Life tables by race: a comparison among methods*

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Abstract: Levels and patterns of mortality by age, sex and race/color are among the most important indicators of health. Research shows that blacks and whites differ widely in their profiles of morbidity and mortality, but little is known about the sensitivity of interracial differences in mortality to different methods of estimation. This paper presents, compares and evaluates life tables by sex and race/color for all of Brazil, constructed on the basis of indirect demographic methods of estimation based on information regarding surviving children and mothers' mortality (variants of the Brass indirect method). The data was

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taken from the Brazilian demographic censuses and nationally representative household surveys (PNADS). Information was also obtained by using direct methods, which combine statistics on reported deaths and intercensal growth rates. We discuss the advantages and disadvantages of each method and present confidence intervals for estimates of mortality by sex, age and race/color. Finally, we discuss the impact that racial reclassification may have on recent estimates.

Keywords: life table, race, mortality, consistency, confidence intervals

Introduction

Brazil is home to the second largest black population in the world (the largest is in Nigeria). Nearly 50 percent of the Brazilian population classifies itself as black and, despite the myth of social democracy, disparities between blacks and whites are still evident in terms of access to public health, morbidity, fertility, reproduction, social mobility, education, income and political participation (Araújo et al 2009; Paixão and Carvano 2008; Theodoro 2008; Ribeiro 2009; Bueno and Fialho 2009). Differentials in mortality by race/color, however, have received little attention in Brazil.

Although life expectancy is one of the most important indicators for planning, monitoring and evaluating health policies, there are few studies that deal with the relationships between life expectancy and race/color. Estimates in this area are considered especially problematic and difficult because of uncertainties related to 1) the quality and availability of the data, 2) the reliability and stability of information per race/color and, 3) the methodologies available for constructing life tables.

The first of these uncertainties is related to the quality and availability of the data. Reliable death records with broad coverage and classified by age and other relevant demographic characteristics still represent an obstacle to the construction of mortality indicators. Errors in reporting and problems of memory are often involved, aggravated by long lapses of time between countings (the national census is carried out only every ten years). Demographers often run into serious problems in their attempts at estimating the levels and structure of mortality for specific racial groups. Sampling errors are also frequent and some authors question the representativeness of certain sectors of the population.

The second challenge related to the calculation of life tables disaggregated by race/color is the different classification criteria used when collecting information about this category over time and across different data sources. The way the data is collected and the racial categories in Brazil (white, black, brown/*pardo*, indigenous and yellow) have remained unchanged since 1940. Nevertheless, the potential process of racial reclassification that has taken place over the years could affect the calculation of life tables, since some of the basic information captured, such as deaths, may actually be reflecting a process of racial reclassification rather than mortality. In other words, the numerical growth of a given racial group is the result not only of low mortality and high fertility rates, but also of "intergroupal migration processes," especially in Brazil.

The third factor affecting the consistency of life expectancy estimates concerns the methodological uncertainties in the construction of indicators. Since there are several different methods for calculating life tables and different assumptions are used, the degree of variability among different methodologies is still unknown. When death records from general register offices are unreliable, for example, life expectancy can be estimated by using indirect demographic methods. Indirect estimates by race, however, have two sources of uncertainty: the first concerns the type and number of parameters used in the model. Indirect estimates may use information on infant mortality, adult mortality, or both. The second uncertainty concerns the mortality pattern chosen to estimate the probabilities of death at intermediate and advanced ages. Moreover, at least three other methods[1] (Preston and Bennett 1983, Bennett and Horiuchi1984, Merli 1998) can be used to calculate life tables by race/color using information on the number of deaths reported between the two censuses and intercensal growth rates by age.

It is therefore essential to further investigate the asymmetries found among health indicators disaggregated by race/color so that they can serve as basic inputs for implementing policies aimed at establishing racial equity in the country. Health estimates that take into account ethnic-racial factors must be used, and they must be as detailed and up to date as possible. Efforts should also be made to improve the indices that already exist.

As a contribution to the debate on how life expectancies should be calculated, this study proposes to construct and compare life tables for the Brazilian population, disaggregated by gender and race/color, using different demographic methods and data sources. The aim is to explore the potentials and limitations of each source

[1] Along the text we refer to these methods as "direct methods" to contrast them to those suggested by Brass et al (1968), which combine infant and adult mortality estimates with age patterns of mortality borrowed from pre-established model life tables.

and method in order to come to conclusions as to the most robust and accurate ways of estimating racial differences in mortality.

Although the production of life tables by race/color is not new in Brazil (Carvalho et al 2004, Funasa 2005, Paixão and Carvano 2008), this study breaks new ground in its methodology by combining possibilities for robust estimates that can be permanently updated in view of the data and methods used. In this regard, the results presented here are a new element in the scientific production in this field.

The first section of this paper describes seven methods for constructing life tables by race/color. The first three are based on indirect demographic methods, the second three use direct intercensal methods, and the last presents a simulation to minimize problems related to racial reclassification and to test the sensitivity of the estimates to variations in intercensal growth rates. In the second part of the paper, the estimates derived from each method are presented and discussed. The third section presents the arguments in favor of the recommended methodology and a comparison between it and the others in statistical confidence intervals. Final remarks are presented in the fourth section.

I. Technical and formal aspects: a brief description of the methods used for obtaining life tables

1. The use of indirect demographic methods (Methods 1, 2 and 3)

Without sound vital statistics and accurate population counts it is virtually impossible to obtain reliable estimates for life tables. Considerable efforts have been made to calculate the impact of death undercounts in the death rates (Bennett and Horiuchi 1981, Paes 1993; Gomes and Turra 2009) and there has been a growing concern to produce demographic projections that are closer to reality. Indirect approaches have been the most widely used way to calculate differences in mortality for certain socio-demographic characteristics. One way to obtain complete life tables is to use estimates from one or more mortality indicators (such as proportions of deaths at certain ages) and seek correspondence between these indicators and probabilities of death by using previously established patterns, such as the United Nations Life Tables (1982), those proposed by Coale and Demeny (1966), and patterns described by individual researchers.

The advantage of indirect methods is that they enable researchers to calculate complete life tables based on a single parameter (infant mortality) or on two parameters (infant and adult mortality) ($_nq_x$ or l_x). When combined with model life tables, these methods provide estimates, by age and sex, of the structure and level of mortality. In the case of a single parameter, the level of the curve is usually given for mortality during childhood, while the structure of the mortality is taken from an already established pattern that is supposedly similar to that of the population being studied.

In this paper, indirect methods are used to obtain life expectancies for black and white males and females based on input parameters related to estimates of infant and adult mortality. The Coale-Demeny West (1966) pattern of mortality was adopted because it is the most commonly used for this kind of calculation for Brazil (Paixão et al 2005).

Considering that both estimates (mortality during childhood and during adulthood) necessarily involve time lapses, we chose to use different sources so that the figures obtained would roughly correspond to the same date. For infant mortality, the source was the Brazilian 2000 Census and, for adult mortality, the 2008 PNAD, which is a nationally representative survey conducted yearly in

Brazil. In both cases the estimated probability of death corresponded approximately to the year 1995.

The first method was to estimate infant mortality using the classical method proposed by Brass, in its improved version by Hill and Trussell (1975). It uses data that includes the total number of women who declared themselves to be fertile, the total number of children conceived and the total number of surviving children. The data was taken from the 2000 Census and classified according to gender and color/race. Average probability of death was then calculated at ages 2, 3 and 5 (q_2, q_3 and q_5), and served as the input parameter for age 3. Levels corresponding to male and female survival in childhood, estimated on the basis of data from the 2000 Census, are shown in Table 1. The table shows the probability of surviving between ages 0 and x, l_x, estimated for the year 1995.

Table 1: Male and female infant survival between ages 0 and x, by race/color. Brazil, approximately 1995

	Female		Male	
$l_{age\ x}$	White	Black	White	Black
l_2	0.974	0.965	0.971	0.958
l_3	0.975	0.962	0.971	0.955
l_5	0.971	0.952	0.966	0.942
Mean	0.974	0.959	0.969	0.952

Source: IBGE, 2000 Demographic Census.

With the second method, adult mortality was estimated by using a procedure that calculates the probability of female survival after age 25 (l_{25+n}), using the information about maternal orphanhood and the mean age at childbirth as initial data, from which one can choose the regression coefficients presented by Brass (United Nations 1983: 118-122). Once these l_{25+n} estimates have been found for white and black females, the mortality level[2] for each adult age group is based on the West pattern model of mortality. The average mortality level from l_{50} to l_{70} was used to find the male survival probability at these ages by interpolating from a West pattern male survival life table. Death probabilities were calculated (q_{50} to q_{70}) and their mean served as the parameter for adult mortality for age 60. The "levels" of both female and male adult mortality (and survival) were estimated from non-conditional adult female survival probabilities (l_{25+n}) for the year 2008. Table 2 shows these levels for Brazilian black and white males and females.

[2] It should be noted that these levels do not correspond to actual mortality, but rather to a classification used in standard life tables, according to which each "level" corresponds to a different life expectancy. The higher the level, the higher the average life expectancy.

Table 2: Survival of female and male adults between ages 0 and x, by race/color. Brazil, 1995

	Female		Male	
$l_{age\ x}$	White	Black	White	Black
l_{50}	0.925	0.879	0.901	0.829
l_{55}	0.902	0.84	0.868	0.783
l_{60}	0.867	0.772	0.815	0.718
l_{65}	0.818	0.706	0.738	0.627
l_{70}	0.740	0.614	0.627	0.509
Mean	0.850	0.762	0.790	0.693

Source: IBGE, 2008 PNAD.

The third method combines an index for child mortality with an index for adult mortality to estimate life expectancies, that is, there are two parameters for input data. Since this method uses data referring to different generations, adult female mortality was calculated on the basis of data from 2008, as was done in Method 2, by finding the l_{25+n} and mortality level for each age group. The average mortality level from q_{50} to q_{70} was then used as one of the initial parameters. Data from the 2000 Census was used to calculate infant mortality, since, as was mentioned above, it can be shown that the estimates obtained for q_3, which is the probability deemed most adequate, refers to the year 1995, and this would therefore make the probability comparable to adult mortality as estimated on the basis of 2008 PNAD. The levels of infant mortality and the average of levels q_2, q_3 and q_5 was used as the second initial parameter.

In order to find the probabilities for survival up to age 20, we interpolated the mean level of infant mortality for each race/color on West model life tables according to the mortality level for both females and males. The same procedure was carried out with the mean level of adult mortality for the probability of survival as of age 25. For a more precise adjustment of the two estimates, a moving average of three points at ages 20 and 25 was used. The life tables were calculated for white and black females and males on the basis of this method.

Table 3 shows the compatibilization between the estimates for infant and adult survival in Tables 1 and 2 by combining the number of survivors in childhood (estimated up to age 20) with those in adult ages (estimated as of age 20). The infant and adult life tables were compatibilized assuming the mortality structure described in the Coale-Demeny West pattern. The estimates of l_x presented serve as raw material for constructing the death probability between ages x and x+n, and can also be used to construct a complete life table with other functions commonly used, such as ${}_nq_x$, ${}_nd_x$, ${}_nL_x$, T_x and life expectancy at age x or e_x.

Table 3: Number of survivors, l_x, by sex and by race/color based on the compatibilization of the estimates of infant and adult survival. Coale Demeny West Model. Brazil, 1995

	Female		Male	
Age (x)	White	Black	White	Black
0	100,000	100,000	100,000	100,000
1	97,967	96,869	97,211	95,154
5	97,581	96,103	96,698	93,911
10	97,395	95,772	96,403	93,363
15	97,242	95,506	96,159	92,936
20	97,069	94,582	95,781	92,101
25	96,847	93,507	95,361	91,162
30	96,577	92,279	94,900	90,118
35	96,080	91,252	94,249	88,945
40	95,403	89,987	93,407	87,490
45	94,413	88,356	92,149	85,498
50	92,857	86,109	90,086	82,600
55	90,504	82,926	86,786	78,367
60	86,944	78,430	81,531	72,231
65	81,465	71,845	73,756	63,689
70	72,749	62,245	62,747	52,421
75	59,598	48,869	48,227	38,569
80	41,989	32,538	31,425	23,683

Source: IBGE, 2000 Demographic Census and 2008 PNAD.

2. Method based on intercensal estimates (Method 4)

Bennett and Horiuchi (1984) developed a method to estimate mortality even when deaths are underreported and age declaration is incomplete. The method is a generalization – for unstable populations – of that presented by Preston and Coale in 1982, according to which the number of deaths ($_nd_x$) on a life table can be inferred on the basis of deaths in the population (nDx) adjusted by specific growth rates by age.

Preston et al (1996), for example, used this approach to estimate mortality rates of African-Americans above age 64, Merli (1998) used it to estimate mortality in Vietnam between 1979 and 1989, and Agostinho (2009), to estimate mortality in Brazil.

The basic idea of the method is to convert the distribution of deaths that have occurred in a population into a corresponding distribution of deaths in the life table. Growth rates by age between the two distributions are used for this purpose, it being assumed that underreporting of deaths is constant by age. The relationship between deaths in the life table and in the population can be expressed as follows:

$$\frac{d(y)}{d(x)} = \frac{D(y)}{D(x)} exp\left[\int_x^y r(a)d\,a\right] \quad (1)$$

where *d(y)* and *d(x)* are the number of deaths at the exact ages of *y* and *x* in the life table, and *y>x*;

D(y) and *D(x)* are the number of deaths at the exact ages of *y* and *x*, with *y>x*; and

r(a) is the annual growth rate of the population at the exact ages of *a.*

All other functions of this table can be derived from the number of deaths in the life table (Preston et al 1996: 204). In particular, for census populations, growth rates and the other functions needed to calculate the complete life tables can be estimated on the basis of the following expressions:

$_{n}r_{x}= [\ln(_{n}N_{x}^{2000}/\ _{n}N_{x}^{1990})]\ /10$ (2)

$_{n}d_{x}/_{n}d_{x-n}=\ _{n}D_{x}/_{n}D_{x-n}*e^{n*(_{n}r_{x-n}+_{n}r_{x})/2}$

(3)

$_{n}d_{x}=\ _{n}d_{x-n}*(_{n}d_{x}/_{n}d_{x-n})$,
assuming that, for the first age group, $_{n}d_{0} =\ _{n}D_{0}$ (4)

$_{n}L_{x}= n*l_{x}+n/2*_{n}d_{x}$ (5)

$_{n}L_{80}= l_{80}*\log_{10}(l_{80})$ (6)

$_{n}L_{0}= n*l_{x}+_{n}a_{x}*_{n}d_{x}$, (7) where $_na_x$ is the separation factor equal to 0.78 (Merli, 1998) for black and white males and females. It should be recalled that the final estimated life expectancies are relatively insensitiveto the choice of separation factor.

Since the Bennett-Horiuchi method (1984) is based on growth rates between two population distributions, it is not immune to problems of coverage, migration between different categories of variables, or to underreporting. However, the method tends to be much less sensitive to these problems than are those based solely on two age distributions (Preston and Bennett 1983)[3]. The Bennett-Horiuchi method (1984) also supposes that the underreporting of deaths is constant by age. Otherwise, the *D(y)/D(x)* ratio would be distorted and would create biases in the estimated life expectancies. If the underreporting of deaths increased with age, for example, the *D(y)/D(x)* ratio would fall and the life expectancies would be underestimated at all ages below which deaths were omitted. (Merli 1998: 352).

3. Iterative method based on age-specific growth rates and

3 Bennett and Horiuchi (1984: 222) show that the sensitivity of life expectancy, at age five, to errors in growth rates is about 10 times greater when the method used is based on two population distributions than when a method is used that combines population and death distributions.

on the intercensal distribution of deaths (Methods 5 and 6)

Merli (1998) developed an iterative procedure in order to combine two methods for estimating mortality. The first, suggested by Bennett and Horiuchi (1984) and later improved by Preston et al (1996), was described in the previous section. A second method was developed by Preston and Bennett (1983), and consists of estimating life tables on the basis of two successive age distributions. The main advantage of this method, also known as the r-method, is that it allows the researcher to infer the conditions of mortality using only census age distributions and age-specific growth rates. The method requires no model life tables nor does it assume population stability. The logic of the r-method is to assume that average growth between censuses is constant by age. Based on this assumption, the number of person-years in the mortality table can be estimated as:

$$ {}_nL_x = {}_nN_x^* \times e^{Sx} \qquad (8)$$

where ${}_nN_x^* = \left[{}_nN_x(t1) \cdot {}_nN_x(t2)\right]^{1/2}$ is equal to the geometric mean of the number of persons between t1; $S_x = 5 \cdot \sum_{a=0,5}^{x-5} {}_5r_a + 2.5\,{}_5r_x$ is the age-specific growth rate accumulated to the middle of the age interval; and $_{n}r_{x}[t1,t2]=\dfrac{\ln\left({}_{n}N_{x}(t2)/{}_{n}N_{x}(t1)\right)}{(t2-t1)}$ represents the age-specific growth rate. Based on these functions one can then calculate a complete life table by assuming that the number of persons who reach age x, l_x, is a linear function over the age interval centered at age x. Thus, the number of survivors is expressed by:

$$l_{x}=\frac{1}{2\cdot n}\cdot\left({}_{n}L_{x}+{}_{n}L_{x-n}\right) \tag{9}$$

l_0 = the average number of births entering this population between t1 and t2. This initial value is calculated iteratively in order to approximate the observed and projected populations in the first two age groups.

But, since the Preston-Bennett method (1983) is based on intercensal growth rates, it is sensitive to age distortions produced by differences in census coverage and net migration. The estimates of life tables by race/color derived from this method are particularly affected by the process of racial reclassification, since the age distribution observed in the most recent period reflects not only the dynamics of mortality and migration, but also on the reclassification processes. Since there is evidence that the racial reclassification process in Brazil is not negligible (Carvalho et al 2004), the population in t2 must be adjusted to minimize the bias that ages cause in growth rates, in order to correctly reflect the probable black or white population before racial reclassification.

To reduce the bias caused by the distortion in the age structure of the population seen in the 2000 Census, resulting from differences in coverage, reclassification, and intercensal migration, the white and black populations should be inferred on the basis of the populations seen in 1990. To do this, Merli (1998) suggests an iterative procedure implemented in two stages. In the first stage the 1990 populations are projected to 2000 using the survival probabilities in the intercensal life tables by race/color calculated according to the Bennett-Horiuchi method (1984). Two age structures result from these projections, one for 1990 and the other projected for 2000, free of migration processes and intercensal racial reclassification. A new life table is then calculated on the basis of these two distributions using the Preston-Bennett method (1983), but this table is much less influenced by differences in coverage, migration and intercensal racial reclassification.

A new series of projections is carried out during the second stage of iteration in order to correct the growth rates initially calculated with the Bennett-Horiuchi method (1984) but now using the new intercensal growth rates obtained from the Preston-Bennett method (1983) that was applied during the first stage. This iterative process between the two methods continues until the life expectancies estimated by each method no longer vary. For both black and white males and females, convergence comes about after approximately ten iterations.

Two new life tables result after the data has converged at the end of the iterative process. The first life table is calculated by Preston-Bennett's intercensal method (1983), using a projected age distribution corrected for problems in coverage, migration and racial reclassification (Method 5). Next, a second life table is calculated on the basis of the intercensal death distributions (Bennett and Horiuchi 1984), but this time using age-specific growth rates corrected by the iterative process (Method 6).

4. Homogenization of the race-specific and age-specific growth rates (Method 7)

Merli (1998) used the Preston-Bennett and (1983) the Bennett-

Horiuchi (1984) methods to estimate mortality in Vietnam between 1979 and 1989. She then applied the iterative method to combine the two procedures. Merli's conclusion was that the Bennett-Horiuchi method, based on the intercensal distribution of deaths, is the more robust, despite differences in coverage, intercensal migration, and non-differential underreporting of deaths by age.

For Vietnam, the Bennett-Horiuchi method (1984) proved to be robust and only slightly sensitive to variations in the intercensal growth rate, especially because Merli herself presented no major variations in the growth rate. First, because net migration was incorporated into her estimates, and secondly because the age structure used to calculate the growth rates were influenced by racial reclassification, as is the case with the Brazilian age structure.

In order to test the sensitivity of life expectancies to changes in the intercensal growth rate by age and race/color, we assumed the same growth rates for blacks and for whites, but we maintained the differences in growth rates by age and by sex. This detail was important for three reasons. First because by homogenizing growth rates by race/color, the sensitivity of the Bennett-Horiuchi (1984) method to variations in growth rate can be evaluated. Second, because, by constructing a counterfactual scenario, one can determine what the life expectancy of black and white males and females would have been if these racial groups had shown the same intercensal growth rates. Third, because this simulation offers a way of getting around a possible bias of reclassification generated in the estimates.

If the specific intercensal growth rates by race/color had been used to calculate the life tables, the effect of the racial reclassification would have been embedded in the estimates of life expectancy, undoubtedly affecting their reliability. The fact is that we are not dealing here with any actual change in the growth rate among populations, but rather with a merely apparent growth generated by reclassification, and it must therefore be taken into account in estimates of mortality. To mitigate the effect of the apparent growth process caused by racial reclassification, we estimated different growth rates only by gender and by age, without considering the race/color variable. By ensuring growth rates for blacks and whites that are the same as those of the total population, this process of homogenizing growth rates minimizes the bias that would have been generated in the estimates due to racial reclassification. The estimates resulting from this simulation are referred to as Method 7.

II. Results

This section discusses proposals for a life table that takes the race/color aspect into consideration. The results of each method will be objectively and succinctly presented in order to provide readers with a possible route to follow, taking into account the methods and data sources available. In so doing, we emphasize not only the methodology itself, but its capabilities and drawbacks as well, especially with regard to the required data source.

Comparison among life expectancies derived from the different proposed methods

Tables 4 and 5 show, respectively, life expectancies of males and females by race/color resulting from each of the applied methods. The steps and intermediary functions derived from each of the methods and used in the construction of the life tables are not presented in this article but are available upon request.

Table 4: Female life expectancy, indirect (1, 2, 3) and direct methods (4, 5, 6 and 7). Brazil, 1995

Age (x)	Method 1		Method 2		Method 3		Method 4		Method 5		Method 6		Method 7	
	White	Black	White	Black	White	Black	White	Black	White	Black	White	Black	White	Black
0	72.46	69.21	72.71	67.03	72.61	67.77	76.71	68.08	76.74	64.09	74.80	70.38	71.68	65.71
1	73.18	70.69	73.37	69.01	73.11	68.95								
5	69.53	67.32	69.70	65.99	69.39	65.49	72.63	65.80	71.21	66.23	71.24	67.05	68.53	63.40
10	64.68	62.57	64.85	61.34	64.52	60.71	67.68	60.98	67.05	60.87	66.32	62.17	63.64	58.60
15	59.79	57.76	59.96	56.60	59.62	55.87	62.74	56.17	61.83	59.53	61.41	57.30	58.76	53.81
20	54.97	53.04	55.13	51.96	54.72	51.39	57.86	51.50	56.38	53.73	56.58	52.51	53.97	49.19
25	50.19	48.41	50.34	47.43	49.84	46.95	52.99	46.88	51.05	47.38	51.76	47.78	49.23	44.65
30	45.44	43.81	45.58	42.92	44.97	42.55	48.15	42.30	47.45	42.97	46.96	43.11	44.51	40.16
35	40.73	39.24	40.86	38.45	40.19	38.00	43.34	37.82	42.95	38.88	42.20	38.54	39.86	35.78
40	36.06	34.72	36.18	34.03	35.46	33.49	38.59	33.50	37.79	34.37	37.50	34.12	35.30	31.58
45	31.49	30.28	31.60	29.67	30.81	29.07	33.95	29.36	33.26	30.14	32.93	29.86	30.90	27.57
50	27.05	25.97	27.15	25.44	26.28	24.76	29.44	25.40	28.43	25.77	28.50	25.79	26.66	23.78
55	22.78	21.83	22.86	21.38	21.90	20.61	25.08	21.64	23.77	21.77	24.25	21.95	22.62	20.25
60	18.70	17.90	18.77	17.52	17.69	16.65	20.88	17.98	19.76	18.16	20.16	18.23	18.76	16.84
65	14.90	14.26	14.96	13.96	13.72	12.95	16.93	14.69	16.30	14.89	16.32	14.89	15.20	13.83
70	11.51	11.01	11.55	10.79	10.06	9.56	13.24	11.62	12.90	12.06	12.72	11.75	11.93	11.02
75	8.62	8.27	8.65	8.11	6.73	6.49	9.99	8.90	8.82	8.51	9.51	8.92	9.12	8.53
80	6.33	6.10	6.35	6.00	3.50	3.50	5.68	4.82	4.43	4.33	5.43	5.07	5.23	4.73

Source: IBGE, 1991 and 2000 Brazilian Censuses and 2008 PNAD.

Table 5: Male life expectancy, indirect (1, 2, 3) and direct methods (4, 5, 6 and 7). Brazil, 1995

Age (x)	Method 1		Method 2		Method 3		Method 4		Method 5		Method 6		Method 7	
	White	Black	White	Black	White	Black	White	Black	White	Black	White	Black	White	Black
0	69.62	65.98	68.64	62.77	69.24	63.99	70.65	60.73	69.65	55.53	67.53	61.3	69.47	63.49
1	70.59	67.87	69.84	65.52	70.22	66.23								
5	66.94	64.53	66.27	62.65	66.58	63.08	66.69	58.03	64.07	57.33	64.11	58.07	65.76	60.24
10	62.14	59.84	61.49	58.08	61.77	58.44	61.76	53.22	60.05	51.93	59.22	53.23	60.85	55.38
15	57.29	55.06	56.66	53.38	56.92	53.70	56.83	48.41	54.99	49.97	54.32	48.39	55.93	50.54
20	52.54	50.43	51.94	48.85	52.14	49.16	52.13	44.30	49.55	44.87	49.73	44.13	51.27	46.30
25	47.87	45.90	47.31	44.45	47.36	44.64	47.58	40.60	44.38	40.10	45.34	40.24	46.76	42.42
30	43.17	41.34	42.65	40.03	42.58	40.13	43.03	36.80	41.13	36.27	40.93	36.34	42.26	38.47
35	38.47	36.78	37.98	35.61	37.85	35.63	38.50	33.00	37.19	32.59	36.54	32.49	37.79	34.50
40	33.82	32.28	33.37	31.25	33.17	31.18	34.05	29.29	32.39	28.77	32.22	28.77	33.40	30.62
45	29.27	27.89	28.87	27.00	28.59	26.85	29.72	25.74	28.21	25.38	28.03	25.21	29.13	26.89
50	24.91	23.71	24.56	22.95	24.19	22.70	25.55	22.30	23.90	21.74	24.02	21.77	25.03	23.29
55	20.80	19.77	20.49	19.14	20.01	18.79	21.59	18.97	19.85	18.29	20.25	18.47	21.13	19.82
60	17.01	16.15	16.76	15.63	16.14	15.17	17.85	15.78	16.45	15.34	16.71	15.34	17.44	16.51
65	13.58	12.88	13.37	12.48	12.58	11.87	14.42	12.90	13.21	12.32	13.50	12.56	14.08	13.5
70	10.55	10.01	10.39	9.70	9.35	8.89	11.30	10.25	10.73	10.10	10.58	10.02	11.04	10.68
75	8.01	7.60	7.89	7.37	6.41	6.18	8.74	8.00	7.78	7.59	8.16	7.82	8.57	8.28
80	6.02	5.73	5.93	5.56	3.50	3.50	5.50	4.74	4.21	4.11	5.22	4.83	5.37	4.95

Source: IBGE, 1991 and 2000 Brazilian Censuses and PNAD 2008.

Life expectancies resulting from Methods 1, 2 and 3 are similar to those found in the literature (Funasa 2005, Paixão and Carvano

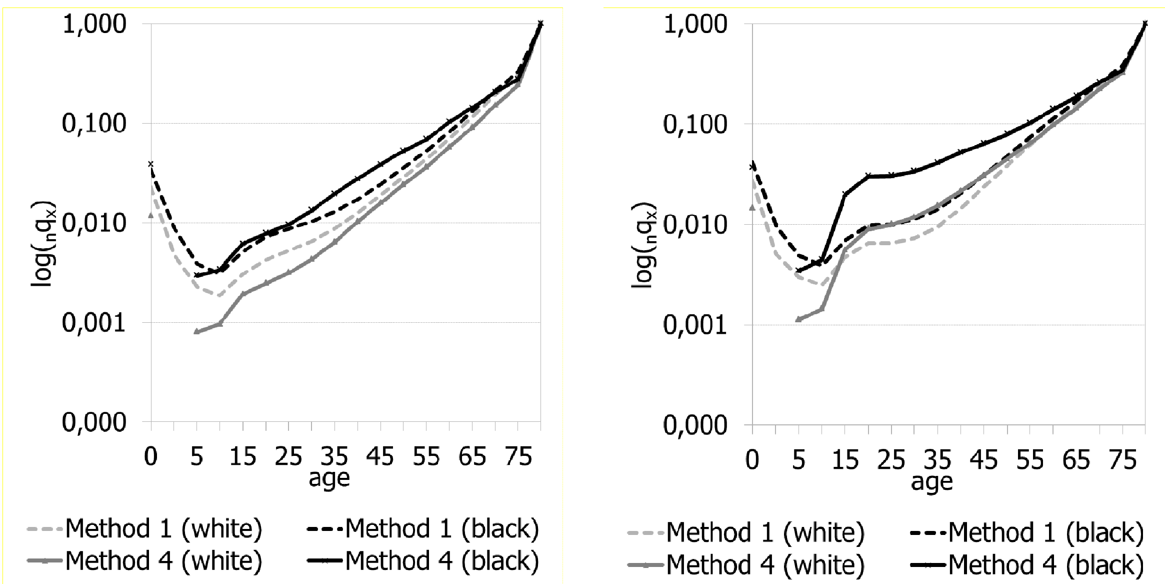
2008) and to those obtained by direct methods. Nonetheless, such estimates have three drawbacks that must be discussed and should serve as indications as to why indirect estimates are not to be recommended. The first drawback is the impossibility of accurately updating the information since the basic data for calculating child mortality is derived from the demographic censuses, which are taken only every ten years.

The second limitation is that the estimates obtained through indirect methods involve time lags. Specifically, these types of procedure do not allow for sufficiently updated estimates of the mortality of the population according to race/color. Although we cannot state that the factor invalidates this type of method, it certainly renders them less adequate as the basis for concrete action in terms of public policies.

A third limitation of indirect methods concerns the mortality pattern that is chosen to complete the mortality estimates for intermediate ages (3 to 60) and for advanced ages (over age 60). The indirect methods presented are based on the assumption that the appropriate mortality pattern for black and white males and females is similar to the Coale-Demeny West model. This assumption, however, is not always true or compatible with the real mortality pattern observed in these populations, especially because the West pattern does not reflect recent gains in survival at advanced ages. Neither does the West pattern reflect the Brazilian mortality structure between the ages of 20 and 30, when the effect of mortality resulting from external causes of death (such as traffic accidents and homicides) is more prevalent. To illustrate this argument, the chart below shows a comparison between the mortality patterns used in (indirect) Method 1 and in (direct) Method 4.

Chart 1: Probabilities of death by age according to sex and race/color. Brazil, 1995

Females   Males



Source: IBGE, 1991 and 2000 Demographic Censuses.
Ministry of Health, 1997-2000 SIM.

The dotted curves refer to the West model and the unbroken curves indicate the mortality pattern estimated on the basis of data from the Brazilian Mortality Information System (SIM) and the Censuses as per Method 4. The chart on the left (Method 4) shows that the difference in mortality between white and black females is higher than that indicated by the estimates obtained on the basis of child mortality (Method 1). In the case of males, the chart on the right shows that the mortality rate for black males is higher than that suggested by the West pattern, especially for adults. The chart also suggests greater differences between blacks and whites when Method 4 is used.

The results reported in Tables 4 and 5 also show that procedures based on the Bennett-Horiuchi method (Method 4) and on that described by Merli (Method 6) show results similar to those calculated on the basis of the indirect methods. The differences are explained by the processes and assumptions of the methods. This is the case, for example, of the higher life expectancies estimated for black males, obtained from the indirect methods, because of the West model used. Life expectancies obtained with indirect methods are about four years higher than that obtained with direct methods (such as Methods 4 and 6). This is mostly due to the fact that the model life tables fail to take into account new trends in adult mortality, which is higher among men.

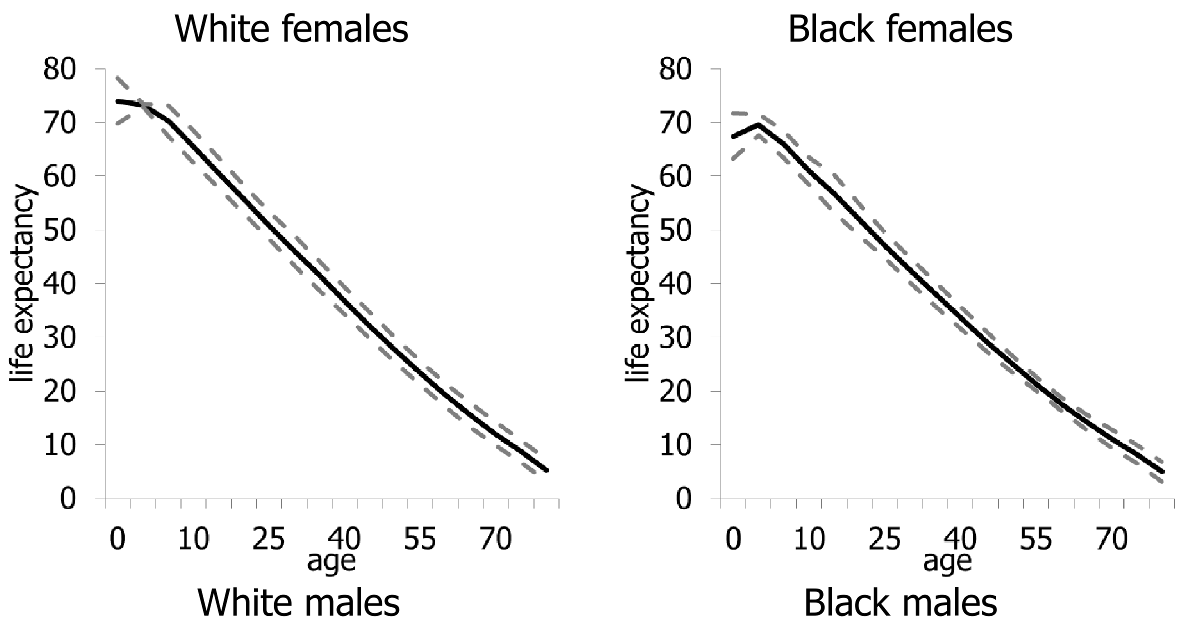
III. Elements that favor the Bennett-Horiuchi Method (No. 4) and the Merli Method (No. 6)

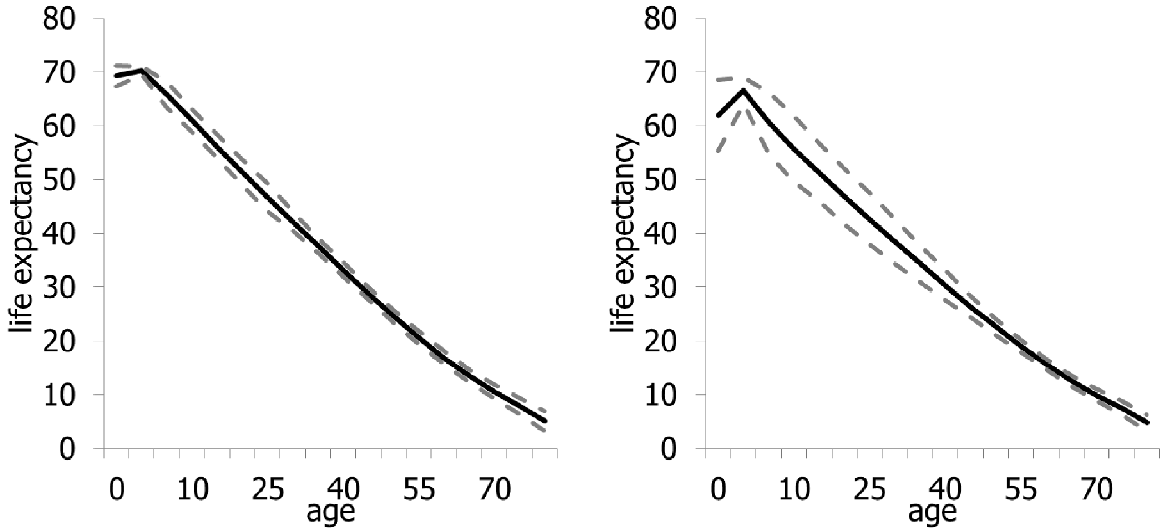
The indirect methods traditionally used to calculate mortality rates have a problem of time lags. It is also important to stress that these methods provide estimates that are generally underestimated, as their creator, William Brass, warned and as was seen in Chart 1.

However, due to the widespread use and recognized usefulness of indirect methods, one cannot fail to refer to them as parameters for testing the robustness of estimates obtained by other methods.

Therefore, in order to contrast the results obtained by the Bennett-Horiuchi Method (1984) and the Merli Method (1998), and using results obtained by the indirect methods as a reference, the consistency of the estimates can then be evaluated by constructing a range of life expectancies using the seven methods described here. To analyze the consistencies and discrepancies among the various estimates, confidence intervals were calculated on the basis of the mean and the standard deviation of the life expectancies according to race/color and to age obtained by the different methods. The intervals were constructed assuming a confidence level of 95% and supposing that the life expectancies by age are normally distributed. The solid lines represent the average life expectancy by age, and the dotted lines represent the confidence intervals corresponding to that of the standard deviations. These intervals are shown in Chart 2.

Chart 2: Statistical confidence intervals of 95% for estimated life expectancies by sex and by race/color derived from different methods.
Brazil, 1995





Source: Tables 4 and 5.

The charts show that the lowest variations among estimates are for white persons. In contrast, the broadest confidence intervals are for black males, which may indicate the presence of significant differences depending on the methodology used to calculate the life tables. Depending on the method used, life expectancy at birth for a black male may vary from 55 to 72 years, a difference of 17. In contrast, the variation in life expectancy at birth for white females is less than ten years, ranging from 72 to 78. The variability of estimates tends to decrease at older ages.

Method 6 was also used to set up the confidence intervals described above. Although this procedure is based on the Bennett-Horiuchi Method (1984), it holds certain advantages over it and over the others. Since Method 6 takes into account growth rates in the populations observed in t1 and projected in t2, it minimizes the possible biases from migration and reclassification processes, and therefore stands out as one of the most suitable options for constructing life tables by race/color.

In sum, comparison with other methods confirms the conviction that the best way to calculate estimates of mortality for both blacks and whites must combine death counts and intercensal growth rates (Methods 4 and 6). At least this is certainly true when one takes into consideration the data available in Brazil, the specific age structure of mortality among white and black populations, and the need to come up with estimates that are as recent as possible and therefore reflect the current state of differential mortality by race/color.

IV. Final observations

One of the major concerns in this study was to present findings as to the differences in life expectancies between two categories of race/color. The article also analyzes methods and data sources that would ensure (or at least maximize) the reliability of the estimations and allow for frequent updating.

Considering the several different methods and data sources discussed in this article, we are of the opinion that the results obtained by the Bennett-Horiuchi method (1984) (Method 4) and that developed by Merli (1998) (Method 6) are the best. The more conventional, indirect, methods for estimating life tables by race/color do not accurately reflect patterns of mortality by race/color and are unable to provide current estimates due to the time lags involved in estimating mortality levels.

Several different reasons have led us to recommend the use of direct methods to estimate life tables by gender and race/color . The first reason, which we consider the most important, is that Methods 4, 5 and 6 do not depend on the choice of a pre-defined pattern of mortality by age. Since the structure of the mortality curve is defined by data from the SIM, one need not know beforehand the most adequate mortality pattern for blacks and whites, males and females, etc. Also, by using data from the SIM, the possibility arises to obtain a specific mortality pattern for the population being studied. This is particularly important for the case of Brazil, given the strong influence of external causes of mortality among young adults, especially males and blacks. This influence can be seen in the higher and irregular behavior of death probabilities between ages 15 to 35, – as shown in Chart 1.

The second reason for choosing Method 4 (Bennett and Horiuchi, 1984) and Method 6 (Merli, 1998) is their greater methodological (they are not overly rigid in terms of theoretical presuppositions) and temporal flexibility in comparison with other methods. Besides demanding no presuppositions as to stability in the racial classification of the population over time and a mortality pattern chosen beforehand, this method requires that one knows only the distribution of intercensal deaths and the growth rate by age for the population under study.

Moreover, these methods are also comparatively convenient since they can be used for recent periods, as long as the growth rate is consistent with the population dynamics to be studied. Since the annual data from the SIM has been significantly improved over time in terms of coverage and quality, especially in reporting race/color, this means that estimates of life expectancy disaggregated by this variable can be updated more frequently on the basis of the annual death count by SIM.

Thirdly, the methods are robust even in the presence of underreporting of deaths by race/color. The methods based on the distribution of deaths remain effective despite the existence of differences in underreporting by race/color as long as the registration of deaths is not severely distorted by age. Nonetheless, the effect that the underreporting of deaths, especially present at advanced ages, might generate in the final estimates of life expectancy by race should be investigated.

However, the proximity between the estimates generated by Methods 4 and 6 and the indirect estimates suggests that the method is robust even when deaths are underreported at advanced ages. This can be evidenced on the basis of life expectancies at birth, shown in Table 6.

Table 6: Estimates of life expectancy at birth calculated by different methods. Brazil, 1995

	Male		Female	
Method	White	Black	White	Black
1	69.62	65.98	72.46	69.21
2	68.64	62.77	72.71	67.03
3	69.24	63.99	72.61	67.77
4	70.65	60.73	76.71	68.08
5	69.65	55.53	76.74	64.09
6	67.53	61.30	74.80	70.38
7	69.47	63.49	71.68	65.71
Mean	69.26	61.97	73.96	67.47

Source: Tables 4 and 5.

Brief description of each method: Method 1: Indirect estimation based on infant mortality, mean of q2 + q3 + q5, and the Coale-Demeny West model life table (1983), specific by sex.

Method 2: Indirect estimation based on adult mortality, mean of q50 + q70, and the Coale-Demeny West model life table (1983), specific by sex.

Method 3: Indirect estimation using two parameters of mortality, q3 and q60, and the Coale-Demeny West model life table (1983); infant mortality is represented by the mean of the mortality level corresponding to ages 2, 3 and 5. Adult mortality is represented by the mean mortality level corresponding to ages between 50 and 70.

Method 4: Direct estimation, based on two age distributions and on the number of intercensal deaths; this method was suggested by Bennett and Horiuchi (1984) and improved by Preston et al (1996).

Method 5: Direct estimation, resulting from the Preston-Bennett model (1983) followed by the iterative procedure suggested by Merli (1998).

Method 6: Direct estimation, resulting from the Bennett-Horiuchi model (1984) followed by the iterative procedure suggested by Merli (1998).

Method 7: The Bennett-Horiuchi method (1984) assuming that the intercensal growth rate by age and gender for whites and blacks is the same as that of the total population.

Mean= arithmetic average of the figures estimated by Methods 1, 2, 3, 4, 5, 6 and 7.

The results of this study, particularly the estimates and the respective methods indicated as most appropriate, attain the study's objectives, because:

1. The study presents an alternative methodology which allows greater flexibility in terms of data quality and continuous updating of the estimates, since they are based on a continuous source of information: death counts tabulated by the SIM, of the Brazilian Health Ministry.
2. The estimates obtained and recommended are seen to be entirely consistent with what was already known about differences in mortality by race/color in Brazil. Nonetheless, they represent an advance in the sense that they are independent of foreign models of mortality, which, as we know, are becoming less and less reliable for reflecting the reality of the phenomenon in Brazil.
3. The real and relatively simple possibility of replication at any time also gives this alternative an advantage over indirect methods, which always depend on special tabulations of the governmental

censuses and/or PNADs, which, as we know, are never immediately accessible.

Here we have defended the advantage of statistical methods that are less conventional than those used until the present for making these types of estimates. The option for such methods has been cause for some concern, but it has also proven to be the most promising path to take in order for estimates of mortality by race/color to be updated more rapidly and accessed more easily by other researchers and health planners.

A number of issues and methodological difficulties have been brought up in this article, many of which have been partially addressed. From the standpoint of the scientific process, therefore, this study took a very interesting path which, if further developed, may contribute to further improvement of these estimates.

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