 15 and 65 years old) [4]. From an economic perspective, these deaths result in a loss of productivity as potential future economic output of the individual is lost and that of the country (Gross Domestic Product) is reduced [3]. Brazil's high premature mortality from cancer compared to high-income countries [2] is particularly important as growth in the economy relies on the labour force and associated human capital. In 2012, lost productivity due to premature cancer mortality in Brazil was approximately Int$1.2 billion [3]. This study used international, and there has been significant epidemiological and health system changes in the last 10 years, and advances in cancer control strategies, which will impact on cancer-related premature mortality and associated productivity losses.

The assessment of the present and forecasted economic impact of cancer – in conjunction with other measures of the disease burden (incidence, mortality and survival) – can support decision makers regarding the allocation of limited public resources and the targeting of strategies for prevention and cancer control [3].

The objective of this study was to determine the economic impact of premature deaths from cancer in Brazil, by estimating the years of potential productive life lost (YPPLL) and productivity lost (in Int$, 2016) for all cancer types, in Brazil, between 2001 and 2015 and project these until 2030.

2. Methods

2.1. Study design and data sources

Mortality at working-age was defined as the occurrence of cancer death at an economically productive age, that is, before retirement. We undertook a population-based study to calculate the YPPLL and productivity lost from cancer deaths in individuals between 15 years old and, for women, 60 years old and, for men, 65 years old. All analyses were carried out for men and women separately as cancer patterns vary considerably by sex, and by dividing the study period 2001–2030 into quinquennia.

Information on premature cancer deaths which occurred between 2000 and 2016 was obtained from the Mortality Information System (SIM) of the Department of Informatics of the Unified Health System (DATASUS)[5]. Premature deaths from cancer at the following sites (as per the 10th edition of the International Classification of Diseases (ICD-10)) were enumerated: lip, oral cavity and pharynx (C00–14); esophagus (C15); stomach (C16); colorectal (C18–21); liver (C22); gallbladder (C23–24); pancreas (C25); larynx (C32); lung with trachea (C33–34); melanoma skin (C43); breast (C50); cervix (C53); uterus body (C54); ovary (C56); prostate (C61); testis (C62); kidneys (C64–66); bladder (C67); brain and central nervous system (CNS) (C70–72); thyroid (C73); Hodgkin's lymphoma (C81); Non-Hodgkin's lymphoma (C82–85, 96); multiple myeloma (C88, 90); leukemia (C91–95) and all neoplasms combined (C00–96), excluding non-melanoma skin cancers. Population data for 2010 were obtained from the demographic census carried out by the Brazilian Institute of Geography and Statistics (IBGE); for the other years, the IBGE inter census population estimates were used [6].

Data on average wages, labor force participation rates (formal and informal) and unemployment rates were obtained from the Continuous National Household Sample Survey (Continuous PNAD) carried out by IBGE (Supplementary material Table 1)[7]. These data were extracted according to sex and age group for 2001–2015. The labor force participation and unemployment rates (by sex and age-group) used in subsequent calculations were based on the median of the values for the period 2001–2015.

2.2. Calculation of mortality projections

Deaths from ill-defined or unspecified causes were redistributed pro rata [8]. In order to avoid overestimation, we attributed 50% of the calculated weight as corresponding to neoplasms [9]. Deaths from unspecified uterine cancer (ICD C55) were proportionally redistributed between cervix (C53) and corpus uterus (C54) [10]. Deaths classified as neoplasms of other digestive organs and ill-defined locations in the digestive tract (C26) were proportionally redistributed among neoplasms of digestive organs (C15–25) [11].

Deaths for the period 2016–2030 were projected using the age-period-cohort (APC) model from the NordPred package in the software R, version 3.6.0 [12]. NordPred is widely used to estimate long-term projections of cancer incidence and mortality. The model requires at least fifteen years of consecutive data (three five-year periods) and provides projections for a maximum of four periods. The model assumption is that current incidence rate trends will continue into the future. This modified version of the age-period-cohort model is used to avoid exponential growth overtime which, can give unrealistic predictions for certain cancer types when the exponential function of the APC model is employed. To curb this exponential growth, the power model uses the functional form x^5 instead of exp(x) when considering age, period, and cohort as explanatory factors [13]. Projections were calculated for each combination of cancer topography, sex, and period.

Crude mortality rates were calculated using IBGE population data [6]. Truncated age-standardized mortality rates (15–64 for men and 15–59 for women) were calculated by the direct method, using the world population proposed by Segi and adapted by Doll et al. [14].

2.3. Productivity lost – Human capital approach

The Human Capital Approach (HCA) is traditionally used to estimate productivity lost due to premature mortality. It is based on the assumption that the wage earned by labour is indicative of an individual's productivity and economic contribution to society [15–20]. In this study, the HCA was used to estimate the cancer-related working-age mortality costs from all types of cancer (ICD-10 00–96) and for each type of cancer between 2001 and 2030. YPPLL were defined as, for each death, the number of years between the occurrence of cancer death and what would have been the retirement age. These are then summed across all deaths. Detailed methods for YPPLL calculation have been previously published [3].

The costs of deaths occurring in working-age people were estimated based on the annual gender- and age-specific wage for the first year of each period, for example, the wage for 2001 was used for the period 2001–2005. Wages for 2001 – 2016 were adjusted for the unemployment rate and the labor force participation rate. Wages for the last three quinquennium (2016–2030) were projected based on data for 2016 (last year with available data), employing a wage growth rate of 2.4%, a discount rate of 3%, and adjusting for the labor force participation and unemployment rate (by sex and age group) [3], (assuming that these stayed the same from 2016). The 2.4% wage growth rate was based on the Organization for Economic Co-operation and Development (OECD) forecast of average growth in Brazilian Gross Domestic Product (GDP) until 2032 [21]. The wages were modelled for changes over time in the population of deaths i.e. someone who was 30-year-old at death would, had they lived, have moved to a 40-year-old wage category in 10 years and 50-year-old wage category in 20 years. Estimates of total productivity lost were obtained by summing the adjusted wages in each age group, multiplying by the number of observed (2001–2015) and projected (2016–2030) deaths in the same age groups. The total productivity lost was divided by the number of deaths in each quinquennium to obtain the productivity lost per death, according to cancer type and sex. Monetary losses calculated in national currency (Reais - R$) were converted to international dollars, 2016 (Int$) by applying Purchasing Power Parity (PPP) method. This parameter removes distortions caused

Table 2
Observed (2001–2015), projected (2016–2030) and total (2001–2030) cancer–related productivity losses due to premature mortality (15–59) among women by overall and cancer type in Brazil. Base-case scenario.

Cancer site (ICD-10)	Periods	Absolute number of deaths	YPPLL	Average YPPLL per death	Productivity losses (Int$)	
					Total	Average Per death
All cancer types	2001–2015	437,917	7545,818	17	12,273,009,664	27,797
	2016–2030	557,669	9088,294	16	26,570,057,728	47,438
	2001–2030	995,586	16,634,112	17	38,843,067,392	39,015
Lips, oral cavity and pharynx (C00–14)	2001–2015	6957	111,783	16	184,327,820	26,278
	2016–2030	8247	131,853	16	376,584,608	45,509
	2001–2030	15,204	243,636	16	560,912,428	36,892
Oesophagus (C15)	2001–2015	7694	102,315	13	182,772,712	23,606
	2016–2030	7870	100,750	13	321,684,040	40,805
	2001–2030	15,564	203,065	13	504,456,752	32,412
Stomach (C16)	2001–2015	24,402	414,345	17	694,375,952	28,273
	2016–2030	29,401	477,123	16	1435,945,952	48,566
	2001–2030	53,803	891,468	17	2130,321,904	39,595
Colorectum (C18–21)	2001–2015	33,983	539,483	16	929,390,096	26,979
	2016–2030	50,507	745,498	15	2290,779,712	45,110
	2001–2030	84,490	1284,981	15	3220,169,808	38,113
Liver (C22)	2001–2015	15,949	244,538	15	408,957,904	25,462
	2016–2030	19,430	276,715	14	825,449,824	42,383
	2001–2030	35,379	521,253	15	1234,407,728	34,891
Gallbladder (C23–24)	2001–2015	8114	108,980	13	193,456,600	23,652
	2016–2030	9982	128,595	13	410,699,880	40,943
	2001–2030	18,096	237,575	13	604,156,480	33,386
Pancreas (C25)	2001–2015	13,765	187,243	14	331,456,216	23,718
	2016–2030	20,809	278,318	13	861,839,984	41,128
	2001–2030	34,574	465,561	13	1193,296,200	34,514
Larynx (C32)	2001–2015	2364	32,285	14	57,269,573	24,098
	2016–2030	2706	34,520	13	106,375,698	39,371
	2001–2030	5070	66,805	13	163,645,271	32,277
Lung with trachea (C33–34)	2001–2015	39,209	541,103	14	958,754,352	24,203
	2016–2030	50,599	644,808	13	1993,734,400	39,416
	2001–2030	89,808	1185,911	13	2952,488,752	32,876
Skin melanoma (C43)	2001–2015	4028	75,425	19	121,259,560	30,025
	2016–2030	4127	73,833	18	205,529,004	49,852
	2001–2030	8155	149,258	18	326,788,564	40,072
Breast (C50)	2001–2015	100,156	1644,215	16	2927,449,600	28,940
	2016–2030	140,169	2276,733	16	7108,589,440	50,343
	2001–2030	240,325	3920,948	16	10,036,039,040	41,760
Cervix (C53)	2001–2015	65,045	1241,368	19	2038,049,536	31,232
	2016–2030	77,518	1532,375	20	4366,873,472	55,870
	2001–2030	142,563	2773,743	19	6404,923,008	44,927
Corpus uteri (C54)	2001–2015	6264	94,500	15	158,943,552	25,037
	2016–2030	10,363	156,878	15	461,513,200	44,050
	2001–2030	16,627	251,378	15	620,456,752	37,316
Ovary (C56)	2001–2015	20,101	338,423	17	552,268,784	27,202
	2016–2030	25,762	398,305	15	1201,354,208	46,428
	2001–2030	45,863	736,728	16	1753,622,992	38,236
Kidney (C64–66)	2001–2015	4534	74,310	16	117,875,862	25,795
	2016–2030	5803	89,403	15	259,345,096	44,518
	2001–2030	10,337	163,713	16	377,220,958	36,492
Bladder (C67)	2001–2015	2527	34,098	14	59,707,747	23,501
	2016–2030	3037	37,908	12	114,947,120	37,939
	2001–2030	5564	72,006	13	174,654,867	31,390
Brain and central nervous system (C70-C72)	2001–2015	25,382	513,970	20	737,605,536	28,849
	2016–2030	30,177	549,403	18	1453,199,712	48,094
	2001–2030	55,559	1063,373	19	2190,805,248	39,432
Thyroid (C73)	2001–2015	1534	23,310	15	38,479,760	24,706
	2016–2030	2481	35,353	14	107,108,708	42,764
	2001–2030	4015	58,663	15	145,588,468	36,261
Hodgkin Lymphoma (C81)	2001–2015	2096	61,500	29	66,018,276	31,181
	2016–2030	2678	69,120	26	149,125,144	55,465
	2001–2030	4774	130,620	27	215,143,420	45,066
Non-Hodgkin Lymphoma (C82–85, C96)	2001–2015	9685	203,908	21	277,007,784	28,482
	2016–2030	10,331	195,253	19	497,522,448	48,121
	2001–2030	20,016	399,161	20	774,530,232	38,696
Multiple myeloma (C88, C90)	2001–2015	4480	58,310	13	103,734,784	22,970
	2016–2030	5690	70,755	12	226,537,772	39,657
	2001–2030	10,170	129,065	13	330,272,556	32,475
Leukemia (C91–95)	2001–2015	18,042	453,165	25	530,816,176	29,348
	2016–2030	18,188	429,900	24	907,083,680	49,926
	2001–2030	20,016	399,161	20	774,530,232	38,696

ICD: International Classification of Disease;
YPPLL: years of potential productive life lost

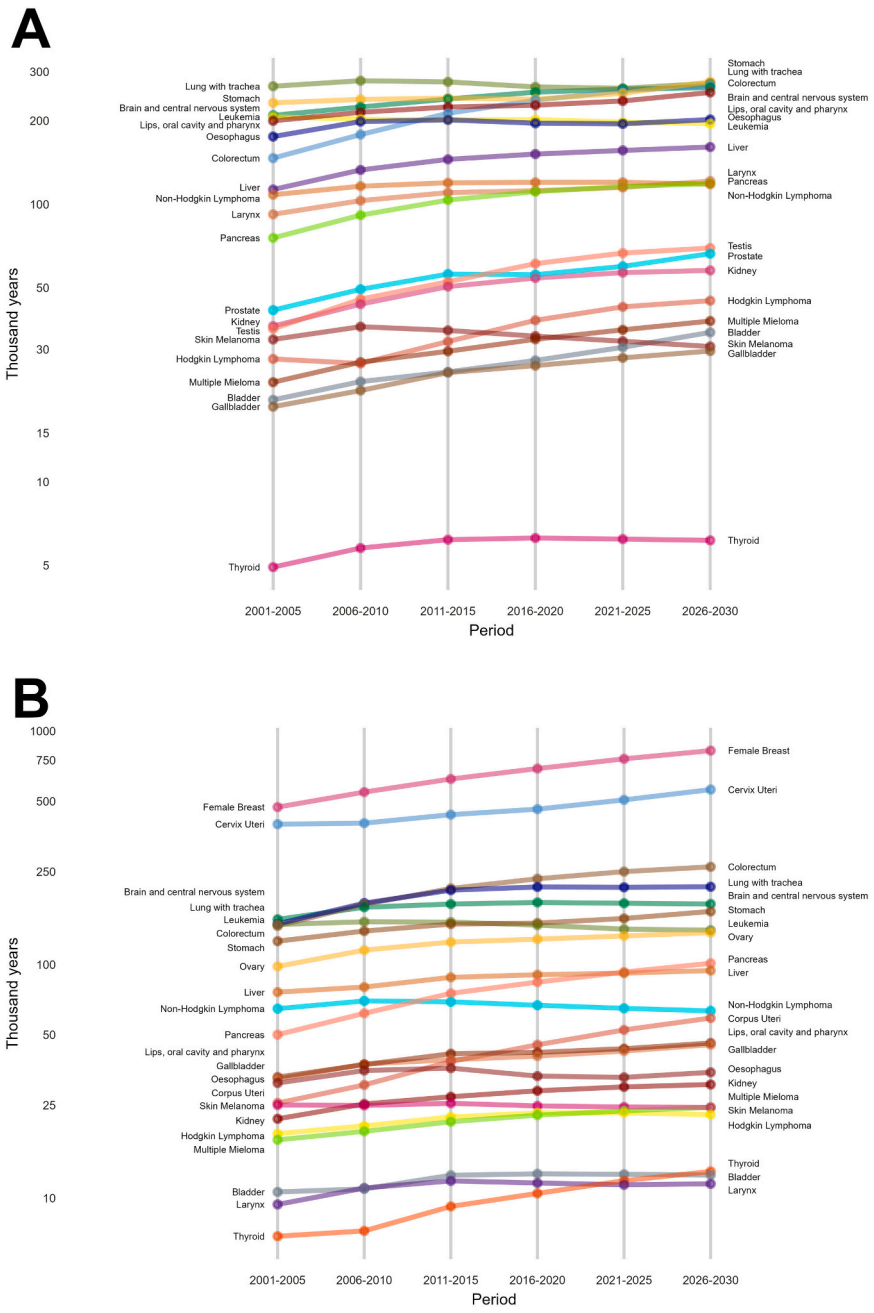

Fig. 1. Years of potential productivity life lost (YPPLL) due to working-age cancer mortality among Brazilian men (A) and women (B) between 2001 and 2030.

by different exchange rates, cost of living and income of the population, allowing the comparison of results between different countries [3,22,23].

Alternative projection scenarios were considered in sensitivity analysis, namely considering a retirement age of 65 years for both sexes and applying different GDP growth rates (0.0% and 4.8%). Analyzes were performed using the STATA statistical package version 15.1.

3. Results

3.1. Mortality

The number of deaths, mortality rates, YPPLL and productivity lost due to premature mortality from cancer according to topography and sex are shown in Tables 1 and 2. Between 2001 and 2015 were observed 1029,558 cancer deaths and between 2016 and 2030 were predicted 1294,876 deaths among people in working age (57% among men) from all cancer types (except non-melanoma skin) in Brazil; in the projected period, deaths corresponded to 55.7% (1294,876) of total. The highest truncated age-standardized mortality rates (ASR) among men were for lung with tracheal cancers (ASR: 12.8 per 100,000 in 2001–2005: 7.2 in 2025–2030); stomach (ASR: 9.4 in 2001–2005: 5.9 in 2026–2030); and lip, oral cavity and pharynx (ASR: 7.3 in 2001–2005: 5.4 in 2026–2030). Among women, the highest mortality rates were observed for breast cancer (ASR: 11.1 in 2001–2005: 11.8 in 2026–2030); cervix (ASR: 8.0 in 2001–2005: 6.9 in 2026–2030); and lung with trachea (ASR: 4.1 in 2001–2005: 3.8 in 2026–2030). ASR are presented in the supplementary material.

3.2. YPPLL and YPPLL per death

Overall, 32.1 million YPPLL were estimated for 2001–2030 for all

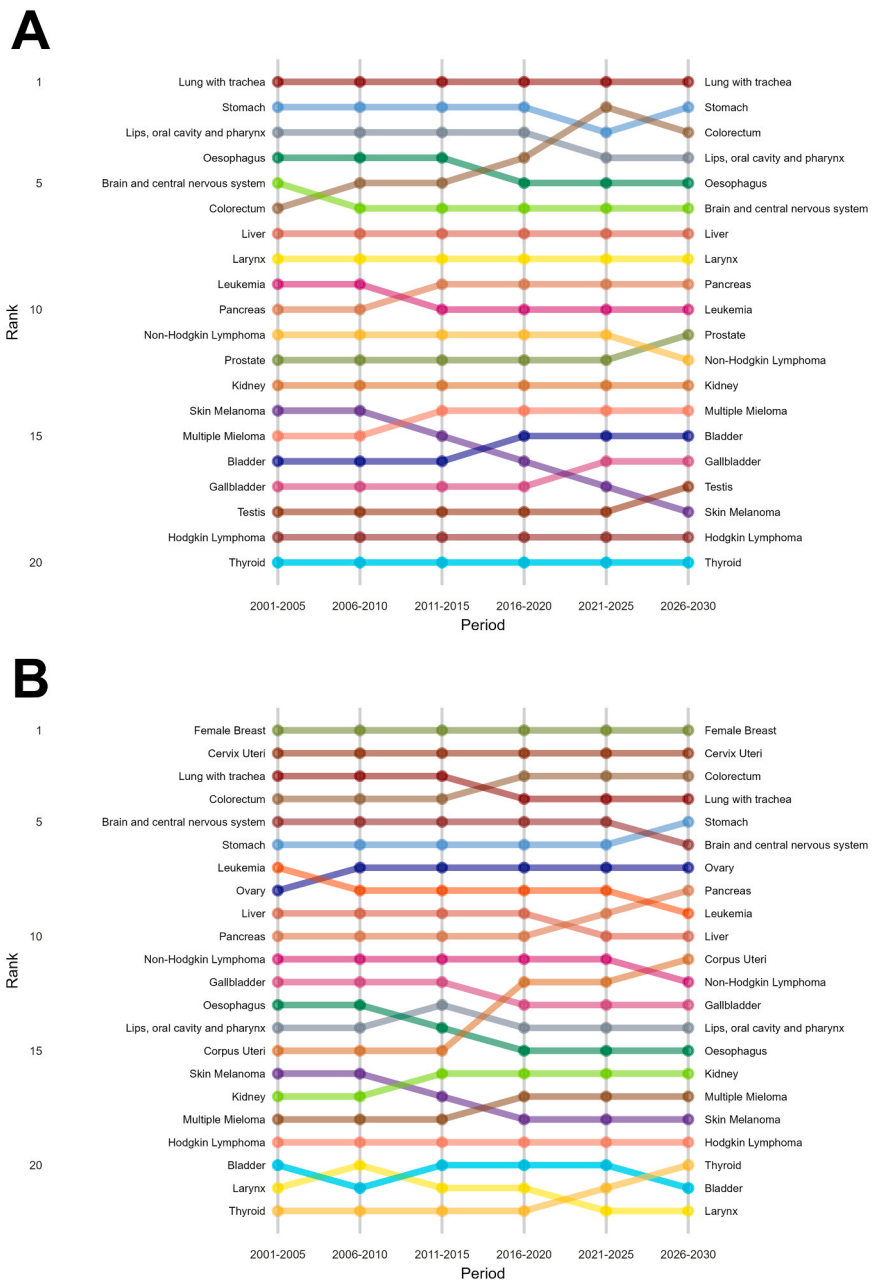

Fig. 2. Rank of productivity losses due to cancer-related working-age mortality by cancer sites in Brazilian men (A) and women (B) between 2001 and 2030.

cancers (48% among men); 14,859,346 (46.2%) in the observed period 2001–2015 and 17,317,698 (53.8%) in the projected period 2016–2030). A reduction in YPPLL over the period was projected for melanoma of skin and leukemia. Among men, the tumors with the highest YPPLL in the first quinquennium (2001–2005) were lung with trachea (266,280), stomach (232,040) and brain and central nervous system (209,138) (Fig. 1). Tumors estimated to have the highest YPPLL among men in 2026–2030 will be stomach (276,378), lung with trachea (272,738) and colorectal (267, 653); together these three cancers will represent 29% of total YPPLL (2.2 million years) expected in 2026–2030. Comparing 2026–2030 with 2001–2005, the largest relative increases in YPPLL were observed for testicular (95%), colorectal (82%) and bladder (75%) cancers. Considering all cancers combined, average YPPLL per cancer death was 13 years in 2001–2005 and is projected to be slightly lower, 11 years, in 2026–2030.

Among women, the tumors with the highest YPPLL in the first quinquennium (2001–2005) were breast (472,593), cervix (399,298) and brain and central nervous system (156,248). Tumor estimated to have the highest YPPL in 2026–2030 will be breast (825,000), cervix (561,728) and colorectal (262,220) cancer, corresponding to 52% of the total YPPLL (2.2 million years) estimated for all cancers. Comparing 2026–2030 with 2001–2005, the largest relative increases in YPPLL were observed for corpus uterine (131%), pancreas (102%) and thyroid (89%) cancers. YPPLL per death for all cancers fell slightly from 18 years in 2001–2005–16 years in 2026–2030 among women. The cancers with the highest YPPLL among women were Hodgkin lymphomas (30 years lost on average in 2001–2005 and 24 years in 2026–2030), leukemias (26 years in 2001–2005 and 23 years in 2026–2030), and non-Hodgkin lymphomas (22 years in 2001–2005 and 18 years in 2026–2030).

3.3. *Total productivity lost and productivity lost per death*

We estimated Int$141,4 billion in productivity lost (69.5% among men) due to premature mortality from all cancers combined during

2001–2030, in which 34.3% (48.5 billion) occurred during 2001–2015 and 65.7% (Int$92.9 billion) were estimated to occur in the projected period (2016–2030). Among men, there was 83% increase in productivity lost between 2001 and 2015 (Int$ 36.2 billion) and 2016–2030 (Int$66.3 billion). Among women, productivity lost increased by 116% between 2001 and 2015 (Int$12.3 billion) and 2016–2030 (Int$26.6 billion); in absolute terms, the productivity lost due to premature death from cancer among men was 3.1 times the productivity lost due to premature death from cancer among women in 2001–2005 and estimated to be 2.5 times in 2026–2030.

Fig. 2 illustrates the rank of productivity lost for by cancer type and sex. Among men (Fig. 2A), lung with trachea cancer ranked first in all quinquennia. In the last quinquennium (2026–2030), the greatest productivity lost among men will occur for lung with trachea (Int$2.8 billion), stomach (Int$2.7 billion) and colorectal (Int$2.6 billion) cancers, corresponding to 31% (Int$8.1 billion) of total productivity lost (for all neoplasms - Int$25.9 billion). Colorectal cancer had the greatest increase (278%) in productivity lost among male cancers between 2001 and 2005 and 2026–2030. In 2001–2005, colorectal cancer ranked sixth (Int$696.4 million) by productivity lost and is projected to rank third position (Int$2.6 billion) in 2026–2030; this is followed by testicular (275%) and kidney cancer (229%).

Among women (Fig. 2B), breast and cervical cancers ranked, respectively, first and second as the largest contributors to lost productivity among women in Brazil in all quinquennia. In the last quinquennium, it has been estimated that productivity lost for breast (Int $2.9 billion), cervical (Int$1.8 billion) and colorectal (Int$905 million) cancers will account for 54% of total productivity lost (for all neoplasms - Int$10.4 billion). Corpus uteri (405%), thyroid (352%) and pancreatic (351%) cancers had the largest increases in productivity lost between 2001 and 2005 and 2026–2030 for women.

In the sensitivity analyses we compared two additional scenarios (growth rates 4.8% and 0.0%) with the base-case scenario (Supplementary tables 2 to 5). When GDP growth was 4.8%, total productivity lost increased by 18.9% (Int$26.8 billion) compared to the base-case scenario; in a more conservative scenario (0.0% of GDP growth), total productivity lost was 14.9% (Int$21.2 billion) lower compared with the base-case scenario.

The use of secondary data of public access, which does not identify the patients, makes the submission to a research ethics committee dispensable.

4. Discussion

We computed YPPLL and used the Human Capital Approach to estimate productivity lost due to premature mortality cancer in Brazil between 2001 and 2030. We estimate 2.3 million deaths from all types of cancers, corresponding to 32.1 million of YPPLL and lost productivity of Int$142 billion (men: Int$102 billion; 72% of total costs). Among men, the greatest productivity losses were for lung with trachea (12% of total costs), stomach (10% of total costs) and colorectal (9% of total costs) cancers; among women the greatest productivity losses were breast (26% of total costs), cervical (16% of total costs) and colorectal (8% of total costs) cancers. In a paper from Europe, using a very similar methodology, lung (23%), breast (9%) and colorectum (8%) cancer also presented the highest productivity lost due to premature mortality [16].

When considering the productivity losses per death, we observed that the less common cancers that affect younger people (and hence incur more YPPLL per death) had the greatest economic impact. Between 2026 and 2030, for example, individual productivity losses for each death from testicular cancer (Int$119,969), Hodgkin's lymphoma (Int$114,416) and melanoma of the skin (Int$108,965) were estimated to be greater than those for lung with trachea (Int$93,528) and colorectal (Int$101,687) cancer in men. Among women, the largest individual (per death) productivity losses were for cervical (Int$63,316), Hodgkin lymphoma (Int$61,344) and breast cancer (Int$56,599). In Europe, the average productivity loss per cancer death in 2008 was €219,241, with melanoma (€312,798), Hodgkin lymphoma (€306,628) and brain and central nervous systems (€288,850) the costliest cancers per death [16].

Until now, only one study has evaluated productivity losses due to premature mortality from cancer in Brazil, pointing to 1.2 million YPPLL and Int$4.6 million in productivity lost in 2012[3]. Although that study used international data (unlike the current study), it showed that lung, breast, stomach and colorectal cancers had the highest costs, corroborating our findings. Considering all cancer types, among men the productivity lost per death was very similar (Int$59,840 vs Int$60,987)[3]. That study also compared productivity loss in BRICS countries (Brazil, Russian Federation, India, China and South Africa). Brazil presented the third higher productivity loss per death (Int$53,377), 22.4% lower than Russian Federation (highest burden) and 271% higher than India (lowest burden) [3]. The differences in the periods studied, the types of cancer and methodological difference to measure the productivity lost due to premature cancer deaths make comparisons difficult; thus, these should be interpreted with caution. However, even in the face of methodological differences, the findings illustrate the sheer magnitude of the economic impact of the premature deaths from cancer internationally and point towards strategies to mitigate it.

Previous studies projected the productivity lost related to premature mortality from cancer in other countries to 2030. In Russia, the indirect costs of premature deaths from all types of cancer were forecast to increase 15% from 2001 to 2005 (Int$6.5 billion) to 2026–2030 (Int$7.5 billion) while in Brazil projections point to a growth near to 2,7 times (Int$13.5 billion to Int$36.3 billion) in the same period [19]. In Ireland, productivity losses were projected to more than double between 2011 (€2.3 billion) and 2030 (€5.4 billion), with lung, colorectal and breast cancers being the biggest losses [24]. In the same period (2011–2030), the productivity losses for all cancer sites in Brazil were estimated to grow 65% (Int$23.7 billion to Int$36.3 billion).

Lung with trachea, stomach, colorectal, head and neck (lips, oral cavity, pharynx) and esophageal cancers will account for half (Int$12.8 billion) of the total productivity lost in 2026–2030 among men in Brazil. In the same period, among women, breast, cervical, colorectal, lung with trachea and stomach cancers will account for almost two-thirds (63.3%; Int$6.9 billion) of total productivity losses.

These neoplasms – and others with high total productivity lost – are related to exposure to potentially modifiable risk factors, such as tobacco smoking, alcohol consumption, inadequate diet, overweight and physical inactivity. Infection agents are also implicated in the aetiology of several cancers with higher productivity loss in this study: cervical cancers, pharynx, stomach and liver [25]. The prevalence of these risk factors in the Brazilian population has increased in recent years, except for smoking, which has decreased from 35% in 1989 to 12.6% in 2019, as a result of the National Tobacco Control Policy that ensures tobacco-free public environments and advertisement regulation [25,26].

Contrary to what is observed for smoking, unhealthy diet has become more prevalent in Brazil with an increase in the consumption of processed and ultra-processed foods, rich in sodium, fat, sugars and chemical compounds, such as nitrites [25,27–30]. The 2019 Household Budget Survey showed that in the last ten years the consumption of healthy food has been decreasing: the consumption of beans (73% in 2008 to 60% in 2019) and fruit 8% (45% in 2008 to 37% in 2019) decreased, while the consumption of sandwiches and pizzas increased (11% in 2008 to 17% in 2019) increased. Cancers where aspects of diet are aetiologically implicated, such as oesophagus, stomach and colorectum, will account for 25% (Int$23 billion) of productivity loss between 2026 and 2030, highlighting the need to strengthen and promote healthy eating as a public policy that can mitigate the burden of productivity losses in Brazil.

Alcohol consumption has also increased in recent decades [31]; between 2010 and 2019 the percentage of alcohol consumers increased in

6% among men and 9% among women [32]. Slightly more than one quarter of the Brazilian adults consumed alcohol at least once a week in 2019, with the prevalence among men (37%) being more than twice the prevalence among women (17%) [33]. In our study, cancer of colorectum, lips, oral cavity, pharynx and oesophagus in men, and colorectum among women were among the top five highest cancers in terms of productivity losses.

Overweight may result from the combination of poor eating habits and an increased prevalence of physical inactivity [31], and cancer related to overweigh such as colorectum and breast were among the highest sites in productivity loss. In 2018, an estimated Int$710 million was spent by the Brazilian Unified Health System (SUS) on the management of cancers attributable to being overweight; 80% of costs were for breast, endometrial and colorectal cancers [34]. While more than half of the Brazilian population was overweight in 2019 (57% men and 54% women), only 30% of adults were physically activity at recommended levels; this was only 20% among the elderly (age group), in whom the incidence and mortality rates from cancer are higher [33]. In our study, productivity losses for colorectal cancer among men increased 3.7 times between 2001 and 2005 and 2026–2030, and moved from being ranked in sixth position (Int$696.5 million) in the first quinquennium to third position in the last quinquennium (Int$2.6 billion). Considering that 16% of colorectal cancer deaths may be direct attributed to overweight, [25] in a scenario where overweight was controlled, an estimated productivity lost of Int$1.5 billion could be avoided. Among women, breast cancer presented the highest productivity lost, representing 26% (Int$38.8 billion) of the total between 2001 and 2030. As 10% of breast cancer deaths in Brazil are attributed to overweight, Int$100 million in productivity lost could be avoided in the absence of overweight.

Cervix cancers, whose main etiologic agents is HPV infection, ranked second in productivity loss among women, representing 16.5% (Int$6.4 billion) of total productivity loss. HPV Vaccination for HPV is effective in reducing the burden of cervical cancer, nonetheless, since the National Immunization Program (PNI) was implemented by the Brazilian Ministry of Health in 2017, the goal of vaccinating 80% of target population (14-years-old girls and 11–14 years-old boys) with two doses has not been reached [35]. Vaccination coverage varies between 7% and 79% depending on the Brazilian region, with the North, Northeast and Midwest regions showing the lowest vaccination coverage; in the North region, the greatest productivity losses among female neoplasms were for cervical cancer (Int$71.2 million in 2001–2005 to Int$282 million in 2026–2030), while in the other regions, breast cancer ranked first (regional data not shown).

Screening and early detection are important strategies to reduce the global burden of cancer, by reducing morbidity and mortality and treatment costs [36]. In Brazil, there are no organized screening programs for any cancer type, and opportunistic screening is recommended only for breast and cervical cancers [36], making early diagnosis difficult and leading to most cancers being diagnosed at late stages (III and IV) [37]. Between 2001 and 2014 more than half (56.2%) of cancer patients in the Brazilian Unified Health System started treatment in stages III and IV, with an average annual cost of approximately Int$10, 600 per patient – 48% more expensive than treatment started in stage I of the disease [37].

We highlight as strengths of this study the fact that while most studies evaluate the most common cancers, we evaluated all neoplasms, showing that less commonly diagnosed cancers - such as testicular cancer and Hodgkin's lymphoma - have a significant impact on productivity lost, since that these neoplasms occur in young adults of working age [20,38]. Furthermore, previous studies are predominantly in Europe and the USA, locations with distinct economic and sociodemographic characteristics from those of middle-income countries. Regarding methods, we used the HCA, which is widely used to assess the productivity lost due to premature death from cancer. Economic and mortality data came from high detailed quality, national sources, which allowed us to include income from formal and informal (not officially registered) jobs. Finally, while most studies have presented cross-sectional results, we presented an overview of the economic impact of premature cancer deaths over three decades (2000–2030). Moreover, by pointing out the economic impact resulting from premature mortality from cancer, we believe that our findings can help public managers in the allocation of public resources for cancer control.

This study has some limitations. Indirect costs associated with cancer-related work absences other than due to death (e.g. time off for cancer treatment) were not considered. Similarly, losses related to unpaid productivity such as childcare, volunteering or household work were not considered, although these have previously been found to account for even greater losses in productivity than paid employment [37]. This study was conducted prior to the COVID-19 pandemic and did not consider possible changes in cancer incidence and mortality or workforce patterns as a result of the disruption due to the pandemic.

This is the first Brazilian study to show that the increasing number of cancer deaths among economically active individuals projected to the next years will result in Int$ 141 billion of productivity lost by 2030. Lung, stomach, breast, colorectal and cervical cancers showed the greatest productivity losses; all of them associated with modifiable behavioral risk factors. Greater investments are needed in prevention and health promotion, including: (i) development of strategies to improve coverage in the National Immunization Program for HPV, in order to reach the target for vaccination coverage of the target-population; (ii) strengthening of the National Policy on Tobacco Control; (iii) promotion of an adequate diet; (iv) implementation of initiatives to encourage the practice of physical activity; (v) implementation of initiatives to promote healthy alimentation; and (vi) increased investment in screening, early diagnosis and treatment.

Funding

This study was funded by the MSD Independent Oncology Policy Grant Program.

CRediT authorship contribution statement

MCC: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Formal analysis, Supervision, Validation, Writing – review & editing. **JEMS:** Data curation, Methodology, Formal analysis, Validation, Writing – review & editing. **LBLS:** Data curation, Methodology, Formal analysis, Validation, Writing – review & editing. **LFLM:** Data curation, Methodology, Formal analysis, Validation, Writing – review & editing. **DLBS:** Data curation, Methodology, Formal analysis, Validation, Writing – review & editing. **AB:** Methodology, Formal analysis, Validation, Review. **PH:** Conceptualization, Methodology, Validation, Writing – review & editing. **LS:** Conceptualization, Methodology, Validation, Writing – review & editing. **IS:** Conceptualization, Methodology, Validation, Writing – review & editing. **AP:** Conceptualization, Methodology, Validation, Writing – review & editing.

Declaration of Competing Interest

This study was funded by the MSD Independent Oncology Policy Grant Program. The sponsor was not involved in the study design, in collection, analysis and interpretation of data; in the writing of the manuscript and in the decision to submit the manuscript for publication.

IARC disclaimer: Where authors are identified as personnel of the International Agency for Research on Cancer / World Health Organization, the authors alone are responsible for the views expressed in this article and they do not necessarily represent the decisions, policy or views of the International Agency for Research on Cancer / World Health Organization.

Availability of data and materials

The data used in this study are available for download at: https://datasus.saude.gov.br/transferencia-de-arquivos/ and https://www.ibge.gov.br/estatisticas/sociais/trabalho/9171-pesquisa-nacional-por-amostra-de-domicilios-continua-mensal.html?=&t=microdados.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.canep.2023.102438.

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