WHIOCE PUBLISHING PTE. LTD.
International Journal of Population Studies

RESEARCH ARTICLE

Socioeconomic differentials and disease-free life expectancy of the elderly in Brazil

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Abstract: The objective of this study was to estimate life expectancy with and without a specific chronic disease among the Brazilian elderly population, by sex and socioeconomic factors, for the years 1998 and 2008. Life expectancy with and without hypertension, diabetes, bronchitis/asthma, and heart disease were calculated using the Sullivan method and prevalence estimates from data collected in the two years through the Brazilian National Household Survey (PNAD). Hypertension was the chronic disease with the largest effect on life expectancy. Among socioeconomic determinants, education proved more relevant than income. Having more years of education increased the average healthy time. Socioeconomic inequality negatively affected the health of women more than men. Despite the social changes in Brazil in recent decades with a reduction in inequality and poverty, the effect of socioeconomic inequality in the country on the health status of the elderly remains evident.

Keywords: *life expectancy; health of the elderly; health inequalities; socioeconomic factors; Brazil*

ARTICLE INFO
Received: December 22, 2017
Accepted: May 11, 2017
Published Online: August 30, 2017

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CITATION
Alves LC and Arruda NM (2017). Socioeconomic differentials and disease-free life expectancy of the elderly in Brazil. *International Journal of Population Studies,* 3(1): 64–78.
doi: 10.18063/IJPS.2017.01.001.

1 Introduction

Since the last decades of the past century, Brazil has witnessed a rapid and accentuated decline in its fertility rates, an unprecedented phenomenon in the country's history, and which stands out even in comparison with other countries, both in the developed world and among emerging countries. As what has happened in the majority of these countries, this decline, in conjunction with the fall in mortality rates, has resulted in population aging processes and higher longevity in the population.

Mortality in Brazil declined significantly from 1940 until the 1970s. This reduction in Brazilian mortality levels was much more rapid than that experienced by developed countries and its evolution over time has caused huge gains in the life expectancy of the population (Carvalho and Garcia, 2003). Life expectancy increased by 30 years between 1940 and 2000, from 37.6 to 64.8 years among men and from 39.4 to 72.6 years among women. The results of the Brazilian Demographic Census in 2010 indicate that life expectancy reached 73.48 years (IBGE, 2010). The process of demographic and epidemiologic transition has led to a greater prevalence of chronic degenerative diseases, which are the main causes of mortality and an important health problem of the population worldwide (WHO, 2004), especially among the elderly.

Like many middle-income countries, Brazil has experienced major demographic and epidemiological changes. One major effect of these transitions has been an increase in the prevalence of chronic diseases and non-communicable diseases, in particular diabetes, hypertension, and heart disease (Pesquisa Nacional de Saúde, 2013). Non-communicable diseases were responsible for 72% of all deaths in the country in 2007 (Schmidt, Duncan, Silva *et al*., 2011). Prevalence of hypertension is high in Brazil, affecting about one-fourth of all adults. The highest rates of mortality and morbidity for these diseases are concentrated among the poorest and those with less schooling (Beltrán-Sánchez and Andrade, 2016).

Socioeconomic status plays a key role in determining the health of individuals. The effect of socioeconomic status on health is the result of interaction between psychological and sociological mechanisms such as behavior, social support, environmental factors, and access to goods and health services (House, Lepkowski, Kinneyet *et al*., 1994). Some studies have showed that low socioeconomic status is associated with poor health and high mortality risk (Arber, 1991; Marmot, Ryff, Bumpass *et al*., 1997). According to Porell and Miltiades (2002), the impact of adverse socioeconomic conditions on the health of individuals is higher in regions with high inequality in income distribution. High income inequality as measured at the national, state or community level is associated with poorer health (Kaplan, Pamuk, Lynch *et al*., 1996).

Brazil has among the highest levels of socioeconomic inequality in the world (Lima-Costa, Matos and Camarano, 2006). However, the past two decades have been marked by important social changes, mainly characterized by reductions in inequality and poverty. This reduction occurs nationally, but differs between the regions. The Gini coefficient, which measures income inequality, fell by almost 12%, ranging from 0.61 to 0.54 between 1990 and 2009. The most pronounced changes were observed in the poverty rates. The poverty rate declined from 41.92 to 11.60 between 1990 and 2009. Despite these reductions, significant regional differences are still present (IPEA, 2011; Andrade, Noronha, Menezes *et al*., 2013), reflecting continued differences in inequalities within and between Brazilian regions (there being lower inequality in the South and Southeast than in the North and Northeast), or by socioeconomic status (comparing poor versus rich).

Since 1994, Brazil launched what has since become the world's largest community-based primary health care program. The Family Health Program has delivered a new, more robust model of primary care services designed to provide accessible for the whole population. This care program is coordinated with other health care services and takes place within family and community contexts. Currently, each Family Health Program team makes visits to every household in the community on a monthly basis, and among their numerous duties they aim to identify individuals at risk of cardiovascular disease, especially hypertension and diabetes, and refer them to a health center (Macinko, Dourado, Aquino *et al*., 2010).

As the Brazilian population is aging and living longer, insight into health status trends among older populations may help with assessment of health policies to control chronic diseases in the country in recent years, as well as estimation of future health care needs and setting priorities to improve public health. We need to know whether increases in life expectancy experienced over the last decades are accompanied by better or worse health at the end of life. Important indicators for health in old age are prevalence of chronic diseases (Jagger, 2000).

Healthy life expectancy is a measure that combines morbidity and mortality information into a single index. The concept is similar to life expectancy, but refers to the average number of years of life that a person of a certain age can expect to live in good health without some chronic condition, given prevailing morbidity and mortality rates at that particular age (Jagger, Hauet and Brouard, 2001).

According to Robine *et al*. (2003), the development of indicators summarizing mortality and morbidity has provided an important tool for understanding how health status and length of life change in actual populations and whether there has been an expansion or compression of healthy life. Studies based on the healthy life model have been extremely important in clarifying the links between changes in mortality and morbidity. These have played a key role in alerting governments to the potential for there to be more years lived with disease unless there are reductions in the rate of morbidity onset or increases in the age at onset. The importance for public health to prevent disease and delay its progression when mortality is declining has been made clear by the health expectancy model. This indicator provides a yardstick for measuring the balance achieved between increasing the length of life and increasing the quality of life.

Thus, measures of healthy life expectancy are important to guide public policy because they help governments to plan specific health policies. They can also provide information on the demand for health services, allowing authorities to consider needs of the population for care in the present and future (Portrait, Maarten, and Degg, 2001). In addition, Bone, Bebbington and Nicolaas (1998) point out that healthy life expectancy is a good indicator of population health trends and can be used to monitor the impact of health and social policies, and allows for comparisons between different populations and subgroups.

Although there are many studies investigating the healthy life expectancy in Brazil (for example, Campolina, Adami, Santos *et al*., 2013; Camargos and Gonzaga, 2015; Camargos, Rodrigues and Machado, 2009; Camargos, Perpétuo and Machado, 2005; Romero, Leite and Szwarcwald, 2005), there are no studies analyzing the healthy life expectancy for a specific chronic disease (disease-free life expectancy) by socioeconomic status and their evolution over time among the elderly.

In this context, the purpose of this study is to investigate whether socioeconomic status plays a key role in determining life expectancy, with and without a specific chronic disease, among the elderly. In addition, our working hypothesis is that changes in the magnitude of disease-free life expectancy will differ when comparing socioeconomic status by income as opposed to comparing by education level. Therefore, this study presents and compares estimates of life expectancy with and without a specific chronic disease among older adult populations in Brazil, for the years 1998 and 2008, by sex and socioeconomic status.

2 Material and Methods

The study was developed based on data provided by the *Pesquisa Nacional por Amostra de Domicílios* (PNAD — Brazilian National Household Survey) from the *Instituto Brasileiro de Geografia e Estatística* (IBGE — Brazilian Institute of Demographic Geography and Statistics), by *Sistema de Informação sobre Mortalidade* (MIS — Mortality Information System), and by Life Tables from IBGE (2014). PNAD is a cross-sectional household interview survey with national coverage, held annually, in order to obtain information on the household of individuals, migration, education, labor force, and fertility characteristics. In 1998, PNAD included a health supplement in its questionnaire, with information to be collected every five years; the 2008 dataset was the most recent available information. We based our calculations on prevalence data from the 1998 and 2008 PNAD cross-sectional surveys. The population and corrected mortality data for underreporting of deaths for 1998 and 2008 were used to generate the estimates of age-specific mortality rates. To calculate this, we used the populations of mid-1998 and mid-2008 and total deaths in the respective years. The estimated population at mid-1998 and mid-2008 was obtained based on the Brazilian Demographic Census of 2000 and 2010.

The prevalence of chronic disease was estimated on the basis of self-reported presence of hypertension, diabetes, bronchitis/asthma, and heart disease. The demographic variables are age (60–64, 65–69, 70–74, 75–79, 80–84, and 85 years or older) and sex. The socioeconomic variables include household income and education level (years of school). In Brazil, formal education is organized into first level (1–8 years of school), second level (9–11 years), and higher. For our analysis, we categorized by years of education: less than 4 completed years as low education and 11 or more years as high education. For income, we considered total household income by quintiles. We categorized the first quintile as low income and the fifth quintile as high income.

We estimated the life expectancy with and without chronic diseases for the Brazilian elderly population in 1998 and 2008 based on the construction of life tables, which combined mortality information and prevalence of chronic diseases, as proposed by the method used by Sullivan (1971). The Sullivan method is the most widely used to estimate healthy life expectancy or disease-free life expectancy (Imai and Soneji, 2007). The most important figures for calculation of life (and therefore health) expectancy are the person-years lived in each age group by a future cohort assuming that the same age-specific mortality rates apply. To calculate these, we need to know the total time spent in each age group by each member of the cohort. Such data are not available at the individual level. Instead, we can do the estimation using the population in each age group and the number of deaths in the age group (Jagger, Hauet and Brouard, 2001).

The age-specific prevalence with and without chronic disease, and age-specific mortality rates in the population, are estimates. The expected years with and without chronic disease are calculated by applying the age- and sex- specific cross-sectional prevalence rates of these two states to the person-years lived in different age categories derived from period life tables (Andrade, Corona, Lebrão *et al*., 2014). So,

$$DFLE_x = \frac{\sum [1 - {}_n\pi_{\dot{x}}]_n L_x}{l_x} \qquad (1)$$

and

$$LED_x = \frac{\sum [{}_n\pi_{\dot{x}}]_n L_x}{l_x} \qquad (2)$$

where $DFLE_x$ is the average number of years that an individual will live without chronic disease, starting from exact age x whereas life expectancy with chronic disease (LED_x) is the average number of years that an individual will live with any disease, starting from exact age x. ${}_n\pi_{xi}$ is the proportion of age group x to $x+n$ with a chronic disease i, which is the disease prevalence based on the PNAD. ${}_nL_x$ is a person years lived in the age interval and l_x is the total number of people who have already survived to age x. Both are obtained from the life table generated based on estimates provided by the Mortality Reporting System. $1 - {}_n\pi_{xi}$ is the proportion of age group x to $x+n$ without chronic disease i. $[1- {}_n\pi_x]^*{}_nL_x$ is a person years lived in an age interval without chronic disease. $[{}_n\pi_x]^*{}_nL_x$ is a person years lived with chronic disease in age interval x to $x+n$. $\Sigma[1 - {}_n\pi_x]^*{}_nL_x$ is a total years lived without chronic disease from age x. It was obtained as the sum of the all $[1- {}_n\pi_x]^*{}_nL_x$ from age x up to the final age group (85+). $\Sigma[{}_n\pi_x]^*{}_nL_x$ is total years lived with at least one chronic disease from age x.

The total life expectancy (TLE) at each age, e_x, is found by dividing the total number of years lived beyond that age by the total number of individuals who have already survived to age x. Life expectancy with and without chronic disease was estimated by sex, education and income. All statistical analyses were performed with the aid of using the software R version 3.2.2 and Microsoft Excel 2010.

3 Results

This section presents the results of chronic disease prevalence and disease-free life expectancy by age (60 or 80), education (high or low) and income (high or low) for four conditions: hypertension, diabetes, bronchitis/asthma, and heart disease.

Table 1 shows the prevalence of chronic diseases among elderly Brazilians in 1998 and 2008. This data reveal that the prevalence of diabetes and hypertension has increased among the elderly and for both sexes during the period. In turn, there has been a reduction in cardiac and respiratory diseases for both sexes. Hypertension is the most prevalent chronic disease in both years observed and both sexes, followed by heart disease (with the exception of those aged 60 in 2008, where diabetes was the second most prevalent condition). It was observed that the prevalence of each chronic disease increased significantly between the ages of 60 and 80 years, except for diabetes in 1998, when prevalence declined somewhat with age (7.7% and 7.1% respectively). For men aged 80, the rate of heart disease rose between 1998 and 2008. Among women, the prevalence of each chronic disease was higher than men in all age groups considered, and much more so at the age of 80, with the exception of bronchitis in 1998 when the prevalence was lower among women aged 80 (8.5%) than men (12.3%).

Tables 2 and 3 present the estimates of total life expectancy (TLE) and disease-free life expectancy (DFLE) by age in 1998 and 2008 for the total elderly population, and with further disaggregation by sex, income and education. Life expectancy increased between 1998 and 2008 for both sexes. In 1998, women aged 60 could expect to live on average 3.4 years longer than men. In 2008, women aged 60 lived on average 3.5 years longer than men the same age. This increased average survival of women compared to men was also observed at the age of 80.

Concerning income, when decomposing the TLE by each chronic disease, we found that, on average, elderly individuals lived longer with hypertension than those with the other diseases investigated. For both sexes and in both years, a higher income increases the DFLE for hypertension. In 2008, the DFLE was lower than in 1998 for both sexes, age groups (except women aged 80), and both income groups. Among those with low income, men had higher DFLE than women, at both ages and in both years, except high-income women aged 80 in 2008 who on average could look forward to more time without hypertension than men of the same age. Despite higher longevity, women are more likely than men to have one of these unfavorable conditions at any given age, and this is more so in the lowest income group.

Hypertension remains the chronic disease in which elderly live on average longer with compared to others diseases analyzed, considering the education group. There are no important differences in DFLE when comparing the low education and low income groups, in both sexes, both age groups and both years. However, there were major differences and in favor of schooling when comparing high income and high education groups. Being in the more educated grouped is associated with longer average disease-free survival than being in the higher income group in terms of hypertension and fewer average total years of living with high blood pressure; in these regards, the situation is more favorable to women than men in both years. As was the case with income, in the low education group men had higher DFLE than women, both at ages 60 and 80 and in both periods.

After hypertension, heart disease is the major chronic disease with the next largest influence on DFLE to both education and income. The average time lived free of this disease decreased between the two periods, for both sexes and across all income

Table 1. Prevalence of hypertension, diabetes, bronchitis/asthma, heart disease among older adults in Brazil by sex and age, 1998 and 2008

Sex and Age	Hypertension		Diabetes		Bronchitis/asthma		Heart Diseases	
	1998	2008	1998	2008	1998	2008	1998	2008
Total	44.0	53.3	10.4	16.1	7.8	5.9	19.1	17.4
60	40.7	48.4	9.3	14.7	6.1	5.1	15.3	13.0
80	46.2	58.4	11.4	17.7	10.0	7.3	23.9	25.1
Men	36.7	46.4	8.1	14.2	7.8	5.5	16.8	16.7
60	34.3	41.7	7.7	13.6	5.5	4.4	13.4	12.4
80	38.3	51.7	7.1	14.9	12.3	6.2	20.6	24.6
Women	49.8	58.7	12.2	17.6	7.7	6.2	20.9	18.0
60	46.1	53.9	10.7	15.6	6.6	5.6	16.8	13.5
80	51.5	62.7	14.3	19.4	8.5	8.0	26.1	25.3

Source: PNAD (1998 and 2008).

Table 2. Total life expectancy, disease-free life expectancy, and percentage of years with disease-free life expectancy among older adults in Brazil by income: 1998 and 2008

Sex and Age	TLE		Hypertension				Diabetes				Bronchitis/asthma				Heart Diseases			
			1998		2008		1998		2008		1998		2008		1998		2008	
	1998	2008	DFLE	%	DFLE	%	DFLE	%	DFLE	%	DFLE	%	DFLE	%	DFLE	%	DFLE	%
LOW INCOME																		
Total																		
60	19.1	21.2	10.0	52.4	9.0	42.5	16.7	87.4	16.9	88.5	16.7	87.4	18.8	88.7	14.9	78.0	16.6	78.3
80	7.6	8.9	3.4	44.7	2.9	32.6	5.7	75.0	5.8	76.3	5.6	73.7	6.3	70.8	4.7	61.8	5.4	60.7
Men																		
60	17.4	19.4	10.6	60.9	9.8	50.5	16.0	92.0	16.3	93.7	15.3	87.9	17.5	90.2	14.3	82.2	15.6	80.4
80	6.8	8.0	3.9	57.7	3.4	42.5	5.6	82.4	5.8	85.3	5.3	77.9	6.0	75.0	4.9	72.1	5.1	63.8
Women																		
60	20.8	22.9	9.7	46.6	8.5	37.1	17.6	84.6	17.5	84.1	18.1	87.0	20.0	87.3	15.5	74.5	17.4	76.0
80	8.2	9.5	3.2	39.0	2.7	28.4	5.8	70.7	5.8	70.7	5.9	72.0	6.4	67.4	4.7	57.3	5.6	58.9
HIGH INCOME																		
Total																		
60	19.1	21.2	10.7	56.0	9.7	45.8	16.3	85.3	16.7	87.4	17.5	91.6	19.0	89.6	14.9	78.0	16.3	76.9
80	7.6	8.9	3.5	46.1	3.2	36.0	5.4	71.1	5.7	75.0	5.9	77.6	6.4	71.9	4.7	61.8	4.9	55.1
Men																		
60	17.4	19.4	10.8	62.1	10.0	51.5	15.1	86.8	15.6	89.7	16.0	92.0	17.8	91.8	14.0	80.5	15.1	77.8
80	6.8	8.0	4.1	60.3	3.5	43.8	5.3	77.9	5.5	80.9	5.4	79.4	6.1	76.3	4.7	69.1	4.6	57.5
Women																		
60	20.8	22.9	10.7	51.4	10.5	45.9	17.5	84.1	17.8	85.6	18.8	90.4	20.1	87.8	15.8	76.0	17.4	76.0
80	8.2	9.5	3.2	39.0	4.5	47.4	5.5	67.1	5.8	70.7	6.2	75.6	6.6	69.5	4.7	57.3	5.1	53.7

Source: PNAD, IBGE, and MRS (1998 and 2008). TLE: Total life expectancy; DFLE: Disease-free life expectancy.

Table 3. Total life expectancy, disease-free life expectancy, and percentage of years with disease-free life expectancy among older adults in Brazil by education: 1998 and 2008

Sex and Age	LOW EDUCATION																	
	TLE		Hypertension				Diabetes				Bronchitis/asthma				Heart Diseases			
			1998		2008		1998		2008		1998		2008		1998		2008	
	1998	2008	DFLE	%	DFLE	%	DFLE	%	DFLE	%	DFLE	%	DFLE	%	DFLE	%	DFLE	%
Total																		
60	19.1	21.2	10.0	52.4	9.0	42.5	16.6	86.9	16.8	88.0	16.9	88.5	18.8	88.7	14.9	78.0	16.4	77.4
80	7.6	8.9	3.4	44.7	2.9	32.6	5.7	75.0	5.7	75.0	5.6	73.7	6.3	70.8	4.8	63.2	5.1	57.3
Men																		
60	17.4	19.4	10.6	60.9	10.0	51.5	15.9	91.4	16.3	93.7	15.5	89.1	17.5	90.2	14.2	81.6	15.5	79.9
80	6.8	8.0	3.7	54.4	3.2	40.0	5.5	80.9	5.6	82.4	5.1	75.0	5.9	73.8	4.8	70.6	5.0	62.5
Women	20.8	22.9	9.4	45.2	8.2	35.8	17.4	83.7	17.2	82.7	18.2	87.5	19.9	86.9	15.5	74.5	17.2	75.1
60	8.2	9.5	3.2	39.0	2.7	28.4	5.8	70.7	5.8	70.7	5.9	72.0	6.5	68.4	4.8	58.5	5.2	54.7
80																		
	HIGH EDUCATION																	
Total																		
60	19.1	21.2	11.8	61.8	10.8	50.9	16.9	88.5	17.2	90.1	17.7	92.7	19.2	90.6	15.2	79.6	16.6	78.3
80	7.6	8.9	4.1	53.9	3.8	42.7	5.6	73.7	5.8	76.3	6.1	80.3	6.4	71.9	5.0	65.8	5.0	56.2
Men																		
60	17.4	19.4	11.2	64.4	10.4	53.6	15.4	88.5	15.5	89.1	16.2	93.1	17.9	92.3	13.8	79.3	15.0	77.3
80	6.8	8.0	4.3	63.2	3.7	46.3	5.2	76.5	5.4	79.4	5.7	83.8	6.1	76.3	4.8	70.6	4.4	55.0
Women																		
60	20.8	22.9	12.3	59.1	11.2	48.9	18.4	88.5	18.7	89.9	19.0	91.3	20.4	89.1	16.4	78.8	18.0	78.6
80	8.2	9.5	4.0	48.8	3.7	38.9	5.9	72.0	6.1	74.4	6.4	78.0	6.6	69.5	5.2	63.4	5.6	58.9

Source: PNAD, IBGE, and MRS (1998 and 2008). TLE: Total life expectancy; DFLE: Disease-free life expectancy.

and education groups, except for women with either of the low socioeconomic status indicators in 2008. In the case of heart disease, there were no major differences when it directly comparing the high-income and high education groups and comparing low income and low education groups. There was a slight advantage in favor of higher education compared to the higher income group among women. Greater education is more highly associated with increased DFLE than high income in both periods among women. Women's average disease-free survival was lower than men's, except for the higher education group in 2008. For women, being more educated was associated with higher DFLE values than was the case for the lower education group. Women experienced greater median survival with heart disease than men. However, being more highly educated improved the scenario, on average reducing the time spent with the disease and reducing the difference between men and women.

Diabetes did not exert important influences on the DFLE values. With regards to income, DFLE did not change considerably between the two periods for the higher income group, both for the population as a whole and considering each sex separately. The biggest differences appear to have been between high and low income groups for men. Women had lower survival without diabetes than men. Median survival without the disease has increased in both periods and in both sexes, and the increase was greater among high income women aged 80. By level of education, it is important to notice the major differences that were observed among women with higher education, who we see as having longer survival without the disease (18.4 years in 1998 and 18.7 years in 2008), compared to those with higher incomes (17.5 and 17.8 years, respectively), in both years.

Bronchitis/asthma was the chronic disease among those considered that caused the least effect; that is, older people had on average a lower lifespan with this disease than those with other conditions. There were no significant differences when comparing those with high-income and those with high education, and when comparing those with low income and those with low schooling. Also, there were no substantial differences between low income and high income groups, in both sexes and both age groups, in 2008. The less educated had the more years living with the disease during elderly years. Women had longer survival with the disease than men at all ages considered, and regardless of which period and socioeconomic status. The DFLE for this condition decreased for both sexes between 1998 and 2008.

4 Discussion

This study estimated the life expectancy with and without specified chronic diseases among the Brazilian elderly population, for the years 1998 and 2008, by sex, income and education. Expected years of survival among elderly individuals with a chronic disease was higher among those with hypertension, followed by heart disease. For hypertension, bronchitis/asthma and heart disease, there was a decrease in average survival without disease between the two periods analyzed, at all socioeconomic levels, for both sexes and for most ages.

Women lived on average longer with hypertension than men, and this difference is more pronounced in the lowest income group. In other words, even at lower income the health situation regarding hypertension is more favorable to men. In 1998, only women aged 60 and with high income had a longer average time hypertension-free. In 2008, both younger elderly women and older elderly women also had a longer survival without the disease than men at comparatively low income. Education has a much more pronounced effect on blood pressure than income. Having more education increases the average time without hypertension; the situation is more favorable in this regard for women than men in both years, except for women aged 80 years.

As for heart disease, the average time lived free of disease is higher for women aged 60 with low education in 1998, and for women 60 years and over who had the lowest education level in 2008. The high education group had higher DFLE and lower LED than the high income group considered as a whole, for women, in both periods. The more highly educated group in 2008 had higher survival without disease in women than in men at both ages. Nevertheless, they experience greater median survival with heart disease than men. This finding is consistent with previous studies showing that women generally have greater insight into disease, are more likely to pursue self-care and seek more medical care than men, all of which would tend to increase the likelihood of having the disease diagnosed and controlled. In contrast, studies highlight that men have higher specific mortality rates, which causes them to leave the cohort earlier (Puts, Lips and Deeg, 2005). Having more education tends to improve this scenario by reducing the average total number of years spent living with heart disease. There is an advantage in favor of the group with more education compared to the group with higher income, among women. That is, the effect of education is strongest among women.

With regard to those diagnosed with diabetes, DFLE rose between the periods for both sexes. Average time without diabetes was higher among low income groups, except for women 60 years of age. The value of DFLE was higher among those with less education in the two periods analyzed, except for women aged 60 in 1998 and women of both ages in 2008. One likely explanation is that women are more attuned to recognizing symptoms and recalling disease history, which may influence their reported diseases. Socioeconomic inequalities were not large, except for the highly educated group of women among whom we found larger differences involving longer disease-free survival and less average time spent living with the disease compared to the high income group. For men, income played a much more evident influence.

Respiratory disease-free survival showed no important differences when comparing income and education. The greatest differences were found in 1998, when those with less education lived more years on average with disease. Women had longer survival with the disease than men of all ages considered, periods and socioeconomic status.

Despite these dissimilar changes between the chronic diseases, this study documented consistent decline in disease-free life expectancy for most chronic diseases investigated in Brazil. Diabetes was the only one of these chronic diseases to increase in disease-free life expectancy. There are some possible explanations for the results found in this study. The first is that elderly Brazilians are living longer. The current trend is that more individuals are living longer and have a larger number of chronic conditions (Chaimowicz, 1998). According to Robine and Michel (2004), the patterns of change in health can be partly attributable to the stage of the epidemiologic transition in a given country. Gu *et al*. (2009) suggests that improvements in health occurred during periods of rapid economic development and epidemiologic transition. Brazil has experienced mostly sustained economic growth and a rapid epidemiologic transition progresses since the 2000s. However, the disease-free life expectancy is decreasing for most diseases between 1998 and 2008.

There is some evidence to suggest that the worsening health trend in Brazil and the changes in health indicated in the present study can be explained by the compression of morbidity and expansion of morbidity hypotheses (Fries, 1980; Gurenberg, 1977). The expansion of morbidity theory puts forward the pessimistic view that the gains in life expectancy are predominantly through the technological advances that have been made in extending the life of those with disease. In addition, living longer exposes more people to the non-fatal diseases of old age. Overall, our findings support the expansion of morbidity hypothesis for older adults in Brazil between 1998 and 2008 for hypertension, bronchitis/asthma and heart disease. On the other hand, the opposing theory is that of compression of morbidity. According to this theory, changes in lifestyle, which modify the risk factors for mortality, will also delay the age-at-onset and the progression of non-fatal diseases. Thus, the time lived with disease will be compressed into a shorter period before death. The results found for diabetes in Brazil indicate some evidence that support the compression of morbidity theory.

The findings of the present study for most of the chronic diseases suggest a possible cohort effect in the country. Younger elderly women showed a trend of morbidity compression. Moreover, over the period it was noted this effect. These findings support the argument that cohort replacement gradually produces a compression of morbidity as mortality continues to decline and new cohorts have better profiles of health and risky behaviors (Robine and Michel, 2004).

Chronic non-communicable diseases, especially hypertension and diabetes, and their inherent complications such as heart diseases and the related morbidity and mortality, are currently the most common public health problems and contribute most to the burden of disease in Brazil. Despite the substantial investment and improvement in the Brazilian National Health System (SUS), the diagnosis and control of hypertension and diabetes are still lower than in countries with similar health care models (Campbell, McAlister and Quah, 2013; Ordunez-Garcia, Munoz, Pedraza *et al*., 2006). The findings of our study indicate that the lowest socioeconomic level had improvements in DFLE for diabetes and heart disease. This may be due to a higher rate of conditions going undiagnosed among the elderly whose socioeconomic situations are more unfavorable, for both sexes, more so due to their lower accessibility to healthcare facilities in this period than a trend towards a compression of morbidity in this group.

During the epidemiologic transition, men and women may experience different trends. With increased longevity, women as a group usually tend to have a higher overall prevalence or incidence of diseases and disability than men. In later stages of epidemiological transition, differentials in socioeconomic status play a greater role in affecting the prevalence, incidence and trends of disability because the socioeconomic condition of individuals largely determines access to health care, environmental exposure, nutritional status, lifestyle and behavioral risks that are important for morbidity and mortality patterns (Gu, Gomez-Redondo and Dupre, 2015).

The results of this study corroborate previous research (Arber, 1991; House, Lepkowski, Kinneyet *et al*., 1994; Kaplan, Pamuk, Lynch *et al*., 1996; Marmot, Ryff, Bumpass *et al*., 1997), in that socioeconomic status plays a key role in determining the health of individuals. Higher socioeconomic status leads to increased health. Socioeconomic status is often measured by education and income. Income and education have differing effects. Education, for example, encourages access to information and the practice of healthy behaviors (Kubzansky, Berkman, Glass *et al*., 1998). Education provides several advantages for health because it influences psychosocial and behavioral factors. Older people with a higher level of education are less likely to expose themselves to risk factors for diseases. Also, the less privileged population has higher prevalence of risk factors which are already established and considered as modifiable factors (dyslipidemia, hypertension, diabetes mellitus, smoking, obesity, physical inactivity and stress). More education favors access to information and lifestyle modification, the adoption of healthy habits, demand for health services, and involvement in activities that prioritize health promotion, especially correctly following recommended follow-up in relation to health. There is also evidence that low income among the elderly negatively impacts healthy behavior, in terms of the home environment, access to services and health care, even if these are in principle available (Alves and Rodrigues, 2005). According to Lima-Costa *et al*. (2003), the poorest elderly seek less health care, have poor adherence to treatment and have little access to drugs, which directly affects the health of the individuals. Income facilitates access to medical services (Zimmer and Amornsirisomboon, 2001). Higher income provides greater opportunity to access goods and services, including quality education and health care with effective diagnostic and therapeutic resources, including skilled and sophisticated diagnostic equipment (Kaplan and Keil, 1993). This study shows that education had a larger impact on life expectancy with disease and disease-free life expectancy than income.

According to data from the Brazilian National Household Survey, in 1998, 26.2% of the total population had less than one year of education, and among individuals 60 years of age the proportion was 31.6%. By 2008, it had changed to 20.0%, representing a 23.7% reduction during the period. By sex, in 1998, elderly men were proportionally more educated than women (27.9% versus 34.7%, respectively), as until the 1960s men had more access to education than women. On the other hand, in 2008 there was a reversal in the sense that 21.7% of elderly women aged 60 had less than one year of schooling compared to 23.2% of elderly men. The data show that, despite the progress, there number of elderly persons with no education in the country remains high, which makes education an important factor in determining health conditions.

Education produced a greater effect on hypertension than income. This can be explained by the fact that high blood pressure is directly related to lifestyle and also because lack of adherence to treatment is one of the greatest problems in controlling blood pressure, both of which directly influenced by education level. Excessive use of salt and high-sodium condiments associated with the consumption of fatty meats, fried foods, sugars and little physical activity depend much more on education than income.

This study points to the existence of socioeconomic differences in cardiovascular morbidity. As with hypertension, schooling introduces major effects. Heart disease is concentrated in the lower socioeconomic levels. Education is an important factor for the adoption of certain behaviors and lifestyles which mitigate or counter the development of this disease. In addition, having less education implies less access to the benefits of prevention and treatment. In Brazil, cardiovascular diseases are the number one cause of death in the 60+ age group.

Socioeconomic status and gender had varying intensities and inter-relations in their influences on the health of Brazilians (Chor, 2013). The gender paradox in health is widely recognized (Lamb, 1997). However, the reasons why women enjoy greater longevity but worse health are complex and are generally attributed to differences in socioeconomic status, genetic and acquired risks, immune-system responses, hormones, disease patterns and prevention, and health-reporting behaviors (Crimmins and Saito, 2000; Idler, 2003; Oksuzyan, Juel, Vaupel *et al*., 2008). The contribution of each sex to total averages differs for several chronic diseases. Gender inequality significantly influences health and wellbeing because it affects most of the determinants of health, including education, occupation, income, social networks, physical and social environment and health services (Plouffe, 2003). Socioeconomic inequality affects the health of women more negatively than men. This study is consistent with there being a slight advantage in favor of high education compare to high income with regard to women's health. Brazilian women entered the 21st century with higher educational levels than men, with a persistent difference that has increased over time in favor of women. The country displays a process of increasing educational levels overall and the reversal of the gender gap. Formerly, at older ages in all cohorts, men had higher levels of education than women. However, in younger cohorts, women have started to exceed men since the mid-twentieth century (Alves and Corrêa, 2009).

The novel contribution of this study was the use of morbidity data with representation at the national level at two periods in time (1998 and 2008), which allowed the monitoring of their evolution over time and ensured comparability. Few studies on Brazil use information on the prevalence of chronic diseases which can be considered as a representative sample of the population. We also recognize some limitations of this study. First, our analyses focused exclusively on the prevalence of health conditions with cross-sectional data, which prevented causal inferences. Unfortunately, Brazil does not have longitudinal studies for this specific subject matter. Second, an important limitation of this study was the use of self-reported morbidity information relating to the presence of chronic diseases, which may be subject to diagnosis bias and avoidance of diagnosis. That morbidity information helps identify individuals who have received the diagnosis at least once in their life, but omits those unaware of the condition and may lead to underestimation of the prevalence. Third, accuracy of self-reporting may also vary by socioeconomic status and access to health insurance. It is possible that those with higher education and income, and thus with higher access to health insurance on average, are more aware of their health. However, if this were to be the case, we would have expected higher prevalence among people with higher education and income. We observed the opposite, thus indicating that this issue is unlikely to explain our estimates of the educational and income gradients in chronic disease over time. It is also possible that those with lower education and income have more difficulty understanding the health diagnosis and answering the survey questions (Burgard and Chen, 2014). Despite these limitations, the findings of our study may have important policy implications in Brazil.

5 Conclusions

The present study is among the first to document changes in disease-free life expectancy in Brazil during its epidemiologically important period. Healthy life expectancy or disease-free life expectancy is an important indicator for public health planning in most countries. In Brazil, some research has studied the healthy life expectancy in the elderly population. However, this study is one of the few that has tried to analyze the disease-free life expectancy and the evolution of selected diseases by socioeconomic status among the elderly.

Regarding our analyses, the findings of this study confirm our initial hypothesis, which states: socioeconomic status plays a key role in determining the health of individuals. On the other hand, an improvement in socioeconomic level as measured by income and education may result in an increase in the number of years lived in good health. Education was found as more important than income as a socioeconomic determinant of chronic diseases.

Despite the social changes in Brazil in recent decades which include reduced inequality and poverty, the effect of socioeconomic inequality on the health status of the elderly in the country is nevertheless continues to be relevant. Therefore, this study adds further discussions involving the aging and longevity of the elderly in Brazil. The lack of and also need for further studies at smaller levels of geographic aggregation, such as regions, are suggestive of a need for further and different analyses with the purpose of exploring socioeconomic inequality and health status among the Brazilian elderly.

Author's Contribution

LCA designed the study, performed the analysis, drafted and revised the text. NMA co-performed the analysis and revised the text. Both authors read and approved the final manuscript.

Ethics Statement

This paper uses publicly available data (PNAD) that has being de-identified and was deemed exempt from human subjects review.

Conflict of Interest and Funding

No conflict of interest was reported by all authors. This research was supported by National Council for Scientific and Technological Development (CNPq) (Process no.: 471517/2013-5) and by Sao Paulo Research Foundation (FAPESP) (Process no.: 2016/09585-0).

Acknowledgements

We thank the editor and the anonymous reviewers for their insightful comments that improve the content of the manuscript.

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