Healthy life expectancy in Brazil: applying the Sullivan method

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INTRODUCTION

Classically, mortality indicators have been utilized to evaluate the general state of health of a population. These indicators highlight life expectancy, which, because it is not influenced by a population's age structure, has been used to compare the health state between populations and also to monitor the impact of different interventions in the health area [1].

The increase in life expectancy is not only a characteristic of developed countries, having also shown significant increased in developing countries, especially in the second half of the 20th century [2]. In Brazil, a gain is observed between 1950 and 2000 where the life expectancy rise from 51 years to 69.4 years during the same timeframe. Demographic projections foresee the continuation of this process, estimating a life expectancy in Brazil around 77.4 years in 2030 [3].

The decline in mortality at young ages and the increase in longevity, combined with the decline of fecundity and the accentuated increase of degenerative chronic diseases, caused a rapid process of demographic and epidemiologic transition, imposing a new public health agenda in the face of the complexity of the new morbidity pattern [4].

Recent studies concluded that long life does not necessarily mean a healthy life [5,6,7]. On the contrary, with increased life expectancy, the proportion of years of life with degenerative chronic diseases, disabilities and socioeconomic disadvantages also increased [8,9]. Advancement in the technologies for saving lives and providing more efficient medical care resulted in the paradoxical increase in the prevalence of chronic diseases, as Gruenberg named [10], "the failure of success".

It is thus arguable that mortality measurements alone are insufficient to adequately evaluate state of health, quality of life in a population, or the comparative impact of medical interventions. The first method to combine morbidity and mortality information was proposed by Sanders [13]and later developed by Sullivan [14].

The Sullivan method has been used to estimate healthy life expectancy in various countries [11,15,16], especially the developed ones, as well as for monitoring health changes and differences in the European countries. In Brazil it was employed to calculate healthy life expectancy using the SABE (*Saúde, Bem-estar e Envelhecimento*; Health, Well-Being, and Aging) research database, which is restricted to the elderly in the city of São Paulo [17].

The objective of this study is to introduce Sullivan's technique and estimate healthy life expectancy in Brazil using different ways of measuring state of health, based on information from the *Pesquisa Mundial de Saúde*(*World Health Survey* WHS), carried out in 2003 on a national scale.

MATERIAL AND METHODS

The Sullivan method

The information necessary for applying the Sullivan method are: (1) population and deaths or specific mortality rates that permit the construction of a life table; (2) prevalence of health states according to age.

In the present study, the morbidity information used in applying the Sullivan method comes from the WHS that was carried out in Brazil in 2003. This research is part of a larger project from the World Health Organization (WHO), in which many other member countries where included.

The WHS sample was comprised of 5,000 Brazilians over the age of 18, selected, probabilistically, in 250 census sectors, in 188 municipalities located in the 25 states of the federation. The sampled population corresponded to the set of private residences in Brazil except for the ones located in rural areas of northern region, in the states of Acre and Roraima, and in special census sectors (military bases, lodgings, encampments, boats, penitentiaries, asylums, orphanages, convents, or hospitals) [18].

Specific mortality rates by age and sex were provided by the Department of Population and Social Indicators; IBGE, Brazilian Institute of Geography and Statistics.

The healthy life expectancy, proposed by Sullivan, is calculated using an adaptation of the traditional life table. The expectancy of healthy life thus reflects the state of health of a determined population adjusted by the level of mortality and, as in a life table, it is not affected by the age structure of a population. In the present study, healthy life expectancies were estimated according to sex, since health states vary considerably between genders, especially at more advanced ages [19,20,21].

The healthy life expectancy (e'_x) is calculated in the following manner:

$$e'_x = \frac{1}{l_x} \sum_{x}^{w} (1 - {}_n\pi_x)\, {}_nL_x \quad (1), \text{ where:}$$

l_x is the number of survivors at the exact age x; ${}_n\pi_x$ represents the prevalence of a determined state of health among individuals with ages in the interval (x, x + n); ${}_nL_x$ is the total number of years lived by a cohort in the age group (x, x + n); w represents the largest age category.

According to what can be observed, the model employs two independent measures of health. The first refers to morbidity, $(1 - {}_n\pi_x)$, which is the specific rate by age of being healthy; and ${}_nL_x$ which is the mortality component. The method thus consists of removing from the total time lived by a cohort the proportion lived without good health.

Indicators of healthy life

Since the Sullivan method depends on how one measures healthiness, the present study employs four distinct estimates of healthy life expectancy covering several dimensions of morbidity: self-rated health, presence of long-term disease or disability, and functional limitations.

The first method refers to the individual self-rated health. There are five possible answers (very good, good, moderate, bad, very bad), which have been dichotomized such that the answers "very bad" and "bad" constitute the category "poor self-rated health", and the other answers compose "good self-rated health". In this case, the specific rate by age of being healthy was established by the proportion of individuals with a good perception of health state in each quinquennial age group.

The second measure is based on the presence of a long-term disease or disability that limits the one's daily activities. For this estimate, the state of having a long-term disease or disability that limits daily activities was used to identify an unhealthy life and the specific rate by age was established by the proportion of individuals with a long-term disease or disability in each age group.

The third estimate takes into consideration the continuum of the severity of functional limitations. For such, this study considered the approach proposed by the WHO in the *International Classification of Functionality, Disability and Health* (ICF) [22], in which the limitations of activities and functionality are not only viewed as a consequence of illnesses but principally as important components in an individual's health. The present study first made use of a factorial analysis of principal components, which was applied to the five levels of difficulty (none, mild, moderate, severe, extreme) in performing daily activities and limitation and deficiencies of the body's functions and structure). The specific rate by age of being healthy is given by the complement of the arithmetic average of the scale's values by age group.

The final method used for measuring state of health is a proposed extension of the Sullivan method, which allows more than one healthy life-defining event to be used simultaneously. In addition, a weight is attributed to each event, establishing the degree of its severity. To illustrate the method, three events were considered: (1) does not have long-term disease or disability; (2) has a long-term disease or disability that does not limit daily activities; and (3) has a long-term disease or disability that limits daily activities. The weights which characterize the degree of severity in each situation were calculated by age group.

Applying the method

In this study, the life table used to illustrate the Sullivan method's calculation has been summarized in quinquennial age groups, beginning at twenty years of age.

Table 2

Healthy life expectancy, for both sexes, based on self-evaluation of poor health. *World Health Survey*, Brazil, 2003.

Age			Traditional life table				Poor health	People-years		Life expectancy		
1	2	3	4	5	6	7	8	9	10	11	12	13
	Mortality rates	Probability of death	Survivors	Years lived between ages x, x+n	Years lived, starting at age x	Life expectancy	Prevalence (%)	With good self-rated health between the ages (x; x+n)	With good self-rated health starting at age x	Healthy since age x	In poor health state	Years lived in poor health state
x	${}_nM_x$	${}_nq_x$	l_x	${}_nL_x$	T_x	e_x	${}_n\pi_x$	$(1-{}_n\pi_x/100)*Lx$	TH^x	e'_x	$e_x-e'_x$	%
20	0.00188	0.0094	100,000	497,656	5,433,619	54.34	3.58	479,829	4,739,131	47.39	6.94	12.8
25	0.00216	0.0108	99,062	492,646	4,935,963	49.83	3.90	473,417	4,259,302	43.00	6.83	13.7
30	0.00256	0.0127	97,996	486,867	4,443,316	45.34	3.80	468,354	3,785,885	38.63	6.71	14.8
35	0.00318	0.0158	96,750	479,933	3,956,450	40.89	6.79	447,324	3,317,531	34.29	6.60	16.1
40	0.00432	0.0214	95,223	471,029	3,476,517	36.51	7.80	434,275	2,870,207	30.14	6.37	17.4
45	0.00602	0.0296	93,189	459,040	3,005,489	32.25	10.98	408,644	2,435,932	26.14	6.11	19.0
50	0.00829	0.0406	90,427	442,961	2,546,448	28.16	13.72	382,183	2,027,287	22.42	5.74	20.4
55	0.01193	0.0579	86,757	421,219	2,103,487	24.25	15.85	354,476	1,645,104	18.96	5.28	21.8
60	0.01700	0.0816	81,730	391,988	1,682,268	20.58	17.12	324,877	1,290,628	15.79	4.79	23.3
65	0.02450	0.1154	75,065	353,666	1,290,280	17.19	21.05	279,210	965,751	12.87	4.32	25.2
70	0.03660	0.1677	66,401	304,174	9,366,15	14.11	20.26	242,544	686,541	10.34	3.77	26.7
75	0.05437	0.2393	55,268	243,275	632,440	11.44	24.14	184,554	443,997	8.03	3.41	29.8
80	0.10803	1.0000	42,042	389,165	389,165	9.26	33.33	259,443	259,443	6.17	3.09	33.3

Table 2 shows the application of the Sullivan method, taking into consideration the proportion of individuals in each quinquennial age group with a self-rated health that is not poor (very good, good, moderate) as the specific rate by age of being healthy. The first column represents the age group 's lower limit, in which the amplitude always equals five, except for the last group in which the interval is right open. The five following columns show the functions of a summarized mortality table, necessary for the calculation of life expectancy.

In the second column are the specific rates of mortality (${}_5M_x$). The probability of an individual with exact age x dieing before completing $x + 5$ (${}_5q_x$) years is calculated based on the specific rate of mortality.

Given these probabilities of death, the number of survivors reaching the initial age of the following age group can be calculated (l_{x+5}). Thus: $l_{x+5} = l_x \times (1 - {}_5q_x)$ (3).

The next column in the life table shows the number of lived years between the ages x and $x + 5$. Every individual that survived the age of $x + 5$ will fully live the period of five years. The ones who die before reaching the age of$x + 5$ ($1_x - 1_{x+5}$) will live half the amplitude of the interval (2.5 years), assuming the deaths are uniformly distributed along the interval. Thus: ${}_5L_x = 5 \times 1_{x+5} + 2{,}5 \times (1_x - 1_{x+5})$. For the open interval,

$$ {}_\infty L_x = \frac{l_x}{{}_\infty M_x} . $$

The survivors reaching twenty years of age will, added together, live 497,656 years in the subsequent five years (column 5).

In column 6 is presented the total number of years to be lived by the survivors in the age group x, until the group extinguishes itself. This is done by accumulating the lived years in each interval:

Survivors reaching the age of twenty will altogether live a total of 5,433,619 years. The life expectancy is calculated by dividing the numbers of years one expects to live starting from a certain age by the number of survivors to the referred age.

According to the mortality rates used for the year 2003, at the age of twenty, one is expected to live an additional 54.34 years (column 7).

The proportion of individuals, of both sexes, that self-reated their health as poor ("bad" or "very bad") is presented in the eighth column. The ninth column shows the healthy years lived in each age group by subtracting the total portion of years lived in an unhealthy state (column 8) from the total years lived (column 5).

Similar to the traditional mortality table, the expectancy of healthy life (e'_x) is calculated by dividing the number of people-years lived in a healthy state from a certain age x by the survivors of the referred age. In column 11 of Table 2, at the age of twenty, one expects to live another 47.4 healthy years. Consequently, 6.9 years are lived in a poor state of health (column 12), corresponding to 12.8% of the life expectancy at that age (column 13).

The method of calculation presented in Table 2 was also used for the second and third estimates of healthy life expectancy. For the second estimate, the prevalence rate of individuals with a poor self-rated health is substituted for each age group by the proportion of individuals who reported having a long-term disease or disability which limits their daily activities. For the third estimate, the specific rate by age of being unhealthy is given by the average score of functional limitations estimated in the factor analysis.

The fourth methodology involved three situations (no disease or disability; with disease or disability but without limitation; with disease or disability and with resulting limitation) and weights to mark the severity of each situation according to the individual's age.

To calculate healthy life expectancy with more than two health events, the population is classified in $s+1$categories, including all individuals, from those with no health problem to those with the most severe cases. Accordingly, $P_0, P_1, ..., P_s$ represents the proportions of the population in each category, and $w_0, w_1, ..., w_s$represents the weight describing the severity of each state of health, measured on a scale from 0 (best health state) to 1 (worst health state). In this case, the specific rate by age of not being healthy ${}_5\square_x$ is given by the average of the scores weighted by the proportion of individuals in each category of each age group:

$$ {}_5\pi_x = \sum_{a=0}^{s} w_a * P_a . $$

Results

Another table displays the total life expectancy and the total healthy life expectancy for the ages of twenty and sixty years, according to sex. The number of unhealthy years lived is also shown, as well as its relative proportion of the total life expectancy.

In reference only to the mortality component, females at the age of twenty expect, on average, to live approximately seven years more than males (57.8 years versus 51.0 years) and at the age of sixty the difference by sex is, on average, three years in favor of females.

Concerning the expectancy of a healthy life, given that females live more years in poor health or with limitations, the difference in healthy life expectancy between males and females is smaller both at the age of twenty and sixty.

Comparing all four methodologies indicates that the estimate with greatest loss in healthy years is the one based only on the occurrence of a long-term disease or disability that causes limitations, not considering the resulting degree of hardship in performing daily activities and the severity of functional limitations (method 2). According to the estimate, at the age of sixty, it is expected that males lose, on average, 35.0% of the years yet to be lived with limitations that result from long-term diseases. This average is 44.0% for females.

The measurement of unhealthiness through poor self-rated health is the one that presents the smallest relative loss in terms of healthy years of life, independent of gender. The tendency for the proportion of individuals in an unhealthy state to increase with age is found in all four estimates.

Final comments

Since its creation, the WHO defined health as a complete state of physical, mental, and social well-being. This definition transcends the absence of death, disease, and disability, and incorporates concepts relative to well-being and to quality of life. In such context, the concept of healthy life expectancy or life expectancy free of disability emerges; a generic term which characterizes a population's indicators that estimate the average timeframe (in years) a person may expect to live in a healthy state.

Ever since the 1980s, a growing number of studies employ the Sullivan method [11,15] due to its mathematical simplicity, the availability of required data, and the ease of interpreting its results. This method has also been employed to evaluate disparity in health by means of estimates of healthy life years according to socioeconomic indicators such as income and schooling [26,27].

There exists a certain consensus as to the potential of healthy life expectancy as a measure to monitor and evaluate the action of health programs and politics [2]. Differences exist in relation to the selection of measurement for indicating a healthy life.

The inclusion of various measures in the present study raises an important methodological question of how to measure healthiness [32], whether it be with simple or combined indicators, or by incorporating or not the severity of each situation.

In this study, the first two measures employed did not consider the seriousness of each situation but only the occurrence of a negative event. Authors such as Crimmins [32] favor the use of various dichotomous health measures, since they provide more specific information than those based on measures involving a continuum in severity, and are thus more efficient for implementing and monitoring health politics.

Some scholars of healthy life expectancy, like Robine & Jagger [31], Mathers et al. [33] and Murray & Frenk [34], have emphasized the need to incorporate the degree of severity to each event. In fact, the estimate based only on the presence of a long-term illness that limits daily activities was what caused the greatest relative loss in healthy years for both sexes at all ages.

The third methodology employed in this study to estimate the healthy life expectancy attempted to establish a continuous degree of severity based on scores of functional limitations constructed with an analysis that reduced the different dimensions of the interviewee's state of health to a single component.

The findings in this study highlight the consistency in the WHS' results. It is observed, for all measures employed, that the proportion of healthy life years lost significantly increases with age and that, even though females have a longer life expectancy than males, they live, relatively, less years in good health.

What is most important to note is that, despite from the index's sensitivity, all measures follow the same pattern, varying only in degree. It is observed that the differences between the various estimates of healthy life expectancy was greatest between younger females but was only relevant when the estimate was based on the presence of a disease or disability that limits daily functions.

Contrary to the multistate life table method, which employs longitudinal data, the Sullivan method has been criticized for not taking into consideration reversible health states [36,37].

This article attempts to introduce the Sullivan method for calculating healthy life expectancy to national Brazilian literature, in order to establish a debate around the various indicators of state of health, based not only on mortality information, but also considering the effects of morbidity. Whereas death is a single event, the loss of healthy life is hard to quantify. Hopefully, the different proposals for measuring well-being, combined with to the simplicity and strength of the Sullivan method, may help stimulate this emergent debate in Brazil.

Contributors

All the authors participated in drafting, analysis and review of the paper.

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