Understanding the changes in the variability of age at death in São Paulo: compression or expansion of mortality?

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Abstract

In this paper we analyzed the changes in the mortality pattern in São Paulo (Brazil) from 1980 to 2005, aiming to identify the effects of these changes on the variability of age at death. We found evidence of a change in the distribution of deaths towards more advanced ages and an increase in the mean length of life of seven years. We observed two different scenarios: first (1980-1995), there was an increase in the variability in the age at death; and second (1995-2005), there was a trend of decreasing the variability. Estimates beyond a given quartile of the death distribution by age indicated that the compression of mortality took place in the whole period. For males, however, the variability of age at death was lower than for females.

1) Introduction

The historical decline in mortality rates in developed countries has two clear effects: the reduction in the variability of age at death and concentration of deaths at older ages (Nusselder and Mackenbach, 1996; Wilmoth and Horiuchi, 1999; Kannisto, 2000; Cheung et al, 2005; Edwards and Tuljapurkar, 2005). This reduction in the variability can be explained by mortality decline among young age groups, especially infant and child mortality; and the concentration of deaths at older ages by structural changes, and medical advances that reduce mortality by non-infectious diseases (Wilmoth and Horiuchi, 1999; Cheung et al, 2005). In the developing world, it is not yet known whether the ongoing process of mortality decline will lead to the same situation.

In Brazil, the changes in the mortality and morbidity patterns are responsible for the reduction in the variability of age at death (Prata, 1992). The changes observed in Brazil follow a similar pattern as observed in the developed countries. Infant and child mortality started to decline rapidly in 1940 what lead to an increase in life expectancy at birth (Prata, 1992). Infant mortality declined from 160/1000 live births in 1940 to 85/1000 in 1980; and reached 24/1000 in 2005 (Prata, 1992, Brasil, 2005). As a consequence of the rapid decline in infant mortality, life expectancy at birth (both sexes) increased by 28 years in 50 years; rising from 44 in 1950 to 72 years in 2000 (Brasil, 2005). The reduction in infant (and child mortality) is mainly explained by an improvement in living conditions that reduced the number of deaths caused by infectious diseases, leading to an increase in the participation of non-infectious diseases as the main causes of deaths and a change in the age pattern of mortality (Prata, 1992; Nunes, 2004; Schramm et al, 2004).

Figure 1 shows the increasing in the life expectancy by sex on São Paulo States between 1940 and 2005. Life expectancy at birth or mean age at death is an important summary measure for the population mortality pattern. In São Paulo, life expectancy has been increasing since 1940 with different gradients. Between 1940 and 1950, the main determinant for the increase was the reduction of death caused by infections diseases (Ferreira & Castiñeiras, 1996; 1998). Stating in1960 the reduction in infant and child mortality did not produce the same effects. We are interested in period between 1980 and 2005 when the infant and child mortality are already low and life expectancy shows two different inclinations.

Figure 1: Expectancy of life by age and sex on São Paulo States - Brazil (1940 to 2005)

SOURCE: Mortality Information System and Ferreira and Castiñeiras (1980).

In the last two decades, we observed several changes in the pattern of mortality in São Paulo. First, the decline in infant and child mortality in São Paulo had an important role in the reduction of the variability of age at death (Ortiz, 2002; Brasil, 2005). However, there was an increase in the number of deaths by external causes (homicides and accidents) affecting mainly young adults. At the same time, Campos and Rodrigues (2004) observed a decline in the mortality rates of the elderly population leading to an increase in the oldest age at death. They also suggest that this phenomenon is still under way, and one could expect further decline in the mortality rates at older ages. In this paper, we analyze how the changes in mortality, can affect the distribution of deaths and the variability in the age at death by sex, in the São Paulo States (Brazil).

2) The hypothesis of compression of mortality and your determinant

The compression hypothesis was proposed in a well-known article by Fries (1980). The main idea is that human survival curve becomes more rectangular when mortality leves decrease. That is, since death concentrate in a narrow age interval, the slope of survival curve in that range becomes steeper, and the curve itself begins to appear more rectangular suggesting that human life expectancy is approaching its maximum potential value (Fries, 1980; Wilmoth, 1997; Wilmoth and Horiuchi, 1999). Following Fries,, several authors have examined whether this hypothesis is true (Meyers & Manton, 1984a, 1984b; Go et al, 1995;

Nusselder & Mackenbach, 1996; Wilmoth, 1997; Paccaud et al, 1998; Wilmoth and Horiuchi, 1999; Cheung et al; 2005; Edwards & Tuljapurkar, 2005; Cheung & Robine, 2007). The main interest of most researchers is the relation between the compression-rectangularization of the survival curve to the biological limits to the human life span. However, Wilmoth (1997) argues that the compression-rectangularization process is related for a reduction in the variability of age at death that can happen while the distribution of age at death is moving to the right. In this case, the existence of biological limits to the human life span implicate a compression-rectangularization process, but a compression-rectangularization happening does not implicate in biological limits to human lifespan (Wilmoth, 1997; Wilmoth & Horiuchi, 1999).

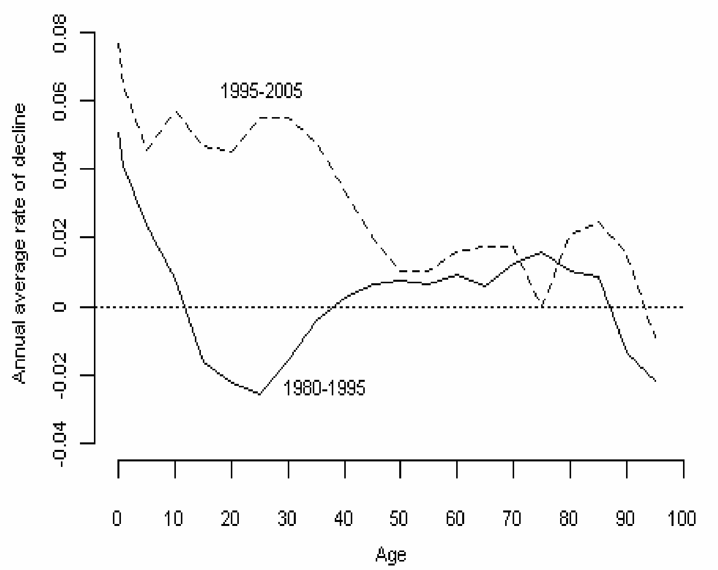
Wilmoth and Horiuchi (1999) demonstrated that the rectangularization of the survival curve is associated with a reduction in the variability of age at death. They examined several measures of variability and rectangularization for Sweden, Japan and United States, and concluded that the Interquartile range (IQR) is the best single measure of variability in the distribution of deaths. Wilmoth and Horiuchi (1999) argued that the main determinant in the reduction of the variability is the reduction in the mortality rates at younger ages. In recent decades, the reduction in the variability is explained by the reduction in the mortality rates at older ages (Wilmoth and Horiuchi, 1999; Meyers & Manton, 1984a). Thus, it is important to consider and analyze the contribution of each specific age to the changes in the variability of the survival curve. Wilmoth and Horiuchi (1999) related the reductions in the variability to the age pattern of mortality decline. A divergent age pattern of mortality decline, where the decline rates are larger in the youngest ages is the main cause of reduction in the variability of age at death.

The mortality decline in São Paulo States (Brazil), between 1980 and 2005 (Ortiz, 2002; IDB, 2005), might have significant effects to changes in the variability of age at death. However, several researchers argued that the number of premature deaths in São Paulo is too high in this period, and since these deaths happen mostly among young adults due to external causes, which might affect the direction of the change in the variability (Ferreira & Catiñeiras, 1996; Ferreira & Catiñeiras, 1998; Gawryszewski & Jorge, 2000). However, the life span of the population of São Paulo is increasing (Campos and Rodrigues, 2004), and the distribution of age at death in São Paulo States is still moving to advanced ages.

Figure 2 shows the annual rate of mortality decline by age in São Paulo in two different periods (1980-1995 and 1995-2005). A high value of the rate means that the decline in any particular age group gets faster than in a low value. We observe that the age pattern of mortality decline in São Paulo is very different between the two periods. In 1980-1995, the annual rate of decline was very low for the age groups between 10 and 40 years of age. Probably, this was caused by the number of deaths due to accidents and violence (Ferreira & Castiñeiras, 1998; Gawryszewski & Jorge, 2000). Thus, it cannot be expected a significant change in the variability of age at death. Between 1995 and 2005, for the same age interval, the average annual rate of decline is positive and large. Thus, one can expect a reduction in variability of age at death in the more recent period. .

Although this picture illustrates evidences of changes in variability of age at death between 1980 and 2005, it is important to construct measures of variability or compression of mortality to reach any plausible conclusion.

Figure 2: Average annual rate of mortality decline by age and sex combined to São Paulo States (Brazil) in two time intervals between 1980 and 2005



SOURCE: Mortality Information System e Brazilians Demographics Census (1980, 1991 e 2000).

3) Data and Methods

We make extensive use of the Mortality Information System - *Sistema de Informação de Mortalidade do Ministério da Saúde (SIM/DATASUS/MS)*. The database contains detailed information on death, causes of death by age and sex since 1979. We obtained population data from the censuses and use traditional demographic techniques to obtain population by age and sex for each year.

In order to analyze the changes in the variability of the age at death it is necessary to estimate period life-tables, both complete and abridge. First, we estimate five-year age group survival functions to deal with possible problems of age declaration. Then, we interpolate the results using Beers interpolation method (Siegel and Swanson, 2004) to transform the function to single age groups. We estimate abridge period life tables for the whole period of analysis (18 in total); we also estimate complete life tables, for the total population and by sex, for some specific periods (1980, 1985, 1990, 1995, 2000 and 2005). We limited our life table to the 100 and over interval, except for 1980 because of data limitations. In our analysis, we excluded the population age 5 and bellow, following Wilmoth and Horiuchi (1999).

We use three different indicators of variability of age at death (interquantile range - IQR, shortest age interval in which 50 percent of deaths take place - C50, standard deviation of the age at death above of quartile p% - SD), together with three measures of central tendency of age at death (median age at death, modal age at death and mean age at death above of quartile p% of the distribution death) to evaluate the compression of mortality in São Paulo.

4) Results

The changes in the distribution of deaths over recent years are very clear from the results. Traditional measures of central tendency such as life expectancy at birth, modal age at death and mean age at death show that the average length of life has increased by 7 years from 1980 to 2005. However, it is also important to investigate whether this movement was accompanied by a reduction in the variability of the age at death providing some support to the hypothesis of compression of mortality in Brazil. Table 1 and Table 2 show the change in the variability of age at death considering three measures (IQR, C50 and SD) and three indicators of central tendency (median, mode and mean). Figure 3 presents a summary of the results by sex from Table 1 and Table 2.

Table 1
Inter-Quartile Range (IQR) and median age at death, Shortest age interval in which a given proportion of deaths take place (C50) and modal age at death - São Paulo State (Brazil), 1980 to 2005 (both sexes)

Indicator	*1980*	*1985*	*1990*	*1995*	*2000*	*2005*
			Both sex			
IQR	19,71	20,25	20,57	20,99	20,59	19,72
Median [1]	73,8	74,2	74,7	75,1	76,6	77,3
C50	17,90	17,88	18,28	18,86	18,53	18,27
Moda [2]	78,9	80,5	80,5	81,8	82,1	79,5
			Men			
IQR	21,21	22,07	22,86	23,46	22,74	21,02
Median	70,6	70,5	70,8	70,8	72,4	73,7
C50	19,33	19,85	20,37	20,82	20,50	19,49
Moda	75,8	76,4	77,7	79,5	79,2	78,2
			Woman			
IQR	17,21	16,90	17,09	17,58	17,28	17,25
Median	76,9	77,7	78,4	79,1	80,4	80,7
C50	15,93	15,50	15,71	15,95	15,70	16,10
Moda	80,6	82,2	83,0	83,3	84,3	82,6

SOURCE: Information System of Mortality - Minister of Heath (SIM/DATASUS/MS) and Demographics Censes Brazilians.
NOTE: [1] median age at death.
[2] modal age at death.

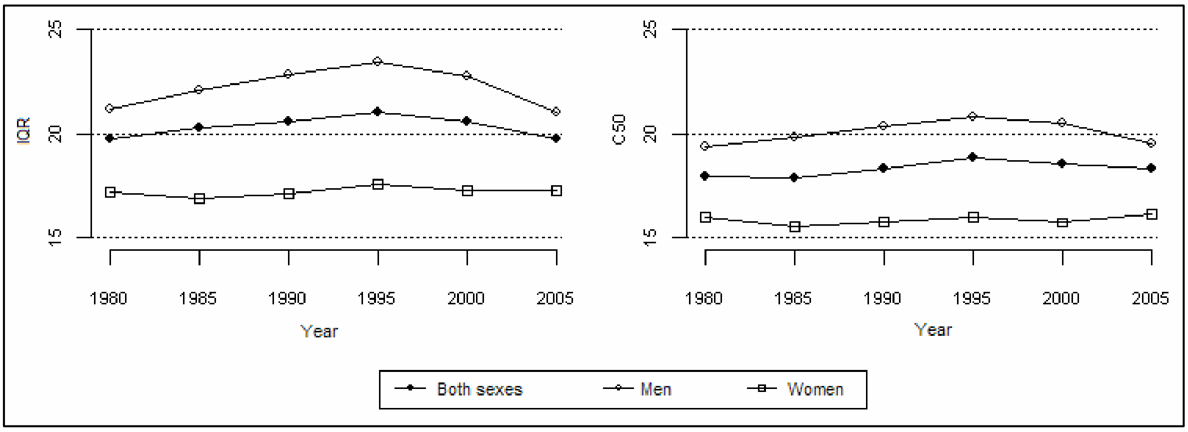
Table 2
Standard Deviation and Age Mean at death of São Paulo State (Brazil), 1980 and 2005 (both sexes)

Quartile	Proportion of death above quartile	1980		2005		1980-2005	1980-2005
		Mean	SD	Mean	SD	Δ Mean	Δ SD
				Both sexes			
-	100%	55,22	27,19	57,74	27,59	2,52	0,40
1º	75%	66,19	18,26	71,30	14,89	5,11	-3,37
2º	50%	87,32	7,54	90,55	6,67	3,23	-0,87
				Men			
-	100%	51,57	27,00	53,64	27,05	2,07	0,05
1º	75%	61,38	21,23	65,91	18,25	4,53	-2,98
2º	50%	85,92	8,42	87,25	7,54	1,33	-0,88
				Woman			
-	100%	59,21	27,92	62,52	28,92	3,31	1,00
1º	75%	69,93	16,41	74,70	13,49	4,77	-2,92
2º	50%	88,52	6,65	92,29	5,94	3,77	-0,71

SOURCE: Sistema de Informação de Mortalidade (SIM/DATASUS/MS) e Ferreira e Castiñeiras (1980).

The results show some evidence of the mortality compression in recent years. Both median age and modal age at death has increased from 1980 to 2005 (Table 1). We also observed two different periods of change in IQR and C50. From 1980 to 1995, our results indicate a movement to the right on median and modal age (Table 1), accompanied by an increase in the variability of age at death (Figure 3). In more recent years, from 1995 to 2005, the movement to the right of the distribution (Table 1) was followed by a reduction in the variability of age at death (Figure 3). The variability of age at death is higher to IQR than C50 (see Figure 3) because IQR measures the variability in a percentile scale its value is more affected by mortality at younger ages (Kannisto, 2000).

Figure 3: Changes in specific-sex in variability of age at death through IQR and C50, median age at death and modal age at death starting from the 5-years-old, São Paulo State, 1980 - 2005



SOURCE: Mortality Information System e Brazilians Demographics Census (1980, 1991 e 2000).

In some cases, when ignoring deaths at young ages (see Table 2 to SD above of first and second quartile), we find that the compression of mortality (reduction in the age variability) occurred for the whole period of analysis. We can observe this by the positive variation in the mean and the negative variation standard deviation (Table 2).

5) Discussion

Historical analysis about the compression of mortality shows that the reduction in variability of age at death is fairly small for the period. However, it is important to compare the trends in Sao Paulo with other countries in the world for periods when life expectancy at birth was similar. Table 3 shows the comparison between Sao Paulo and three countries (Sweden, United States and Japan) using IQR. In São Paulo, from 1995 to 2005, life expectancies at birth ranged from 69.3 to 73.3 years, and the variation in IQR was 1.27 years. The same change in life expectancy in Japan, between 1961 and 1971, (see table 3) showed variation in IQR of 1.60 years. In case of the United States, variation at IQR was 1.20 years when life expectancy rose from 69.1 to 74.5 years. And in Sweden, variation at IQR was higher than Japan and the United States (see table 3). The variation in IQR in São Paulo was very similar to the one observed in Japan and United States when life expectancy were at similar levels (but for different periods of time).

We also compared the compression by sex, and find that female deaths are much more concentrated around an specific age than male, as was observed by others (Go et al, 1995; Paccaud et al, 1998; Edwards & Tuljapurkar, 2005). Such differences by sex can be explained by differences in the risk to hazard situations, the lower socioeconomic of males, and biological heterogeneity (Edwards & Tuljapurkar, 2005).

Finally, another interesting aspect in São Paulo is the tendency of greater compression to males than females, as showed in Figure 3. This can be explained because the survival in advanced ages was greater for females than for males (Camargos, Machado and Rodrigues, 2008). We can also argue that female deaths are having a more evident process of dislocation to advanced ages than the males. Indeed, in the period analyzed, the increasing in mean, median and modal ages were more evident to females than males.

Table 3
Life expectancy at birth and IQR to São Paulo State and three countries developed in different periods of time.

Population and Period	*e(0)*	*IQR*	*Variation at IQR*
São Paulo			
1995	69,25	20,99	1,27
2005	73,27	19,72	
Sweden			
1945	68,30	19,80	3,40
1955	72,50	16,40	
Japan			
1961	69,40	17,50	1,60
1971	73,50	15,90	
United States			
1951	69,10	20,60	1,20
1981	74,50	19,40	

Source: Datasus/IBGE, Wilmoth e Horiuchi (1999) e Human Mortality Database (2007).

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