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Material deprivation, racial inequalities and mortality from female breast, prostate, and cervical neoplasm in the Brazilian adult population: an ecological study

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Abstract *This article aims to identify the relationship between material deprivation and mortality from breast, cervical, and prostate neoplasms in the Brazilian adult population and the relationship between ethnicity/skin color and material deprivation. This cross-sectional ecological study calculated the mean mortality rate per 100,000 inhabitants, and deaths were standardized by age and gender and redistributed per to ill-defined causes, stratified by age group and ethnicity/skin color. We applied the Negative Binomial model, containing the interaction between ethnicity/skin color and the Brazilian Deprivation Index (IBP). We analyzed 85,903 deaths, and the most prevalent were those due to female breast neoplasms. The risk of death from cervical cancer was 8.5% higher for Black women than white women. In other places, mortality was higher among white people. For all causes, mortality increased with age. There was a significant interaction between ethnicity/skin color and IBP for all causes. Only deaths due to cervical neoplasms increased with higher IBP, while a decline was observed in other causes but was less significant among Black people. The IBP offers a multidimensional view of the socioeconomic conditions of the Brazilian population, allowing a better understanding of how social determinants operate on selected neoplasms.*

Key words *Material deprivation, Racism, Mortality, Neoplasms, Social inequalities*

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Introduction

The Global Cancer Observatory estimated approximately 10 million deaths from cancer worldwide in 2022. The escalating increase in cancer mortality is linked to higher life expectancy and aging of the population[1], besides changes in the prevalence and distribution of risk factors for diseases, mostly related to socioeconomic development[2].

Neoplasms are not distributed evenly among different social groups, and this is primarily due to unequal exposure to associated economic, social, and environmental determinants, and access to disease prevention, diagnosis, and treatment, which are modifiable factors[3,4]. Thus, neoplasms are now an issue on the agenda of policies to combat health inequalities[4,5], with the understanding that this is a matter of social justice and human rights and that it would also generate broad benefits in the economic sphere[5,6]. Non-modifiable factors such as race/ethnicity are also associated with the incidence and mortality from different types of neoplasms and generally intersect with modifiable social factors[7,8]. Studies on the relationship between race/ethnicity and mortality from neoplasms in the Brazilian population are still incipient and have sparked the interest of researchers on the subject. As a result, there is a greater understanding of this relationship and, subsequently, of the social adjustment mechanisms.

Using one-dimensional indicators such as education[9] and income[10] is expected to understand the relationships between social inequalities and morbidity and mortality due to neoplasms. However, adopting multidimensional indicators such as the Human Development Index[1,11] has been in the rise to learn about the multiple factors producing these diseases. In the Brazilian context, we can study the correlations between morbidity and mortality indicators, sociodemographic indicators, and access to health goods and services, stratifying them per the social attributes of interest[5].

The literature lacks studies that use multidimensional indicators to measure inequalities in mortality due to neoplasms[12]. The demand for this analysis model has grown worldwide[5,13]. Some authors argue that multidimensional indicators would be more efficient in observing health inequalities than unidimensional indicators[13,14]. Brazil's most widely used multidimensional indicators consider poverty measured through income and other dimensions essential to social dignity, such as access to health and education services and other dimensions of living conditions[15,16].

In 2019, in response to the demand for the use of multidimensional indicators based on data from the Population Census, which measures the social dimensions experienced by individuals or groups, the Center for Data Integration and Knowledge for Health (CIDACS) launched the Brazilian Deprivation Index (IBP). The IBP measures material deprivation, classifying it into levels of socioeconomic position in different Brazilian geographic areas, namely, census tracts, municipalities, states, macro-regions, and Brazil. The IBP measures social inequalities in health at different levels of spatial aggregation. It comprises the following variables: income, literacy, household characteristics, and access to adequate garbage collection, water, and sewage services[17].

This study specifically aimed to identify the relationship between material deprivation and mortality from female breast, cervical, and prostate cancer, which are common in the Brazilian population and whose outcomes are directly or indirectly associated with the most unfavorable socioeconomic conditions. Furthermore, we sought to verify the relationship between ethnicity/skin color and material deprivation, measured by the IBP.

Methods

A cross-sectional ecological study[18] was conducted on mortality from female breast, cervical, and prostate cancer in 2009, 2010, and 2012 among the Brazilian adult population aged 20 years or older. Demographic and socioeconomic data by census tract were extracted from the 2010 Demographic Census database of the Brazilian Institute of Geography and Statistics (IBGE). Mortality data due to neoplasms were retrieved from the CIDACS[17] georeferencing database and classified under the International Classification of Diseases, 10th Revision (ICD-10). The study period was defined to cover the 2010 Demographic Census, the last Brazilian census with consolidated population microdata made available by the IBGE at the time of the analyses. We excluded 2011 from the study period due to its elevated percentage of data entry errors, which allowed the georeferencing of only 30.9% of deaths[19]. Regarding the three neoplasms, 84.03% of deaths recorded in the Mortality Information System (SIM) were georeferenced by CIDACS. This level of coverage

is considered acceptable for ecological studies since Brazil has a 40% to 90% variation in the efficiency of georeferencing health data[20] at sub-municipal scales.

The Bayesian method was applied to redistribute deaths from ill-defined causes in the census tracts[21-23], considering as a reference the mortality pattern by gender (male and female), age group ('20~34', '35~49', '50~69', and '70+') and ethnicity/skin color (white, composed of white and yellow individuals, and Black, composed of Black and brown individuals) of Brazil as a whole. We grouped white and yellow individuals[24,25] because the latter group corresponded to only 0.59% of the deaths analyzed and had similar mortality profiles. Bayesian redistribution is employed to minimize underreporting of deaths from a specific cause from the classification of deaths as deaths from ill-defined or very general causes (garbage codes) and to smooth out possible fluctuations resulting from the reduced number of cases, especially when it comes to rare outcomes or when the area analyzed does not have a considered sufficiently large sample size[26]. In this study, under Chapter II of ICD-10, the garbage codes redistributed were C76 (Malignant neoplasm of other and ill-defined sites), C79 (Secondary malignant neoplasm of other sites), C80 (Malignant neoplasm without specification of site) for all neoplasms, and C55 (Malignant neoplasm of uterus, part unspecified) for cervical neoplasms.

The material deprivation index used was the IBP, a single relative deprivation measure to analyze small areas (census tracts) with potential for aggregation to other geographic levels developed by CIDACS in partnership with the University of Glasgow-Scotland[17]. This index aims to verify and compare material deprivation calculated from variables extracted from the Population Census. The IBP was calculated by combining z-scores of the following variables: percentage of households with per capita income ≤1/2 minimum wage; percentage of illiterate people, aged 7 or over; and mean percentage of people with inadequate access to sewage, water, garbage collection, and lack of toilet and bathtub/shower. The z-score for each variable (x) was calculated using the formula $z=(x-\mu)/sd$, with the mean (μ) and standard deviation (sd) for the individual indicators considering weights related to the population size of the census tracts. These z-scores were added and weighted into a single deprivation measure[17].

The total number of deaths obtained after redistribution was aggregated into the 557 Brazilian microregions for each cause of mortality. Microregions are groups of contiguous municipalities defined as parts of the mesoregions that present specificities regarding space organization[27], maintaining stratification by gender, ethnicity/skin color, and age group. For the IBP, the mean between the census tracts of the microregion was considered.

In order to descriptively explore the data, the mortality rate per 100,000 inhabitants was calculated for the three neoplasms in the 557 Brazilian microregions. Due to the large number of sampling units (combination of microregion, gender, ethnicity/skin color, and age group) with zero deaths due to the outcome, Poisson and Negative Binomial models with and without adjustment for excess zeros were tested to verify the analyses' robustness and consistency[28,29]. Fixed effects of gender, ethnicity/skin color, and age group were included, considering the categories previously defined in the formulation of the database. The IBP was included in the model to analyze its effect on the incidence rate of the outcomes. The inclusion of an interaction term between ethnicity/skin color and the IBP was also analyzed.

The AIC (Akaike Information Criterion), BIC (Bayesian Information Criterion), and RMSE (Root Mean Squared Error) metrics were employed to select the best model in each case[30]. For all three metrics, the lower their value, the better the model fits the data. The analyses were performed using the R software[31] with MASS (Modern Applied Statistics with S)[32] packages to adjust the Negative Binomial models and *pscl* (Political Science Computational Laboratory)[33] to adjust the zero-inflation models. The analyses are shown in tables with the results of the adjustment, containing the estimate of the coefficient of each effect included in the model (Estimate), the p-value of the significance test of the effect (P-value), the Relative Risk (RR), and its 95% confidence interval (95%CI).

Results

The model that best adjusted the data for all outcomes analyzed was the Negative Binomial (BN), without zero inflation and containing the interaction between ethnicity/skin color and the IBP. This model had the lowest values for the goodness-of-fit metrics considered (AIC, BIC, and RMSE). A total of 85,903 deaths were georeferenced for the three conditions investigated, with 60.7% of deaths recorded among women

(for breast and cervical neoplasms). In the individualized observation of each neoplasm, mortality was observed for breast neoplasm (40.52%), followed by prostate (39.31%), and cervical (20.17%) neoplasms (Table 1).

Cervical

A total of 17,332 deaths from cervical neoplasms were georeferenced during the study years, and 36.4% (n=203) of the microregions did not have records of deaths from these neoplasms. The results of the adjustment of the model to the data on mortality from cervical neoplasms are shown in Table 2. It was estimated that (i) women aged 35-49 years were 4.827 times more likely to be at risk of dying from cervical neoplasm than those aged 20-34 years; (ii) Black women's risk of dying was 8.5% higher than for white women; (iii) the individual effect of IBP in the presence of the interaction was not significant with 10% significance, but it was relevant to the model since the interaction term of IBP with ethnicity/skin color is significant; (iv) the risk of death of Black women increases by 5.3% with every IBP unit increase.

Breast

Regarding mortality due to breast cancer, 34,805 deaths were georeferenced, and there were no deaths recorded due to this neoplasm in 34.9% (n=195) of the microregions. Table 2 shows the results of the model adjustment to the data on mortality due to breast cancer. It was estimated that (i) women aged 35-49 years are 9.132 times more likely to be at risk of death from breast cancer than women aged 20-34 years; (ii) the risk of death for Black women is 29.2% lower than for white women; (iii) the risk of death for white women decreases by 12.9% with every IBP unit increase; (iv) however, due to the interaction effect between ethnicity/skin color and IBP, the risk of death decreases by only 7.6% for Black women with every IBP unit increase; that is, the reduction is smaller than for white women.

Prostate

A total of 33,766 deaths from prostate neoplasms were georeferenced during the period, and 53.9% (n=298) of the microregions did not have records of prostate neoplasm deaths. Table 2 shows the results for mortality due to prostate neoplasms. It was estimated that (i) Men aged 35-49 are 18.330 times more likely to be at risk of dying from prostate cancer than men aged 20-34; (ii) Black men risk of dying is 6.4% lower than white men; (iii) The risk of dying among white men decreases by 8.1% for every IBP unit increase; (iv) However, due to the interaction effect between ethnicity/skin color and IBP, the risk of dying for Black men decreases by only 2.3% with every IBP unit increase.

Figure 1 shows the spatial distribution of the IBP and the incidence rates of mortality from cervical, breast, and prostate cancer per 100,000 inhabitants in the Brazilian microregions. In general, the North and Northeast regions of the country have a higher IBP; that is, these populations are exposed to more significant deprivation and are where mortality from cervical cancer is more significant. The same does not occur

Table 1. Descriptive characterization of the study population.

	Cervical		Breast (female)		Prostate	
	N° (%)	Rate	N° (%)	Rate	N° (%)	Rate
Population	17,332 (20.18%)	36.79	34,805 (40.52%)	55.55	33,766 (39.30%)	157.92
Age group						
≥20-34	1,197 (6.9%)	21.8	1,004 (2.89%)	2.79	15 (0.04%)	0.04
35-49	4,536 (26.18%)	42.6	7,462 (21.44%)	28.1	207 (0.62%)	1.20
50-69	7,213 (41.64%)	78.4	15,823 (45.46%)	67.1	7,316 (21.67%)	43.7
70+	4,386 (25.32%)	34.3	10,516 (30.21%)	124	26,228 (77.67%)	587
Ethnicity/Skin color						
White (White/ Yellow)	8,655 (49.94%)	36.79	23,295 (66.93%)	66.6	20,074 (59.45%)	158
Black (Black/Brown)	8,677 (50.06%)	4.42	11,510 (33.07%)	44.5	13,692 (40.55%)	158

Source: Authors.

Table 2. Negative binomial regression model adjusted to evaluate the mortality rate due to neoplasms of the cervical, female breast, and prostate, Brazil, 2009, 2010, and 2012.

Coefficient	Cervical				Breast (female)				Prostate			
	Negative binomial regression				Negative binomial regression				Negative binomial regression			
	RR	(95%CI)	Estimate	P-value	RR	(95%CI)	Estimate	P-value	RR	(95%CI)	Estimate	P-value
Model constant (intercept)	-	-	-10,076	<0,001	-	-	-10,085	<0,001	-	-	-14,305	<0,001
Age 35-49	4.827	(4.411-5.284)	1.574	<0.001	9.132	(8.341-10.006)	2.212	<0.001	18.330	(11.168-32.522)	2.909	<0.001
Age 50-69	9.422	(8.636-10.286)	2.243	<0.001	22.146	(20.285-24.200)	3.098	<0.001	809.422	(504.387-1413.127)	6.696	<0.001
Age 70+	17.872	(16.333-19.567)	2.883	<0.001	40.229	(36.784-44.034)	3.695	<0.001	10558.274	(6583.876-18424.016)	9.265	<0.001
Black Ethnicity/ Skin color	1.085	(1.026-1.148)	0.082	0.005	0.708	(0.676-0.741)	-0.346	<0.001	0.936	(0.892-0.981)	-0.066	0.007
IBP	1.013	(0.995-1.031)	0.013	0.153	0.871	(0.858-0.884)	-0.138	<0.001	0.919	(0.905-0.933)	-0.084	<0.001
Interaction IBP: Ethnicity/ Skin color	1.053	(1.029-1.079)	0.052	<0.001	1.061	(1.038-1.083)	0.059	<0.001	1.062	(1.041-1.084)	0.061	<0.001

CI: Confidence Interval. RR: Relative Risk.

Source: Authors.

when it comes to mortality from breast and prostate cancer, which, in general, are more significant in the Midwest, Southeast, and South, which are less deprived.

Discussion

Mortality from the neoplasms studied does not follow a single distribution pattern, varying between age, ethnicity/skin color, and material deprivation. Understanding how it emerges in different scenarios is necessary to move toward reducing inequality in mortality.

Cervical neoplasms are still a relevant pathology despite the availability of effective technologies for its control. It is the fourth most common cause of incidence and mortality in women worldwide[34]. This study observed that mortality from cervical neoplasm increases with age. This finding corroborates the study by Arbyn *et al.*[34], which describes that mortality is more pronounced among women with a mean age of 56. Mortality was higher among Black women, a finding also evidenced by Góes *et al.*[35], who observed that mortality among Black and brown women was 18% and 27% higher, respectively, than white women. In this same study, the interaction between socioeconomic status and ethnicity/skin color evidenced that differences in mortality were more significant among women living in poorer household conditions; in the current research, the interaction between IBP and ethnicity/skin color showed that increased material deprivation is associated with a higher risk of death among Black women.

Breast cancer is the most common cancer among women worldwide[1]. Mortality from this condition increases with age. Camargo *et al.*[36] affirm this is justified by the fact that this disease is associated with prolonged exposure to risk factors; that is, the time of exposure to its synthesizing factors increases with age. Another observation of this research that corroborates the literature is that mortality is affected by ethnicity and is rather pronounced among white women. In 2017, in São Paulo state, the mortality rate per 100,000 among white women was 16.46, higher than Black women, which was 9.57[37]. This study reduces the risk of death among the most unfavorable economic strata. This finding was also described by Góes *et al.*[35], where women living in worse household conditions had a lower mortality risk than those with better conditions. Duarte *et al.*[10] also discuss the social effect on mortality from breast cancer; ac-

cording to the study in the State of Minas Gerais in the Brazilian southeast, the highest mortality rates were found in the most developed and urbanized microregions of the state. The effect of social status on breast cancer is associated with exposure to risk factors. Women with better socioeconomic conditions tend to have greater access to hormonal contraceptives, nulliparity, or low parity, a long interval between menarche and the first pregnancy, higher age at first birth, and parity with lower breastfeeding rates, all of which are associated with the risk of developing neoplasms[38-40].

Racial inequalities in reducing mortality due to increased material deprivation occurred for white women to a greater extent than for Black women, which can be explained by the fact that Black and white women tend to have access to diagnosis and treatment at different stages even in poor conditions, which directly impacts mortality. In 2019, a study by dos-Santos-Silva *et al.*[41] observed that the diagnosis of advanced-stage

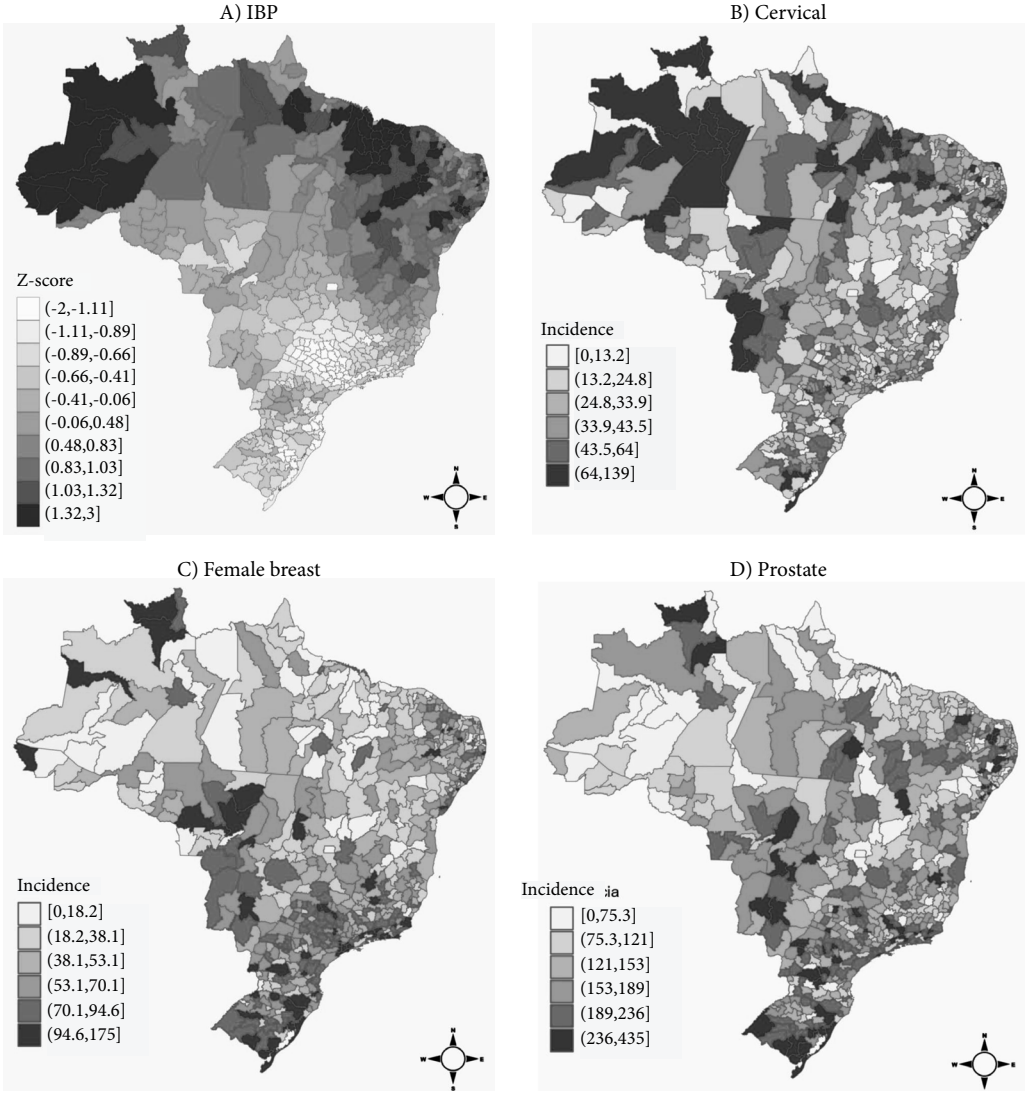

Figure 1. Spatialization of the Brazilian Deprivation Index (IBP) (A) and the incidence rates of deaths due to cervical (B), female breast (C), and prostate (D) neoplasms per 100,000 inhabitants in the Brazilian microregions in 2009, 2010 and 2012.

Source: Authors.

breast cancer was more prevalent among Black and brown women with little or no formal education. This finding is corroborated by the study by Santos *et al.*[42], which reaffirms that Black and brown women are most often diagnosed late. In 2019, a study by Cabral *et al.*[43] showed that less educated Black women attended to by the public health system were 37 times more likely to have treatment started more than 90 days after diagnosis.

Prostate cancer is the second most common cancer among men in Brazil[44]. Increasing age is related to higher mortality, which its slow development[45,46] may explain. Another important fact is the impact of race on mortality. This study showed that white men are more likely to be at risk of dying than Black men, but this finding is not consensual in the literature. In 2023, Zeng *et al.*[47] evaluated the racial/ethnic disparities reported in the United States, concluding that the mortality rate was higher among Black people. In Brazil, a study by Oliveira *et al.*[48] with data from the 2013 National Health Survey revealed that the diagnosis of neoplasms was higher among self-declared white people, which may justify the finding of this study since incidence affects mortality. People's deprivation condition also impacts mortality, in which it was inversely proportional to mortality. This finding does not corroborate the literature, where populations with better socioeconomic conditions have lower mortality[49,50]. However, this finding may be justified by the fact that in Brazil, people living in areas with worse socioeconomic conditions have less access to diagnosis and timely diagnosis[51] and have underreported cases, with poorer data quality and a high proportion of deaths recorded as ill-defined causes, which reflect unsatisfactory care conditions and hinders the identification of the real cause of death[52]. An interaction between material deprivation and ethnicity/skin color was observed in this study; mortality was reduced with higher deprivation, but this reduction was less significant among the Black population. In other words, even in similar conditions of deprivation, Black and white men tend to have access to diagnosis and treatment at different stages. Zacchi *et al.*[53] affirm that non-white men were more likely to be diagnosed at more advanced stages than white men. Corroborating this, Souza *et al.*[54] describe that Black men and less educated men (<8 years) were more likely to have advanced disease at the time of diagnosis.

Different mechanisms of racial inequalities affect mortality from neoplasms. The finding of this study deserves special attention, where, under similar conditions of deprivation, the reduction in mortality among Black people due to female breast and prostate cancer is less pronounced than the reduction among white people. This fact points to Black people's social disadvantage in Brazil because of structural racism, which affects the health-disease process[55]. Racism is a socially organized system that causes avoidable and unjust inequalities of power, resources, capabilities, and opportunities between racial groups[56]. Racism submits individuals to disparate exposure to risk factors and systemic barriers to screening and treatment, partly due to underlying socioeconomic inequalities[35,55-58].

Regarding the effect of deprivation on mortality from neoplasms, the differences found in this study can be justified by the varying socioeconomic measures adopted to measure inequalities, with studies using primarily one-dimensional measures, which cannot fully describe the complex disparities between diverse groups[13]. Employing the IBP aimed to unify the different dimensions of inequalities and offer a more realistic response regarding the health conditions of the Brazilian population.

The current age profile is marked by population aging, which makes individuals more susceptible to illness and mortality from neoplasms, directly impacting the health budget and encouraging the reorganization of spending and policies to address these conditions. In 2022, Brazil invested approximately R$ 3.9 billion in cancer treatment[59], but it is known that financial investment in health does not guarantee overall favorable results[60]. This fact is evident in the significant inequalities in the incidence of specific neoplasms and mortality rates affecting different social strata. When designing and proposing health policies to reduce inequalities, one should consider the social and environmental contexts in which individuals are "born, grow, work, live and age"[61] and have measures, such as the IBP, that broadly reflect inequalities. There is a growing need to disseminate through policies the timely access to specialized services and preventive measures and reduce exposure to risk factors, such as high body mass index, low consumption of fruits and vegetables, lack of physical activity and alcohol and tobacco use, which are currently responsible for one-third of mortality from neoplasms worldwide[62,63].

This study highlights the use of a composite measure validated in Brazil, developed to fill the gap in health research resulting from the lack of a tool that could be applied at different geo-

graphic levels but for the entire national territory. The IBP is an estimate, and as such, it has some degree of uncertainty about the exact level of deprivation for all areas caused by different factors, such as small population size and differences in deprivation estimated by the indicators adopted in the measure. The IBP gains in health research are that uncertainty is sufficiently small to place the area reliably in a deprivation category[17] for most census tracts (95.5%) and population (97.5%).

A limitation of this study is that it lacks essential measures in assessing the effect of deprivation on mortality from neoplasms, such as geographic accessibility to specialized services, measurement of the time between diagnosis and start of treatment, and difference in the diagnosis stage in different social contexts. Furthermore, no other indicator or index for assessing socioeconomic position was used with the IBP, as recommended for research, as no single measure can answer all questions[14]. Data temporality is another limiting factor, mitigated by using consolidated census data. This methodology should be replicated using data from the last demographic census (2022).

Collaborations

ACO Costa: conception, planning, analysis, interpretation and writing of the work. DO Ramos: conception, planning, analysis, interpretation and writing of the work. R Paes-Sousa: conception, planning, supervision, interpretation and writing of the work. All authors approved the final version submitted.

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