Regional Disparities in Brazilian Adult Mortality: an analysis using Modal Age at Death (M) and Compression of Mortality (IQR)

Abstract

This paper examines mortality differentials in Brazil and states between 1980 and 2010, using the Brazilian Ministry of Health Database. We use Modal age at death and measures of mortality compression to analyze regional and gender differences. We estimate age-specific mortality rates by single ages using two approaches: Wilmoth and colleagues Log-Quad approaches and Topal´s method proposed by Schermtmann and Gonzaga. Our results show that provincial disparities in mortality across regions of the country diminished, mortality seems to be converging at that level. In Brazil, for males and females, the modal age of deaths has been rising since the 1980, at the same time as mortality became more concentrated in a shorter age range. We found that there is a process of compression of mortality with increasing modal age at death. Female have higher modal age at death and lower IQR. In all cases, the TOPALS estimates were higher than the Log-Quad.

Keywords: Brazil, Modal age, mortality levels, regional differences

Introduction

Life expectancy has been rising for, at least, the last 160 years (OEPPEN & VAUPEL, 2002). Although there is an important debate about the biological limits of longevity, there is no evidence that human lifespan reached a ceiling (OEPPEN & VAUPEL, 2002; CANUDAS-ROMO, 2008; OUELLETTE & BOURBEAU, 2011). In more developed countries, mortality reduction, since the 1960, is concentrated in older ages (HORIUCHI et al., 2013; OEPPEN & VAUPEL, 2002), and there are clear signs of a compression of mortality and increasing in the modal age of death (WILMOTH & HORIUCHI, 1999; CHEUNG et al. 2005; CHEUNG & ROBINE,2007; CANUDAS-ROMO & WILMOTH, 2007; CANUDAS-ROMO, 2008).

In recent years, a large body of literature used the modal age at death (M) to analyze mortality change in countries with low mortality (KANNISTO, 2000; KANNISTO, 2001; CHEUNG & ROBINE, 2007; CANUDAS-ROMO, 2008, 2010; BERGERON-BOUCHER et al., 2015). This indicator is more sensitive to the mortality change at higher ages and can be understood as a good tool to explain the current pattern of mortality variation in such countries. The associated processes of compression of mortality and the rectangularization of survival curve have been used to explain how mortality changed. The first process refers to the concentration of the deaths in a smaller age interval. While in the second, the survival curve becomes more rectangular as the probability of surviving to higher ages increases (OUELLETTE et al., 2012, WILMOTH & HORIUCHI, 1999). More recently, in low mortality countries, the compression of mortality stopped and the shifting of the mortality curve has been observed. In that process, modal age of death rises while the variability above the mode remains stable (CANUDAS-ROMO, 2008; CHEUNG et al. 2009; CHEUNG & ROBINE, 2007).

In developing countries, there are few studies using modal age at death or the compression of mortality. Part of the challenges posted to analyze the evolution of mortality indicators in such countries is related to the poor data quality (WILMOTH et al., 2012), especially in countries with great regional heterogeneity in socioeconomic and demographic indicators. In recent decades, most countries

in Latin America, and especially in Brazil, experienced an accelerated decline in infant, child and adult mortality. The average gain in life expectancy at birth between 1950 and 2010 was about 15 years, a much faster process than what happened in developed countries. In 1950, life expectancy at birth in the region was around 51 years, reaching 67 years in 1990 and over 70 years in 2010 (ARRIAGA & DAVIS, 1969; PALLONI& PINTO-AGUIRRE, 2011; BARRETO et al., 2012).

Given that there are few studies on regional variations in Brazil with respect to the rectangularization of the survival curve and the compression of mortality, the present work aims mainly at shedding light on these topics at the level of Brazilian States. Gonzaga, Queiroz, and Lima (2017) estimated IQR and C-50 for a series of Latin American countries, they show a rapid process of the compression of mortality for females, reduction of the IQR, and a stagnation for males, mainly due to the increase in external causes of deaths in recent years. Gonzaga et al. (2009) analyzed the variability in age at death in the state of São Paulo and observed two distinct periods, one with increase in the variability (1980-1995) and one marked by decrease in variability (1995-2005). Gonzaga and Costa (2016) focused on the regional differences in Brazil between 1980 and 2010. They observed the rectangularization of the survival curve was more expressive for women and in the southern and southeastern regions. This paper estimates and analyzes trends in the modal age at death (M) and in the interquartile range (IQR) in Brazil and in its states, by sex, between 1980 and 2010.

Literature Review

In the last century, human populations experienced unprecedented rise in longevity. For women, for example, life expectancy at birth rose uninterruptedly for at least 160 (OEPPEN & VAUPEL, 2002). According to Wilmoth (2000), longevity gains are, probably, the most important achievement in human history. The linear extension in human lifespan means that mortality gains should not be seen as a sequence of great revolutions but as regular progressive evolution (OEPPEN & VAUPEL, 2002; VAUPEL, 2010). In countries like Japan, Sweden

and Spain three quarters of 100 newborns will reach age 75. In contrast, most children born in the 19th century died at young ages (VAUPEL et al., 2011

Since 1950, in developed countries, mortality reduction was more expressive in older ages (HORIUCHI et al., 2013; OEPPEN & VAUPEL, 2002). Consequently, we saw a deceleration in life expectancy evolution since the 1950's and a rise in the maximum lifespan registered (CANUDAS-ROMO, 2008; HORIUCHI et al. 2013; VAUPEL, 2010; WILMOTH, 2000, 2002; RAU et al., 2008).

The trajectory of mortality decline was different in most developing countries. Since the 1950's, those countries experienced rapid mortality decrease (PALLONI & PINTO-AGUIRRE, 2011). Cutler et al. (2006) understand that the rapid decline in mortality in such countries observed since the end of Second World War (WWII) was consequence of the knowledge accumulated in 200 years of mortality decline in rich countries.

Mortality decline at older ages in LAC, according to Palloni and Pinto-Aguirre (2011), traced a faster path than the observed in rich countries. Among the laggard countries, since the 1980 decade, the rate of gain $e°_{60}$ accelerated. In the same sense, Borges (2017) observes that mortality decline in ages above 60 contributed substantially to the rise in life expectancy in Brazil, especially for women since the 1980's. At the same time, between 2000 and 2010, there still were significant gains in life expectancy in young ages.

Since life expectancy at birth is highly sensitive to mortality variation at younger ages, in rich countries context, it might not be the best indicator to study longevity gains and the aging process (KANNISTO, 2001; HORIUCHI et al., 2013). In ageing analyses, a disadvantage of indicators such as the age specific death rates, life expectancy at age x, probability of dying or surviving is that they require an arbitrary selection of age limit. In contrast, the mode, as the most common length of life in a given mortality regime, is a good indicator for ageing and longevity and is free from arbitrary age limit definition (KANNISTO, 2001). In low mortality countries, the modal age at death can be an important reference to understand variations in mortality not captured by the life expectancy (CANUDAS-ROMO, 2008).

The mode to change depends that mortality improvement occurs in ages above the mode (CANUDAS-ROMO 2010). Mortality reductions in ages before the mode will make the number of survivors (and consequently the number of deaths) higher in some ages, still the number of deaths will not be greater than the amount observed at the modal age at death. Since more survivors will reach age M, consequently more deaths will be registered at this age (CANUDAS-ROMO, 2010) In that sense, a rise in M implies mortality reductions in ages above the mode.

The death distribution by age in a given mortality regime is bi-modal (KANNISTO, 2001; CANUDAS-ROMO, 2010). The first mode is observed at age 0, while the second mode is placed in advanced ages. In high mortality countries, the first mode is higher than the second one, although it is not the case for most countries these days (KANNISTO, 2001; HORIUCHI et al. 2013; CANUDAS-ROMO, 2008). In Russia and in other countries like Brazil, the increase in mortality for young adults made identifiable another mode in those ages. However, still, it was lower than the old age mode (CANUDAS-ROMO, 2008; CANUDAS-ROMO, 2010).

As the probability of surviving to higher ages rises, the survival curve becomes rectangular. Related to this process, the compression of the mortality makes the age at death distribution more concentrated in a narrower interval, as we observe a reduction in the age at death variability (WILMOTH & HORIUCHI, 1999). According to Wilmoth and Horiuchi (1999), the main contribution of the analysis of the variability in the age of death rests on the way the individuals live and plan their lives. They understand that the expressive extension of human life and reduction of the variability in the age death have influence on how individuals structure the way they live. Variability in the age at death, measured by the interquartile range (IQR), reduced expressively since mortality decline started.

Authors like Canudas-Romo (2008), Cheung & Robine (2007), Cheung et al. (2009) observed, that the compression of the mortality curve stopped in countries with low mortality, while the modal age kept rising. The shifting of the mortality curve hypotheses, formulated by Boongarts (2005), refers to the shifting of the pattern of the force of mortality, while its shape do not change. In this process,

while the curve is shifting, the hazard function fall, but maintains the same age profile, while the survival curve increases (CANUDAS-ROMO, 2008; BERGERON-BOUCHER et al., 2015). Based on the analyses of six low mortality countries, Canudas-Romo (2008) observed that the shifting of the mortality curve may well describe the current pattern of mortality chance in such countries.

The literature on the modal age of death considered mainly mortality changes in countries with low mortality (CANUDAS-ROMO, 2008; CANUDAS-ROMO, 2010; OUELLETTE & BOURBEAU, 2011; OUELLETTE et al., 2012; KANNISTO, 2000; KANNISTO 2001). Yet, there is a lot of heterogeneity in these countries. Canudas-Romo (2008) and Ouellete & Bourbeau (2011), for example, observed that the USA had the less concentrated age at death distribution. France and Japan presented the highest value of M (CANUDAS-ROMO, 2008). Ouellete et al. (2012) looked at the retangularization and compression of mortality process in the Canadian provinces. They observed that there was an upward trend in the modal age in all provinces. Although, the regional disparities remained practically the same in the period analyzed.

In Brazil, there are few studies of the compression, rectangularization and shifting of the mortality curve processes. Gonzaga and Costa (2016) observed that the rectangularization of the survival curve and the compression of mortality processes are more advanced in the southern and southeastern (the more socioeconomically developed) regions and among females. For the state of São Paulo, Gonzaga et al. (2009) identified that the modal age at death showed two different paths. For females, the mode rose between 1980 and 2000 and then diminished until 2005. Gonzaga, Queiroz, and Lima (2017) observed the rapid process of the compression of mortality for females, reduction of the IQR, and a stagnation for males in LAC countries.

Data and Methods

We make extensive use of the Ministry of Health Mortality Database (Datasus). We concentrate our analysis on the state level (27) data and include information by sex. We focus our analysis in the period between 1980 and 2010 (MINISTÉRIO DA SAÚDE, 2014). To estimate the mortality curves by single

ages, the modal age at death and IQR we perform a two step-methodology. First, we adjusted mortality levels to the degree of completeness of death counts registration. Age and specific mortality rates (for males and females) were estimated considering a three year moving average for every census year in the numerator and the population by single age for every census year (1980, 1991, 2000, and 2010) available at IPUMS[1](Minnesota Population Center, 2017). Then, to generate a smoothed complete mortality schedule by age we applied two methods: Log-Quad (Wilmoth et al. 2012) and TOPALS (Gonzaga & Schmertmann, 2016).

To deal with the undercount of deaths in official registry system we used the Adjusted Synthetic Extinct Cohort (SEG-adj) estimates produced by Queiroz and his colleagues (2017). SEG-adj is a Death Distribution Method (DDM) proposed by Hill et al. (2009) that combines the Growth Balance Method (Hill 1987) and the Synthetic Extinct Cohort (SEG), developed by Bennett and Horiuchi (1981).

The first method applied for mortality estimation was the system of mortality tables developed by Wilmoth et al. (2012). The log-quadratic model (LQ) estimates a complete set of age specific mortality rates using as inputs the probability of dying before age five (0q5) and the probability of death between age 15 and 60 (15q45). Equation 1 formalizes the model:

$$\log(m_x) = a_x + b_x h + c_x h^2 + v_x k \qquad \text{(Equation 1)},$$

where log(mx) is the log age specific mortality rate, h = log(5q0) reflects the level of child mortality, k reflects the level of excess adult mortality and is chosen to match 45q15 or other global measure of adult mortality, the other variables are constants in the model. The x represent each age group (0,1-4,…110+).

The main disadvantage with LQ is that the constants (ax,bx,cx) in the model were constructed using 719 life-tables from countries in the Human Mortality Database (HMD)[2]. As it developers pointed out, there are only two developing countries (Chile and Taiwan) among the life-tables considered and only one large country with a non-European majority population (Japan). Naturally, the experience of those countries might not reflect the experience of less developed countries or

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[1]https://international.ipums.org/international/sda.shtml

[2] www.mortality.org

countries more ethnically diverse. However, the method is very flexible and one could re-estimate the constants by adding other countries to the database. The main issue is that those additional countries might have data limitation and mortality age-profiles might have been estimated using indirect methods or model life-tables. According to Wilmoth et al. (2012), a tradeoff between accuracy and representativeness is unavoidable.

The second method applied to estimate the whole mortality curve for Brazil and it states was the TOPALS regressions developed by Gonzaga e Schmertmann (2016). They propose a Poisson regression method based on a relational model. Their model "builds complete schedules of age-specific rates via mathematical adjustments to a specified standard schedule. Our version of TOPALS constructs a fitted schedule of log mortality rates at ages 0…99 by adding a linear spline function with seven parameters (α0 ... α1) to a pre-specified standard schedule. We estimate parameters by maximizing a penalized Poisson likelihood function for age-specific deaths, conditional on age-specific exposure" (GONZAGA & SCHMERTMANN, 2016).

As authors observe, their version of TOPALS is not sensitive to the pattern chosen, since mortality estimates change very little with the schedule. Another important feature of the method is that it can handle well when there are zero deaths or people counted in a specific year or age.

From both LQ and TOPALS mortality rates estimation, we derived life-tables specific to sex, year, and location. From the number of deaths by age (ndx) function we calculated the modal age at death, according to Kannisto (2001) proposition, as Equation (2) presents:

$$M = x + \frac{d_{(x)} - d_{(x-1)}}{\left[d_{(x)} - d_{(x-1)}\right] + \left[d_{(x)} - d_{(x+1)}\right]} \qquad \text{Equation (2)}$$

Interquartile range (IQR) measures the size of the age range (between the first and third quartiles of the distribution of deaths) in which 50% of deaths occur around the median age at death. A simple way to calculate IQR is to use a life-table with an initial cohort of size 1 and one only needs the survival function (lx),

which in this case ranges from 0 to 1, where 25% and 75% of the cohort are alive. The difference between the ages of these is the IQR.

Results

Modal age at death estimated using TOPALS, for females, was 83.15 in 1980 and 85.31 in 2010. It seems that the compression of the mortality is in progress at least since 1980, and there is no sign that process stopped. The Interquartile Range (IQR), the indicator of variability in age distribution considered here, for females, was 20.67 in 1980 and diminished to 17.83 in 2010. When we look at the evolution of the age of deaths distribution estimated (TOPALS) for the Brazilian males (Figure 1), there was a similar pattern of change. In both cases (for males and females), M rose about 2.2 years in the between 1980 and 2010.

Figure 1 – Age at death distribution, Brazil, Males, 1980, 1991, 2000, 2010, TOPALS
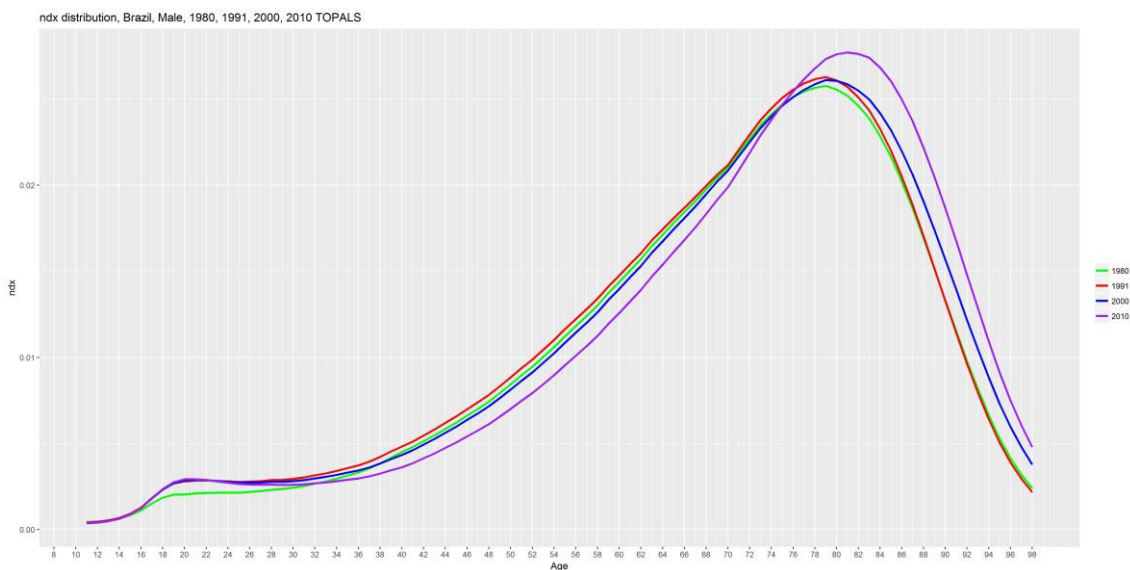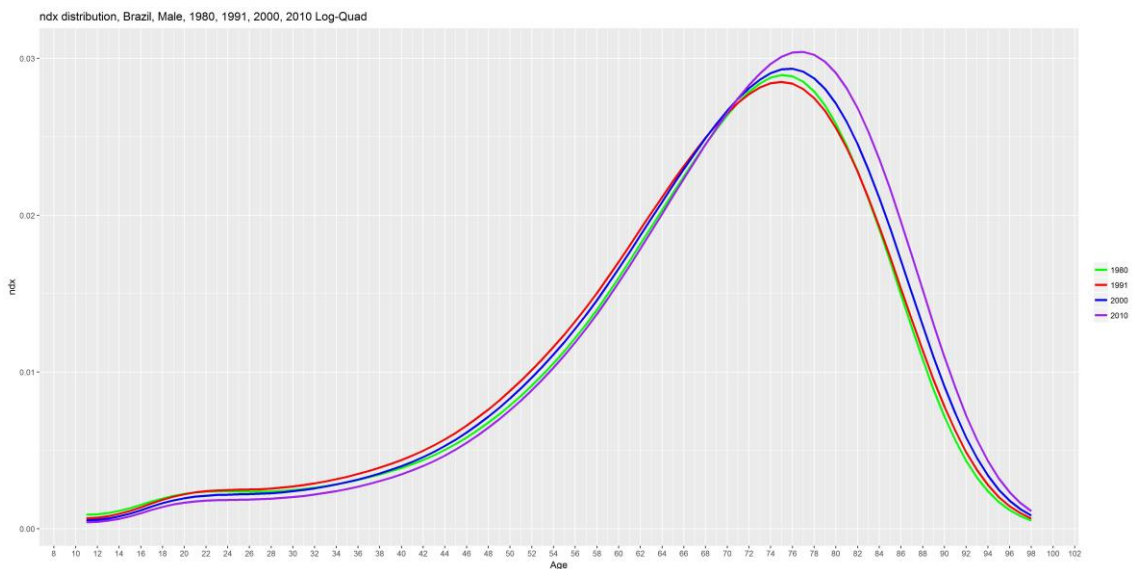

Source: SIM;IPUMS;IBGE

For men, M estimated was 79.34 in 1980 and 81.54 in 2010. However, the male age at death distribution show a distinguish feature in the young-adult ages, the high incidence of violent deaths makes visible a local mode (KANNISTO, 2001; CANUDAS-ROMO, 2010). It is important to highlight, as well, that there is a

higher proportion of deaths concentrated among young-adults in 2010 than in 1980. Based on IQR, we can affirm that the since 1980 the compression of mortality process is in course for Brazilian males as well. At the same time, the curve shifted to the right. IQR estimated (TOPALS) was 22.98 in 2010, 2.38 years lower than it was in 1980 (25.36).

The application of the Loq-Quad model shows similar pattern of mortality variation, although the modal age at death was lower for both males and females, compared to the TOPALS estimate. M rose from 79.33 (1980) to 82.73(2010). The female LQ estimates also showed a shift in age at death distribution, at the same time as the death became concentrated in a narrower interval (IQR). The female IQR estimates was 18.18 in 1980 and 16.07 in 2010. In every year considered, there were a substantial diminution on the IQR.

For males, the Log-Quad estimates shows a higher concentration of deaths in young and adult ages, compared to females, but it is still considerably lower than the TOPALS results. For males, M estimates LQ rose 1.54 years (75.67 to 77.21), from 1980 to 2010.A more modest increase that observed in the previous model.

Figure 2 – Age at death distribution, Males, Brazil, 1980, 1991, 2000, 2010, Log-Quad

Source: SIM;IPUMS;IBGE

The IQR for males reduced from 22.56 (1980) to 19.60 (2010). This result indicates that the mortality reduction in the period was concentrated in ages

below the mode (CANUDAS-ROMO, 2008). As observed in modal age, compared to TOPALS, the IQR Log-Quad estimates were lower in every year for both male and females.

Males X Females

The differences in the age at death distribution curve starts approximately at age 14 (left side of Figure 03) and rises until it reaches the local modal in AADD for males, around age 20. From that point on, until age 38, the gap in the number of deaths by age diminishes modestly. Since that age, however, the male higher proportion of deaths by age rises until it reaches its maximum at age 61. Another interesting feature about age at death comparison between the maximum heights that male and female reach. For females, age 85 concentrated 0.035 per cent of the deaths, while 0.028 per cent of the males exposed to that mortality regime died at age 81.

Looking at the probability of dying at age x graph (nqx) in the right side of Figure 3 may help understand this picture better. In 2010, the mortality differential between males and females increases steadily from around age 11 until it reaches its highest point at age 20 (same age as the local mode is placed in Figure 03). The differences in young-adult mortality between males and females is striking, explained, mainly, by violent deaths (MOURA et al. 2015). From that point on, the mortality differentials starts to narrow up to the end of the curve. It is important to highlight, however, that mortality was never lower for men.

Figure 3 – Age at death distribution (left), probability dying at age x (right), Males X Females, Brazil, 2010, TOPALS
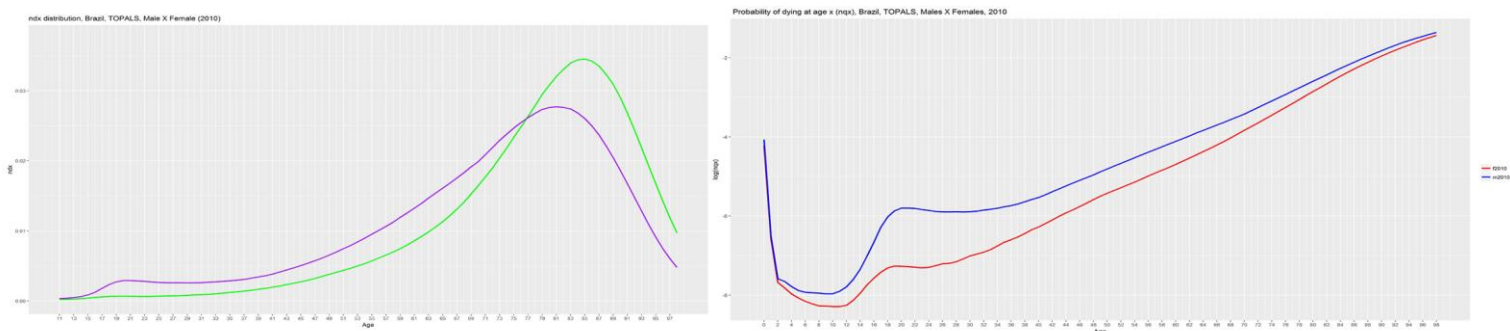
With the last assertion in mind, we can see that the point when the number of female deaths, at age 77, surpasses the number (left side in Figure 03) observed in men distribution is consequence of a higher number of women reaching ages with higher mortality. The same picture holds for every year considered in this study. At age 77, more than 61% of the female synthetic cohort were still alive, contrasting with 45% of men.

Log-Quad X TOPALS

Another topic of interest in this work is the differences between the methods used to smooth the mortality curves. As already discussed, we applied two different methods to estimated age specific mortality rates and the life table functions of interest. Figures 05 shows the female age at death distribution curve for both methods in 2010), as well as the curve estimated without any smoothing method.

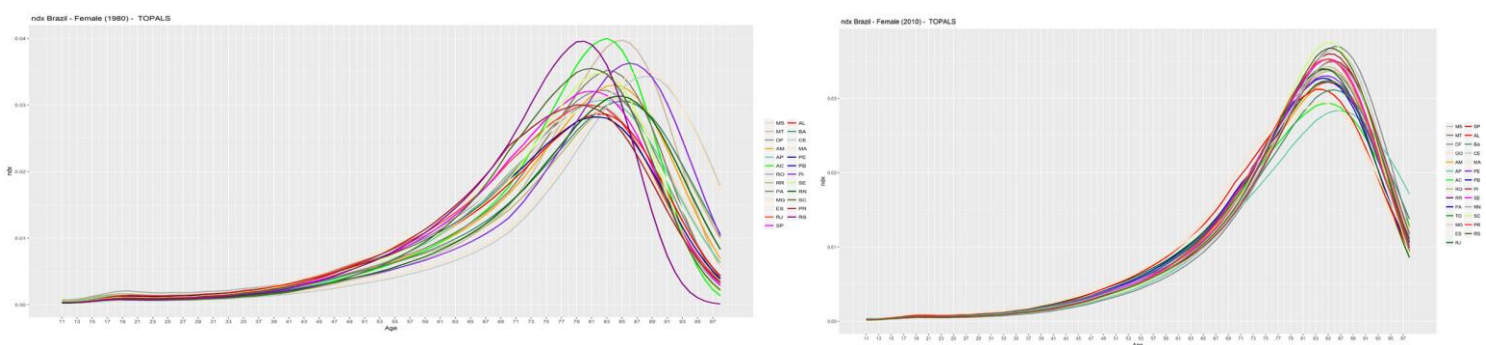Figure 4 – Age at death distribution, Males X Female, Brazil, 2010
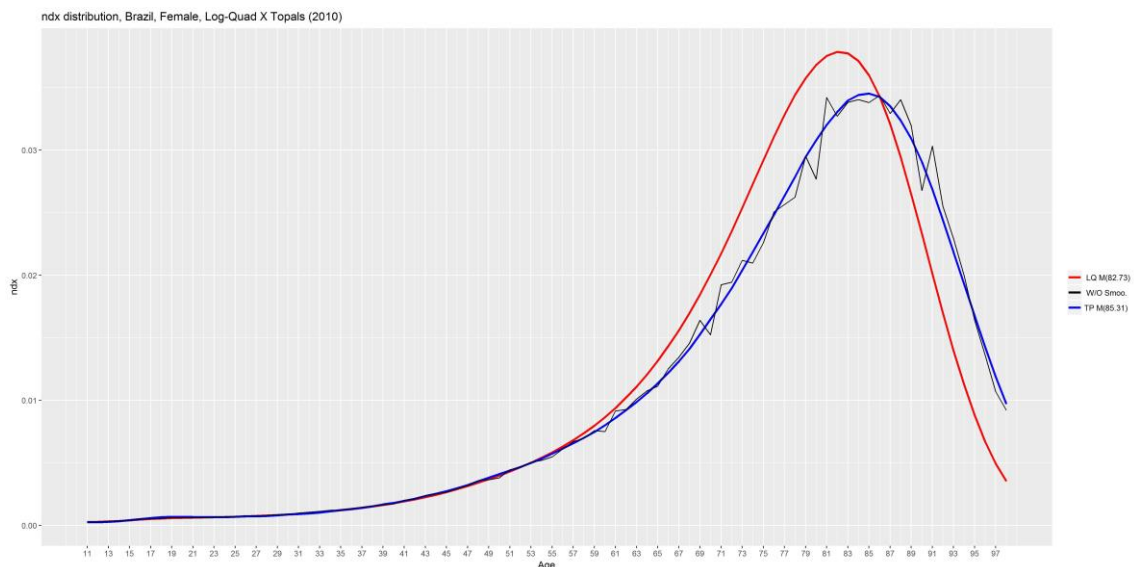
When we look at the female methods comparison (Figure 06), both curves trace practically the same path from the first age considered (11) until around age 55. From that point on, the LQ age at death distribution rises at a steeper pace and registers a higher number of deaths in the age interval that contains the modal age at death (82).Those differences in the pace of rise in the death distribution curves, for both sexes, are, probably, related to age overstatement problems. (PALLONI & PINTO-AGUIRRE, 2011; PRESTON et al., 1996).

States

Brazil is highly heterogeneous in socioeconomic and demographic terms. In part, this heterogeneity is exposed in Figure 6. In 1980, there was much more variation in the death distribution curves than it was in 2010. Clearly, for males and females, there were convergence in the patterns of the death distribution by age. The difference between highest and the lowest M estimates for the states reduced in the period in both applications, for males and females. The difference between the highest and the lowest M diminished from 9.03 in 1980 to 3.14 in 2010. There are clear signs that the modal age is converging in Brazilian states. The same can be said for men. The difference between the highest and lowest M passed from 9.39 to 4.72.

Figure 5 – Age at death distribution by state 1980 (left) and 2010 (right), Females, TOPALS

Source: SIM;IPUMS;IBGE

In Figure 7 we present the age at death distribution for males, in 2010. Particularly, the differences in local mode in young-adult ages is very expressive. States like Alagoas, Paraiba and Pará among others showed the highest proportion of deaths in those ages. States like São Paulo and Rio de Janeiro, that were among those with highest mortality in those ages, in 1991 and 2000, presented mortality reduction in those ages.

Figure 6– Age at death distribution by state 2010, Males, TOPALS
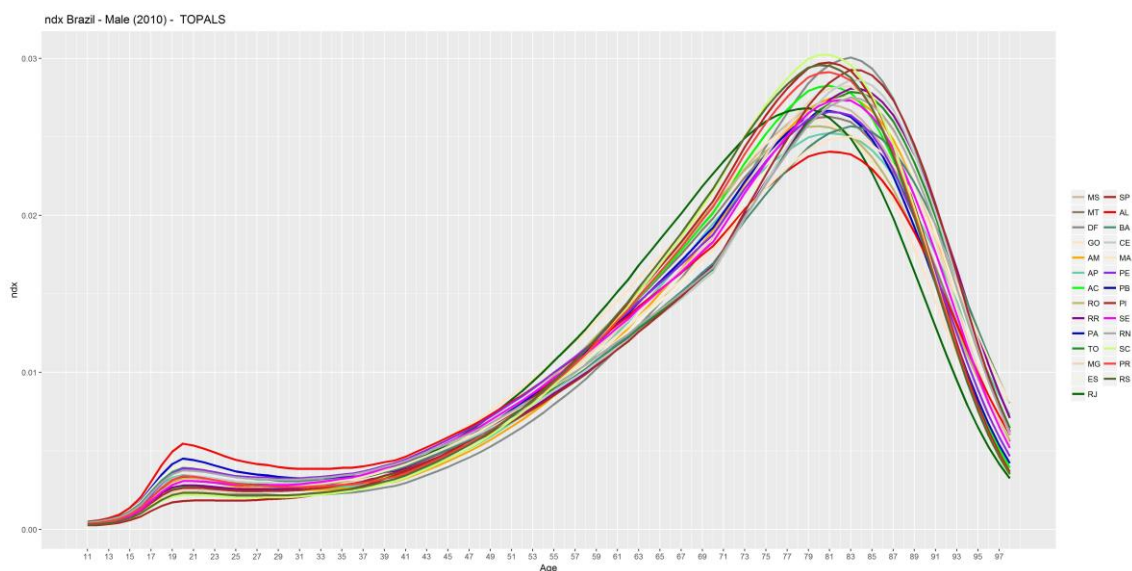
Source: SIM;IPUMS;IBGE

Discussion

Results showed that in Brazil, for males and females, the modal age of deaths has been rising since the 1980, at the same time as mortality became more concentrated in a shorter age range. Both smoothing methods, despite some differences, showed the same picture. So far, there are no signs that the shifting of the mortality curve is the dominant process. Unlike developed countries, besides the rapid decline in mortality (PALLONI & PINTO-AGUIRRE, 2011), Brazil still have to deal with high mortality in younger ages at the same time as

we observe decline in older age mortality (Borges, 2017). Since there was mortality reduction above and below the mode, age at death distribution shift to the right at the same time as the age at death variability diminished (CANUDAS-ROMO, 2010).

For both sexes, we saw the sharpest rise in M between 2000 and 2010. As already discussed, a rise in modal age at death is consequence of mortality decline in ages above the mode (CANUDAS-ROMO, 2010). Borges (2017), accordingly, identified that mortality diminution above age 80 represented expressive gains in Brazilian life expectancy at birth for males and females in the same period. It is noteworthy, that female contribution was quite expressive according to this author.

Based on the IQR, we observed that the compression of mortality is still dominant in Brazil, for both males and females. That results goes in the same direction as Gonzaga et al. (2017) found for Brazil and other Latin American Countries. Differently from the parallel rise in the second and third quartile observed by Wilmoth and Horiuchi (1999) in developed countries context, the IQR diminution was guided by a sharper rise in the second quartile than observed in the third. For males, the period in which the third quartile rose the most was between 2000 and 2010, which goes in the same direction with Borges (2017) that showed that in the period the old age mortality decline was most expressive for males. For women, the TOPAL results shows the 2000 to 2010 period as the more important rise in Q3. Although LQ shows an import rise in Q3 in the same period, the more expressive rise in that indicator was between 1980 and 1991.

For all estimates, female had higher modal age at death and lower IQR. One of the reasons is that men have much higher risk of dying from external causes. In Brazil, for each death of a women related to external causes, eight men died (MOURA et al., 2015).   Although, there is regional heterogeneity in sex differentials. Moura et al. (2015) found out that the in the North region the mortality rates are 8.9 times higher for males, while the lowest differential was observed in the South region (6.5). Other causes of death, naturally, influence the gender differentials as well. For example, Borges (2017) highlights that mortality reduction from cardiovascular diseases were the most important for

older adults in relation to life expectancy gains between 1980 and 2010, the decrease for was more expressive for women.

Once that local mode that capture male excess mortality in young ages rose, from 1991 to 1980, it stabilized and did not diminish in the period analyzed (Figure 1). Besides the diminution in the proportional distribution of deaths in other ages. Probably, the main reason is Brazil's internal mortality disparities. Most states in the Northeast region are among those with the highest concentration of male deaths in young-adult ages (Figure 6). In Alagoas, for example, the differences between 2000 and 2010 age at death distribution curves for young adult males is quite striking. These states have high homicide and other violent causes of death rates (WAISELFISZ, 2013). Differently, Rio de Janeiro and São Paulo. Rio de Janeiro, São Paulo and Pernambuco showed a diminution the height of the local mode from 2000 to 2010.

As expected, the variation of the indicators in the states considered so far indicates that there was a lot of regional heterogeneity. States placed in the North region of the country showed a more irregular path in M and in IQR, although, probably, not related to a regional feature in mortality. States of the North are among the poorest and less institutionally developed. This means that registration systems may be more fragile, even though they evolved in the period considered (QUEIROZ et al., 2017). Another potential source of problems with the North region data (not exclusively), especially in the 1980's and early 1990's, is related to internal migration, what may influence the death coverage estimates (HILL et al.2009) and, consequently, the modal age at death and the IQR estimates.

In all cases, the TOPALS estimates were higher than the Log-Quad. The principal potential explanation to the difference the between methods, concerning the modal age at death, is that age specific mortality in older ages in TOPALS estimates are underestimated in consequence of age misreporting. LQ coefficients were based on better quality data, their results might be less sensitive to age misreporting in higher ages. Which is not the case for TOPALS. Age misreporting in higher ages usually underestimates mortality, independently of the direction of the bias (PRESTON et al., 1999). Preston and his colleagues identified that when ages were overstated, mortality, starting at age 55, was lower

than it would be if ages were correctly stated. It is interesting the observe that, as showed in Figure 4, the differences if LQ and TOPALS estimates (females) starts close to the age Preston et al. (1999) pointed. In Brazil, there are clear signs that age misreporting affects old age mortality. Below age 75, Brazil had proportionally higher mortality, in comparison with countries known to have high good quality vital statistics (TURRA, 2012).

The LQ estimate, on the other hand, was not able to capture the young adult mortality hump for males. The young-adult age at death distribution for the LQ is considerably lower the TOPALS estimate and the curve without any smoothing. Among other models, Sharrow et al. (2014) observed that Log-Quad could not fit the HIV mortality hump in Lesotho, the method produced a high flat pattern in age specific mortality that match an overall level of mortality. It seems that we are handling with same kind of problem in the young-adult male mortality, as the differences in the model fits those ages suggest (Figure 1 and 2).

The modal age at death rose in almost states considered so far, as well as the variability in the age at death diminished. It seems that the process of compression of mortality is still in progress, mainly related to the mortality reduction in younger ages. At the same time, the modal age rose in practically all states. This means that mortality above and below the mode reduced in the period (CANUDAS-ROMO, 2010). Figure 6 showed that the age at death distribution among the states are more similar in 2010 than they were in 1980. The difference between the state with highest and the one with the lowest modal age diminished. That is an indicator that the mortality patterns among Brazilian states seems to be converging.

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