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ORIGINAL ARTICLE

Mortality by skin color/race, urbanicity, and metropolitan region in Brazil

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Abstract

Aim This study investigated the mortality rate distribution in Brazilian cities based on skin color/race and according to level of urbanicity and aggregation into metropolitan region (MR) in 2010.

Subjects and methods The age-adjusted all-cause mortality rate (AMR) was calculated according to skin color/race (white, brown, or black). Municipalities were used as analysis units and classified into six categories: Rural within MR; Rural outside MR; 'Rurbano' within MR; 'Rurbano' outside MR; Urban within MR and Urban outside MR.

Results Racial inequality intensified in line with increasing urbanicity level, from rural to urban areas. However, these differences depended on how the city was aggregated to MR, thus suggesting that the mortality spatial structure was based on skin color or race in these locations. The black population presented the worst AMR risk, mainly in cities outside MR. In addition, it was found that there was an excess mortality in the black population as compared with white people.

Conclusion Mortality-related racial inequalities were associated with urbanicity and MR level. They were also dependent on a complex combination of risk factors in these areas. City categorization may serve as an intervention point to reduce racial inequalities in health among populations in Brazilian cities.

Keywords Mortality · Urbanicity · Metropolitan area · Distribution by race or ethnicity · Cities

Introduction

Analysis of health inequalities, including the occurrence of death, still uses approaches through the collected information level. There are researches that investigate mortality variations at the individual complexity level according to income, education, gender, and age group (Szwarcwald et al. 2011a; Belon et al. 2012; Smedley 2012; Chiavegatto Filho et al. 2014). On the other hand, spatial or geographic aggregate analyses evaluate the contextual characteristics that influence mortality risk (Diez-Roux and Mair 2010; Hoffmann et al. 2014; Krieger et al. 2014). Although these analysis formats present a relevant mortality interpretation, they still restrict understanding of the combination and interaction of individual and contextual determinants. Also, they do not express the influence of other determinants on different spatial configurations (Diez-Roux and Mair 2010; Nogueira 2008; Sharkey 2013; Oliveira and Luiz 2017).

Therefore, other attributes, such as skin color or race, urbanicity, and aggregation into metropolitan region (MR), need detailed analyses due to their influence on mortality. These attributes are well known as individual and population health structural determinants (Nogueira 2008; Sharkey 2013; Oliveira and Luiz 2017). Due to the collaborative establishment of social stratification, residential segregation, and racial discrimination, these factors result in uneven risk and protection factor exposure, and poor access to social and health services and health care (Nogueira 2008; Diez-Roux 2012; Sharkey 2013; Oliveira and Luiz 2017). These disadvantages accumulate for generations and define the inequalities in the lives and deaths of different racial groups (Diez-Roux and Mair 2010; Sharkey 2013; Oliveira and Luiz 2017).

Skin color or racial characteristics represent a sociopolitical construct, and reflect the organizational and structural principles of any given society. They are still used in different

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mechanisms to order and create distinctions and to preserve racial hierarchies, prejudices, and stigmas that systematically restrict access to the goods, social services, opportunities, and resources distributed in the population (Telles 2004; Diez-Roux 2012; Sharkey 2013). Skin color/race are therefore capable of revealing the vulnerabilities, social and economic deprivation, and discrimination that are related to health inequalities.

Urbanicity represents the status or pattern of urbanization in a certain area in a certain time frame, as well as reflecting the artificialization level and intensity of changes made by human activities (Veiga 2002; Vlahov and Galea 2002; Nogueira 2008; Novak et al. 2012; Cyrill et al. 2013). Urbanicity also refers to a group of social, physical, and health services attributes that allows distinctions among different locations (Vlahov and Galea 2002). Furthermore, it clarifies health inequalities due to living and health condition changes that occur or increase in relation to these attributes (Vlahov and Galea 2002; Novak et al. 2012; Cyrill et al. 2013). In different societies, the impact of the urbanization process is materialized in the cities, which become complex social structures of varying size, population density, heterogeneity, and diversity (Vlahov and Galea 2002). As a result, the cities present mutual multiple obstacles to social and health care services, which are mainly present in more vulnerable or marginalized population groups (Vlahov and Galea 2002; Harpham 2009; Chandola 2012; Oliveira and Luiz 2017). In this way, cities are configured according to characteristics and properties that are specific to each place. They model particular living and health conditions, which explains the social, health, and well-being differences observed between them (Vlahov and Galea 2002; Oliveira and Luiz 2017). The level of urbanicity gradations can prove that an analysis of their differences is of great importance (Vlahov and Galea 2002; Harpham 2009; Chandola 2012; Oliveira and Luiz 2017).

The growth of MRs has led to the emergence of new territories and the modification of existing ones in order to meet increasing demands on shared spaces (Ruiz 2015). Large, complex, dynamic, and expansive metropolitan areas have been created through the conglomeration of cities (Harpham 2009; Ruiz 2015; Oliveira and Luiz 2017). Living, health, and death situations in urban and rural areas are shaped by the social and physical changes that are created or intensified in these metropolitan areas (Diez-Roux and Mair 2010; Nogueira 2008; Sharkey 2013; Oliveira and Luiz 2017).

Skin color/race, urbanicity, and MR are attributes which are particularly important in the Brazilian context. Brazil's racial composition is neatly stratified into three color or racial groups: white, black, and brown. The last demographic census in the country in 2010 demonstrated growing racial heterogeneity (Chiavegatto Filho et al. 2014; Oliveira and Luiz 2017). However, studies have shown that the general conditions of life and health of the black population in Brazil have always been worse than those of the white population (Telles 2004; Oliveira and Luiz 2017). Blacks still occupy unequal positions in society. There are marked inequalities between the racial life cycles and death experiences in the two genders, thus indicating that blacks are more exposed to various risk factors, plagued with social problems, in great need of quality health care, and deprived of equity (Telles 2004; Chiavegatto Filho et al. 2014; Oliveira and Luiz 2017). The urbanization process in Brazil has occurred in a short time, specifically since the 1960s. The intensive displacement of rural populations to the cities and the concomitant conglomeration of metropolitan areas led to an increase of populations living in the peripheries and irregular areas with precarious social infrastructures (Veiga 2002; Oliveira and Luiz 2017).

The increase in the number of cities in Brazil, with different population sizes throughout all regions, has been shown to be one of the features of urbanization in the Brazilian context (Veiga 2002; Oliveira and Luiz 2017). These phenomena have produced profound changes in such places and in the daily lives of people in Brazil, which in turn have led to poverty concentration, increased health needs, segregation, and disorderly expansion of urban areas. Furthermore, it has also consequently subjected non-white people to more absolute poverty, unemployment, violence, crime, suboptimal social and health services and sanitary infrastructures, encouraged unhealthy lifestyle choices, and resulted in worse morbidity and mortality estimates (Vlahov and Galea 2002; Nogueira 2008; Szwarcwald et al. 2011a; Belon et al. 2012; Sharkey 2013; Chiavegatto Filho et al. 2014; Oliveira and Luiz 2017).

The breakdown of health-related data in Brazilian cities has demonstrated the advantage of national sample surveys held in the country as they allowed assessment of health conditions in areas that had not been included in previous studies (Szwarcwald et al. 2011b; Brasil 2014). Nevertheless, most mortality ecological analyses still focus on global levels, such as states, regions, or the more central southeastern areas of Brazil (Szwarcwald et al. 2011a; Belon et al. 2012; Smedley 2012). However, all of these geographical units presented internal heterogeneities, and the information present in them concealed diversities among the municipalities (Veiga 2002; Ingram and Franco 2012; Smedley 2012).

Therefore, this study was designed to examine whether age-standardized, all-cause mortality rates (AMRs) varied by race, gender, level of urbanicity, and MR aggregation in Brazil in 2010.

Materials and methods

This ecological study analyzed the AMRs of Brazilian cities in 2010 using the death data recorded in the Mortality Information System (MIS; Sistema de Informação sobre Mortalidade), as well as in the Brazilian Institute of

Geography and Statistics (IBGE) population records. The MIS data were obtained from the Ministry of Health through the Computing Department of the Brazilian National Health System (SUS; DATASUS) (Brasil 2014), whereas the census population data were accessed online from the Automatic Data Recovery System (SIDRA) of the IBGE (IBGE 2011).

The existing municipalities in the 2010 census ($n = 5565$ municipalities) were used as the analysis units. They were classified by combining population size and demographic density (DD) and by taking into consideration whether the city was aggregated into an MR or not. The levels of urbanicity were obtained through the criteria available in Veiga (2002), which categorizes them as follows: Rural (< 50,000 inhabitants [inh.] and DD < 80 inh./km^2), 'Rurbano' (50,000–100,000 inh. or DD ≥ 80 inh./km^2 albeit total population is < 50,000 inh.), and Urban (> 100,000 inh.). 'Rurbano' areas were deemed to present an intermediate level of urbanization and thus were characterized as a rural/urban (hybrid). MR aggregation was defined according to whether the municipalities fulfilled one of the following conditions: MR, integrated development region (RIDE), or urban settlement. According to the IBGE, these are the territory-clustering methods of Brazilian bordering cities (IBGE 2011). Conceptual aspects and detailed information regarding these clusters can be found on SIDRA's website (IBGE 2011).

Cities were grouped into six categories, classified according to level of urbanicity and MR aggregation: (1) Rural within MR; (2) Rural outside MR; (3) 'Rurbano' within MR; (4) 'Rurbano' outside MR; (5) Urban within MR; and (6) Urban outside MR. This categorization was intended to improve comparability between cities by making socioeconomic, demographic, and health conditions more homogeneous within each category. The number and proportion of the cities and their total populations were detailed for each category (Table 1). Figure 1 shows a map of the six categories under study.

Aside from municipality of residence at time of death, death certificate (DC) variables, such as skin color or race, gender, and age, were also used for AMR analysis. The data on mortality were collected according to gender for each race or skin color; namely, white, brown, black, yellow, Indian, as well as those with no declared color or race, as they are spread throughout each municipality. A total of 1,136,947 deaths were registered in the MIS in 2010, of which 99.6% included information about municipality of residence at time of death. The skin color or race was reported for 1,061,113 (97.2%) of

Table 1 Number (N) and proportion (%) of municipalities, total population, and crude and age-standardized all-cause mortality ratios (AMRs) per 100,000 inhabitants, derived from Poisson regression models according to level of urbanicity and aggregation to metropolitan region (MR)[1] of Brazilian municipalities in 2010

Level of urbanicity and aggregation to MR[1]	Municipality		Total population			All-cause mortality ratios (AMR) per 100,000 inh							
						Crude[3].				Age-standardized[3,4].			
	N	%	N	%	Aggregated[2]	Mean	SE*	Rate ratio	95% CI[5]	Mean	SE*	Rate ratio	95% CI[5]
Rural within MR	323	5.8	4,006,766	2.1	545.7	591.8	10.4	1.00	(Ref.)	557.6	8.4	1.00	(Ref.)
'Rurbano' within MR	220	4.0	8,883,346	4.7	525.1	567.5	8.4	1.07**	1.04–1.10	604.4	6.9	1.12**	1.10–1.14
Urban within MR	153	2.7	78,383,453	41.1	578.2	583.8	10.5	1.10**	1.06–1.15	632.2	7.6	1.17**	1.15–1.20
Rural outside MR	4134	74.3	48,754,949	25.5	523.8	574.8	3.2	1.00	(Ref.)	531.7	2.3	1.00	(Ref.)
'Rurbano' outside MR	605	10.9	24,674,061	12.9	550.6	610.7	6.5	0.96	0.92–1.00	595.8	4.5	1.06**	1.02–1.11
Urban outside MR	130	2.3	26,053,224	13.7	568.7	627.3	11.0	1.04	0.96–1.13	626.7	6.4	1.08**	1.03–1.14
Brazil	5565	100	190,755,799	100	556.3	581.2	2.6	–	–	548.8	1.94	–	–

Source: Demographic Census 2010, http://www.sidra.ibge.gov.br (IBGE, 2011a)

Rural = population < 50,000 and demographic density < 80 inh./km^2 ; 'Rurbano' = population 50,000–100,000 or demographic density ≥ 80 inh./km^2 ; Urban = population > 100,000

1 — Municipalities belonging to metropolitan region (MR)/integrated development region (RIDE)/urban area

2 — Aggregated all-cause mortality rate (AMR) obtained by dividing sum of total deaths by sum of total population, multiplied by 100,000 inhabitants, in each one of the levels of urbanicity and aggregation to MR in 2010

3 — All-cause mortality rate (AMR) corrected for skin color/race by redistribution of number of deaths per skin color/race ignored for groups of skin color/race defined

4 — Age-standardized all-cause mortality rate using default to Brazil's population in 2010 census and corrected for skin color/race by redistribution of number of deaths per skin color/race ignored in 2010

5 — CI = confidence interval

*SE = standard error.

**$p < 0.05$ – mortality rate ratios were statistically significantly different from 1 at this level of urbanicity and aggregation to MR.

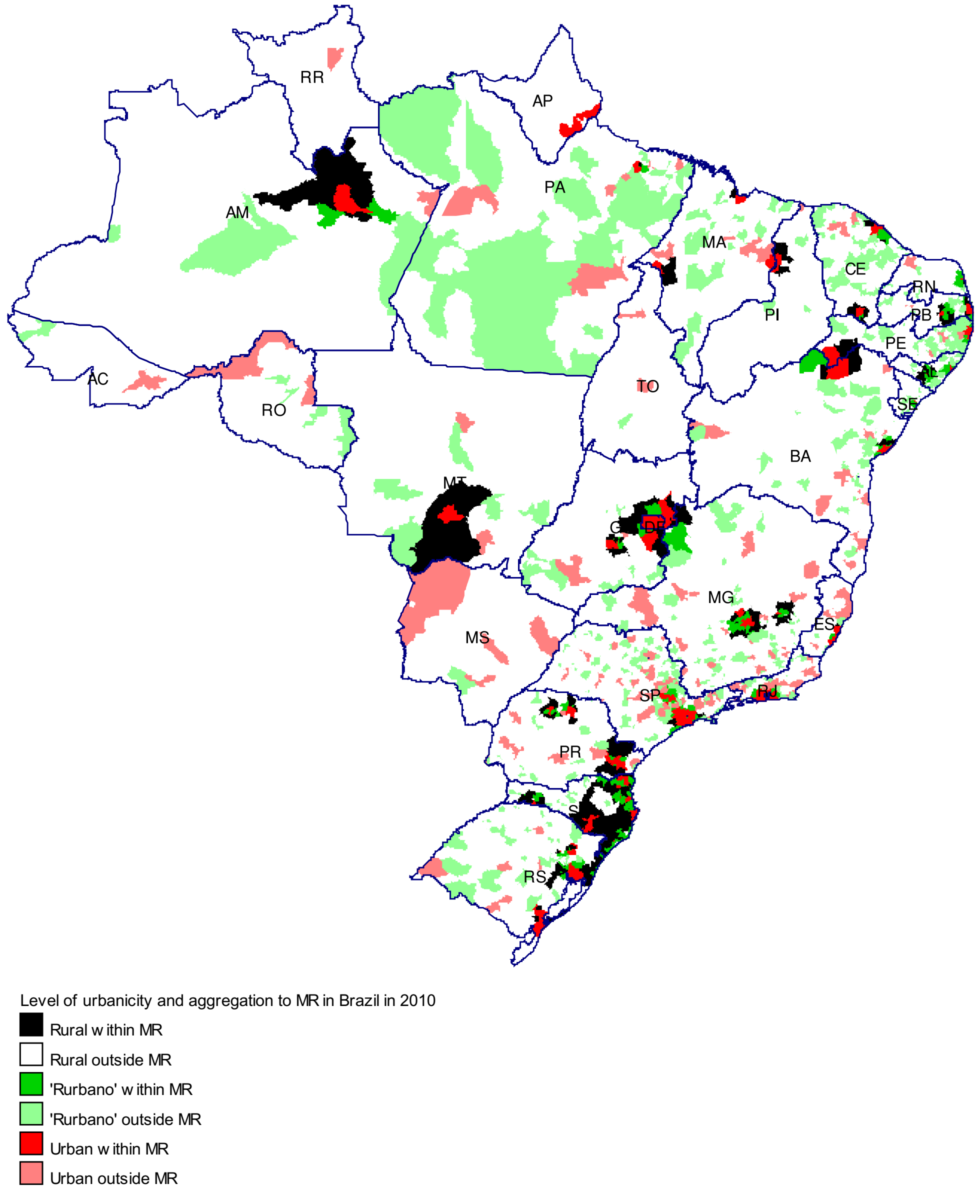


Fig. 1 Geographical distribution of cities according to level of urbanicity and aggregation to MR in Brazilian municipalities in 2010. Notes: For more information about states and cities from Brazil, see the website: http://www.ibge.gov.br

DCs, whereby 1,052,031 (99.1%) of the declared deaths were from the white, brown, and black populations. Although yellow and indigenous people are present in Brazil, their distribution is still restricted to a small number of cities in a few regions of the country, and there are insufficient data regarding mortality and populations (≤ 1.5%), thus making the comparison of mortality indicators for these groups and the six categories of cities impossible. Therefore, the yellow skin color/race ($n = 6162$; 0.6%) and indigenous ($n = 2920$; 0.3%) categories were not considered in the analyses, also because their frequencies were lower than 1% of all deaths with information on skin color/race, and because these categories were not the focus of interest in our study.

Before calculation of AMR, the correction of the number of deaths in both genders through the proportional redistribution of deaths, with and without declared color or race, was made for each municipality. The final total number of deaths of the white, brown, and black populations was 1,123,337 (99.8%) after redistribution. This correction assumed that the distribution of skin color or race with no declared deaths was the same as the distribution of the skin color or race with recorded deaths, allowing proportional redistribution among the three racial groups, and sought to minimize the losses for registry items on skin color or race, and the possibility of bias associated with the loss due to differences in the quality of registration of DC between cities (Szwarcwald et al. 2011b; Chiavegatto Filho et al. 2014; Malta et al. 2014; World Health Statistics 2016). This procedure has commonly been implemented by Brazilian authors to overcome limitations related to data recording and the issue of MIS coverage among Brazilian regions regarding poorly defined causes of death, so as to obtain racial group life expectancy calculations and

Northeast region and Brazilian Legal Amazon birth and death estimates (Szwarcwald et al. 2011b; Chiavegatto Filho et al. 2014; Malta et al. 2014). After the corrections had been made, the aggregate, crude, and age-standardized AMRs of 100,000 inhabitants were calculated. To allow comparability of the proposed six categories despite their different age composition, the AMRs were age-standardized for both genders through the direct method (Hinde 1998), which used the population information from the 2010 census, and the age brackets of 0–4, 5–14, 15–24, 25–64, and ≥ 65 years.

The aggregate, mean crude (plus standard error), and age-standardized AMRs are presented according to the level of urbanicity and aggregation to MR. These measures were obtained after calculating the AMRs for each city and subsequent mean AMRs in each level of urbanicity and aggregated MR. The crude and age-standardized AMRs are illustrated in the box plots by race group; the mean (plus standard error) and the rate ratio of age-standardized AMR by color or race, gender, level of urbanicity, and aggregation to MR are presented in the tables. Furthermore, the age-standardized AMR distribution by skin color or race is presented in maps, and the four ranges of deaths per 100,000 inh. (< 500; 500–999; ≥ 1000; and unregistered), which resembled the cutoff points recommended by the WHO (2016), are considered. (See Annex Table 4).

Poisson regression, which is a generalized linear model with robust variance, was used to estimate the rate ratio and 95% confidence interval (95% CI) of mortality based on the level of urbanicity in metropolitan and non-metropolitan areas. Specifically, the logarithm of the age-standardized mortality number was modeled as a Poisson linear function, yielding exponential mortality rates. The disparities in mortality were described by rate ratios, which were tested for statistical significance at the 0.05 level.

This research was exclusively developed using online secondary aggregate data on deaths and populations. Sensitive data, such as names and addresses, were not featured; thus, our study was exempt from approval by a research ethics committee. The study was carried out in accordance with National Health Council Resolution 466 of 12 December, 2012.

Results

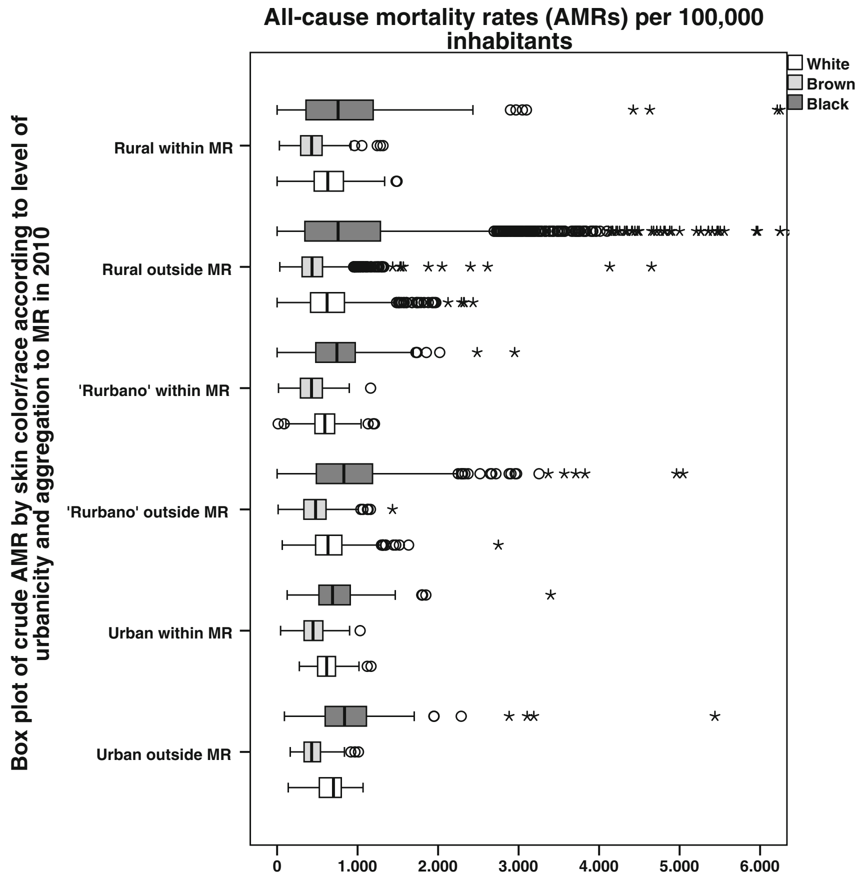
There were 5565 Brazilian municipalities in 2010, with 190,755,799 million inhabitants. Figure 1 shows a map of the six categories under study. Most of these cities were classified as rural outside MR (74.3%), although the greater part of the country's population (41.1%) was residing in cities classified as urban within MR (2.7%). The aggregate AMR in Brazil was 556.3/100,000 inh. Cities aggregated into MRs presented with a higher mean AMR after age adjustment at urbanicity level. The mean age-standardized AMR increased the higher the level of urbanicity, even though the difference between these measurements was never higher than 7.0 deaths/100,000 inh. between within and outside MRs — thus indicating an existing symmetry. As presented in Table 1, the age-standardized AMR rate ratio increased as the level of urbanicity increased, with cities aggregated into MR having higher values. The urban within MR category showed a greater risk of age-adjusted AMR (1.17; 95% CI: 1.15–1.20).

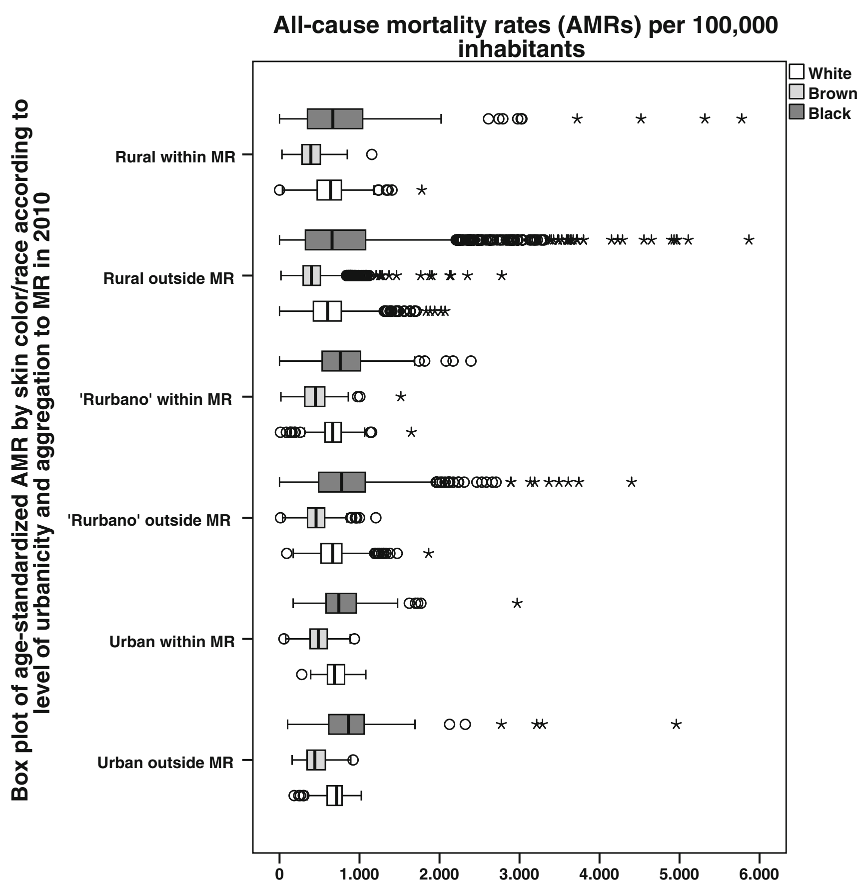
The box plots of crude and age-standardized AMRs illustrate mortality inequalities regarding skin color or race in every city group by modifying these inequalities within and between cities. The AMR was always higher in relation to blacks, especially when outside MR, although AMR was unexpectedly lower in relation to browns and whites. When age adjustments were taken into account, however, the racial groups presented a similar AMR distribution among the various city types, thus showing a lower adjusted AMR dispersion as compared with the crude rates. Nonetheless, blacks are still disproportionally represented. Aberrant measurements decreased with higher urbanicity levels, and AMR became more unstable in rural areas outside MR. The urban area was the most unfavorable area for all three racial groups, with urban within MR being detrimental for the browns, and urban outside MR being detrimental for the blacks and whites (Fig. 2). The all-causes mortality rate was corrected by taking into consideration previously excluded skin color/race deaths. The value of death rates was restricted to 6000 deaths/100,000 inhabitants. The crude and age-standardized death rates represent 100% mortality for the white and brown populations and 99.5% mortality for the black population.

In 2010, the age-standardized AMR ecological distribution per 100,000 inhabitants varied among the whites, browns, and blacks, as shown in the maps in Fig. 3. Presumably due to the absence or low number of deaths or residents in the respective racial groups, AMR was not recorded for white, black, and brown people in 47, 475, and 181 Brazilian cities respectively. Most cities that presented skin color/race death and population records (64.0%; $n = 3561$) indicated that there were around 500 to 1000 whites registered, especially in southern and southeastern cities. Most municipalities (63.9%; $n = 3559$) presented rates for the brown population below 500. The values ranging from 500 to 1000 were observed more often in northeastern and midwestern cities. Most municipalities (61.8%; $n = 3437$) indicated that ≥ 500 black people were recorded. Nevertheless, 44.7% (1538) of them presented rates ≥ 1000, being more evenly distributed in most of the country.

Table 2 presents the mean and rate ratios for AMRs standardized by age, skin color or race, and gender. Mortality rates have always been higher for brown and black people as compared with the white population; furthermore, the rates are greater in men than in women for all three racial groups. Black men and women indicated a higher-risk AMR in urban areas within MR.

Fig. 2 Box plots of crude and age-standardized all-cause mortality rate (AMR) per 100,000 inhabitants, for white, brown, and black populations according to level of urbanicity and aggregation to MR of Brazilian cities in 2010





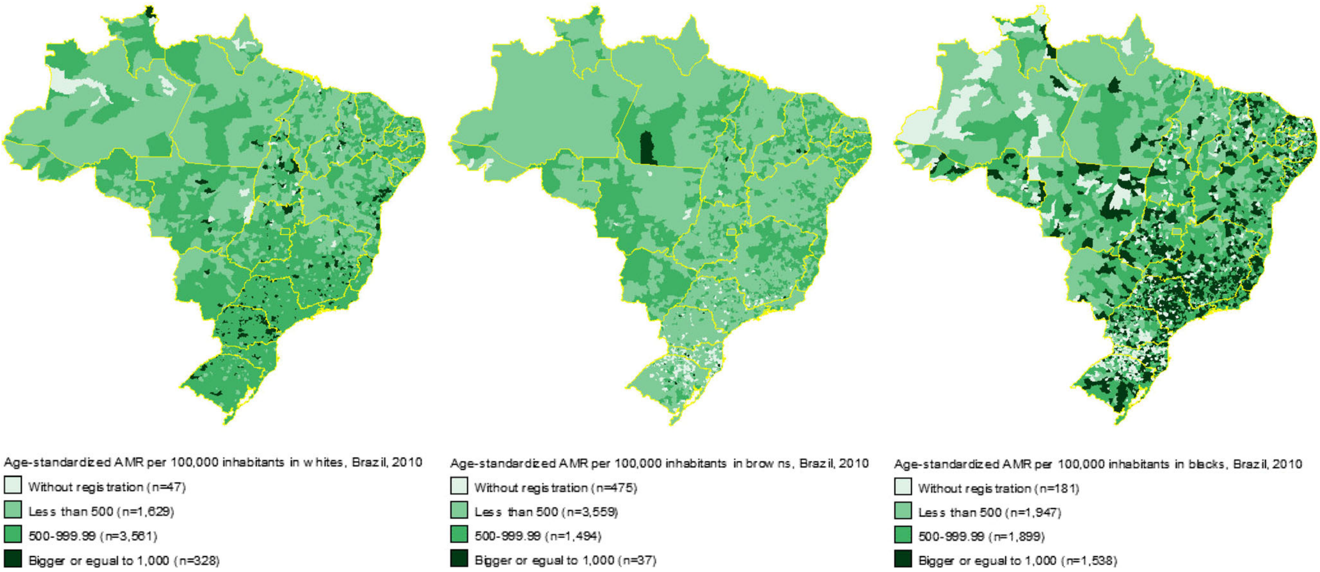


Fig. 3 Geographical distribution of age-standardized all-cause mortality rate (AMR) per 100,000 inhabitants in whites, browns, and blacks in Brazil in 2010. Note: Age-standardized all-cause mortality rate (AMR) utilized the 2010 census as the standard, corrected for number of deaths by skin color/race not reported in 2010

However, risk AMR has always been higher for brown and black people, regardless of the city type. Risk mortality of whites was associated only in areas within MR, for men in urban (1.14; 95% CI: 1.10–1.18) and 'rurbano' (1.07; 95% CI: 1.04–1.10), and for women in urban (1.07; 95% CI: 1.04–1.11) and 'rurbano' (1.05; 95% CI: 1.03–1.08), whereas risk mortality of brown people was associated for women both within and outside MR. The urban within MR category showed a higher risk of age-adjusted AMR for brown men (1.89; 95% CI: 1.58–2.25) and black women (1.27; 95% CI: 1.13–1.43). In outside MR, mortality was only associated with a higher risk for women in 'rurbano' (1.10; 95% CI: 1.02–1.18) and urban (1.18; 95% CI: 1.09–1.18) localities.

Table 3 presents differences of medians (excess) of the age-standardized AMR to estimate racial inequality among the city categories. Differences of medians varied according to the category of the city; regardless of gender, the blacks presented excess death rates and the browns lower death rates as compared with the whites. Cities outside MR demonstrated a greater inequality in median death for both genders of the black population, but mainly for black men, whereas for areas within MR, the median death rate was higher for black women. However, rural areas presented the least unequal context for both brown and black people, regardless of gender. Greater excess mortality of black people was observed in urban areas outside MR (147.3), for black men in 'rurbano' areas outside MR (172.6), and for black women in urban areas within MR (110.3).

Discussion

The mortality measurements in 2010 varied among the racial groups and city categories observed, thus indicating that AMR racial inequalities in Brazil are related to city classifications. The geographical patterns differed across races, presumably due to a combination of segregation and social causation. Death risks were associated with an increase in the level of urbanicity, with disparities growing between rural and urban areas that were influenced by the aggregation of a city into an MR. Urban areas were the most unfavorable location for all racial groups. The brown and black populations presented suboptimal rate ratio age-adjusted AMRs, mainly in the cities aggregated into MRs, hence implying that these cities have inferior social, sanitary, and health infrastructures. The brown and black populations demonstrated excess mortality risks as compared with the white population, indicating that brown and black people still subsist in unfavorable living and health conditions inside the cities. Moreover, age-adjusted AMRs also underscored the importance of interaction and interdependence among different races, genders, and city classifications so as to effectively define the mortality structure of Brazil.

In 2010, Brazil presented a significant geographic and demographic municipality diversity, which was simultaneously characterized by a continuum of urbanicity levels with different population sizes within MR, and population concentrations in some cities classified as urban within MR. This set of conditions shaped the living context within populations and defined the exposure of a population to risk and protection factors through multiple mechanisms. In addition, it determined segregation and associated health levels of the racial groups.

The evaluated mortality standard was proven to be similar to ones observed in other countries (Votruba and Kling 2009; Szwarcwald et al. 2011a; Singh and Siahpush 2014; Hoffmann et al. 2014; Rossen et al. 2016). Numerous explanations have been proposed to understand this lack of

Table 2 All-cause mortality mean (SE*) and age-standardized[2] ratios for whites, browns, and blacks per 100,000 inhabitants, derived from Poisson regression models, according to gender and specific to levels of urbanicity and aggregation to MR[1] of Brazilian municipalities in 2010

Level of urbanicity and aggregation to MR[1]	All-cause mortality rate (age-standardized)	Male			Female		
		White	Brown	Black	White	Brown	Black
Within MR							
Rural	Mean (SE*)	708.1 (17.3)	520.1 (25.5)	869.9 (71.5)	577.1 (15.5)	256.0 (16.4)	715.5 (62.2)
	Rate ratio	1.00	1.00	1.00	1.00	1.00	1.00
	95% CI[3]	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)
'Rurbano'	Mean (SE)	745.4 (17.2)	547.1 (21.6)	894.3 (41.6)	580.7 (12.1)	324.5 (12.8)	683.1 (37.1)
	Rate ratio	1.07**	1.26**	1.14**	1.05**	1.13**	1.14**
	95% CI	1.04–1.10	1.13–1.41	1.07–1.21	1.03–1.08	1.09–1.17	1.06–1.24
Urban	Mean (SE)	793.3 (14.7)	592.5 (17.9)	876.3 (27.9)	634.3 (10.6)	371.6 (9.7)	734.1 (29.2)
	Rate ratio	1.14**	1.89**	1.23**	1.07**	1.16**	1.27**
	95% CI	1.10–1.18	1.58–2.25	1.12–1.34	1.04–1.11	1.09–1.23	1.13–1.43
Outside MR							
Rural	Mean (SE)	663.6 (5.2)	503.1 (4.2)	883.8 (29.7)	546.0 (4.5)	302.4 (3.8)	684.4 (15.1)
	Rate ratio	1.00	1.00	1.00	1.00	1.00	1.00
	95% CI	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)
'Rurbano'	Mean (SE)	719.1 (10.4)	560.2 (9.5)	954.9 (27.3)	594.8 (9.1)	347.3 (6.4)	766.2 (29.8)
	Rate ratio	1.04	1.09	1.06	1.00	1.10**	1.07
	95% CI	0.98–1.10	0.85–1.41	0.94–1.21	0.94–1.06	1.02–1.18	0.93–1.23
Urban	Mean (SE)	776.6 (17.4)	559.8 (17.8)	994.9 (48.7)	597.2 (12.4)	363.9 (11.9)	865.1 (60.0)
	Rate ratio	1.02	0.98	1.05	1.02	1.18**	1.06
	95% CI	0.97–1.08	0.75–1.29	0.91–1.20	0.96–1.08	1.09–1.28	0.90–1.24

Rural = population < 50,000 and demographic density < 80 inh./km^2 ; 'Rurbano' = population 50,000–100,000 or demographic density ≥ 80 inh./km^2 ; Urban = population > 100,000

1 — Municipalities belonging to metropolitan region (MR)/integrated development region (RIDE)/urban area

2 — All-cause mortality rate (AMR) age-standardized using Brazil's population in 2010 census and corrected for skin color/race by redistribution of number of deaths per skin color/race ignored in 2010

3 — CI = confidence interval

* SE = standard error

**p < 0.05 —mortality rate ratios were statistically significantly different from 1 at this level of urbanicity and aggregation to MR

advantage or excess mortality for residents of urban cities, within or outside MR, in relation to rural areas. For instance, urban areas harbour significant socioeconomic, sanitary, and health inequalities, in addition to the fact that urban life benefits are not evenly shared among different social and racial groups. The concentration of negative effects on individual and contextual factors in urban areas may lead to the overlapping and accumulation of risk factors, as observed in the case of multiple disease burden, in which the coexistence of standards, morbidities, and premature deaths are considered. This contradictory social and health situation can also cause excess mortality in urban contexts (Harpham 2009; Votruba and Kling 2009; Chandola 2012; Oliveira and Luiz 2017). Therefore, urban mortality has been attributed to individual and contextual socioeconomic deprivation associated with residential segregation (Vlahov and Galea 2002; Votruba and Kling 2009; Chandola 2012; Sharkey 2013). The results also suggest that rural towns tended to present a more similar death level distribution among racial groups, indicating fewer health disparities in these areas. However, it is possible that due to the vast geographical range and differences in the quality and collection of data, great heterogeneity existed between information gathered from different cities. Furthermore, larger cities may have had better data-handling capacities, which could have subsequently influenced the results observed.

The effect of urbanicity and aggregation to MR on mortality was not similar for genders in the different racial groups, which can be attributed to socioeconomic, living, and health conditions differences between the racial and gender groups. Social, physical, and psychological consequences of discrimination among these racial groups also exist, leading increased exposure to stress and negative health behaviors, such as smoking, alcoholism, drug abuse, physical inactivity, aggression, and unprotected sexual activity (Telles 2004; Smedley 2012; Sharkey 2013; Oliveira and Luiz 2017). Together, these differences demonstrate the racial interaction and

Table 3 Difference of medians* (excess) of age-standardized all-cause mortality rate (AMR) ratios** for browns and blacks with regard to rates for whites per 100,000 inhabitants, according to gender and specific to levels of urbanicity and aggregation to MR[1] of Brazilian municipalities in 2010

Level of urbanicity and aggregation to MR	General		Male		Female	
	Browns	Blacks	Browns	Blacks	Browns	Blacks
Urban within MR	−201.7	56.0	−176.4	80.8	−238.5	43.7
'Rurbano' within MR	−217.0	97.5	−213.1	84.2	−247.0	33.9
Rural within MR	−241.8	−4.1	−229.5	−116.6	−302.1	−88.8
Urban outside MR	−272.1	147.3	−291.3	100.9	−282.2	110.3
'Rurbano' outside MR	−208.5	105.6	−170.8	172.6	−240.3	29.4
Rural outside MR	−212.0	30.1	−179.8	21.0	−245.7	−81.8

1 — Municipalities belonging to metropolitan region (MR)/integrated development region (RIDE)/urban area

Rural = population < 50,000 and demographic density < 80 inh./km^2 ; 'Rurbano' = population 50,000–100,000 or demographic density ≥ 80 inh./km^2 ; Urban = population > 100,000

*Obtained by difference between skin color/race categories (black/brown vs white)

**All-cause mortality rate (AMR) corrected for skin color/race by redistribution of number of deaths per skin color/race ignored in 2010

interdependence of physical and social attributes and access to resources in each city category (Telles 2004; Novak et al. 2012; Singh and Siahpush 2014; Sharkey 2013; Oliveira and Luiz 2017). Social stratification, social space segregation, and associated processes create iniquities, which greatly impact underprivileged racial groups who mainly reside in areas with higher material deprivation, precarious assistance, environmental degradation, and inadequate social services (Telles 2004; Singh and Siahpush 2014; Sharkey 2013; Krieger et al. 2014; Oliveira and Luiz 2017). Consequently, individuals may exhibit certain characteristics depending on which racial group they belong to, making them more vulnerable to adverse conditions existing in these residential areas, or they may be equipped with personal and sociocultural resources that allow them to cope with these insufficiencies (Votruba and Kling 2009; Novak et al. 2012; Singh and Siahpush 2014; Krieger et al. 2014; Oliveira and Luiz 2017). Our findings determined that the most excessive AMRs are seen in the black population, whereby black women (110.3) were at more of a disadvantage than black men (100.9) when they resided in urban areas outside MR (Table 3).

Studies in Brazil have also shown that the worst cause-of-death structures are related to browns and blacks when compared with whites, as well as that brown and black people die younger than white people, who frequently survive to reach old age (Chiavegatto Filho et al. 2014; Oliveira and Luiz 2017). It has been observed that the analysis of age-adjusted death rates indicated that the highest rates were observed in cities considered as urban in all racial groups. However, the black population had the worst rates, and for both genders (Chiavegatto Filho et al. 2014; Oliveira and Luiz 2017). Similar to other countries, the level of urbanicity and aggregation to MR represents an important category of analysis of the living conditions and health of the racial groups in Brazil (Vlahov and Galea 2002; Harpham 2009; Chandola 2012; Oliveira and Luiz 2017).

The urbanicity and metropolitanization characteristics of a city are also associated with the AMR of racial groups according to gender. This could explain the racial health inequalities among municipalities, as well as the high mortality rates of browns and blacks, mainly in the context of areas within MR, which may present a substandard set of physical, socioeconomic, sanitary, and health aspects as compared with the ones available to the whites living in metropolitan areas (Sharkey 2013; Oliveira and Luiz 2017). However, in the United States, poor black people living in nonmetropolitan areas presented a higher mortality rate for all ages, in contrast to the poor black or white people in metropolitan areas (Singh and Siahpush 2014). This suggests that in different countries, races with inferior contextual socioeconomic status suffer intensified racial inequalities.

The maps in Fig. 3 illustrate the spatial expression of health racial inequalities in Brazil. They also indicate that most Brazilian cities presented similar AMRs for the black population in 2010. These AMRs were similar to the age-adjusted mortality rates observed in 2012 for the total populations from Central, Eastern, and Southern Africa. These AMRs were also higher than those observed in Southern Asia, Eastern Europe, and in other countries, such as India and Pakistan (World Health Statistics 2016).

In the United States, Canada, and the United Kingdom, studies investigating the effect of location on mortality rates have provided evidence of excess mortality in black neonates, children, young adults, and adults (Bécares et al. 2012; Sharkey 2013; Singh and Siahpush 2014; Rossen et al. 2016; World Health Statistics 2016). These researches also indicated a lower life expectancy and more premature deaths in black than in white populations (Bécares et al. 2012; Sharkey 2013; Singh and Siahpush 2014; Rossen et al. 2016; World Health Statistics 2016). Mortality inequality may be two or three times higher in some cases, suggesting that black people are more subjected to overlapping risks in addition to individual and contextual vulnerabilities, with complex social mechanisms remaining associated with these poorer living and health conditions over generations (Nogueira 2008; Krieger et al. 2014; Bécares et al. 2012; Sharkey 2013; Singh and Siahpush 2014; Rossen et al. 2016; World Health Statistics 2016; Oliveira and Luiz 2017). Aggregate data analysis for deaths from 2005 to 2009 in the United States also indicated a higher AMR for black people at every level of urbanicity, although death risk was typically even higher in rural cities (Singh and Siahpush 2014).

This study is not free of limitations, despite the clean-cut results. For instance, in Brazil, the classification of racial groups can occur in imprecise settings, resulting in a vague set of racial categories that spread through a continuum of color. This is because the terminology of Brazilian color varies according to individual strategies used to handle race relations in various contexts, such as work, family, leisure, and friendship, and also age, education, and income (Telles 2004; Oliveira and Luiz 2017). In Brazil, it is possible that racial categories do not form homogeneous groups, and that individuals would not always belong to a certain racial group since they can arbitrarily classify which racial group they belong to (Telles 2004). This lack of distinction can also be due to the color or race categories in the IBGE, which are generally pre-established and remain as they are between censuses, whereas racial perceptions can change with the context and more differences can arise over time (Telles 2004; Oliveira and Luiz 2017).

Thus, one of the consequences of this phenomenon is the lack of statistically significant disparities in AMRs of both genders within and outside MRs, which may be due to a numerator–denominator bias arising from the lack of matching between DC skin color or race records and demographic census records for the population (Chiavegatto Filho et al. 2014). There might have been deaths or population data transfer from the brown category to the white category, diluting death risks among brown people while concentrating them in the whites, for example. This effect could have caused mortality rates to be higher among whites than browns, consequently causing an inversion of the expected health levels between these groups. This could then have been transferred to DCs as they were filled in by a doctor, and the skin color or race of the deceased obtained through patient observation and communication with their family and other professionals. Thus, the racial classification of death may differ from what would have been expected if color/race had been self-reported or reported by family members (IBGE 2011). Racial classification bias has been considered in previous researches (Laurenti et al. 2005; Chiavegatto Filho et al. 2014). However, this effect has never been individually estimated for each city in the country.

Although improvements in the quality and number of racial aspect records have been noted, there are still variations with regard to their coverage and completeness among the cities (Ruiz 2015). A considerable number of cities do not present death records at all, and it is unknown whether there are failures in data recording or if there is an actual non-occurrence of death in specific racial groups. The institutional death-registration capacity of different cities may be associated with higher AMR and with large cities aggregated to MR, which may then present higher death record rates as they have better structured health care services. Nevertheless, our study only included occurrences of those deaths where it was clear what the city of residence was at the time of death, in order to determine the true AMR impact. Hence, by using the death records concerning place of residence at the time of death, major cities that have better health services networks could lead to an increase in the recorded deaths of patients treated in these cities; at the same time, cities that have insufficient social and health services could lead to an underestimation of death rates.

Researchers have often used overall population mortality data to obtain corrections with regard to the number of deaths. AMR validity for the observed racial groups was improved in this study. Therefore, it is believed that corrected and age-adjusted AMR represented a good alternative for the interpretation of Brazilian standards for skin color or race-based mortality among the municipality categories. This is due to the fact that these AMRs control the effect of age distribution disparities among the cities, reduce limitations associated with variations in undeclared skin color or race in death records, and indicate death estimates for more disaggregated levels of analysis, such as municipalities.

Conclusions

This study observed that urbanicity level and aggregation to MR may influence racial health inequalities in Brazil. These constructs represent an important dimension of sociospatial stratification. In addition, they indicate the way in which economic circumstances, social organizations, health infrastructures, social and health care services, and the typical cultural practices and standards of a location seem to contribute to racial inequality definitions in mortality structures. These contextual units may be useful for monitoring inequalities among Brazilian cities, since municipalities represent the first political unit in the government, incorporating programmatic significance for federal and state levels. This perspective turns these urbanicity levels, whether aggregated to MR or not, into attractive intervention points for the management of public policies that aims to reduce Brazilian social and racial inequalities in health.

Authors' contributions The authors participated in the design, analysis, and interpretation of the data, writing, and critical review of the article, as well as final approval of the version to be published.

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Compliance with ethical standards

Ethics This study was elaborated based on aggregated databases on death that are available online. These did not include confidential information regarding personal or home identification. All work was performed in accordance with Resolution No. 466 of the National Health Council [Conselho Nacional de Saúde (CNS)] of 12 December 2012.

Conflict of interest The authors declare that they have no conflict of interest.

Annex

Table 4 All-causes mortality mean (SE*) and crude and age-standardized[2] ratios for *negros*[3] per 100,000 inhabitants, according to genders and specific to levels of urbanicity and aggregation to MR[1] of Brazilian municipalities in 2010

Level of urbanicity and aggregation to MR[1]		All-cause mortality rate					
		General		Male		Female	
		Crude	Age-standardized	Crude	Age-standardized	Crude	Age-standardized
Within MR							
Rural	Mean (SE*)	502.9 (15.5)	481.1 (26.4)	613.7 (18.9)	570.0 (25.4)	354.8 (20.4)	337.4 (21.1)
	Rate ratio	1.00	1.00	1.00	1.00	1.00	1.00
	95% CI[4]	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)
'Rurbano'	Mean (SE)	485.1 (14.6)	500.2 (13.9)	591.4 (19.0)	609.1 (19.6)	365.3 (13.1)	382.1 (12.5)
	Rate ratio	0.94	1.15**	1.10**	1.28**	1.07**	1.14**
	95% CI	0.89–1.00	1.11–1.18	1.06–1.13	1.16–1.41	1.03–1.11	1.10–1.18
Urban	Mean (SE)	505.8 (13.3)	536.3 (11.7)	607.6 (15.9)	647.3 (15.2)	406.5 (11.8)	431.1 (9.6)
	Rate ratio	1.02	1.22**	1.09**	1.81**	1.04**	1.23**
	95% CI	0.96–1.08	1.17–1.28	1.02–1.15	1.55–2.11	0.98–1.09	1.16–1.29
Outside MR							
Rural	Mean (SE)	502.6 (3.6)	455.0 (3.0)	607.8 (4.5)	543.2 (3.9)	374.5 (4.2)	341.4 (3.5)
	Rate ratio	1.00	1.00	1.00	1.00	1.00	1.00
	95% CI	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)	(Ref.)
'Rurbano'	Mean (SE)	541.8 (8.2)	515.7 (6.9)	650.5 (9.8)	620.6 (8.7)	426.7 (8.2)	403.2 (6.8)
	Rate ratio	0.91	1.11**	1.04	1.13	0.99	1.10**
	95% CI	0.83–1.00	1.04–1.18	0.97–1.12	0.90–1.42	0.92–1.07	1.03–1.18
Urban	Mean (SE)	541.3 (16.3)	544.6 (15.5)	641.0 (17.1)	641.3 (16.4)	441.7 (17.3)	446.9 (16.5)
	Rate ratio	0.93	1.19**	1.12**	1.04	1.10	1.19**
	95% CI	0.85–1.02	1.12–1.27	1.02–1.22	0.80–1.31	0.99–1.23	1.11–1.28

Rural = population < 50,000 and demographic density < 80 inh./km^2 ; 'Rurbano' = population 50,000–100,000 or demographic density ≥ 80 inh./km^2 ; Urban = population > 100,000

1 — Municipalities belonging to metropolitan region (MR)/integrated development region (RIDE)/urban area

2 — All-cause mortality rate (AMR) age-standardized using default to Brazil's population in 2010 census and corrected for skin color/race by redistribution of number of deaths per skin color/race ignored in 2010

3 — *Negros* (in quotes) refers to the combined categories of blacks and browns color/race as reported in death certification (DC)

4 — CI = confidence interval

*SE = standard error

**$p < 0.05$ — mortality rate ratios were statistically significantly different from 1 at this level of urbanicity and aggregation to MR

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