Published in final edited form as:

Res Aging. 2016 April ; 38(3): 283–298. doi:10.1177/0164027515620245.

The Effect of Changes in Educational Composition on Adult Female Mortality in Brazil

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Abstract

The last century in Brazil was witness to profound changes. Female life expectancy at birth increased from 34.6 years in 1910 to 77.26 years in 2010. At the same time, the educational composition of the population has changed dramatically. In the 1940s, only 25 percent of the children aged 5 to 14 years old were enrolled in school. Currently, nearly all children attend school. We examine the extent to which changes in the age-specific distribution of education have contributed to the decline in adult mortality among women in Brazil. Our analysis follows other applications in the literature to measure the mortality reduction that would occur if exposure to specific risk factors were changed at the counterfactual level. The effects are not trivial: between 1960 and 2010, about 38 percent of the increase in life expectancy at age 30 can be attributed to changes in the educational composition of women. An additional 22 percent increase is expected until 2040.

Keywords

adult mortality; education; Brazil; longevity gains; mortality differentials

Introduction

The last century in Brazil was witness to profound social, economic and demographic changes. Following the pioneering societies in the demographic transition, both mortality and fertility declined rapidly after the 1940s. According to the Brazilian Census Bureau, female life expectancy at birth increased from 34.6 years in 1910 to 77.26 years in 2010 due in particular to a significant reduction in infant mortality (Valle e Silva e Barbosa, 2003). As expected, this process has not ended. As life expectancy in Brazil has been below that of other Latin American countries and most developed societies, mortality gains will continue to improve, mostly at adult and older ages. Explanations of the mortality transition in Brazil range from large improvements in public health, including immunizations, sewage treatment and the creation of a universal public health system after 1988, to the sharp increase in income levels throughout the last decades (Merrick, 1985; Sastry, 2004; Sawyer, Fernandez-

Castilla, Monte-Mor, 1987). Unfortunately, previous research has paid little attention to the effects of educational changes on survival gains in the more recent decades.

Examining the association between adult mortality and education helps cast light on the causes of disease and death, which may lead to better public policies and improved distribution of overall well-being. Not surprisingly, the international literature has extensively examined this issue and demonstrated the existence of a negative association between education and mortality in both the U.S. (Kitagawa & Hauser, 1973; Feldman, Makuc, Kleinman & Cornoni-Huntley, 1989; Elo & Preston, 1996; Cutler, Lange, Meara, Richards & Ruhm, 2010) and various European countries (Valkonen, 1993; Vagero & Lundberg, 1995; Kunst & Mackenbach, 1994; Huisman *et al.*, 2004). Many other studies have already looked at the mechanisms used to explain this association by emphasizing the roles played by higher income and occupational status, better family background and childhood conditions and health related behavior changes, along with several other variables at the household and community levels (Leigh 1983; Preston & Taubman 1994; Liu, Hermalin & Chuang, 1998; Hayward & Gorman, 2004).

Ironically, in the case of Brazil and many other developing countries experiencing educational inequality, it remains unclear as to how the distribution of education translates into survival disparities, which affects the mean level of mortality. Whereas Brazil has a long tradition of studies on socioeconomic inequality (e.g. Barros, Foguel & Ulyseia, 2006), the greatest difficulty is in finding reliable data to generate robust estimates that correlate individual characteristics to mortality. Brazil lacks nationally representative mortality follow-up studies. Community-based samples from particular geographic areas are available, but raise questions of external validity. In addition, conventional mortality data (death records and demographic census data) suffer from a lack of information and inconsistencies in the reporting of socioeconomic variables. For example, death records miss, on average, almost one third of the education information of the deceased and, certainly, omissions in this case are not random. To overcome these limitations, at least partially, scholars have examined mortality differentials at different geographic levels and according to the distribution of several aggregated socioeconomic variables, such as household income, Gross Domestic Product (GDP) per capita, literacy rates and varying other measures. These studies have confirmed that better social indicators, such as better literacy rates, increased urbanization or GDP per capita, are highly correlated with greater life expectancy (Wood & Carvalho, 1988; Duarte, Schneider, Paes-Sousa, Silva & Castillo-Salgado., 2002; Messias, 2003; Ishitani, Franco, Perpétuo & França, 2006; Drummond & Barros, 1999; Silva, Paim & Costa, 1999; Szwarcwald *et al.*, 1999).

Despite these efforts, no one has looked at how the education transition has affected mortality gains in Brazil. At the macro level, a better education distribution may have reduced mortality indirectly through the improvement of other social and economic dimensions, including higher economic growth and lower inequality and poverty rates. However, there is also a more direct association that comes from compositional changes. If relative mortality risks among adults vary significantly across education levels in Brazil, as in most parts of the world, one should expect an increase in life expectancy resulting from a more favorable relative distribution of the population by education. We hypothesize that the

compositional effects on life expectancy are not trivial given the documentation of profound changes in both mortality and education levels over the last decades. Since the previous literature on the evolution of adult life expectancy in Brazil has neglected these compositional effects, we attempt to fill this void by examining the extent to which changes in the age-specific distribution of education, between 1960 and 2010, have contributed to the decline in adult female mortality. Our study is based on individual data and benefits from the use of new mortality estimates by education level in Brazil, which have been discussed elsewhere (Renteria, 2010; Renteria & Turra, 2009). We also speculate about further potential declines in adult mortality by comparing actual and counterfactual mortality measures by utilizing the education scenario projected for 2040.

The association between educational changes and mortality gains is particularly important in Brazil, where a deep education transition is taking place. Whereas, the political discourse to improve children and youths' access to education has been present since the country's first constitution in 1824, it took more than a century for public investments in education to begin. Accordingly, in the 1940s, only 25 percent of the children aged 5 to 14 years old were enrolled in school. In this context of historical neglect, the main goal of the last decades has been to ensure universal primary schooling and eliminate illiteracy. Following the promulgation of the 1988 constitution, the national government promised larger public transfers to education. As a result, the Brazilian educational system has undergone major improvements in access to schooling, as well as to the retention of students. Current data indicate that nearly all children aged 7 to 14 years old attend school (Rios-Neto & Guimarães, 2010). The gross enrollment rate for the secondary education level is also high at about 80 percent (INEP, 2012). However, the dropout rate from upper secondary schooling is also relatively high, as reflected in the low proportion of students in the 16 to 18 year old age group who graduate (63 percent in 2011) (OECD, 2013). With regard to the tertiary education level, Brazil experienced a significant expansion in college enrollment, from 2 million to 4.5 million students, between 1997 and 2005. This occurred for both tuition-free public universities, but was more intensive for tuition-charging private higher education institutions (INEP, 2012). According to the OECD (2011), 65 percent of Brazilian upper secondary graduates (or 34 percent of the age group) entered bachelor's-level higher education programs in 2011. However, these figures are still very modest compared with those from other countries in the region.

The purpose of this study is to explore whether these transformations in educational attainment have resulted in improved mean levels of female mortality by answering the following question: What would happen to female mortality measures if the only change during the period of analysis had been the education profile of adult women? To do that, we benefit from adult mortality estimates by level of education available from a recent study in Brazil (Renteria 2010). There are two reasons for examining the effects exclusively on women. First, the education transition among women has been substantially faster than among men. Recent data for Brazil evidence gender differentials in the trend toward greater educational attainment, especially in the high school and college levels. Since the 1980's, net attendance rates in Brazil are growing, but female students often outnumber their male counterparts. Using data from National Representative Samples, Rios-Neto et al. (2010) showed that, from 1981 to 2008, the net attendance rate for females and males was close to

100% in the primary level, with no systematic differences by sex. However, for the high school level, the net attendance rate went to less than 20% for both sexes in 1981 to 53% for males and 67% for females in 2008. In the addition, in the college-level, gender disparities in educational attainment increases are clear: the net attendance rate went to less than 6% for both sexes in 1981 to 37% for males and 46% for females in 2008. These differences are even more evident when comparing different birth cohorts, since men were more likely to attain higher educational levels than women in the first half of the XX century in Brazil.

There is a second reason that explains our focus on women. Mortality estimates by education levels available in this study come from orphanhood data (Renteria 2010). It is well known that surviving children report poorly about the survivorship of their fathers than mothers (Preston et al. 2001), and therefore, our adult mortality estimates are for women only.

Methods

Analytic Strategy

In order to estimate the proportion of female deaths at a particular age and period that is attributable to changes in education composition, we hypothetically redistribute the population at the baseline year according to the distribution of women by education level at the end of the period of analysis. We then calculate the proportional reduction in mortality that would occur under this redistribution, which is also known as the population attributable fraction (PAF). Our analysis follows other applications in the literature (e.g. Mehta & Change 2009; Preston & Stokes 2011), which also estimated the PAFs to measure the population mortality reduction that would occur if exposure to specific risk factors were changed to a counterfactual level. We estimate age-specific PAFs for the female population in Brazil as

$$PAF_i = \frac{\sum P_{ij}RR_j - P_{ij}^*RR_j}{\sum P_{ij}RR_j}$$

where, P_{ij} is the proportion of the population at each age group i and education level j in the baseline year, P_{ij}^* is the counterfactual proportion of the population at each age group i and education level j (as of the education level at the end of each period of analysis). RR_j is the relative risk of mortality by education level. One should note that in our estimates RR_j does not vary by age. Therefore, as it will be discussed later, we apply the same relative risk ratios for all age groups. We measure education according to three categories: none, 1–8 years, and 9 or more years of schooling. Age is measured in 5-year age groups from 30–34 to 65–69.

We calculate the proportion attributable fraction (PAF) for each age group over two periods: 1960–2010 and 2010–2040. We apply the 1960–2010 age-specific PAFs to the death rates in 1960 to estimate what the rates would be in 1960 under the scenario of educational attainment observed in 2010. Further, we apply the 2010–2040 age-specific PAFs to the death rates in 2010 to calculate future mortality gains, under the scenario of education

attainment projected for 2040. Instead of simply comparing age-specific death rates for the actual and counterfactual scenarios, we calculate two life table measures: life expectancy at age 30 truncated at age 70 and the probability of surviving between ages 30 and 70. We estimate the life tables by applying the methods described in Preston et al. (2001).

Data

Mortality Risk Ratios by Education (RR_i)

The relative mortality risks specified in Equation 1 are obtained from a recent study that estimates adult mortality by education in Brazil based on individual data (Renteria & Turra 2009; Renteria 2010). Renteria (2010) was inspired by the orphanhood method for adult mortality, which was developed by Henry and Lotka and later improved upon by Brass and Hill. The technique combines information on mother's survival and mother's education, drawn from the 1996 Living Standards and Measurement Survey in Brazil, to estimate mortality rates for different subgroups of women. Renteria developed a stochastic method to randomly generate the main parameters of the model (age at maternity and age at death) and estimate the period of exposure for each respondent's mother. She then fit a Poisson regression to model the number of female deaths as a function of age, education level and period of exposure. Luy, Di Giulio & Caselli (2012) generated a similar methodological approach, following Brass's original method, although they did not build individual life histories as in Renteria's (2010) design.

To obtain robust estimates, Renteria (2010) limited the sample to women ages 30 to 70 years old. Interaction terms between age and education proved not to be statistically significant in the models, despite earlier findings for the U.S. and other western countries demonstrating a decline in SES mortality differences by age (Kitagawa & Hauser, 1973; Elo & Preston, 1996; Lauderdale, 2001; Marmot & Shipley, 1996). In addition, no significant variations were found for different cohorts of women. Table 1, included below, summarizes the coefficients and their corresponding standard errors and relative risk ratios for the three education categories. Not surprisingly, the differentials are substantial and suggest that obtaining at least 9 years of schooling can more than halve the risk of dying. In our study, we assume that these estimates are applicable for the entire period of analysis and are invariant by age. Therefore, as mentioned before, when estimating the age-specific PAFs, we use the same relative risks of mortality by education for all age groups and for the two periods of analysis. Also, we restrict our calculations to the ages 30 to 70, in order to keep our results consistent with the original sample examined by Renteria (2010).

Distribution of women by education and age (P_{ij})

We use census data (MPC, 2014) to estimate the relative distribution of women by five-year age groups and education in 1960. In the 2010 census data collection, the Brazilian Census Bureau introduced a few changes to the questionnaire that affected the comparability of education measures across census years. Therefore, to estimate a distribution of women by age and education in 2010 comparable to 1960, we interpolate household data from the 2008 and 2012 *Pesquisa Nacional por Amostra de Domicílios* (PNAD), a nationally representative stratified random sample of the Brazilian population that has been collected annually, except

during census years, since the late 1970s. PNAD data have been used extensively in the literature on social sciences (see, for example, Marteleto, 2010; Torche, 2010). Since we also estimate potential mortality gains from future changes in the distribution of education, we use the projected education distributions for 2040 prepared by Guimarães (2013). These projections are based on the decomposition and extrapolation of historical trends of age, period and cohort effects.

Figure 1 presents the distribution of women by education and age for 1960, 2010 and 2040. The transformations in the last five decades are substantial. For example, the proportion of women aged 45 to 49 years old with no schooling reduced from 58 percent in 1960 to 9 percent in 2010. At the same time, there was a sharp increase in the proportion of women with 9 years of schooling or more, which was the majority subgroup in 2010, particularly for ages 45 years old and younger. The education transition has not concluded, thus we expect additional changes in the education distribution throughout the next decades. In 2040, almost all women aged 30 to 69 years old are projected to have some schooling, and the largest majority of them (73 to 92 percent, depending on the age group) are expected to have at least 9 years of schooling. If projections are correct, over the entire 80 year period (1960–2040), the proportion of women with 9 years of schooling or more will have increased from a mere two percent to levels above 85 percent.

Female age-specific death rates

We obtained age-specific mortality rates for 1960 from the 2012 Revision of the World Population Prospects, which was prepared by the Population Division of the United Nations (UN, 2013). The rates for 2010 come from the official abridged life table constructed by the Brazilian Census Bureau (IBGE, 2013).

Results

Fractions of all-cause mortality attributable to compositional changes in education by age (PAF_i) are presented in Table 2. Confidence intervals reflect uncertainty in the risk ratios. We show the PAFs for the two periods of analysis: 1960–2010 and 2010–2040. Since we used the same mortality risk ratios for all age groups and time periods, differences in the PAFs depend mostly on the proportion of women in each educational level by age group. Between 1960 and 2010, the fraction of deaths attributable to compositional changes in education varied from 0.175 to 0.313. This fraction is lower at older ages since younger cohorts were more affected by improvements in education. This pattern will probably invert from 2010 to 2040, varying from 0.159 at the 30–34 age group to 0.254 at the 55–59 age group. This occurs because the educational transition is completed among the youth and the distribution of educational gains becomes more concentrated among the cohorts born in earliest decades.

Table 3 presents what would be the impact on life expectancy at age 30, truncated at age 70, as well as on the survival probability between ages 30 and 70, implied by the estimates of attributable mortality to compositional changes in the education profile of women presented in Table 2. Between 1960 and 2010, the actual female life expectancy at age 30 increased 4.12 years, from 33.46 to 37.57 years. Reallocating women in 1960 to the education levels

as of 2010 would increase life expectancy in 1960 to 35.03 years. Therefore, an estimated 1.58 years (95 percent CI = 1.18, 1.93) are attributable to changes in the distribution of women by education; about 38 percent of the actual gains. Consistently, we also estimate an important effect on the survival probability. Throughout the period from 1960–2010, about 23 women out of 100 were saved between ages 30 and 70 because of actual mortality declines (the survival probability increased from 0.56 to 0.79). About eight of these women were saved because of the compositional changes in education alone (95 percent CI = 0.06, 0.10).

We can expect further improvements in mortality levels from 2010 to 2040 because of compositional changes. Reallocating women in 2010 to the projected education levels as of 2040 would increase truncated life expectancy at age 30 to 38.10 years; representing an additional 0.53 years of life. One should notice that the maximum life expectancy between ages 30 and 70 is 40 and thus, the potential gains after the year 2010 are limited to 2.43 years. Therefore, although the projected compositional effects for the next 30 years look small in absolute terms, they still represent about 22 percent of the total potential gains. Likewise, the expected maximum improvement in the conditional survival probability is 0.21 (or 21 lives out of 100). According to our analysis, another five out of 100 women will be saved between ages 30 and 70 because of the compositional changes in education alone.

Yet, there are a few reasons for the effects between 2010 and 2040 to be relatively smaller than those for the period from 1960–2010. First, it is a shorter period of time. Second, compared to 1960, in 2010 there was less room for improvement in the distribution of education as the transition process is already in the more advanced stages. Third, in 2010, mortality rates were already significantly lower than in 1960. Therefore, a similar relative reduction in the mortality rate translates into smaller absolute changes in the number of years a person lived in 2010 compared to 1960.

Discussion

In this article we provide the plausible pure effects of compositional changes in the distribution of education on adult mortality in Brazil. As we show in our counterfactual analysis, life expectancy at age 30, truncated at age 70, would have been 38 percent lower in 1960 if the distribution of education were similar to the one in 2010. Between 1960 and 2010, about 35 percent of the lives saved from ages 30 to 70 were due to more favorable distribution patterns. New mortality gains are expected in the future. However, these gains tend to be relatively lower, compared to those from the 1960–2010 period, with diminishing marginal improvements in the distribution of education by age. Our results should not be viewed as a measure of the direct casual effect of education on adult mortality. Instead, we offer a much less pretentious estimate of the influence of changes in the distribution of education on adult mortality in Brazil. Nevertheless, we still believe this type of analysis is useful for comparing mortality gains over time in a country where (i) the mean number of years of schooling has more than doubled over the course of three decades (from 3.7 in 1981 to 7.5 in 2011) and (ii) educational differences in mortality are substantial. Indeed, the large educational differences in mortality among women in Brazil contrast with the results for developed countries. Brazilian female mortality risk ratios are comparable in magnitude only

to the mortality differentials found for men in the developed world, which is a group known to experience higher health inequality than women (Elo & Preston, 1996; Kunst & Mackenbach, 1994; Huisman *et al.*, 2007).

Whereas our study is innovative for Brazil because it is the first to show empirical evidence of the mortality benefits from the rapid educational transition, the results should be interpreted in the context of several limitations. First, as in any other counterfactual analysis, we isolate only one source of an effect out of many that may have impacted mortality levels during the same time period. Other contributing factors to consider include the implementation and expansion of vertical health programs under the Unified Public Health System. Accordingly, our results reveal that adult mortality gains happened mainly because of significantly lower mortality risks across all education groups. Out of the total lives saved between 1960 and 2010, for example, 65 percent were due to improvements in mortality levels, regardless of changes in the distribution of women by education level.

A second limitation of the study relates to the fact that we measure only the first order effects of composition changes in education. We do not consider any implications that may have arisen from Brazil having a population that is significantly more educated. We believe such higher order effects exist, however, and may include stronger political pressure for improvements in access to health care and better income distribution, for example.

Furthermore, a lack of detailed mortality estimates by education limits the precision of our decompositions. In Brazil, as in many other countries, the mortality gradient by education is probably not restricted to certain education levels. Unfortunately, we are not able to break down the mortality rates into smaller education groups, including the tertiary. This is because the only set of mortality risk ratios available for Brazil is based on large education groups (0, 1–8 and 9 or more years of schooling). Thus, we expect our estimates are underestimated and the true upper limit of the composition effects to future mortality gains will most likely be higher as the female population rapidly moves into tertiary education. According to Guimarães (2013), about 30 percent of the women aged 20 to 59 years old will have 12 or more years of schooling by 2028.

Another limitation of this study is the assumption that relative mortality risks by education are fixed over time. The international literature has shown that mortality differentials by SES have increased over the last decades, although this pattern is true mostly for men (Feldman *et al.*, 1989; Elo & Preston, 1996; Molla, Madans & Wagener, 2004). Improvements in the education profile of the Brazilian population are too recent for its implications to be totally known. Social mobility may have modified the population's composition with respect to other observable and unobservable characteristics, thus affecting mortality variance within the education groups and, therefore, longevity gains for each additional year of schooling. Our hypothesis for Brazil is that longevity gains are diminishing over time as members from the younger cohorts, who have more detrimental family and socioeconomic backgrounds than members of the older cohorts, move up into the higher education groups. This is certainly a central and open-ended question for anyone interested in understanding adult mortality differentials in Brazil and the implications for past and future longevity gains.

Conclusion

On the basis of our results, the rapid and deep transformations of the education profile of the female population in Brazil over the last five decades has increased life expectancy at age 30 (truncated at age 70) by about 38 percent. We project additional improvements – at least another 23 percent – during the next 30 years as the education transition progresses. However, the future effect will depend on the extent to which longevity gains due to increasing education vary because of changes in the prevalence of other sources of mortality risk. Our results reinforce one of the many benefits of expanding education and raising the educational standards in a country where premature adult death is still highly prevalent. We believe our findings indicate the urgency of Brazilian society's need to create the conditions for further improvements in secondary and tertiary education achievements.

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Figure 1. Proportionate Distribution of Women by Age and Education Groups. Brazil: 1960, 2010, 2040

Source: 1960 (Brazilian census data); 2010 (Brazilian household survey data, interpolated); 2040 (Guimarães, 2013)

Table 1

Estimates from the Poisson model for the number of deaths, as a function of age, education and time of exposure, women, Brazil

Education	Coefficient	S.E.	Relative Risk Ratio
None (Reference)			1.000
1–8 years of schooling	−0.340***	0.045	0.712
9 or more years of schooling	−0.772***	0.115	0.462

Notes: Although not shown, the model includes controls for age.

p<.01

Source: Renteria (2010)

Table 2

Estimated Proportion of All-Cause Female Mortality Attributable to Compositional Change in Education, Brazil

Age Group	1960–2010		2010–2040	
	PAF	C.I. (95%)	PAF	C.I. (95%)
30–34	0.313	(0.235 , 0.381)	0.159	(0.108 , 0.210)
35–39	0.301	(0.227 , 0.366)	0.189	(0.130 , 0.246)
40–44	0.298	(0.226 , 0.361)	0.204	(0.142 , 0.265)
45–49	0.282	(0.213 , 0.341)	0.230	(0.161 , 0.296)
50–54	0.265	(0.201 ,0.320)	0.246	(0.174 , 0.313)
55–59	0.238	(0.181 ,0.288)	0.254	(0.182 , 0.321)
60–64	0.210	(0.160 ,0.254)	0.252	(0.183 , 0.316)
65–69	0.175	(0.133 ,0.212)	0.248	(0.182 , 0.309)

Notes: PAF = population attributable fraction; CI = confidence interval. The 95% CIs for PAFs incorporate uncertainty in the relative risks of mortality.

Table 3

Estimation of changes in mortality measures attributable to changes in the age distribution of education, women, Brazil, 1960–2010 and 2010–2040

	Life expectancy at age 30 (truncated at age 70)	Conditional probability of surviving from age 30 to 70
Actual Estimates		
1960	33.46	0.56
2010	37.57	0.79
Total Difference	4.12	0.23
1st Simulation: 1960–2010		
1960 estimated with the distribution of education as of 2010	35.03	0.64
Difference to actual 1960	1.58 (1.18,1.93)	0.08 (0.06,0.10)
2nd Simulation: 2010–2040		
2010 estimated with the distribution of education as of 2040	38.10	0.84
Difference to actual 2010	0.53 (0.37,0.68)	0.05 (0.03, 0.06)

Notes: 95% CI for the simulated differences are in the parentheses