POPULATION AGING AND MORTALITY BEHAVIOR IN BRAZIL, 2000 - 2050.

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ABSTRACT

Objective: to describe the process of population aging in Brazil and its mortality trends between 2000 and 2050. **Methods:** We collected data from Brazilian demographic census and mortality information system and obtained aging indicators and studied mortality compression in the years 2000 and 2010. Still, we projected those analysis to 2020 – 2050. **Results:** We could observe population ageing and demographic momentum in Brazil. There is a declining in birth rates, and Brazil began to present an older age structure, gradually replacing the standard pyramidal shape. It can be reflected on some ageing indicators, such as dependency ratio, ageing index, mean age of population and life expectancy. Also, the indicators of mortality compression show the shifting trend of deaths towards more advanced ages between 2000 and 2050, and some phenomena are described, such as survival curve rectangularization, reduction of the variability of age at death and increasing mean age of death. **Conclusion:** Changes in age structure have occurred rapidly in Brazil and require rapid and adequate responses through the implementation of fundamental public policies.

Keywords: Ageing; Mortality; Population Estimates; Elderly; Brazil.

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INTRODUCTION

The increasing life expectancy, driven by the decline of birth rates and by the reduction of mortality, is one of the main challenges contemporary society. Historically, in developed countries, the rising life expectancy is related to the age at death variability, especially with the reduction of infant-juvenile deaths, which reflect the lower incidence of infectious and parasitic diseases and preventable maternal causes[1-3].

Beyond the reduction of premature mortality, fertility rates have been showing a significant declining trend since the half of last century. The total fertility rates of 5 children per women of the period 1950-1955 have reduced to the half for the period 2010-2015[4,5]. World Health Organization (WHO) estimates that in 2020, for the first time in history, the number of people aged over 60 years old will overcome the number of children aged less than 5 years old. Furthermore, a child born in Brazil in 2015 has a life expectancy up to 20 years higher than a child born 50 years ago[5,6].

This phenomenon is a direct result of the demographic transition and is experienced by almost all the countries in the world, with different timing and pace (WHO, 2014). Studies conducted in countries in the early stages of demographic transition observed a low premature mortality and a concentration of deaths among higher ages. However, the increasing life expectancy at birth and the mechanism underlying the decline in mortality among the elderly continue to have unknown causes, which brings new challenges to the practice of health services and systems management[1,7].

Traditionally, some indicators express the evolution of relative population aging, such as the aging index and the dependency ratio of the elderly, and of absolute population aging, such as longevity and life expectancy. Despite the secondary role of mortality in relative population aging – strongly marked by the fertility decline, it manifests its strength in absolute population aging. Hence, in the long run, mortality reduction results the absolute increase of the elderly. In this sense, Rousson and Paccaud[8] argue that the secular increase in life expectancy can be characterized by two non-parametric quantitative indicators: longevity and rectangularity.

Longevity represents the increase of mean age of death and reflects directly the mortality reduction in advanced ages. In addition, the survival probability over the life course can be used as an evaluative indicator. It reflects the reduction of premature mortality and a higher concentration of deaths around a higher mean age. Actually, these two indicators can be naturally combined, since the retangularization of the survival curve and the increase of longevity are simultaneous[7,8].

Brazil follows a pattern marked by a rapid process of demographic transition, typical of developing countries. However, the population aging of Brazil is singular due to its continental dimensions, institutional arrangements for decision making and institutional informalities in general[9]. The country already has an important fraction of elderly in its population and this amount is expected to increase rapidly over next years, thus, increasing the demand for specialize public services and also the demand for a complex planning of the priorities of social policies. Moreover, the population aging brings up health issues that challenge the health and social security systems[10].

In this context, the introduction of the population aging issue in the formulation of public policies represents a challenge for the implementation of preventive and care actions towards social protection. For this reason, it is important to recognize the phenomenon of population aging, considering its rhythm over time and the future forecasts. On that account, the objective of the present study is to describe the process of population aging in Brazil and its mortality trends between 2000 and 2050.

METHODS

Study Design

The present work is an ecological study about population aging and mortality indicators of Brazilian population over census years of 2000 and 2010 and decennial forecasts from 2020 to 2050.

Data

The population information was collected from Brazilian National Census for 2000 and 2010 conducted by the Brazilian Institute of Geography and Statistics (IBGE). The data referring to deaths by quinquennial age were extracted from the Mortality Information System (SIM) of the Brazilian Ministry of Health, also for 2000 and 2010.

Data Analysis

Forecasts

Using census information for the years of 2000 and 2010 made available by the Brazilian Institute of Geography and Statistics, we estimated the Brazilian population forecasts for the years 2020, 2030, 2040 and 2050 through the demographic component method. We considered fertility, mortality and migration trends for each component level and standard.

Interpolaton

Using the estimated forecasts and census information for 2000 and 2010, we computed life tables to derive population survival functions, mortality trends and life expectancy by sex and five-year age group. Then, by applying the Karup-King interpolation method, we obtained estimates for the population in single-year ages, from which we computed the population aging and mortality compression indicators.

Indicators

We considered absolute and relative population aging indicators, described below:

i. **Population Aging**

a. Mean age of Population = $\frac{\sum {}_1P_x * X}{N}$, where ${}_1P_x$ is the number of people aged x ;
b. Child Dependency Ratio = $\frac{{}_{15}P_0}{{}_{44}P_{15}}$
c. Aged Dependency Ratio = $\frac{P_{60}}{{}_{44}P_{15}}$
d. Total Dependency Ratio = $\frac{{}_{15}P_0 + \ P_{60}}{{}_{44}P_{15}}$
e. Ageing index = $\frac{P_{60}}{{}_{15}P_0}$
f. Mean age of Population Variability = $\frac{\sum idades^{a+1}}{N}$ - $\frac{\sum idades^{a}}{N}$
g. Longevity = $\frac{P_{75}}{P_{60}}$
h. Life expectancy at birth = $\frac{T_0}{l_0}$, where T_0 = cumulative time lived by a generation until an upper-bound age; and l_0 = total number of people born from the same generation.

ii. **Mortality Compression**

In order to evaluate mortality compression, we used indicators of the verticalization of the survival curve and of central longevity. Also, we considered some other life table functions computed for each evaluating year:

a. Mean age at death = $\frac{\sum {}_1d_x}{N}$

b. Standard-Deviation of age at death = $\sqrt{\frac{\sum(d_i - \acute{d})^2}{N}}$

c. Interquartile range = $Q_3 - Q_1$, e.g., the result of the third quartile, which represents 75% of death distribution (Q_3, minus the first quartile (Q_1), 25% of deaths.

d. ${}_1l_x$ = indicates the number of individuals in the age range between the ages x and x + 1.

e. ${}_1d_x$ = indicates the number of deaths in the age range between the ages x and x + 1

Data Analysis Approach

First, we constructed the population pyramids in order to observe the behavior of the population age composition and the changing demographic dynamics over the analyzed period. Then, we estimated the population ageing indicators and thus, we described graphically the mortality compression indicators for Brazil from 2000 to 2050.

Ethical Considerations

This study used aggregate data of a public nature, without any type of individual identification of the records. In this sense, according to the Brazilian resolution number 466/2012, this work is exempt from the need for submission to the Research Ethics Committee.

RESULTS

Two aspects can be highlighted from the observed evolution of the Brazilian population pyramids from 2000 to 2020: population ageing and demographic momentum (Figure 1). Population ageing represents the relative increase of the elderly population as a result of the decline of birth rates. From 2010, Brazil began to present an older age structure, gradually replacing the standard pyramidal shape, as a result of the fertility decline which started in 1960s. Additionally, the demographic momentum reflects the evolution of cohorts along the pyramid. In this sense, the decline of birth rates results in a relative increase of older age groups. Hence, the Brazilian population pyramid follows a tendency of base reduction and increasing adult and elderly population.

The course of population ageing can be better evaluated by looking at some specific indicators: dependency ratio, ageing index, mean age of population and life expectancy (Table 1). The dependency ratio can be divided into two: child dependency ratio and aged dependency ratio. This measure represents the capacity of the population in productive ages (15-60 years old) to economically support the young and the elderly population. In between 2000 and 2010, Brazil experienced a decline of its total dependency ratio as a result of the faster decrease of the child dependency ratio in contrast to the increase of the aged dependency ratio. Gradually, the reduction of child dependency ratio slows its pace and the aged dependency ratio becomes the main driver of the total dependency ratio increase observed for the population forecasts from 2020 to 2050. This indicator is extremely relevant for the analysis, evaluation and planning of social security systems for the elderly and the youth.

The evaluation of the ageing index is used to analyze the process of population ageing. As a result of declining fertility trends towards replacement levels and of increasing life expectancy, Brazil observes an increase of its elderly population share and the reduction of the proportion of young population. Thus, the estimated forecasts indicate ageing indexes higher than 100, as presented in table 1.

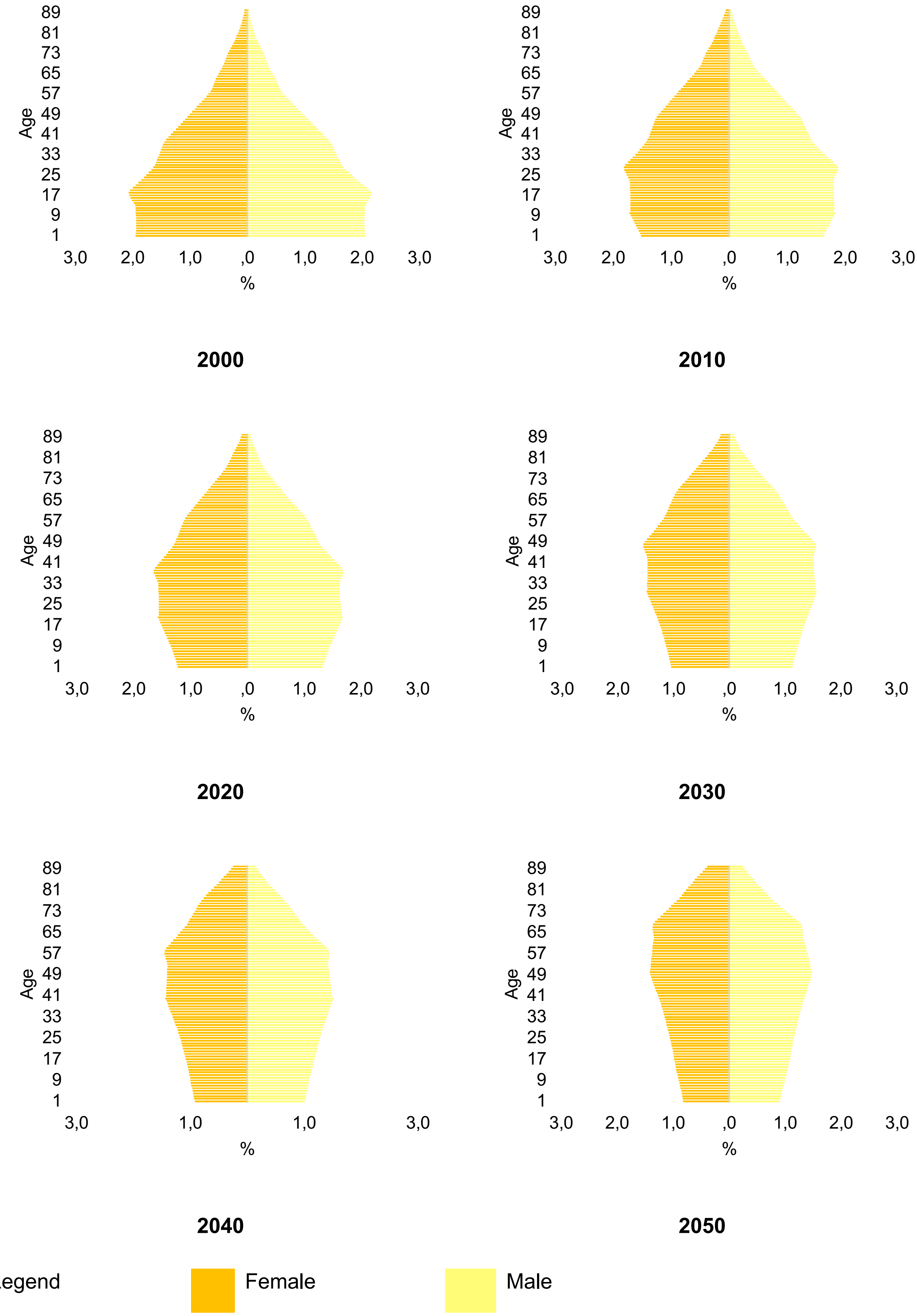

Figure 1: Brazilian Age Pyramids, 2000 – 2050.

Source: IBGE, 2018.

The life expectancy is an indicator constructed by using life table models and represents the expected time of life for a synthetic cohort that is submitted to specific mortality rates of the current period. It reflects the increase of Brazilian population longevity through time, especially due to the reduction of infant and youth mortality. Moreover, the observed forecasts show that the female advantage in life expectancy is expected to continue as long as male adult mortality remain as an issue in Brazil.

The tendencies observed for these three indexes for Brazil can be seen as a result of the processes of mortality compression and population ageing. Hence, they result in the increase of the mean age of the population.

The indicators of mortality compression are shown in figure 2. Subfigures a, b and c represent the death indicators of the synthetic cohorts used for life expectancy estimates from life tables. They show the shifting trend of deaths towards more advanced ages between 2000 and 2050. We highlight the sex differences due to the mentioned higher male adult mortality and the higher concentration of deaths in the elderly group. Subfigures d, e and f point out the survival indicators of the life tables synthetic cohorts. They show the share of population surviving along the ageing process. The forecasts indicate the process of rectangularization of the survival curve. Thus, we observe the increase of population longevity, directly entangled to the increase of the population life expectancy.

Table 1: Ageing indicators. Brazil, 2000 – 2050.

Year	Sex	Child Dependency Ratio	Elderly Dependency Ratio	Total Dependency Ratio	Ageing Index	Longevity	Populational Mean Age	Life expectation at birth	10 yrs variation
2000	Male	47.87	7.70	55.57	16.09	22.87	26.35	66.01	
	Female	45.52	9.70	55.22	21.32	26.38	27.63	73.92	
	Total	46.68	8.71	55.39	18.66	24.81	26.99	69.83	
2010	Male	38.86	8.67	47.53	22.32	23.51	29.02	70.21	2.67
	Female	36.64	11.34	47.98	30.94	27.97	30.59	77.60	2.96
	Total	37.74	10.02	47.76	26.54	26.00	29.81	73.86	2.82
2020	Male	30.92	11.76	42.69	38.04	22.98	32.36	73.26	3.34
	Female	29.07	15.25	44.32	52.46	27.96	34.16	80.25	3.58
	Total	29.99	13.52	43.51	45.09	25.75	33.28	76.74	3.47
2030	Male	26.25	17.05	43.30	64.94	26.19	35.80	75.28	3.44
	Female	24.78	21.90	46.68	88.39	31.42	37.84	82.00	3.68
	Total	25.51	19.49	45.00	76.39	29.09	36.84	78.64	3.56
2040	Male	23.84	23.00	46.84	96.48	30.96	38.94	76.62	3.14
	Female	22.62	29.56	52.18	130.71	36.74	41.25	83.17	3.41
	Total	23.23	26.29	49.52	113.19	34.16	40.12	79.88	3.28
2050	Male	22.74	31.36	54.10	137.89	33.17	41.62	77.48	2.68
	Female	21.73	40.23	61.96	185.15	39.42	44.20	83.93	2.95
	Total	22.24	35.79	58.03	160.96	36.62	42.94	80.69	2.82

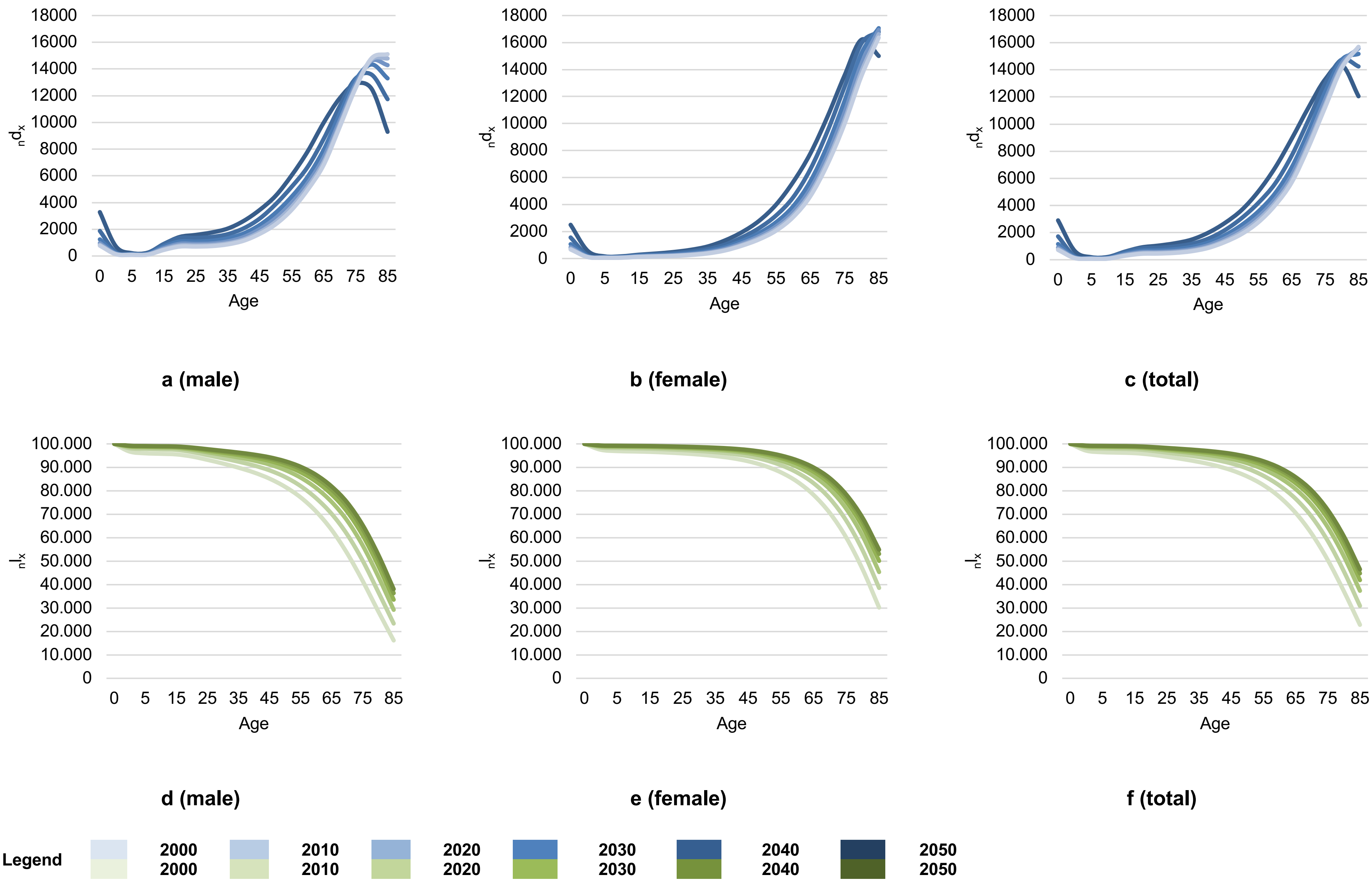

Figure 2: Life table functions (deaths ($_nd_x$) and survival ($_nl_x$). Brazil, 2000 – 2050.
Source: IBGE, 2018

As the country experiences the processes of increasing population longevity and rectangularization of the survival curve, Brazil observes the reduction of the variability of age at death and the increase of the average age at death. This process is described as mortality compression and is represented in figures 3 and 4. Figure 3 shows the interquartile ranges of age at death, an important measure to verify the process of mortality compression. The graphs show an increase of age at death for both first and third quartiles. The former, however, increases at a faster pace due to the more pronounced increase in the longevity of younger cohorts and thus, the difference between them reduces over time. Again, we observe a female advantage in this process: women are at a more advanced stage of mortality compression. Figure 4 shows the mean age of death and its respective standard deviations. An expected continuous increase over time is observed for the mean age at death with the reduction of the standard deviation, indicating a higher concentration of deaths around advanced ages.

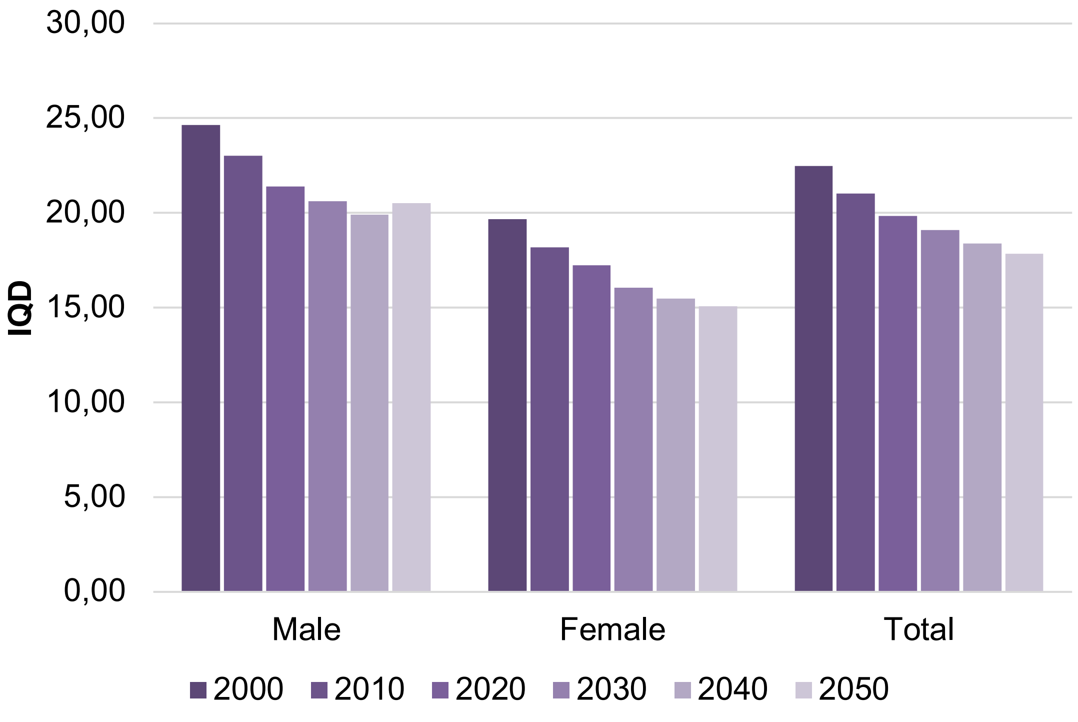

Figure 3: Mortality compression indicators (interquartile distance(IQD)), according to year and sex. Brazil, 2000 – 2050.

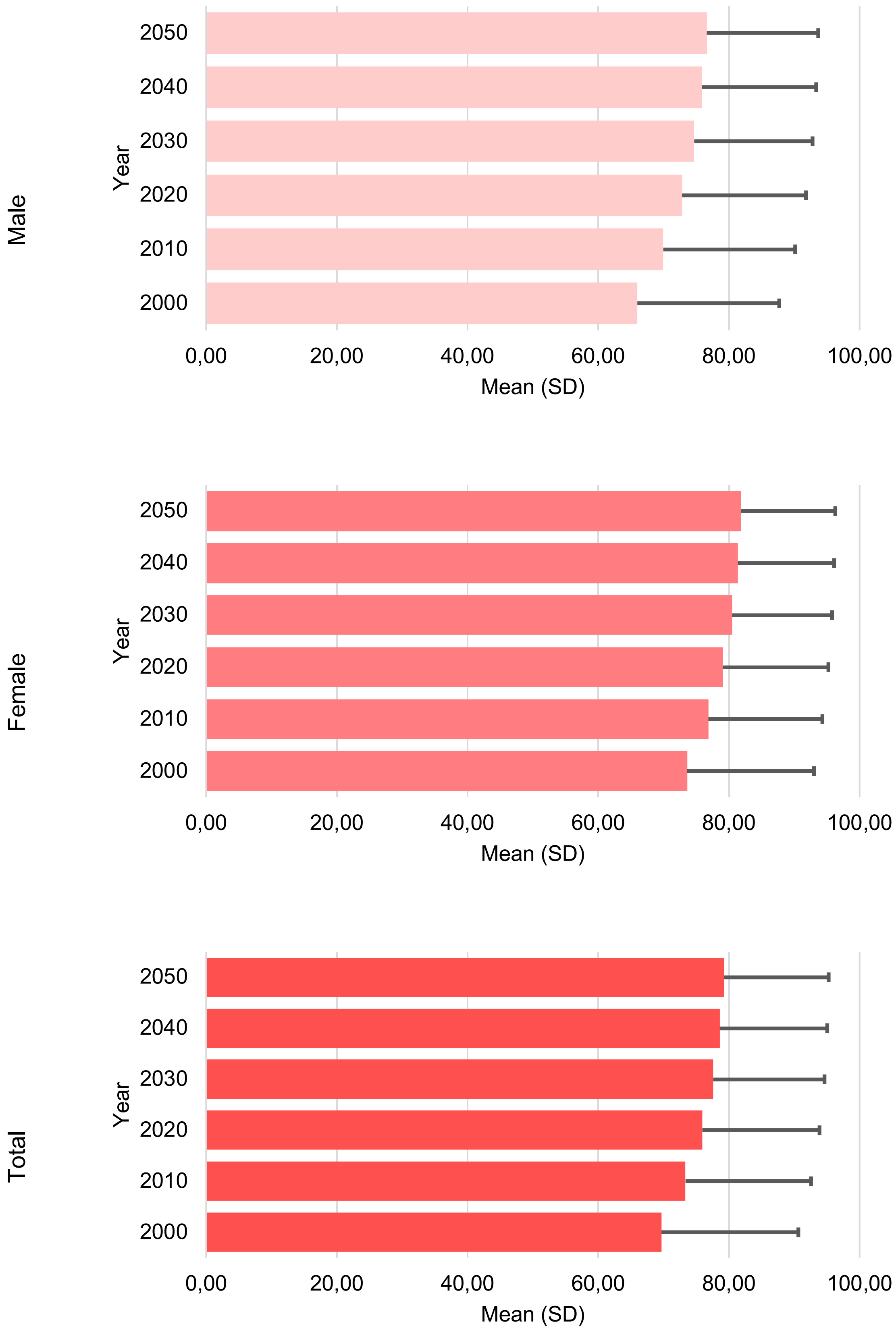

Figure 4: Mortality compression Indicators (Mean and standard deviation (SD)), according to year and sex. Brazil, 2000 – 2050.

DISCUSSION

The changes in the Brazilian Demographic Profile became more evident by 1970s with the overall reduction in family size (and its new relationship structures), the overcome of infant mortality and the rapid urbanization process. Consequently, the young age structure of the population was replaced by an increasing contingent of elderly aged 60 or more[10].

The evaluation of the ageing index over the last 40 years highlights the intense process of population ageing of the Brazilian population[11]. The evolution of the Brazilian population for the next years seems to be already defined: while the elderly population will increase in an accelerated way, the young population will tend to decrease. As a result, some age groups will present positive growth while others will present negative growth[12]. Furthermore, the projections indicate that in 2050 the Brazilian population will be of more than 250 million inhabitants, marked by fertility rates tending to remain below the replacement level and by an increasing life expectancy at birth and after 60 years. This scenario is not unknown, and it has been widely discussed for at least 10 years in the country[13].

It is worth noting that the age structure of a population carries the marks of the past demographic dynamics. In examining the functions of age-specific population growth rates over a given period of time, Myrrha et al[14] identified the beginning phase of mortality decline in the 1940s, the period of the onset of birth reduction in the 1960s and the effect of the influx of international young adult immigrants in the second half of the 1940s (postwar). In this way, they accurately describe how the demographic variables corroborate for the aging of the age structure.

The Brazilian socioeconomic development process also presents some intern heterogeneities. The Northern part, for example, exhibits lower socioeconomic development indexes in relation to the Southern part of the country. Nevertheless, the differences of population ageing process and age structure are evident when we describe the population ageing of these different regions, especially, in relation to socioeconomic conditions and size of the municipalities, pointing to the need for specific public policies that contemplate the particularities of this process in each locality[15,16].

Over the last few years, the scope of the debate on the possible consequences of aging has been growing, encouraging studies to incorporate more methodological possibilities and more theoretical support from diverse areas such as public health, economics and sociology[17].

Brazil observed a substantial improvement in the health conditions of the elderly and also a more equal distribution of chronic diseases among all income groups, especially for the groups of diseases associated with a more aged population, such as circulatory diseases and neoplasms[18]. We highlight the importance of changing age structure for hospital and public health services expenditures. In this sense, this progress represents a greater burden of diseases and disabilities and brings up the necessity of permanent evaluation of the Brazilian public health policy[19].

As the Brazilian population experiences an increasing life expectancy, there are also relevant changes in the mortality and morbidity patterns of the population. Therefore, it is important to know the pattern and level of the mortality indicators, considering that the population aging process is already in a stage in which mortality influences its behavior[20].

The forecast of mortality trends is one of the great strategies for the support of public policies and planning of public health systems. The projections permit to evaluate the process of mortality compression, which allows the identification of future trends and needs for the health of the elderly, especially when the average age at death presents a linear increase, which may result in better performance of forecasts[21,22].

Mortality compression occurs due to a reduction of the variability of age at death. Thus, survival functions from the life table become more rectangular. The rectangularization of survival curve represents a lower variability in age at death, e.g., it is related to indicators that analyze the life expectancy increase, which reflects a higher concentration of deaths at advanced ages as well as a lower death dispersion through ages[7,8,23]. In studies conducted in developed countries, that are in advanced stages of the demographic transition, it is possible to observe a higher interaction between the access to health services and the retangularization of the mortality curve. However, the increase of life expectancy at birth and the mechanism underlying the decline in mortality among the elderly continue to have unclear causes[7,8,22].

The transformation of the population pyramid reflects in different spheres of society, such as its social, economic, political and cultural structures.

Nevertheless, the setup of public policies aimed to fulfill the necessities of this new age structure in Brazil do not follow the same pace of the country's demographic transition; hence, its social security and health (SUS) systems are not suited to guarantee full assistance to the life quality for the elderly[2,17,24-26].

In this sense, the heterogeneity of the ageing process of each country encompasses different expectations and generates social consequences that are reflected in distinct health conditions, which bring up new challenges to health care systems and to the formulation of public policies for this age group[27]. We must also emphasize that public policies aimed to protect the elderly usually consider the family, the state and society equally responsible for care[28].

The demographic transition is, therefore, a gradual phenomenon and must be evaluated, in the long run, its impact on social politics, including some new challenges to health management. Specifically, from the point of view of educational, social security and health public policies of Brazil, national surveys have shown that there is a rapid and sustained increase in costs, with a projected duration of several decades[25]. In addition, the expansion of some productive sectors has accompanied the process of population ageing, in a way that this demographic phenomenon has a direct impact on the pattern of consumption and generation of goods, although this does not mean a change in the productive structure of the country[29].

CONCLUSIONS

Changes in age structure have occurred rapidly in Brazil and require rapid and adequate responses that will not be achieved without the intervention of the State through the implementation of fundamental public policies. Therefore, it is important to discuss current and future challenges related to public policy planning and population aging in a context of demographic transition and demographic change in the coming decades. This means addressing the impact of aging on society, due to disparities in access to goods and services, and discussing the need to create a support network (including State action and the role of the family) and highlighting the difficulties in accommodate this large population in absolute and relative terms in a country still in development. Finally, it is important to recognize that the analysis performed is still initial, and it is necessary to evaluate other indicators that more deeply assess longevity and mortality, including indicators of central longevity and survival curve behavior.

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