Rural-Urban health and mortality differentials in Brazil, 2010-2013

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## Introduction

The rural-urban mortality differential is a topic of great concern of demography, public health and public policy researchers. Different access to services and public health equipment may reflect in different mortality outcomes for population groups. This is broadly documented in the literature and its results are evident from mortality differentials in terms of geographic location. In this paper we target urban-rural mortality and morbidity differentials in Brazil using national census data of 2010. The addition of mortality inquiry in the Brazilian 2010 national census represented an opportunity to implement analysis which could not be done by using regular mortality information system data from the Ministry of Health.

Most of the studies developed about Brazilian socioeconomic differentials in mortality until 2010 national census used indirect methods to construct estimates using census or household surveys data [@carvalho\_wood1978;@merrick1985;@sastry1997;@sastry2004]. From 1980 to 2010, Brazil experienced a great increase of its death registers coverage [@queiroz\_etal2017]. Most of its states have coverage rates higher than 90%. Further, the country’s register system also enhanced its death cause classification, reducing the number of unknown causes of death [@lima\_queiroz2014]. These analyses usually are related to small areas mortality estimation, subnational populations studies or socioeconomic disparities, topics documented in census data [@queiroz\_sawyer2012]. Then, this additional inquiry fomented new studies on educational mortality differentials [@silva\_etal2016], indigenous mortality [@campos\_etal2017], socioeconomic strata differentials [@pereira\_queiroz2016] and on urban groups mortality differentials [@pereira2018]. Moreover, the first estimates of urban-rural mortality differentials were performed by @albuquerque2019 and verified a mortality advantage for rural areas, especially for male population. The author’s paper presented estimates of 73.6 and 69.3 for the male rural and urban population life expectancies, respectively, and of 77.8 and 77.1 for females. In recent decades, an important discussion has emerged in less developed economies about the urban death penalty as living conditions in urbanized centers deteriorate individuals health compared to the rural counter-parts as was observed in the past [@reher2001].

By the beginning of the urbanization and industrialization processes in the developed West countries, urban areas exhibited higher mortality rates than their rural counterparts [@davis1973;@woods2003]. The mortality levels among young age-groups (0-14) were more sensible to the urban environment than adult mortality levels, which incurred in higher youth mortality rates in cities than in rural areas [@woods2003]. Indeed, infant and child mortality rates are affected by wealth and socioeconomic determinants through variables such as sanitation conditions and dietary intake of a population [@mosley\_chen1984]. Cities of the XIX century, however, presented poor living conditions and high population density, contributing to the spread of communicable diseases responsible for most deaths in urban centers in that period [@davis1973].

This scenario changed considerably with socioeconomic development and economic growth of Western countries which subsidized better living conditions in cities [@preston1975] and provided resources to overcome communicable diseases deaths, fostering the epidemiological transition in the end of XIX century period [@omran1971]. The differential economic growth between metropolitan and non-metropolitan areas, nevertheless, created gaps in access to public services such as health equipment and transportation [@woods2003,@jedwab\_vollrath2019,@torres\_etal2019]. In the United States, for example, rural and non-metropolitan residents are broadly known for its disadvantaged position in regard to life expectancy and to health indicators [@singh2003;@singh\_siahpush2013;@spencer\_etal2018;@chen\_etal2019;@henning\_etal2019]. This negative position in relation to their urban counterparts follows a higher health information illiteracy among rural residents, lack of access to health equipment and other kinds of socioeconomic deprivation that affect non-metropolitan areas [@singh2003;@henning\_etal2017;@spencer\_etal2018;@chen\_etal2019;@henning\_etal2019;@voigt\_etal2019].

In Brazil, the advantaged urban mortality situation prevails on some specific conditions. @carvalho\_wood1978 showed that urban-rural life expectancy differentials favored the urban areas for wealthy social strata whereas the opposite is observed in poor areas of the country in 1960-70 period. In this sense, being poor in Brazilian rural areas would be better than being poor in urban areas. The urban periphery of Brazilian metropolis are known for its poor urban assets and damaged social conditions, with high violence and criminal rates and also lack of public assets such as public sanitation [@merrick1985;@worldbank2015] which result in worsened health and mortality status [@pereira\_queiroz2016;@albuquerque\_etal2017;@pereira2018]. Under-five mortality, however, is more impacted by community-level characteristics and socioeconomic situation [@mosley\_chen1984;@gould1998;@sastry2004;@fink\_etal2016;@garenne2016]. Then, the urban advantage in Brazilian urban-rural under-five mortality indicators results from its better socioeconomic conditions [@soares\_etal2016;@sastry2004]. Those results are in consonance with other studies on geographic mortality differentials in developing countries. Despite the urban advantaged observed in child and infant mortality levels, adult mortality rates are lower in rural areas for lower income countries [@sastry1997;@gould1998;@sastry2004;@gunther\_harttgen2012;@fink\_etal2016;@oren2018;@albuquerque2019]. In a similar way of what have been observed in Brazil, cities of developing countries exhibit mortality differentials across its own borders due to the unequal access to essencial public services - health equipment, education and sanitation - as a consequence of a rapid urbanization process [@gunther\_harttgen2012;@fink\_etal2016;@brueckner2019].

This debate about urban-rural mortality differentials in Brazil has gained momentum over the last years due to the changes proposed in the social security system. Since 1988, rural groups were guaranteed access to almost universal age-retirement pensions at lower ages than urban residents (60/65 for males and 55/60 for females) [@beltrao\_etal2000]. During the 1990s and 2000s, the public pension system income represented a great opportunity for rural poor and resulted in a continued reduction of poverty rates within this population groups, especially in impoverished regions of the North and Northeast [@beltrao\_etal2000;@camarano2002;@gori2015]. However, the continued deficits of the Brazilian social security system resulted in the need for reforms on age of retirement which brought up the discussion on whether rural residents should continue to retire 5 years before the urban residents [@paiva\_etal2018]. Some researches using data from the social security system estimate ages at the end of the benefit higher for rural residents than for urban residents and argument in favor of ending this lower age of retirement benefit [@paiva\_etal2018]. However, other studies highlight the different access to public health equipment and other health disadvantages of the rural population to justify keeping this lower retirement age [@arbex\_galiza2017].

Such as in the case of USA, Brazilian rural residents experience higher deprivation in access to services and health facilities and usually report worse health status conditions and are in worse economic situation than urban residents [@camarano2002;@wanderley2008;@paiva\_etal2018;@arruda\_etal2018]. This scenario echos the higher vulnerability condition of rural and areas other territories with lower economic integration [@travassos\_etal2006]. The distance of health equipment, lack of resources to pay for the transportation, the lack of health professionals or higher complexity health services are barriers to the access of public health systems by the rural population [@kassouf2005;@travassos\_viacava2007]. This situation is worsened in the case of the elderly, population group with higher demand for such services [@travassos\_viacava2007}. Moreover, the access to health services of rural residents relies almost exclusively on the universal public health system (SUS) and on visits of family-care doctors of the Family Health Program while urban residents have higher access to health insurance and to a higher diversity of health equipment [@kassouf2005;@malta\_etal2016;@albuquerque\_etal2017;@arruda\_etal2018]. Additionally, rural poverty is concentrated in the already disadvantaged Northern regions of the country [@worldbank2015;@soares\_etal2016].

The different tasks and activities demanded by the living environment also shapes the mortality and morbidity outcomes of a population. In this aspect, rural populations observe higher prevalence of specific disabilities and diseases such as chronic pains, back pains, arthritis and urban populations are usually more susceptible to diabetes, high blood pressure, heart diseases and depression [@camarano2002]. Further, rural residents are more prone to report worsened health status [@camarano2002;@arruda\_etal2018;@paiva\_etal2018]. @moreira\_etal2015 found that back pain, rheumatism, arthritis and high blood pressure were associated to the agricultural activities and results from intense physical effort in work.

This study aims to provide further information for the discussion on urban-rural mortality differentials. The rural life expectancy advantage expressed in the Brazilian national census of 2010 [@albuquerque2019] may not reflect a real disease free life expectancy or healthy life expectancy advantage, e. g., people from rural areas might live for longer periods, but they would have to live with disabilities that can mitigate their capacity to develop daily activities. In this sense, we investigate the prevalence of some specific diseases in urban and rural populations and construct disease-free life expectancy estimates for both residents using data from the national census of 2010 and from the national health survey of 2013. Our hypothesis is that urban areas may exhibit relative advantages in disease/disability-free life expectancy than rural areas for health problems related to physical effort while a higher prevalence of chronic diseases may be more harmful in the urban environment. This work contributes to the evaluation of urban environment penalties on adult mortality in developing countries by analysing specific groups of diseases and disabilities that result in different mortality levels in urban and rural areas [@gunther\_harttgen2012]. In the next sections we provide further details on data sources, methodological approaches and some preliminary results.

## Materials and Methods

### Data

This paper uses data from Brazilian national census of 2010 and Brazilian National Health Survey of 2013 to estimate life table functions such as mortality rates and life expectancy of rural and urban population groups. The inclusion of mortality inquiries in national census is a recommendation of the United Nations for countries with deficient register systems [@UN2017]. Several Latin American and Caribbean countries have included a question of deaths in the household within 12 months before the reference period in their national censuses [@queiroz\_sacco2018]. Despite some issues, in particular those related to deceases in mono-parental households or deaths that result in breaks in family ties, the mortality inquiry in national censuses is important for performing complex analysis which might not be assessed by national register systems, such as urban-rural mortality differentials [@UN2017;@queiroz\_sacco2018].

The national census of 2010 investigated household deaths over the last 12 months before the reference period of the census (August 2009 - July 2010). Household respondents answered questions about age and sex of household’s deceases within this period. The use of death counts from national census for computing death rates has the advantage of considering both numerator and denominator from the same data source. Thus, this approach provides robustness at least for mortality curves patterns. However, mortality levels computed from national census must be corrected. Death counts from national census are under-enumerated in comparison to mortality information system data, presenting a death coverage of about 80-85% according to death registration coverage estimation methods [@queiroz\_sawyer2012].

In 2013, the Brazilian Institute of Geography and Statistics (IBGE) conducted the National Health Survey (PNS) in Brazil. PNS was created to describe and assess the health situation and lifestyles of the Brazilian population by asking questions in regard to access and use of services, to preventive actions and also to socio-demographic characteristics [@pns2014;@damacena\_etal2015]. The survey also conducted checking on some physical measures - blood pressure, weight, height - and collected biological materials from respondents [@damacena\_etal2015]. Hence, the PNS survey permits to evaluate specific morbidity indicators of the population, such as the prevalence of chronic diseases, by socioeconomic strata or geographic location (urban-rural) of the household.

### Methods

Our methodological strategy encompasses three stages of analysis: 1) estimation of basic life table functions by geographic area; 2) analysis of disease and disability prevalence data from PNS and National Census by geographic area; and 3) Construction of disease/disability-free life expectancy (DFLE) indicators by geographic area.

#### Correction of mortality levels

As mentioned by @queiroz\_sawyer2012, death coverage from Brazilian national census mortality information ranges from 80-85%. Since death registry coverage is sensitive to regional inequalities [@queiroz\_etal2017], census mortality data might also exhibit this pattern and may also present differences by urban-rural location. Therefore, our first attempt was to estimate death coverage by geographic location of deaths applying synthetic extinct generations (SEG) [@bennett\_horiuchi1981], generalized growth balance (GGB) [@hill1987] and adjusted synthetic extinct generations (SEG-adjusted) [@hill\_etal2009] methods built in the R package ‘DDM’ (Death Registration Coverage Estimation) [@riffe\_etal2017]. However, all methods presented poor performance, showing much lower and unexpected completeness of death counts coverage in rural areas. We speculate that intense rural exodus to urban areas may affect the estimates and decrease the death coverage rates of rural areas by considering the population reduction due to migration as omitted deaths, as a result of the assumption of closed population of these methods.

Then, we developed a different strategy for completeness of death counts correction. We considered that regional inequalities of death coverage may already account at some extent for urban-rural differences in death coverage, especially because the regions with lower coverage (Northern regions) are the ones with a higher percentage of population in low-density areas [@ibge2017]. Then, we computed death coverage by the SEG-adjusted method for the five regions: North, Northeast, Central-West, Southeast, South (table 1). Death counts were then corrected by region by dividing the presented death coverage values by the observed death counts. Death coverage values higher than 1 were considered as 1, since there is no information that supports an over-counting of deaths in the national census at any region of the country.

SEG-adjusted death coverage estimates by sex and region, 2010. Source: Brazilian national census 2010.

|  |  |  |
| --- | --- | --- |
| Region | Males | Females |
| North | 0.89 | 0.92 |
| Northeast | 0.78 | 0.84 |
| Central-West | 0.93 | 0.94 |
| Southeast | 0.98 | 1.03 |
| South | 1.05 | 0.94 |

#### Disease-free life expectancy (DFLE) by Sullivan method

The Sullivan method of life tables uses data from diseases prevalence to construct a single index of mortality and morbidity, named disease-free life expectancy (DFLE) [@sullivan1971;@EHEMU2014]. This index provides an estimate of years free of disability a member of the life table’s synthetic cohort would experience if the current age-specific rates of mortality and disease/disability prevalence prevailed throughout the cohort’s lifetime [@sullivan1971].

The basic inputs of the method are the age-specific mortality rates for life table functions estimation and age-specific disease or disability prevalence. After estimating the life table functions by the mortality rates of the synthetic cohort, the complement of the disability prevalence are multiplied by the person-years lived () by the respective age group (equation 1).

Then the Sullivan person-years lived by the age-group represents the person-years lived without the disease or life-years free of disability in the given age interval. This value is used to estimate the remaining functions of the life table ( and ). Therefore, the life expectancy computed by the Sullivan method is an estimate of the disease-free life expectancy (DFLE) of the respective age-group.

In the process of mortality transition, as countries and population groups converge to similar life expectancy levels, other public health indicators may still differ substantially. Hence, Sullivan’s index for disease-free or disability-free life expectancy can provide further insights to compare those groups with different health standards even though they exhibit similar mortality levels [@sullivan1971].

We intend to evaluate the prevalence and compute DFLE for some specific sets of diseases grouped in 4 categories available from the two data sources:

* Cardiovascular diseases: high blood pressure, high cholesterol, cerebrovascular accident - PNS, 2013;
* Diabetes: citar quais doenças - PNS, 2013;
* Osteopathies: arthritis, rheumatism, chronic spine problems (back pain, neck pain, etc), work-related musculoskeletal disorders (WMSD) - PNS, 2013;
* Incapacities/disabilities: to walk, see or listen (severe or total incapacity) - Brazilian National Census, 2010;

Since differences in urban-rural mortality are expected to favor rural residents [@albuquerque2019], we compare both populations by the relative measure of DFLE. That is, we compute the proportion of life expectancy that the synthetic cohort is expected to live without the disability/disease (, equation 2). We adopt this strategy to compare relative measures and avoid distortions that might come from absolute values. We focus our attention to adult mortality differentials (15-64 age-groups) because PNS had disease prevalence data available only for adult population (18+)[[1]](#footnote-2).

## Results

### Urban-Rural mortality differentials

Figure 1 presents age-specific mortality rates by place of residence with and without correction of death coverage factors estimated by SEG-adjusted. In consonance to the literature about rural-urban mortality differentials in Brazil and in other developing countries, the infant and child mortality rates are higher in rural areas than in urban areas and rural adult mortality are lower than urban adult mortality rates [@sastry2004;@gunther\_harttgen2012;@fink\_etal2016]. This compensatory effect of rural adult mortality advantage in relation to lower under-five mortality indicators results in the higher life expectancy estimates for rural populations, especially for males (table 2).

[ FIGURE 1 : Age-specific mortality rates by sex and geographic area - Brazil, 2010. Source: Brazilian National Census 2010. ]

These adjusted mortality rates yields different life expectancy estimates from @albuquerque2019 (table 2). The author used the official life tables estimated for Brazil from IBGE for 2010 as reference to adjust the observed deaths from the 2010 census while we used the SEG-adjusted method taking in account regional differences in death coverage completeness. In this sense, our estimates resulted in higher life expenctancy at birth values, since two of the three most populated regions (Southeast - the most populated and South - the third most populated) have census death coverages close to completeness. The rural mortality advantage is more pronounced in males than in females and it gets higher in advanced ages life expectancies. Female mortality does not seem to be affected by urban-rural geographic areas at the same level as male mortality.

[ TABLE 2 : Life expectancy (SEG-adjusted) estimates by sex, age and geographic area, 2010. Source: Brazilian national census 2010. ]

The sex differentials in mortality also favor females for Brazilian rural areas according to 2010 census data (figure 2). Nevertheless, the female advantage in rural areas is lower than the urban female mortality advantage. Large differences from male/female mortality ratios are observed between rural and urban areas especially in ages 15-24 and 30 onwards. In this sense, the male mortality excess observed in Brazilian young adult males is more evident in urban areas and, in particular, in disadvantaged and suburban areas of cities [@pereira\_queiroz2016;@pereira2018].

[ FIGURE 2 : Female-male mortality ratios by geographic area - Brazil, 2010. Source: Brazilian National Census 2010. ]

### Urban-rural health conditions

Urban and rural environments condition the life styles and type of work performed by each population. These environment differences have direct impacts on workers health [@moreira\_etal2015]. Also, disadvantages in self-reported health conditions have been observed in rural populations in addition to their socioeconomic and transportation disadvantages to access public health equipment [@arruda\_etal2018]. The difficulties to access health equipments due to distance or lack of resources were mentioned by 56% of rural residents who did not access health services and needed to against 17% of urban residents in the PNS survey of 2013. Urban residents mostly did not access health services when they needed to because of long waiting time (28% against 8% of rural population. Thus, these differentials in access to health services may incur in lower disease diagnosis. Indeed, the 2013 PNS survey showed that rural population had higher percentage of people that never had measured their glycemic levels (21% against 10% for urban residents) or blood pressure (6% against 3% for urban residents). This scenario could have been worse if the Family Health Program of the Brazilian Ministry of Health was not successful in reaching remote communities of the countryside of Brazil [@malta\_etal2016;@albuquerque\_etal2017;@bhalotra\_etal2019]. Even though rural residents showed lower diagnosis rates than urban residents, we still had sufficient data to evaluate disease prevalence of urban and rural populations (table 3).

[ TABLE 3 : Urban and rural disease and disability prevalence of adult population (15-64) by sex - Brazil, 2010-2013. Source: Brazilian National Census 2010 and National Health Survey 2013. ]

For the adult population (15-64 years old) as a whole, there are clear rural penalties (higher rural-urban prevalence ratios) in prevalences of osteopathies and physical incapacities for males and of cardiovascular diseases and physical incapacities for females. Also, adult women had higher prevalence rates of all diseases investigated. Figure 3 extends the analysis by age group. We present the prevalence rates estimated in the PNS survey of 2013 for cardiovascular diseases, diabetes and osteopathis and in the national census of 2010 for physical incapacities and their respective smoothed estimates[[2]](#footnote-3). The smoothing methods were used to minimize the high variability of prevalence rates, especially for the lower counts of rural residents of the PNS survey of 2013. Smoothing of incapacities prevalence for census information are presented, but the original prevalence rates were used for Sullivan method estimation of next section.

[ FIGURE 3 : Urban and rural disease and disability prevalence by sex and age - Brazil, 2010-2013. Source: Brazilian National Census 2010 and National Health Survey 2013.]

As expected, rural males presented higher prevalence rates of osteopathies, mainly in advanced ages, for women there is no clear pattern due to high data variability for rural residents. On the opposite direction, rural men are in better off situation in regard to diabetes prevalence rates, which presented a wide gap for advanced ages, and for cardiovascular diseases prevalence rates, which presented a small but contiuous gap from age group 30-34 onwards. Female prevalence curves for diabetes did not present any significant gap while the prevalence curves of cardiovascular diseases for women in rural areas exhibited higher rates than urban curves. For both males and females, the prevalence rates of physical disabilities declared in the national census of 2010 were slightly higher in rural settlements. Hence, results are in conformity with previous analysis performed for rural workers in Brazil [@moreira\_etal2015].

### Disease-free life expectancy (DFLE)

Tables 4 and 5 present the results of disease-free life expectancy (DFLE) estimates for males and females of rural and urban areas at birth, at 20 years old, at 40 years old and at 60 years old. For males, rural-urban disease-free life expectancy ratios show a continuous increase in the rural-urban gap through advanced ages. Indeed, these results corroborate to the idea of an existing urban mortality penalty in lower income countries and announces also a morbidity penalty for the urban elderly. These absolute values present worse scenarios in urban areas for life expectancy without cardiovascular diseases and without diabetes estimates, the two groups of diseases the exhibited higher prevalences for the urban population than their rural counterparts among the adult and the older age groups. Female absolute values estimates did not show any significant difference between urban and rural areas, even though a slight rural advantage was observed for diabetes-free life expectancy at ages 40 and 60.

Absolute differences highlight rural advantages in mortality and morbidity indicators. We now turn our attention to relative differences in healthy life expectancy estimates, e. g., we evaluate the ratio of disease-free life expectancy by life expectancy for age groups 15-74 (figure 4). This ratio can be interpreted as a proxy of the proportion of life expected to be lived without the disease/disability for a synthetic cohort with a set of age-specific disease prevalence rates and age-specific mortality rates.

When we analyze relative estimates of disease-free life expectancy the rural advantage observed for all groups of diseases/disabilities changes. The rural advantage prevails only for cardiovascular diseases and diabetes whereas a relative urban advantage in relative disease-free life expectancy is observed for osteopathies and incapacities. These results confirms that rural residents are more prone to develop physical incapacities and disabilities and suffer of musculoskeletal pain due to the physically demanding labour required in agriculture [@moreira\_etal2015]. Therefore, the absolute advantages observed in DFLE numbers may not reflect in actually better life conditions in terms of life span relative measures.

[ TABLE 4 : Disease-free life expectancy estimates by age and geographic area - males, 2010. Source: Source: Brazilian National Census 2010 and National Health Survey 2013. ]

[ TABLE 5 : Disease-free life expectancy estimates by age and geographic area - females, 2010. Source: Source: Brazilian National Census 2010 and National Health Survey 2013. ]

[ FIGURE 4 : Proportion of life expected to be lived without disability/disease by sex and geographic area - Brazil, 2010. Source: Brazilian National Census 2010 and National Health Survey 2013. ]

These results should be analyzed with caution. As mentioned, rural population lower access to health services reflects in lower measurement rates of health indicators such as glycemic level and blood pressure. Then, prevalence rates for rural groups might be underestimated due to lack of diagnostic. In spite of this important detail, the data collected is robust enough and went in the same direction of previous studies on rural and urban health and mortality differentials. Thus, we verified the existence of an urban adult mortality penalty and also in an urban adult morbidity penalty for cardiovascular diseases and diabetes. Finally, it was verified a rural morbidity penalty in regard to incapacities (to walk, see and listen) and osteopathies, e. g., physical disabilities. Therefore, rural residents have a higher life expecancy, but a higher fraction of this life expectancy is accompanied by physical disabilities or musculoskeletal pain.

## Discussion

## References

1. Even though PNS had prevalence data available only for adults aged over 18 years old, we considered the prevalence distribution of diseases for age group 15-19 equal to the rates observed for the age group 18-19. For age groups 0-14 the prevalence rates for PNS survey were considered equal to 0, in order to get estimates for disease-free life expectancy at birth. [↑](#footnote-ref-2)
2. Prevalence rates of diseases and disabilities were smoothed by apply the localy estimated scatterplot smoothing method (LOESS) [↑](#footnote-ref-3)