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The effect of redistributions of garbage codes on the evolution of mortality from Chronic Diseases in Brazil, 2010 to 2019

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Abstract *This study aimed to estimate premature mortality (30-69 years) for four priority NCD groups in Brazil from 2010 to 2019, comparing crude data from the Mortality Information System (SIM), SIM data adjusted by GC redistribution and underreporting, and data extracted from the Global Burden of Disease (GBD) study. Premature mortality rates due to NCDs declined in the period analyzed. Although the adjustment methods hardly changed temporal trends, we observed that mortality rates calculated with adjusted data were significantly higher than those without adjustment. This variation was heterogeneous among the Federated Units. The rates estimated by the crude SIM method ranged from 322.0 to 276.1 deaths per 100 thousand inhabitants, while the redistributed SIM rates ranged from 340.4 to 296.8 deaths per 100 thousand inhabitants. The estimated rates for the GBD ranged from 371.6 to 323.0 deaths per 100 thousand inhabitants. In conclusion, this study highlights the importance of adopting methods that can be applied to achieve more reliable mortality statistics, which continuously improves the definition of death causes in the SIM.*

Key words *Noncommunicable Diseases, Vital statistics, Cause of death, Data accuracy, Health Information Systems*

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Introduction

Mortality statistics are crucial and well-established for understanding the health status of a population, especially for monitoring chronic noncommunicable diseases (NCDs)[1,2]. Analysis of the causes of death allows us to measure the main problems that affect the health of a population. Estimating mortality rates allows for measuring the risks of death to which different population groups are exposed and the possible inequalities between groups, periods, generations, or locations[3]. Such rates can also support the targeting of priorities in policies related to health services, situation analyses, and planning and evaluation of actions and programs in the field[4,5].

Created in 1975, the Mortality Information System (SIM) allows storing and monitoring data on deaths in Brazil. It is an important tool for health surveillance in the country[6]. Despite being considered a consolidated system, the SIM still has regional inequalities in coverage and data quality[7]. It is consensus that, death certificates and investigation forms (essential system documents) must show accurate information on the underlying cause of death[8] to achieve SIM's adequate performance.

The World Health Organization (WHO) defines the underlying cause of death as (a) the disease or injury that initiated a series of events culminating in death or (b) in cases of accidents or violence, the circumstances that produced the fatal injury or injuries[9]. Although the underlying causes of death are coded using the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10), this classification does not provide adequate codes to declare the underlying cause. Codes for non-fatal diseases, signs, symptoms, and complications[10] exist. These so-called "Garbage Codes" (GC) are unsuitable for completing the underlying cause of death since they provide information that is not very useful for directing public health actions[11], hindering the identification of the actual diseases and conditions that caused the death[12,13].

A high proportion of GC limits the usefulness of mortality statistics, undermining their importance as a primary source of information for planning and evaluating health policies and interventions[6,14]. In this sense, different approaches have been adopted to classify and reduce the impact of GC, generally involving their redistribution to the plausible cause of death codes[15], after consulting with experts, fixed proportional redistribution, and proportional redistribution computed based on information from the cause of death chain and regression models[16]. In the Global Burden of Disease (GBD) 2019 study, the redistribution of GCs was based on weights generated by statistical models and redistributed by algorithms in the groups of defined causes[17,18]. Although this study is the gold standard for GC redistribution, countries need to move forward in implementing and improving their methodologies adapted to the local reality[19].

Chronic noncommunicable diseases (NCDs) are the leading cause of morbimortality in Brazil and worldwide, resulting in deaths, disabilities, loss of quality of life, and significant economic impacts[20,21]. It is estimated that, annually, NCDs are responsible for 41 million deaths worldwide (71% of all deaths). Of these, 15 million are premature deaths (30-69 years of age), and approximately 12 million occur in low- and middle-income countries[20].

Due to their magnitude and impact on the population, NCDs' continuous surveillance and monitoring are essential for public health[22]. This group of diseases was included in Target 3.4 of the Sustainable Development Goals (SDGs), which proposes reducing premature mortality from NCDs by one-third[23].

In Brazil, NCDs are the most frequent causes of death, accounting for 76% of deaths in 2017[24]. A study conducted by Malta et al. showed that premature mortality rates due to NCDs increased between 8% and 12% in Brazilian capitals with the redistribution of GCs. This variation was more significant in capitals with higher social deprivation rates[25]. There are no similar studies covering the Brazilian Federative Units.

Thus, this study aims to estimate premature mortality due to NCDs in Brazil and Federated Units (UF) from 2010 to 2019 by comparing data obtained from the crude SIM, SIM adjusted by the redistribution of GCs and the GBD, and its temporal trend. The association between the UF's Human Development Index (HDI) and the adjustment's impact on their mortality rates will also be analyzed.

Methods

This study of the time series of mortality due to NCDs from 2010 to 2019 compared three different calculation methodologies: using crude SIM data, SIM data adjusted by the redistribution of

GCs and under-registration, and data extracted directly from the GBD[18] study.

Variables - Mortality data

Premature mortality rates (30-60 years) were calculated for the total number of deaths from NCDs and categories that make up this group of diseases (diabetes, cardiovascular diseases, respiratory diseases, and neoplasms), considering the study period. The mortality rates for the total of NCDs were also calculated disaggregated by the state of residence of the victim for 2010 and 2019.

To calculate mortality rates, deaths whose underlying cause was coded as malignant neoplasms (codes C00-C97), diabetes mellitus (E10-E14), cardiovascular diseases (I00-I99), and chronic respiratory diseases (J30-J98, except J36) were considered in the numerator. The denominator was composed of the population of the same location and period, obtained from the GBD study, publicly available on the Institute for Health Metrics and Evaluation (IHME) website. This same population was considered for all study methods and the rate constant (100,000 inhabitants). Using population estimates from the GBD study to compose the denominator of mortality rates in the three calculation methods makes them comparable. However, it makes the values different from those observed in other studies using different population estimates.

Premature mortality rates from NCDs were measured using three different methods:

a) Mortality rate considering crude SIM data: Death data were obtained directly from SIM, and made publicly available by the Ministry of Health on the DataSUS website.

b) Mortality rate considering corrected SIM data: Death data were obtained from SIM, and the Brazilian correction method developed by Teixeira *et al.*[22] in 2021was applied to them. The first stage consisted of processing the "missing data" through the proportional redistribution of data by year, age, sex, and place of residence that were unknown and left blank[26]. Subsequently, the GCs were redistributed, considering the GCs listed in the GBD 2017 study[27,28]. We analyzed the codes in this list to identify which GCs were explicitly related to the four groups of NCDs under study. Subsequently, redistributions were made by GC levels and their respective GBD targets[29]. To this end, the four levels of GC severity described by the GBD study were considered per the magnitude of their implications for Public Health[30]: (i) very high (level 1) for causes with severe implications; (ii) high (level 2), for GCs with substantial implications; (iii) medium (level 3), containing GCs with significant implications; and (iv) low (level 4), in which GCs have limited implications. According to the GBD, levels 1 and 2 are the most important due to their significant impact on mortality analyses[30]. Besides the proportional redistribution process, the study considered the results of the GC investigations initiated in 2016 to assign weights to the redistribution[31]. The target causes were defined through the results of the death investigations of the project that investigated the main GCs in 60 Brazilian cities[32]. After analyzing the main GC groups, those that showed the most significant differences for the target codes analyzed were pneumonia, X59, and Y34[29,33,34].

c) Mortality rate using GBD data: Deaths were estimated by the Institute for Health Metrics and Evaluation (IHME) at Washington University as part of the Global Burden of Disease (GBD) study, produced in partnership with the GBD Brazil Network. This study uses SIM[35] as its primary source of information in Brazil, with adjustments by other national and international sources. For all Brazilian states, the data quality is considered high and close to that of high-income countries[36]. Specific redistribution algorithms defined by the IHME are applied for each age-sex-year. Details on the methods and results of the GBD study can be found in several publications[22,37,38].

The three methods used mortality rates standardized by the direct method, considering only premature death from 30 to 69 years old, using the GBD 2019 world standard population.

Data analysis

Initially, we analyzed the trend in deaths and premature mortality rates due to NCDs from 2010 to 2019, calculated using the three methods, for Brazil. The Prais-Winsten linear regression method was adopted to estimate the trends. This method is designed for data that may be influenced by serial autocorrelation, which often occurs in population data measurements. The critical value adopted to determine whether the trend was significant was P=0.05. The annual percentage change (APC) was calculated using the following formula[39]:

$$\textit{Annual Percentage Change} = -1+10^{b}$$

Where *b* corresponds to the slope coefficient of the line obtained in the regression analysis relating the decimal logarithm of the indicator under analysis with the year of occurrence. The 95% confidence interval of the average annual percentage increase rate in the period was calculated from the following formula[39]:

$$95\%\ CI = -1 + 10^{(b \pm t^{*}SE)}$$

Where *t* is the value at which the Student's t distribution shows nine degrees of freedom at a two-tailed 95% confidence level, and SE is the standard error of the estimate of *b* provided by the regression analysis.

The percentage variations in premature mortality rates due to NCDs were calculated using the crude and adjusted SIM methods for Brazil and UF in 2010 and 2019, besides the percentage of correction calculated from the percentage variation in premature mortality rates due to NCDs between the methods. Because these are smaller values, the time series of UF indicators display considerable variability, hindering the implementation of the regression analysis. Therefore, we decided to analyze only the percentage variations.

A Pearson correlation analysis was also performed between the Human Development Index (HDI) and the percentage variation in premature mortality rates due to NCDs estimated from the crude and adjusted SIM, by UF, from 2010 to 2019. The HDI is an index of three indicators: longevity, income, and education. It can range from 0 to 1; the closer to 1, the better the human development. It has been widely used in studies, generating comparability[40]. The magnitude of correlations was categorized through the classification proposed by Shimakura[41] for positive or negative correlation coefficient (r) values: (i) Very weak correlation (r=0.00 to 0.19); (ii) Weak correlation (r=0.20 to 0.39); (iii) Moderate correlation (r=0.40 to 0.69); (iv) Strong correlation (r=0.70 to 0.89); (v) Robust correlation (r=0.90 to 1.00). Correlations in which the p-value was less than 0.05 were considered significant.

Statistical analyses were performed using R software (R Core Team 2024. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria: https://www.R-project.org/).

Ethical aspects

This research complies with Resolution No. 466 of the National Health Council (CNS), dated December 12, 2012. It was approved by UFMG's Human Research Ethics Committee under Opinion No. 3.258.076.

Results

Figure 1A shows the absolute number of deaths estimated per the three calculation methods. A similar increase was observed among the three methods, and the highest values were estimated by the GBD method. Approximately 253 thousand deaths were recorded in 2010 in the crude SIM, reaching 288 thousand deaths in 2019 (APC=1.55%; 95%CI=1.28%; 1.81%). Considering the adjusted SIM, this number ranged from 267 thousand to 310 thousand deaths in the same period (APC=1.74%; 95%CI=1.44%; 2.03%). The GBD method estimated 292 thousand deaths in 2010, reaching 337 thousand in 2019 (APC=1.59%; 95%CI=1.42%; 1.77%).

Premature mortality rates due to NCDs decreased during the analyzed period (Figure 1B). The rates estimated using the crude SIM method decreased from 322.0 to 276.1 deaths per 100,000 inhabitants (APC=-1.64%; 95%CI=-1.96%; -1.32%), while the adjusted SIM rates ranged from 340.4 to 296.8 deaths per 100,000 inhabitants (APC=-1.47%; 95%CI=-1.88%; 1.06%). Those estimated by the GBD ranged from 371.6 to 323.0 deaths per 100,000 inhabitants (APC=-1.58%; 95%CI=-1.83%; 1.33%).

Figure 2 shows the mortality rates for each of the four groups of NCDs studied during the period. We also observed a reduced magnitude of these rates. Deaths from cardiovascular diseases showed a similar declining pattern among the three methods studied. For the other groups, although all methods indicated a reduction in the magnitude of the mortality rate, we observed a variation in its behavior during the historical series per the calculation method analyzed. The estimates calculated using the GBD method were the highest, followed by the adjusted SIM and crude SIM for all groups of diseases studied and throughout the period analyzed.

Table 1 shows the values and percentage variation in premature mortality rates due to NCDs calculated under the crude and adjusted SIM methods in the UFs and Brazil for 2010 and 2019. Considering both methods, in 2010, the highest mortality rate was observed in Rio de

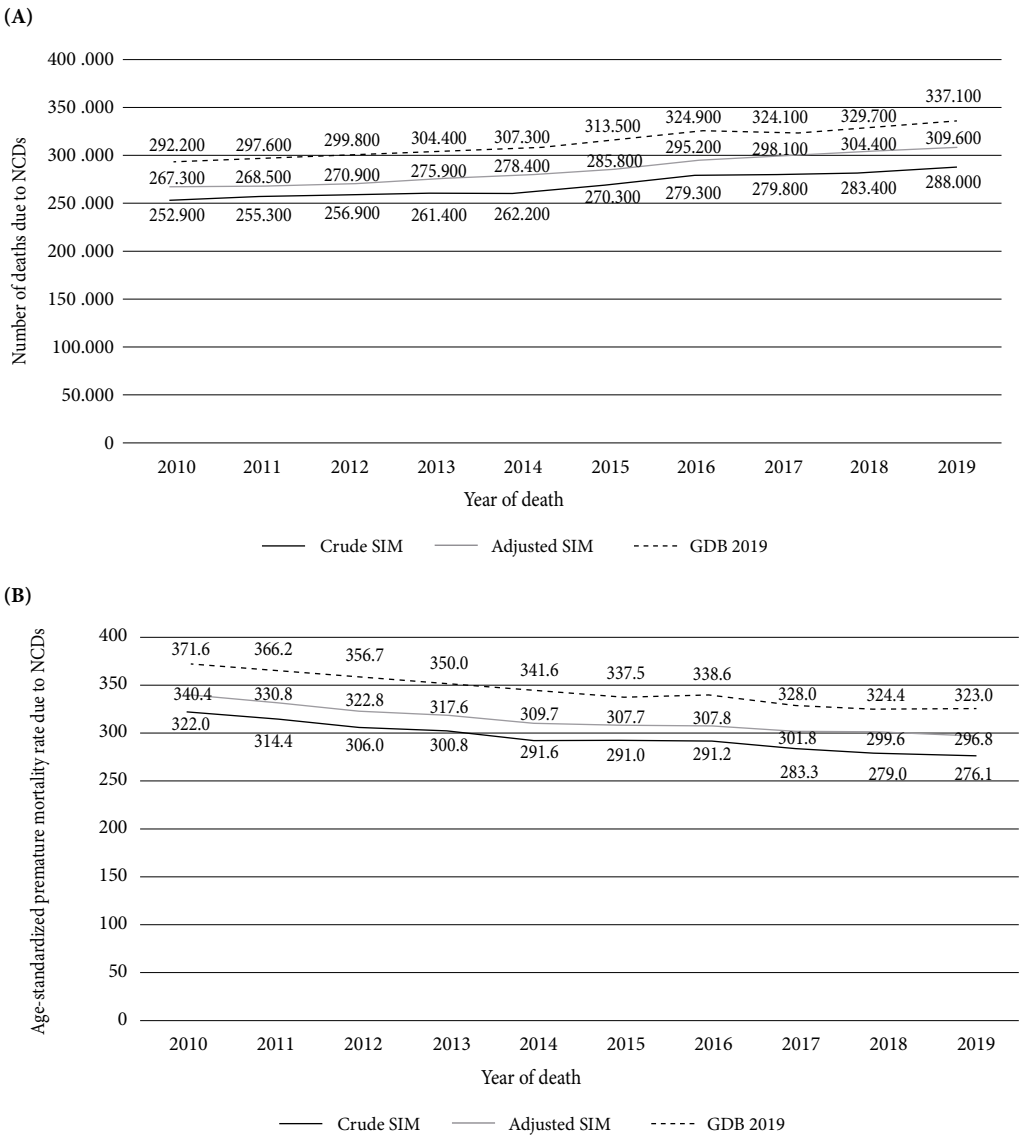

Figure 1. (A) Number of premature deaths due to NCDs by crude SIM, adjusted SIM, and GBD methods. (B) Age-standardized premature mortality rates due to NCDs, by crude SIM, adjusted SIM, and GBD methods Brazil, 2010 to 2019.

Source: Authors.

Janeiro (384.0 deaths/100,000 inhabitants per the crude SIM and 392.3 per the adjusted SIM) and the lowest in Amapá (189.1 deaths/100,000 inhabitants per the crude SIM and 218.3 per the adjusted SIM). In 2019, per the crude SIM, the highest rate was recorded in Pernambuco (314.8 deaths/100,000 inhabitants). Under the adjusted SIM, the highest rate was observed in Alagoas (376.4 deaths/100,000 inhabitants). Also, in 2019, the lowest premature mortality rate due to NCDs occurred in the Federal District (222.9 deaths/100,000 inhabitants per the crude SIM and 232.9 per the adjusted SIM). The most significant positive percentage variation between the mortality rates of 2010 and 2019 was observed in Amapá (40.5% per the crude SIM and 30.0% per the adjusted SIM). The most significant negative percentage variation occurred in

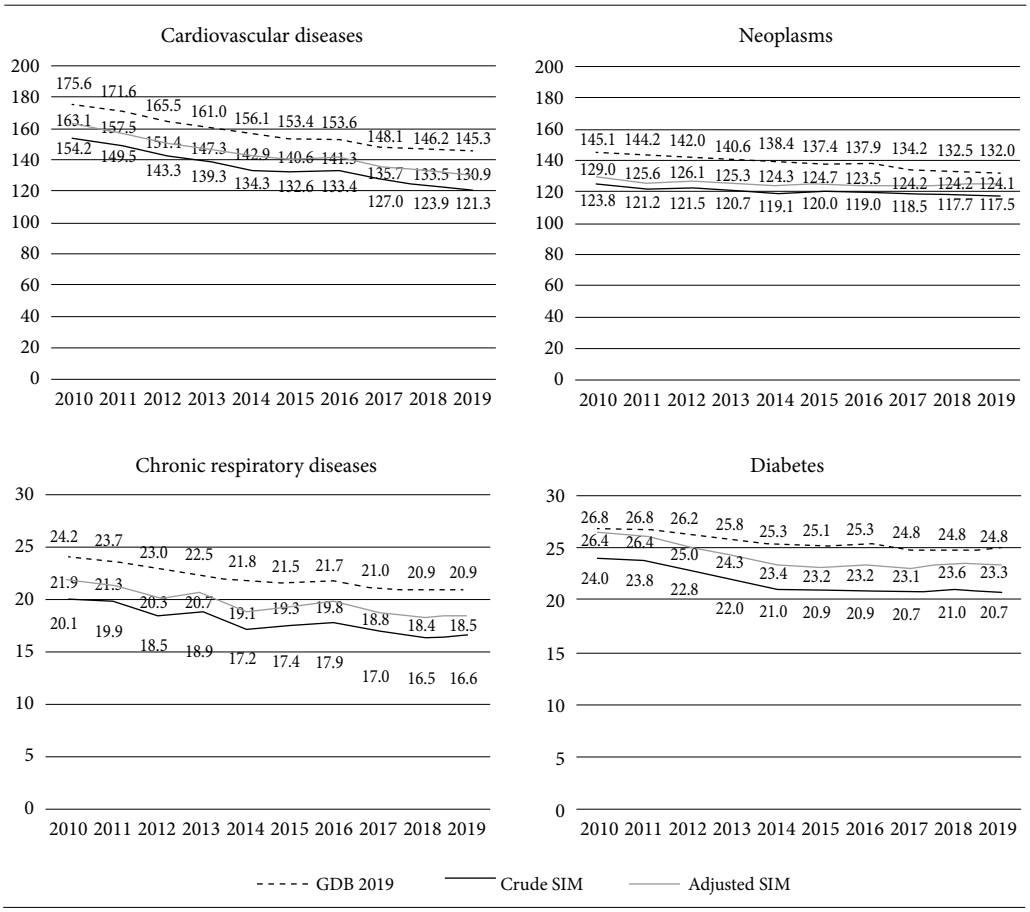

Figure 2. Age-standardized premature mortality rates for the four NCD groups (cardiovascular diseases, neoplasms, chronic respiratory diseases, and diabetes) by crude SIM, adjusted SIM, and GBD methods. Brazil, 2010 to 2019.

Source: Authors.

Mato Grosso do Sul (-20.6% per the crude SIM and -19.6% per the adjusted SIM).

Table 2 shows the percentage of correction of premature mortality rates due to NCDs calculated using the crude and adjusted SIM methods for 2010 and 2019. In Brazil, the percentage of correction was 5.7% in 2010 and 7.5% in 2019. Among the states, Maranhão had the highest percentage of correction (26.7% in 2010 and 33.9% in 2019). The lowest percentage of correction was observed in Rio Grande do Sul in 2010 (1.5%) and São Paulo and Mato Grosso in 2019 (2.7% for both).

Figure 3 shows the results of the correlation analysis between the percentage variations in premature mortality rates due to NCDs in the UFs and their HDI. We observed a moderate correlation considering both methodologies (crude SIM: r=-0.46; P=0.015 and adjusted SIM: r=-0.54; P=0.004), which means that the UFs with higher HDIs presented more minor variations.

Discussion

The study showed the impact of correcting death data on the estimate of the number of deaths and premature mortality rates due to NCDs. For all disaggregated values, we observed that the rates increased after the redistribution of GCs, with very similar temporal trends between adjusted and unadjusted rates. The adjustment percentage varied among Brazilian states, and the percentage variation in rates between 2010 and 2019 was inversely proportional to their HDI.

This study shows the importance of using adjustment methods for NCD mortality data

Table 1. Age-standardized premature mortality rates due to chronic noncommunicable diseases and percentage change by the Crude and Adjusted SIM methods. Brazil and Federated Units, 2010 and 2019.

Location		Crude SIM mortality rate		Adjusted SIM mortality rate		Percentage variation between 2010 and 2019	
		2010	2019	2010	2019	Crude SIM	Adjusted SIM
Brazil		316.9	276.1	334.9	296.8	-12.9	-11.4
North	Rondônia	273.1	241.3	286.4	272.5	-11.6	-4.9
	Acre	256.8	267.9	268.7	280.3	4.3	4.3
	Amazonas	252.2	243.4	263.1	251.2	-3.5	-4.5
	Roraima	272.4	303.5	278.7	316.2	11.4	13.4
	Pará	244.4	235.9	269.4	255.0	-3.5	-5.3
	Amapá	189.1	265.6	218.3	283.8	40.5	30.0
	Tocantins	288.6	255.3	300.5	300.0	-11.5	-0.2
Northeast	Maranhão	261.4	249.2	331.3	333.6	-4.7	0.7
	Piauí	263.8	251.2	277.5	261.9	-4.8	-5.6
	Ceará	254.4	249.9	299.3	291.6	-1.8	-2.6
	Rio Grande do Norte	259.9	277.4	283.3	290.0	6.7	2.4
	Paraíba	292.7	283.1	329.8	305.4	-3.3	-7.4
	Pernambuco	351.9	314.8	385.5	372.7	-10.5	-3.3
	Alagoas	317.5	310.4	357.6	376.4	-2.2	5.3
	Sergipe	299.3	247.9	307.6	271.1	-17.2	-11.9
	Bahia	258.5	240.5	310.4	288.6	-7.0	-7.0
Southeast	Minas Gerais	285.8	246.2	299.3	257.6	-13.9	-13.9
	Espírito Santo	331.1	292.2	350.9	333.3	-11.7	-5.0
	Rio de Janeiro	384.0	308.7	392.3	319.0	-19.6	-18.7
	São Paulo	337.1	292.7	345.9	300.7	-13.2	-13.1
South	Paraná	348.3	279.2	353.6	295.1	-19.8	-16.5
	Santa Catarina	317.9	266.9	324.3	275.8	-16.0	-15.0
	Rio Grande do Sul	353.7	297.3	359	306.9	-16.0	-14.5
Midwest	Mato Grosso do Sul	362.7	287.9	370	297.6	-20.6	-19.6
	Mato Grosso	320.8	257.4	326.9	264.3	-19.8	-19.1
	Goiás	308.5	280.8	326.4	307.1	-9.0	-5.9
	Federal District	287.6	222.9	293.5	232.9	-22.5	-20.7

Source: Authors.

in Brazil, particularly in the Brazilian North and Northeast states. The adjustment percentage of up to 33.9% (observed in Maranhão in 2019) shows the need for caution in using mortality estimates calculated from crude SIM data. Other studies have pointed to this need to produce mortality estimates with more credible magnitudes, favoring epidemiological surveillance[22,27,31,38].

The SIM has shown significant advances in coverage and qualification of records in recent years[42]. However, between 30 and 40% of the causes of death are GCs[31]. This study showed a significant difference between Brazilian states, with higher percentage of correction in the North and Northeast. This regional inequality has also been observed by several other authors[12,27,38]. Despite the efforts of the Brazilian Ministry of Health in partnership with states and municipalities to improve the capture of deaths by SIM (such as the project to reduce ill-defined causes and the project to reduce regional inequalities and reduce infant mortality in the states of the Northeast and Legal Amazon)[33], these inequalities remain, reinforcing the need to use treatment methods in the SIM database, especially the adjustment for underreported deaths and the redistribution of GCs[22,33,38].

Analyzing mortality estimates, we observed declining mortality rates due to NCDs in Brazil, considering the three calculation methods. Similarly, Malta *et al.*[43], when analyzing GBD data from 1990 to 2017, identified a 35.9% decline in premature mortality due to NCDs, and

Table 2. Percentage of correction of age-standardized premature mortality rates due to chronic noncommunicable diseases, Brazil and Federative Units, 2010 and 2019.

Location		Adjustment percentage (%)*	
		2010	2019
Brazil		5.7	7.5
North	Rondônia	4.9	12.9
	Acre	4.6	4.6
	Amazonas	4.3	3.2
	Roraima	2.3	4.2
	Pará	10.2	8.1
	Amapá	15.5	6.9
	Tocantins	4.1	17.5
Northeast	Maranhão	26.7	33.9
	Piauí	5.2	4.2
	Ceará	17.7	16.7
	Rio Grande do Norte	9.0	4.5
	Paraíba	12.7	7.9
	Pernambuco	9.5	18.4
	Alagoas	12.6	21.2
	Sergipe	2.8	9.4
	Bahia	20.1	20.0
Southeast	Minas Gerais	4.7	4.6
	Espírito Santo	6.0	14.1
	Rio de Janeiro	2.2	3.3
	São Paulo	2.6	2.7
South	Paraná	1.5	5.7
	Santa Catarina	2.0	3.3
	Rio Grande do Sul	1.5	3.2
Midwest	Mato Grosso do Sul	2.0	3.4
	Mato Grosso	1.9	2.7
	Goiás	5.8	9.4
	Federal District	2.1	4.5

*Percentage of correction calculated from the percentage variation in premature mortality rates due to NCDs between the crude SIM and adjusted SIM methods.

Source: Authors.

cardiovascular diseases had the most significant reduction (47.9%)[43]. These advances can be explained by improved living and health conditions, reduced poverty, improved access to goods and services, and an expanded Unified Health System (SUS), besides advancing health policies[43].

Besides the higher percentage of correction of mortality rates due to NCDs, the UFs in the North and Northeast mostly showed smaller reductions or even increases in mortality rates due to NCDs, both in the analysis of crude and adjusted SIM data. These states have the lowest HDI in the country, resulting in a negative correlation between the HDI and the percentage variation in mortality rates from 2010 to 2019. A study conducted by Malta *et al.*[38] in 2023 showed similar results, with more significant decreases in mortality rates due to NCDs observed in Brazilian capitals included in the strata of lowest vulnerability[38].

These results can be explained by the prolonged polarized epidemiological transition experienced by the country since the 1950s. Besides the overlapping burden of infectious diseases, chronic diseases, and noncommunicable conditions, this process is characterized by epidemiological polarization, with different transition levels between and within countries per the socioeconomic level[44]. Thus, the states in the Southeast, South and Midwest were more likely in more advanced stages of the epidemiological transition during the study period, with high mortality rates from NCDs. In contrast, in the same period, the states in the North and Northeast still had residual challenges of an originally rural and traditional society, with high mortality from infectious diseases and a high risk of death in childhood, and while transitioning to a predominantly urban society, with a reduced risk of death in childhood and higher mortality from NCDs[45].

The study innovates by presenting the effects of applying the revised method proposed by Teixeira *et al.*[22]. This method applied the correction of the SIM databases using Brazilian empirical data, such as the result of the death investigation project in 60 cities[34] and the investigations conducted in the state health secretariats[27,33]. One of the strengths of the current study is the improved method of Teixeira et al., with a review of the GCs and target codes and the use of empirical data from death investigations[32]. The use of more than 20,000 deaths with defined underlying causes altered after investigation strengthens the result of the causes, as it is a project that considered the Brazilian reality, which enhances the richness of these data. These data should be further explored so that other quality treatments of causes of death can be applied to the national crude data. Another strength is using similar population estimates for the different calculation methods, ensuring the comparability of the indicators under study.

Despite the methodological advances in handling missing data and redistributing GCs, this study has limitations. Among them, the algorithms were analyzed per the empirical data in studies conducted in 60 cities, but they do not

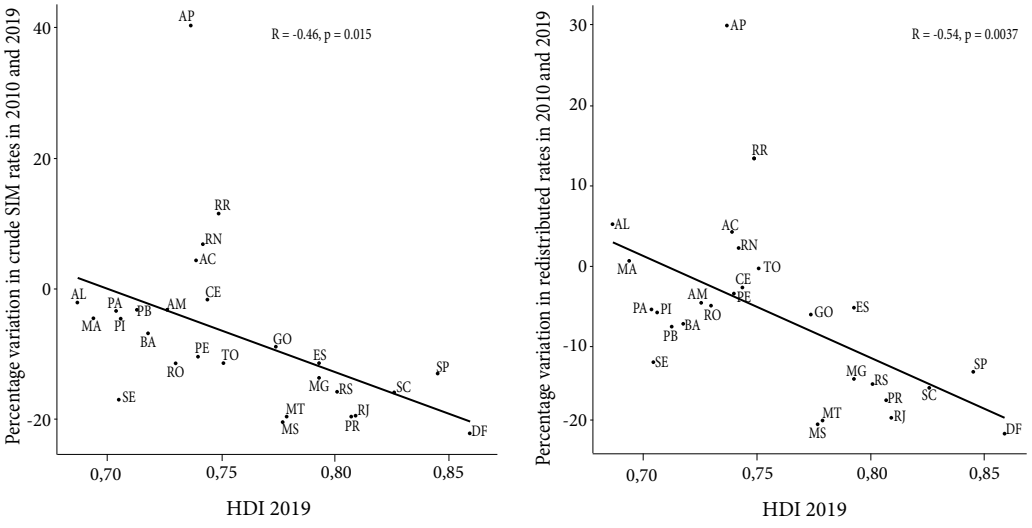

Figure 3. Scatter diagram and correlation analysis between the percentage variations in premature mortality rates due to chronic noncommunicable diseases in the Federative Units and their Human Development Index. Brazil, 2010 and 2019.

Source: Authors.

cover the entire national territory and there may be local particularities. Furthermore, the data may not have been fully adjusted for underreporting, especially in the North and Northeast. The adjustment was implemented up to severity level 2, classified per the GBD[30] study, and redistribution methodologies for more disaggregated underlying causes should also be further developed. Furthermore, 2020 and 2021 were not included in the analysis due to the pandemic, when SIM data deteriorated, requiring another proposal for redistribution of GCs, which is still under development.

A mortality data processing method is constantly being developed. These analyses and the future availability of these GC redistribution algorithms are expected to support local managers in adequately analyzing the health situation. It is crucial to advance in the surveillance of ill-defined causes and the training of doctors to complete death certificates correctly.

In conclusion, this study highlights a reduction in premature mortality rates due to NCDs from 2010 to 2019, especially in the states with the highest HDI. The redistribution of GCs represented increased mortality rates due to NCDs, which was more significant in the North and Northeast states. Thus, it is important to adopt methods that can be applied for more reliable statistics related to mortality, which contributes to the continuous improvement of the definition of causes of death in the SIM.

Collaborations

All authors participated in the conception, design, analysis and interpretation of data, writing of the article and critical review of it. All of them read and approved the final version.

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