

New and old paradigms on mortality: evolution of mortality patterns in Latin America

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Abstract

We present a preliminary analysis of the comparative quality of data that underlie national-level mortality estimates and the evolution of causes of deaths and mortality age profile for Latin America populations over various time periods (beginning with the date noted and ending in some recent year): Chile (1920), Mexico (1930), Brazil (1979), Argentina (1980), Colombia (1980), and Peru (1985), Costa Rica (1963) and Puerto Rico (1960). The analysis focuses on three main points: (i) evolution of the quality of death records registration in Latin America; (ii) changes in the causes of death of time and (iii) evolution of the distribution of deaths over age. Although the limitations of this sort of analysis must be kept in mind, this study suggests several important conclusions concerning the quality of available mortality data; rapid change in the epidemiological profile and rapid concentration of mortality at older ages for these populations.

Keywords: mortality, Latin America, compression, variability, data quality

Preliminary and rough draft. Comments are welcome.

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1. Introduction

We present a preliminary analysis of the comparative quality of data that underlie national-level mortality estimates and the evolution of causes of deaths and mortality age profile for Latin America populations over various time periods (beginning with the date noted and ending in some recent year): Chile (1920), Mexico (1930), Brazil (1979), Argentina (1980), Colombia (1980), and Peru (1985), Costa Rica (1963) and Puerto Rico (1960). The analysis focuses on three main points: (i) evolution of the quality of death records registration in Latin America; (ii) changes in the causes of death of time and (iii) evolution of the distribution of deaths over age. In a recent paper, Palloni and Pinto-Aguirre (2011) produce estimates of mortality curves for Latin America and investigate the contribution of changes in causes of deaths to improvements in life expectancy and how socioeconomic factors are related to changes in mortality levels. In this paper, we contribute to this discussion by estimate quality of mortality data, estimates by mortality curves by sex for seven (7) Latin America countries. In addition to that, we investigate the distribution and variability of deaths by age.

The mechanisms that determine the transition from high to low mortality was investigated for several developed countries. low mortality. The transition of mortality in these countries, especially Western Europe, has demonstrated, albeit with some controversy, the importance of economic development, mediated by improvements in living standards for the historical decline of mortality in these populations (McKeown & Record, 1962; Preston, 1975; Cutler & Miller, 2005; Cutler, Deaton & Lleras-Muney, 2006).

Much of the reductions in mortality would be consequence, at first, of improvements in the levels of nutrition and economic development, with some improvement in public health (Fogel, 1986, Preston, 1975). In a second stage, public health would take a more prominent role, with improvement in sanitary conditions (Cutler & Miller, 2005) and practical personal care being the main determinants. Finally, from the mid-twentieth century, medical interventions, through development of vaccinations and antibiotics for the treatment of diseases are the most prevalent factors.

In Latin American, the decline in mortality did not follow the historical course observed in developed countries. In little more than half a century most LAC countries experienced major changes in health conditions related to structures demographic, socioeconomic and environmental processes as a result of rapid industrialization and urbanization (Palloni, 1981 Palloni & Wyrick, 1981; Palloni, 1985; Palloni, Hill & Pinto-Aguirre, 1996; Palloni & Pinto-Aguirre, 2011). It is estimated that the mortality transition in Latin America began around 1930 to 1940, when the transition process in developed countries was already in a much more advanced stage (Palloni, 1981, 1985). Although the rapid transition of mortality is an intrinsic feature of Latin America, there are arguments for some diversity in the process causing some countries initiate the transition before others (Palloni, 1981, 1985). Only after 1950 began a widespread reduction in mortality in Latin America, thus reducing the gap with developed countries (Palloni 1981).

Parallel to the mortality transition, epidemiological transition in Latin America occurs in a context of heterogeneous health profile, where different countries were at different stages of transition (Frenk et al, 1991). It is unlikely, however, that any of these countries are experiencing a transition stage similar to that of many developed countries. The overlapping stages, the resurgence of some diseases that had been controlled and a peculiar epidemiological polarization, both between countries and between different geographical areas and population sub-groups within a country, it would rank the epidemiological transition in Latin America, according to Frenk et al (1991) as a template and extended polarized transition. The intrinsic process of epidemiological transition in some countries produces a scenario where the incidence of communicable diseases in adult and advanced ages is relatively high compared to developed countries (Frenk et al 1991). Guatemala, for example, would be a more pre-transitional stage, with a high proportion of causes of death from diseases, while countries such as Mexico, Chile and Uruguay, were in more advanced stages (Brevis et al, 1997). Among these last three countries, Mexico present a longer transition situation similar to that observed in Brazil (Chaimowicz, 1997), while Chile, Uruguay would be closer to a post-transitional stage (Brevis et al, 1997).

At the same time, there are some evidence of a important reduction in the variability of age at death in some regions of Latin America (Gonzaga, Queiroz and Machado, 2009), in a process related to what Fries (1980) called the compression of mortality hypothesis. The main idea, developed by Fries, is that survival curves would become more rectangular when mortality levels decline. 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 (1980), 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 implicates a compression-rectangularization process, but a compression-rectangularization happening does not implicate in biological limits to human lifespan (Wilmoth, 1997; Wilmoth & Horiuchi, 1999).

In contrast to epidemiological transitions and mortality in developed countries, the peculiarities of these transitions in Latin American countries suggest some more optimist conjectures for the future longevity of the population (Palloni & Pinto-Aguirre, 2004; 2011). Will some LAC countries are experiencing a reduction in the variability of age at death concomitant displacement of these deaths for ages more go along? How recent changes in the profile of causes of deaths, especially increase in external causes of deaths, could affect trends in the variability of age at death in Latin America? And how could these changes inform mortality forecast? In this sense, the paper discusses old paradigms of mortality studies in Latin America (data quality) and new paradigms (variability of age at death).

2. Data and Methods

2.1 Mortality Data

In order to estimate age mortality pattern in Latin American Countries we make extensive use of the death and population data available on Human Mortality Database (HMD) and Latin American Human Mortality Database (LAHMD). The database contains historical and detailed information on death and population by age and sex. The LAHMD The web-site aims at disseminating human mortality data and literature of human mortality in Latin America, in order to provide detailed information for researchers, students, policy makers and the general public interested in knowing trends and developments in the study of mortality in the region. The project is inspired by the Human Mortality Database (HMD). At present the database contains detailed information on mortality for five countries in Latin America: Argentina, Brazil, Colombia, Mexico and Peru. We use data from populations over various time periods (beginning with the date noted and ending in some recent year): Chile (1920), Mexico (1930), Brazil (1979), Argentina (1980), Colombia (1980), and Peru (1985), Costa Rica (1963) and Puerto Rico (1960). We also use data from Sweden obtained from the Human Mortality Database.

All information is broken down by age, sex, region and cause of death. Additionally there is information on the academic literature on the study of mortality for these same countries. The data are available for download at www.lamortalidad.org.

2.2. Death Distribution Methods

Several methods based on equations of population dynamics have been developed to evaluate the coverage of reported deaths relative to population. The death distribution methods (DDM) are commonly used to estimate adult mortality in a non-stable population (Timeaus, 1991; Hill et al, 2005). There are four major approaches: the General Growth Balance (GGB) Methods (Hill, 1987), the Synthetic Extinct Generation (SEG) method (Benneth & Horiuchi, 1981), the Adjusted Synthetic Extinct Generation (SEG-adj) method (Hill, You & Choi, 2009), and the Synthetic Extinct Generation plus delta (Dorrington, 2011). The death distribution methods make several strong assumptions: that the population is closed to migration that the completeness of recording of deaths is constant by age, that the completeness of

recording of population is constant by age, and that ages of the living and the dead are reported without error.

In this paper, we estimate coverage of deaths using three approaches (GGB, SEG and SEG-adj). It should be pointed that the results from the three methods show very small differences, even though the assumptions involved for each of them are different (Hill, You and Choi, 2009). This indicates that the methods are reasonable robust, but researchers should be careful when applying and analyzing estimates of adult mortality, especially for small areas and sub-population groups.

The GGB method is derived from the basic demographic balancing equation, which expresses the identity that the growth rate of the population is equal to the difference between its entry rate and exit rate. This identity holds for open-ended age segments $x+$, and in a closed population the only entries are through birthdays at age x . The entry rate $x+$ minus the growth rate $x+$ thus provides a residual estimate of the death rate $x+$. If the residual estimate can be calculated from population data from two population censuses and compared to a direct estimate using the recorded deaths, the completeness of death recording relative to population recording can be estimated (Hill, 1987; Hill, Choi & Timeaus, 2005; Hill, You & Choi, 2009). The GGB method use information on deaths and growth rates accumulated above a series of ages x . If there is some age x above which net migration is negligible, the performance of the methods above that age will be unaffected. In this paper, since we are working with sub-national populations we used the age range 35+ to 65+, as done elsewhere (Hill et al, 2009; Queiroz, 2011) to avoid possible problems of migration and also to overcome limitations of old age errors (in age declaration).

The SEG method makes no formal allowance for any systematic error in population growth rates, as would be caused by an across-the-board change in census coverage, though Bennett and Horiuchi (1981) suggest the possibility of adjusting for any such change by adding or subtracting a constant from all age-specific growth rates. Bennett and Horiuchi (1981) also explore the sensitivity of their SEG method to deviations from other assumptions, but without examining combinations of errors. An additional shortcoming of DDMs should be noted: that they compare a distribution of deaths to an intercensal population; thus they strictly estimate

intercensal completeness of recording, not the completeness at the beginning or end of the intercensal period. The implications of these assumptions for estimates will be discussed later.

The issue of the reference period of the deaths is of particular importance when a distribution of deaths comes from data on household deaths collected by the latter of the two censuses. Say the deaths pertain to the year before the second census. Their age pattern will reflect the age distribution of the population shortly before the second census, not to the average age distribution of the population over the intercensal period. In order to take this into account, we should first use the deaths and the population from the second census to calculate age-specific death rates, and then estimate average annual deaths for the intercensal period by applying the death rates to an estimate of the age distribution of the intercensal population.

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The assumption of both the SEG and GGB methods that the population is closed to migration is also of importance to Peru, since it has experienced recent net emigration. Both the SEG and GGB methods use information on deaths and growth rates cumulated above a series of ages x . If there is some age x above which net migration is negligible, the performance of the methods above that age will be unaffected. Though we present results for all ages, we focus on results from age 35 and up as being most robust to possible distortions introduced by migration. The intercept and slope of the GGB method were obtained by orthogonal regression to points for the ages 35+ to 75+. The coverage of deaths for the SEG method was obtained by averaging the estimates for the age ranges 35+ to 75+. Finally using GGB

estimates to adjust the data for the estimated census coverage change and then applying the SEG method applied the combined method.

2.3 Estimates of death rates and survival curves by single age

First, we estimate five-year age group death rates to deal with possible problems of age declaration. Then, we use a relational model (Himes, Preston & Condran, 1994; Palloni & Pinto-Aguirre, 2011) to fit and extrapolate the mortality rates from 5 to 110 years old for all countries, years and sex in 7 Latin American Countries. That strategy allows us to produce a linear relationship between a logit transformation of the observed death rates and the same transformation in “standard” death rates. Then, the age pattern of mortality in the population under study can be expressed as the following linear function:

$$\Psi_{j,t}(x) = \alpha_{j,t} + \beta_{j,t}\Psi_s(x) \quad (1)$$

Where: $\Psi_{j,t}(x)$ is a logit transformation of the death rate at age x in population j and year t ; $\Psi_s(x)$ is a logit transformation of the death rate at age x in the standard and $\alpha_{j,t}, \beta_{j,t}$ are parameters to be estimated for each population and year.

In order to apply the relational model in (1) we need to find a “good standard” that can express the mortality pattern for LAC. After get the pattern we can use (1) in order to estimate the mortality rates for each country and year (separately by sex).

The strategies that we used to find the LAC Standard Mortality Patterns was very similar to that proposed by Himes, Preston and Condran (1994). Based on the pooled data with observed adjusted mortality rates by country, year, sex and age (five-year-age from 5 to 85+ or 100+ depend on the data availability for each country) we constructed the Standard by estimating the following ordinary least squares for each sex:

$$\Psi_{j,t}(x) = \delta + \sum \beta_x I_x + \sum \lambda_{j,t} C Y_{j,t} \quad (2)$$

Where, $\Psi_{j,t}(x)$ is a logit transformation of the observed death rates in the country and year t ; I_x is a dummy variable for age x ($=1$ if the death rates relates to age x , 0 otherwise). Since we have five-age intervals, we have considered the middle of each five-age intervals from $7.5, 12.5, \dots, 107.5$. Then we have 20 dummies for age. CY_j is a dummy variable for a combination between country j and year t ($=1$ if the death rates relates to country/year j, t and 0 otherwise). Since we have 38 country/year combinations we have 37 dummies of which Chile/1920 was omitted as reference category. $\delta, \beta_x, \lambda_{j,t}$ are the parameters appropriate that need to be estimated;

After estimation of the model (2) we have one β coefficient for each age and one λ coefficient for each country/year combination. In order to get a logit of the standard death rate at age x from $7.5, 12.5, \dots, 102.5$ exact years old we used the mean of the λ coefficients to obtain a predict value for the entire sample. Then, as was done by Himes, Preston et al (1994), we used weighted least squares regression to fit and extrapolated the logit of the standard death rates from age 5 to 110 (one-year-age interval). The weights are the number of observations (country/period combinations) available for each age.

Those adjusted and extrapolated logit standard rates, by single ages, were used on the relational model in equation (1) in order to get smoothed logit death rates by sex and single ages for each country and year. Finally, to recover the age-specific death rates for each country and year we used the following relation:

$$\widehat{M}_{j,t}(x) = \frac{1}{(1+e^{\widehat{\Psi}_{j,t}(x)})} \quad (3)$$

Where: $\widehat{\Psi}_{j,t}(x)$ is a smoothed logit death rate in the country j , year t and age x and $\widehat{M}_{j,t}(x)$ is a smoothed death rate in the country j , year t and age x .

2.3 Variability of Age at Death: interquartile range

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 Latin American Countries it is not yet known whether the ongoing process of mortality decline will lead to the same situation.

The interquartile range (IQR) based on the survival function (l_x) is a leading indicator of the variability of age at death (Wilmoth and Horiuchi, 1999). Together with measures of central tendency of age at death, the IQR has been used to evaluate the compression of mortality hypothesis (Fries, 1980). The IQR measures the concentration of deaths between first and second quartile around median age at death. All we need to do is to find the exact ages where survival function is equal 0,75 e 0,25, respectively. Then the age range between $l_x = 0,75$ and $l_x = 0,25$ represents the IQR. van Raalte, and Caswell (2012) provide a detail overview of different methods to calculate lifespan variation and its limitations.

3. Results

3.1 Evolution of death counts coverage data

The quality of mortality data in Latin America, for both males and females, improved steadily over the last half-century. Death registration coverage in the 1960s, in countries such as Brazil, Mexico and Argentina, were about 60% in the 1960s and reached 100%, or almost 100% completeness in the most recent intercensal period. The vital records in Chile are considered to be complete since the 1970s and show a very good quality.

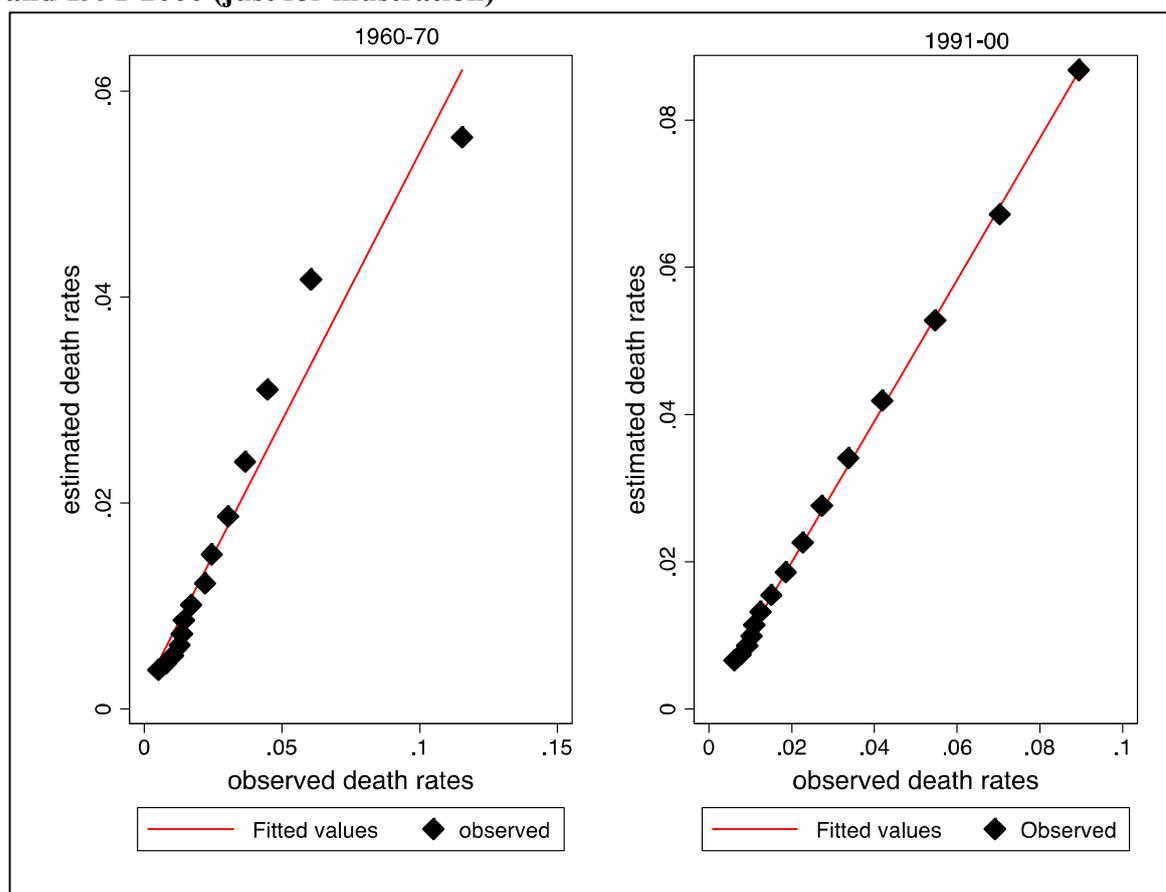
Mortality data from the 1960s and 1970s are very limited. Diagnostic plots produced by the General Growth Balance method, we show results for Brazilian females to illustrate the changes in the last few decades, the x-axis shows the observed death rate for ages $x+$, and the y-axis represents the death rates for ages $x+$ obtained by residual. The slope of the fitted line to the points estimates the adjustment factor necessary to correct observed death rates to the death rates estimated by residual. The intercept of the line provides an estimate of the relative coverage between the two censuses used in the analysis. The analysis of the graph indicates the improvement in data quality overtime in Latin America. In general, for the earlier decades the points at young ages for both males and females are very irregular and off the fitted line, and the estimate of census coverage indicates better coverage in the first census what is consistent with problems arising from low quality, net emigration and errors in age declaration. Overall, the fit of the observations (death rates) improved over time and are relatively good for the most recent periods. The estimates are even better when fitting the for age groups 35 and above. In general, from 1990 (and for some countries since 1980) the results imply that age reporting is good and the assumptions of the methods are met.

Table 1 – Estimates of death counts completeness, Latin America, 1950-2000

Period	Argentina	Brazil	Chile	Colombia	Mexico	Peru	Puerto Rico
Males							
1950			115.7				
1960	50.32		123.1	135.1			138.7
1970	145.3	59.02	113.4	97.82			119.1
1980	95.89	84.3	107.1	109.1	111.0	72.0	128.3
1990	95.7	94.6	101.46	97.8	100.0	77.0	116.2
2000		98.0			100.0		
Females							
1950			123.4				
1960	45.0		126.4	173.9			171.6
1970	192.5	70.99	113.19	101.1			123.4
1980	88.0	76.3	106.86	102.7	115.1	72.0	120.3
1990	100.0	90.0	95.59	111.5	98.0	81.0	104.8
2000		96.0			100.0		

Source: Latin America Human Mortality Database

Figure 1 – General Growth Balance, diagnostic plots, Brazil, females, 1960-1970 and 1991-2000 (just for illustration)

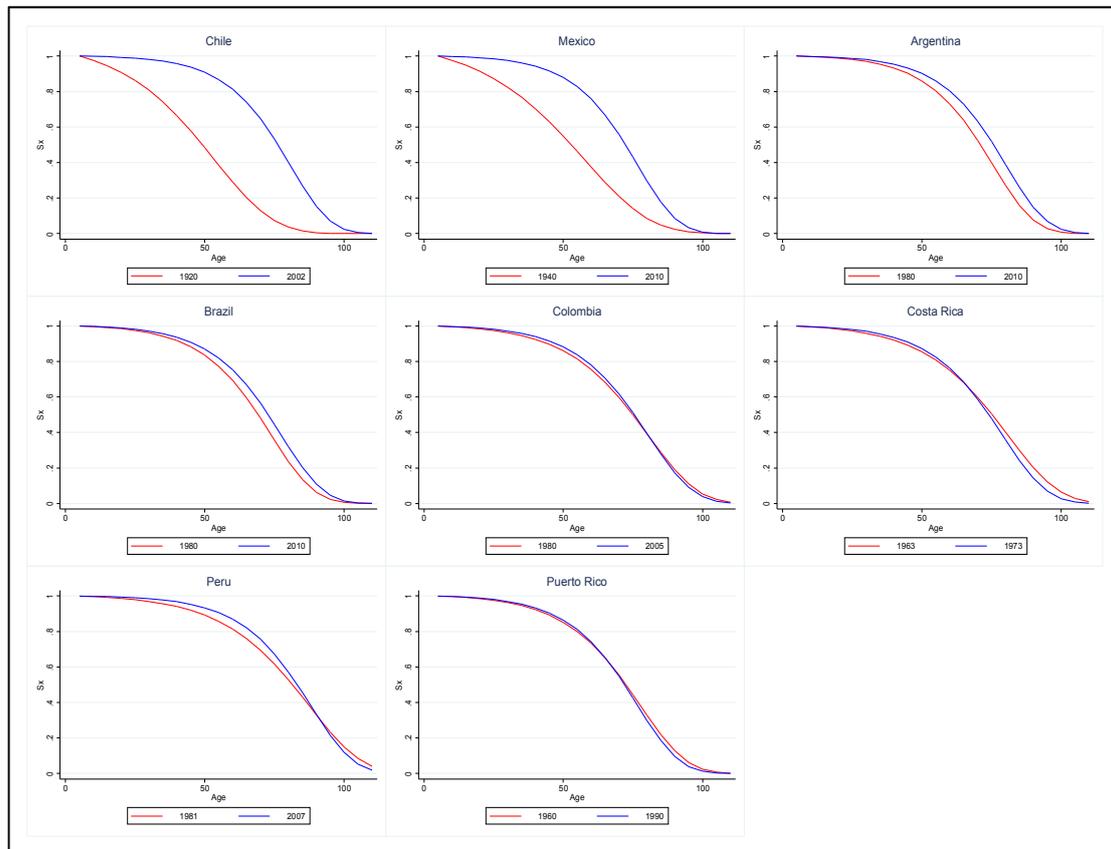


Source: Latin America Human Mortality Database (2013)

3.2 Evolution of Survival Curves

Figure 2 show survival curves, for males, in the first and last year of available data. The changes in the age profile are clearer for Chile and Mexico that have the longer series. In both countries it is possible to observe a movement towards a more rectangle survival curve as is observed in more developed countries. Since the curves do not show age groups below 5, one cannot observe the fast decline in infant and child mortality. It is also interesting that in some countries, more specific Brazil and Colombia, changes in the probability of survival change very slowly for young adults. This pattern is mostly explained by the increase in external causes of deaths (violence and accident) that happened in the 1980s and early 1990s in the region.

Figure 2- Estimated survival curves (S_x), Latin America, males (extreme points)



Source: Latin America Human Mortality Database (2013)

The changes in mortality levels in Latin America implied in a rapid change in the life expectancy at birth. On average, the countries we studied observed an improvement of life expectancy at birth of almost one year (1) per decade. For instance, in Chile life expectancy went from 52 years in 1950 to about 75 years in 2005. For males, in Brazil, life expectancy at birth was about 60 years in 1980 and went to almost 70 years in 2005. Similar trend is observed for all countries and both sexes in the past few decades.

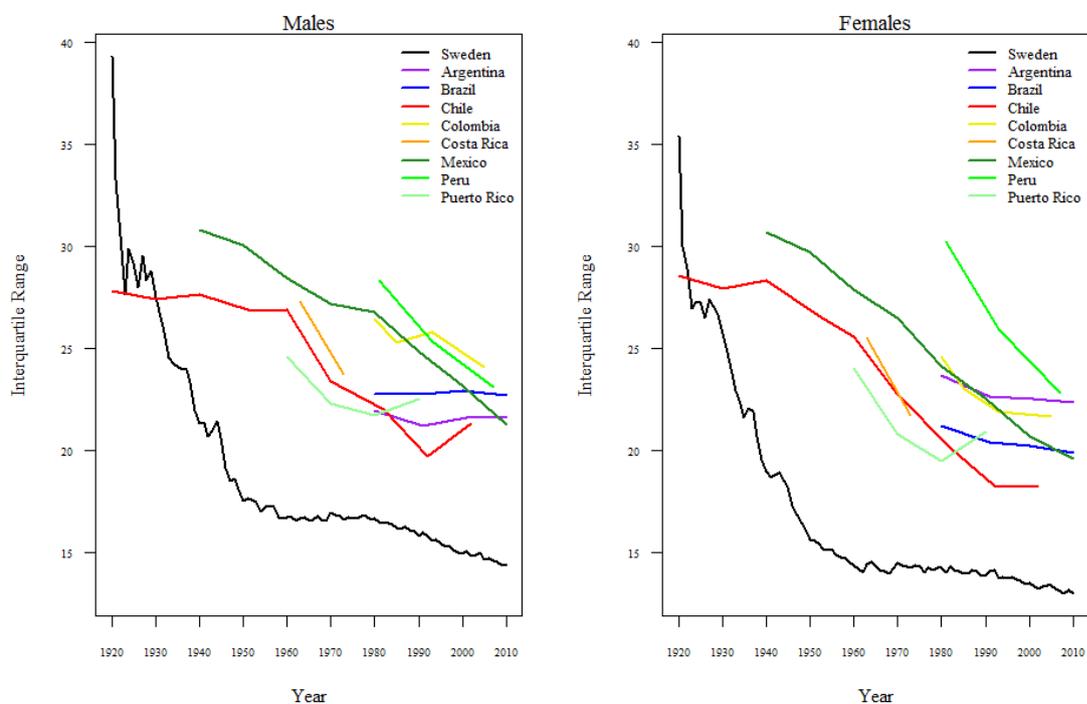
3.3. Variability of age at death

We show the interquartile range (IQR), in Figure 2, as a measure of variability at age of death for countries in this paper. Wilmoth and Horiuchi (1999) discussed different measures of variability and compression and argue for IQR and the more objective and simple one. We also plot estimates for Sweden from 1920 to 2010 in order to compare the changes in the mortality variation and concentration in Latin America.

We obtained data for Sweden from the Human Mortality Database. Wilmoth and Horiuchi (1999) studied the compression of mortality in Sweden in more detail.

In the early 1920s, for both sexes, the IQR in Sweden was higher than Chile, the only LAC country with available data in the early 1900s. This higher variability in age at death could be explained by high incidence of young adult mortality due to tuberculosis (Horiuchi, 1999). It is also possible that since infant and child mortality in Chile, around 1920, were so much higher than in Sweden that those who survived the first few years of live went on to die in more concentrated ages. On the contrary, deaths in Sweden were more distributed across the age range in the same period of time, especially for young adults. However, the levels of IQR in Sweden fell very rapidly during the following decades. Among Latin America countries the reduction in the variability of age of death was much slower. For instance in Chile significant declines in IQR starts 20 years after Sweden for females. For males, more significant decline in the variability of the age at death started only in the 1960s.

Figure 3: Interquartile Range (IQR), Latin America, by sex, 1920-2010



Source: Latin America Human Mortality Database (2013) and Human Mortality Database

Despite the short period of analysis, Costa Rica shows the strongest IQR decline among all countries we investigated. Despite not having access to a longer series of mortality data for Costa Rica, we observed the country is moving rapidly to a variability level compared to more developed countries in later stages of the demographic and epidemiological transition. It was also noted in a recent paper, by Rosero-Bixby (2008), the concentration of mortality at older ages in Costa Rica and the low levels of mortality for those aged 90+ in comparison to a series of developed countries.

In Mexico, for both sexes, we also observed significant changes in the variability of age at death. The variability of age at death decreased from more than 30 years (for both sexes) to under 20 years for females and 21 years among males. That represents almost 10 years compression of mortality in 70 years period. It is interesting, and somewhat surprising, that trends for both sexes follow similar pattern. It is also interesting to note that we could not find any significant impact of the recent rise in the number of deaths by external causes among young adults, as noted in a paper to be presented in the IUSSP meeting by Canudas-Romo.

Chile shows an unusual development in the mortality compression indicator, at least among males in recent years. Between 1990 and 2000, the interquartile range showed a considerable rise, that is, an increasing trend in the variability of age at death. The same tendency is observed in Porto Rico for both sexes. This fact holds perhaps due to association with external causes of death that are also increasing in both countries, and that is avoiding further development of mortality compression.

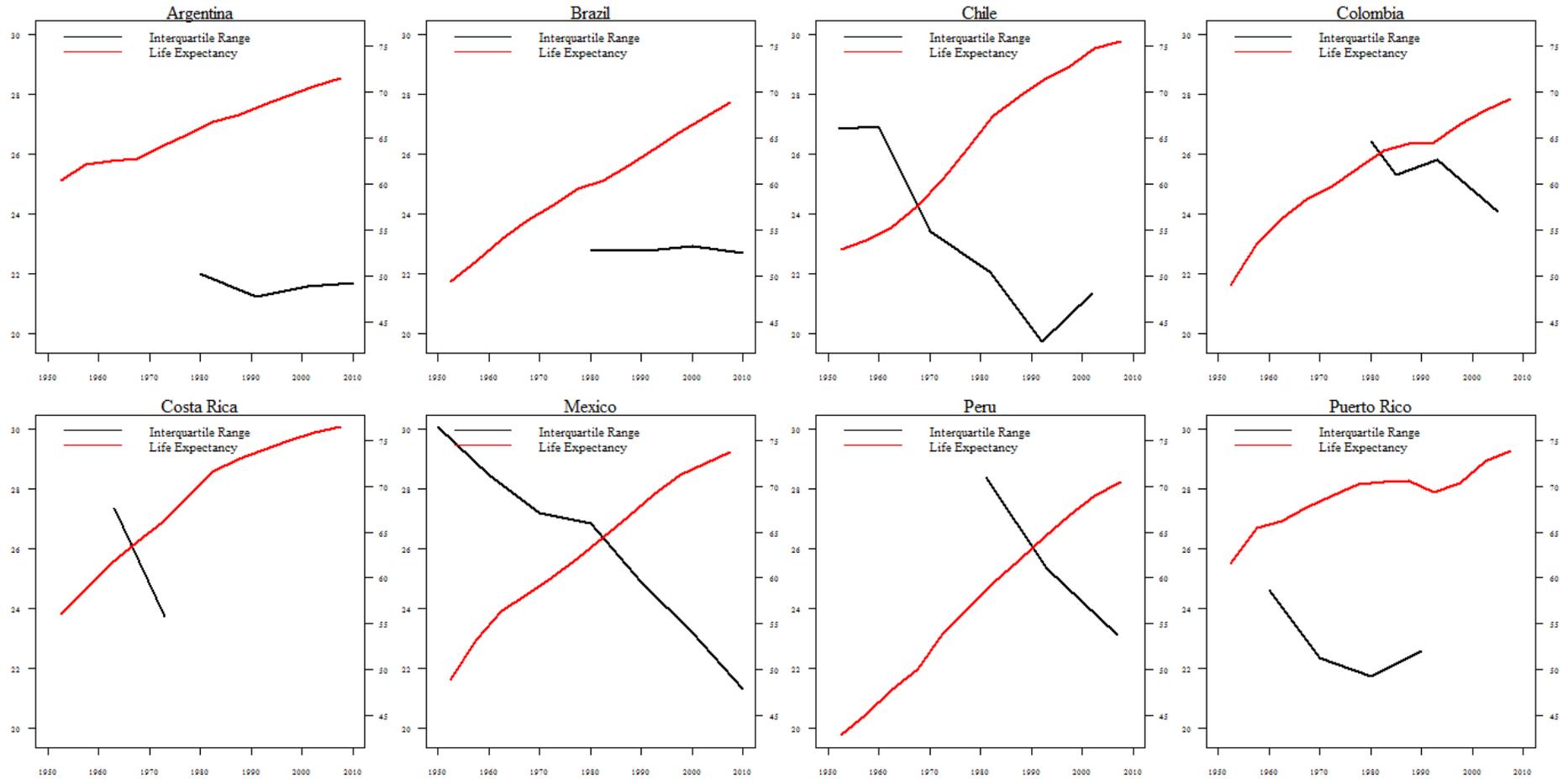
In Argentina and Brazil, we observed a slightly reduction in female variability of age at death between 1980 and 1990 but, for more recent years, the IQR is quite stable and almost unchangeable. Furthermore, Argentina is the only where the variability in age at death is higher among females compared to males. Of course, we need to be cautious and do not jump into harsh conclusions since data quality maybe play a role in these results. The most striking result is found in Peru, which shows a later onset in mortality compression followed by a fast decline in IQR during the following years. In 26 years, the mortality has been compressed by 5 to 7 years. This means that for

each 1 year that has passed, the variability in age at death was reduced by 2 to 3 months.

Figure 4 and Figure 5 shows that as life expectancy at birth increase we observe a decline in the variability of the age at death. This finding holds with Canudas-Romo (2008) conclusion, which states the increasing modal age at death illustrates changes from a dominance of child mortality reductions to a dominance of adult mortality reductions. This process has been described as a shifting mortality process where the bulk of deaths around the modal age at death move toward older ages. Probably, this process has taken place in many Latin American and Caribbean countries for the last fifty years.

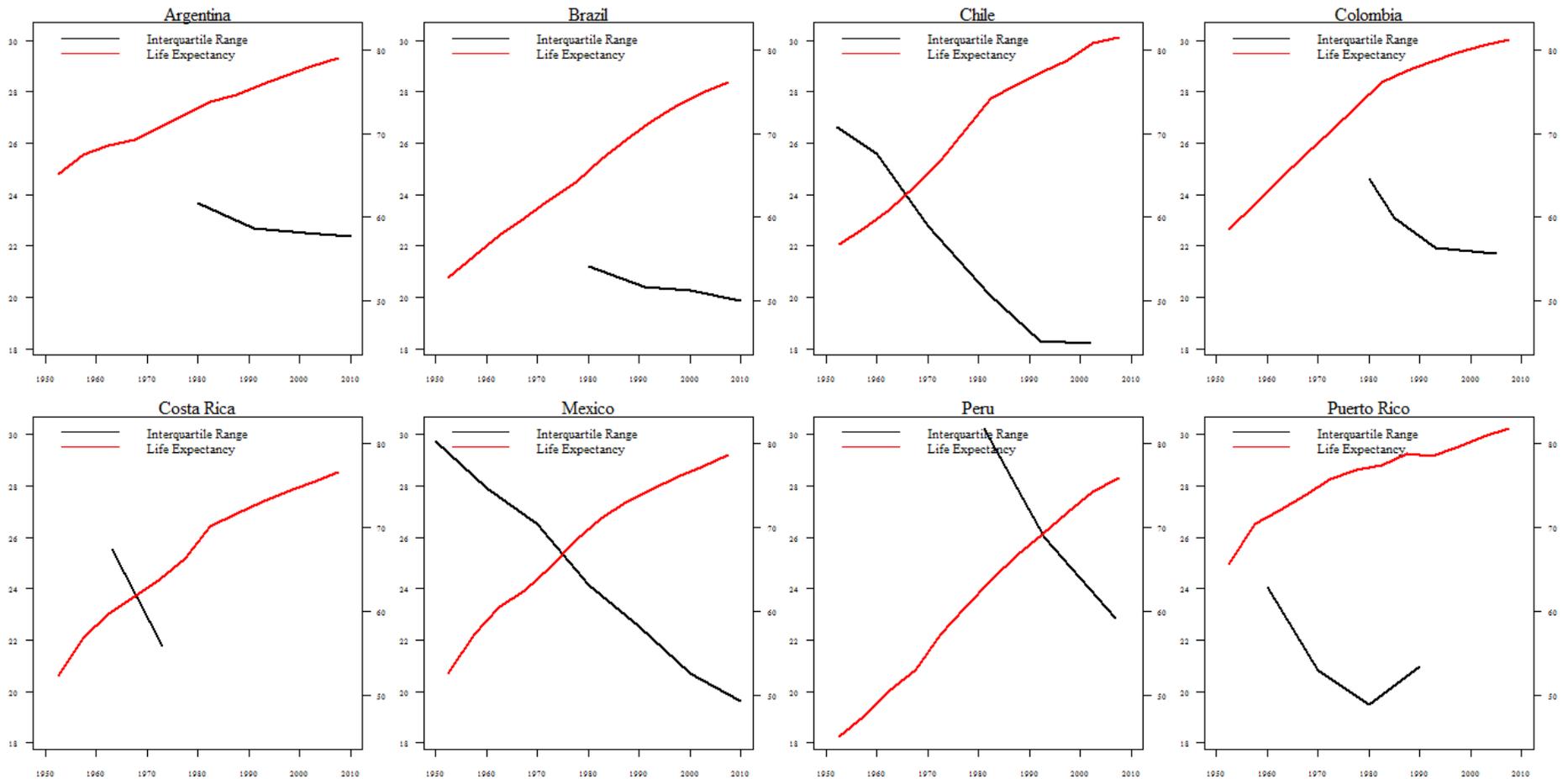
However, countries in Latin America are at different stages of this transition. Peru, for example, still presents high levels of child mortality if compared to other Latin American and Caribbean countries, like Chile and Costa Rica (Guzman et al., 2006). But, Peru has also showed the most expressive gains in mortality reduction in the last five decades (Guzman et al., 2006). Moreover, these gains might, in the future, imply in the continuous increase in life expectancy together with a concentration of deaths around one age.

Figure 4: Interquartile range and life expectancy at birth, Latin America, 1920-2010, males



Source: Latin America Human Mortality Database (2013)

Figure 5: Interquartile range and life expectancy at birth, Latin America, 1920-2010, females



Source: Latin America Human Mortality Database (2013)

The relationship of IQR and life expectancy is also clear when we look at the countries like Colombia and Puerto Rico. Between early 1980s and mid-1990s, the male life expectancy in Colombia, for example, has almost stabilized around 65 years, and during the same period the IQR varied between 26.4 to 25.8 years. After 1993, life expectancy increased again and the interquartile range declined to 24.07 years. Moreover, in Puerto Rico, between 1980 and 1990, life expectancy even decreased and that reflected in an increase IQR from 21.7 to 22.6 years.

4. Discussion and Conclusion

In this article, we evaluate the quality of information on deaths available for a series of Latin America countries in the past half-century. We contributed to the analysis of data quality, following Palloni and Pinto-Aguirre (2011), by producing estimates for males and females separately. The results indicate that the quality of mortality data is improving over time for all countries included in this study, and could be considered of high quality and can be a very useful tool for studies of mortality in Latin America. We

We also examined the changes in the mortality pattern of the population in each country in the past few decades, in order to identify changes in the variability of age at death. A reduction in this variability, accompanied by a shift in the distribution of deaths for older ages, would indicate that the process of compression of mortality, observed today in most countries experiencing low levels of mortality. The analysis of reduced variability of age in some developed countries such as Japan and the U.S., indicated that the reduction in variability was also low, as observed for most of Latin America countries. For example, for Japan, between 1961 and 1971 (life expectancy at birth, respectively, 69.4 and 73.5, close to what is observed in Latin America in recent years) the variation in IQR (17.5 and 15.9, respectively) was 1.60. In the case of USA, between 1951 and 1981 (life expectancy at birth, respectively, 69.1 and 74.5) the variation in IQR (20.6 and 19.4, respectively) was 1.20.

The analysis by sex indicates that variability of age at death for females is less significantly less than for males. This difference in variability of age at death

corroborates historical analyzes performed in developing countries. This may be associated with a lower risk exposure or a lower socio-economic heterogeneity and biological among women. Another interesting aspect of the analysis by sex is the clearest trend among men in the process of compression of mortality. One possible explanation would be the fact that, among women, the gains in survival at older ages were higher than among men, as observed in this study and also corroborated by other studies. This would indicate that the distribution curve of female deaths is undergoing a shift toward more apparent older ages.

The study of compression of mortality and variability of age at death are very important and contribute to a better understanding of the evolution of health status of the elderly population, especially regarding the duration of active and disable years of life around the age of death. In fact, a reduction in the variability of age at death concomitantly with the increase in the average age of death is of crucial importance for public health planners, since the diseases that affect these individuals are chronic, mostly requiring monitoring of conditions these elderly health over a long period of time. As pointed by Canudas-Romo, et.al (2010) delay mortality implies that a more heterogeneous group of the population is reaching older ages and we can expected that health differential and disparities that we common in early life in Latin America are now moving towards older age groups. In the near future, health systems in Latin America, and families, will have to deal with a larger and more diverse group, regarding health status, at older ages. This might imply larger costs and more complex interventions to mitigate the differences.

This is a preliminary investigation of the variability of the age at death in Latin America. Additional studies, including more countries and other measures, should be pursued. A better understanding of trends in the variability of age at death (dispersion of life span, modal age at death, compression) might be very informative and useful to produce better mortality forecasts.

An important limitation of the study is related to the data sources used to produce the estimates of survival curves. In addition to the under-registration of

death counts in most of the vital registration systems in Latin America, we might find problems with errors in the age declaration of age, which may occur in the source of deaths and population. The tendency to over-state the age is lower in death records compared to live population. In this case, considering that defective age declaration is higher in the census than in the registration of deaths, at advanced ages, where the errors are larger, an over-statement of ages in the census may underestimate the specific mortality rates and the result would be a lower number of estimated deaths at these ages. If the trend in the census is to declare an age lower than the true number of deaths at older ages could be over-estimated, leading to the false impression of a higher concentration of deaths at advanced ages. However, it is reasonable to assume that the standard errors of the old statement has been roughly constant over time, the results would not be compromised, because the changes in the variability of age at death are related to changes in the structure of mortality and not on their level. An additional limitation refers to the use of period data to estimate compression of mortality in a period of declining mortality. The trends would be better observed if we had available cohort mortality data. But, as pointed by others, our results provide, at least, a conservative measure of the compression of mortality in Latin America.

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