Title: Temporal and spatial estimation of adult mortality in small areas of Brazil.

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Introduction
In Brazil, a lot is known about variations of infant and child mortality (Souza, Hill and Dal Poz, 2010; Castro and Simões, 2009), however, very little is known about spatio-temporal trends in adult mortality. We argue that producing proper estimates of adult mortality for small areas in Brazil is very relevant, because recent and future changes in life expectancy are probably going to be explained by future variations in adults and elderly mortality, since in the country there is a clear trend in convergence in the levels of infant and child mortality (Souza, Hill and Dal Poz, 2010).

However, small areas mortality estimates often have small risk populations that produce unstable estimates, even when one uses data from large household surveys, population censuses or administrative data. Besides that, the mortality data for small areas are also affected by regular fluctuations (small numbers) in the region. That is to say, with traditional demographic techniques, the small-populated areas often produce extreme estimates, dominated by sampling noise that may have little relationship to underlying local mortality risks (Bernadinelli and Montomoli 1992). In this context, the public health administrations are faced with limited information to allocate resources and it is also difficult to study the progress of public policy interventions at the sub-national levels, limiting the action of government agencies in improving the quality of life of these sub-populations. Given all the limitations and estimation problems, this paper aims to study the evolution of adult mortality in small areas in Brazil from 1980 to 2010 based on alternative approaches. We produce estimates of adult mortality, measured by 45q15, across small areas in Brazil by two methods. The first method combines the death distribution methods (DDM) to indirect standardization in order to produce more reliable estimates of adult mortality for small areas. The second method is based on Bayesian statistics estimates.

The two-stage (indirect standardization + DDM) method was first applied to estimate by Lima et.al (2012), in order to produce mortality estimates for health microregions of the state of Minas Gerais (about 10% of the Brazilian population). They produce estimates for both sexes combined and in only one point in time. In this paper, we extend their analysis and produce adult mortality estimates for the whole country (to 137 small areas), estimating mortality for males and females separately and covering the period from 1980 to 2010. We expect that this paper will provide spatio-temporal estimates useful for future research, especially to analyze trends in adult mortality in Brazil and investigate how changes in socioeconomic conditions are related to changes in adult mortality. We also presume that the methods here applied can also be used for future research in other less-populated areas.
Data and methods

We make use of the mortality database available at the Brazilian Ministry of Health Database - Datasus (França, et.al, 2008; Ministério da Saúde, 2012). The data are collected by age, sex and causes of death at the municipality level. Population by age and sex comes from national household census conducted by the National Statistics Office in 1980, 1991, 2000 and 2010. We aggregated municipalities by comparable small areas, using the National Statistics Office (IBGE) definition of comparable mesoregions. These regions are constructed utilizing regional and socioeconomic similarities. The regions only serve a statistical purpose; therefore, they do not represent a political or administrative entity. The main advantage of working with these comparable areas is that they have not changed their boundaries over the period of analysis. Thus, we are able to follow and study 137 small areas between 1980 and 2010.

Mortality Coverage Evaluation

To evaluate the coverage of reported deaths we use traditional demographic methods, called Death Distribution Methods – DDM henceforth (Hill, You and Choi, 2009; Dorrington, 2012a; 2012b). The DDM are commonly used to estimate adult mortality in a non-stable population and analyze mortality data quality in intercensal periods (Timeaus, 1991; Hill et al, 2005; Hill, You and Choi, 2009) They make several strong assumptions: 1) that the population is closed to migration; 2) that the completeness of recording of deaths and population are constant by age; and 3) that ages of the living and the dead are reported without error.

Combining indirect standardization with death distribution methods

The estimates for adult mortality in Brazil followed the methodology applied by Lima et al (2012) for Minas Gerais, Brazil. The methodology consists in a combination of indirect standardization with death distribution methods (DDM). In order to evaluate the mortality data and to estimate adult deaths rates in small areas, the authors first applied an indirect standardization as smoothing method to get more stable mortality age schedules for small areas in Minas Gerais, Brazil, between 1991 and 2000. Afterwards, they applied the DDM to correct the mortality levels of these small areas and subsequently estimate adult mortality. The indirect standardization is a useful technique since it allows not only to compare rate levels between different populations, but also to estimate vital rates schedules in population which does not have reliable data information (Preston et al., 2001). The method takes a function (or a set of age-specific rates) from a population that, a-priori, is considered similar to the study population (Lima et al., 2012). In that study, the function is originally taken from the bigger region from where the small belongs and it is assumed that the pattern of mortality for both populations, small and big, are very similar during the period of analyses. The principal is similar to the Bayesian idea of minimize rates fluctuation errors by using the vital record information of the neighborhood (Marshall, 1991). The indirect standardization is as follows:

\[ n \bar{\sigma}_{x_i} = nN_{x_i} \times n\bar{m}_{x_i} \]  

Where:

\[ n \bar{\sigma}_{x_i} : \text{Number of expected deaths in the small area } i \text{ in time } t \text{ between the ages } x \text{ e } x+n; \]

\[ nN_{x_i} : \text{Population in small area } i \text{ in time } t \text{ between ages } x \text{ e } x+n; \]

\[ n\bar{m}_{x_i} : \text{Age-specific mortality rates between ages } x \text{ e } x+n \text{ in big area } j \text{ in time } t. \]
Thus, using the age-specific mortality rates of bigger areas, they estimate the expected number of deaths for the smaller areas between the years 1991 and 2000. In the second step, they analyze the quality of mortality data for small areas (comparing the new observed death counts to the death counts expected by demographic changes) of death records and estimated measures of adult mortality for the same period (Lima et al. 2012).

Figure 1 shows the results from Lima et al (2012) for Minas Gerais. The application of the proposed methodology involves an evaluation of mortality schedules of small areas in the given period. The figure shows the age-specific mortality rates with and without standardization in a health microregion. According to figure 1, the observed mortality rates present a very unstable age structure. These variations are even more pronounced when compared with the age-specific rates estimated by indirect standardization. It should be noted, however, that the levels of both schedules are relatively similar, i.e. the proposal method is correcting the age-specific mortality fluctuations, but it does not to impose a very different levels of mortality.

Figure 1: Age-specific mortality rates, estimated directly and through indirect standardization. Small region of Health of Padre Paraíso, 1991-2000

Source: Lima et al. (2012).

Expected results: analyzing data quality and estimating adult mortality for small areas in Brazil. We present some results of mortality schedules and cumulative deaths probability of one selected mesoregion in the Brazilian north (Norte do Amapá), this region is characterized by presenting one of the worst quality in mortality data in Brazil. Figure 2 shows the results for males and females, respectively, from the intercensal period 1991-2000. The figure shows that age-specific mortality rates have a very erratic pattern, making it impossible to produce adequate estimates of adult mortality (see table 1). For some ages, in particular areas, the vital records indicated that not a single death occurred at that age. This could happen for many reasons: it can be a problem of death count under-registration, problem of small numbers or a real feature of the data. In any case, it is important to find ways to produce more reliable estimates of adult mortality for small areas in Brazil.

Table 1 presents preliminary estimates of adult mortality, 45q15, for males and females. These estimates are presenting an enormous variation in 45q15, ranging from 40% to 50% between both methods. Thus, there is a clear problem with the mortality schedules of these areas that affects the 45q15. The next step of the paper is to produce adult mortality probabilities using the two-stage (indirect standardization +
DDM) and Bayesian methods. This way, we expect to obtain more trustworthy adult mortality estimates for these small areas. These estimates will further be helpful for public health administrations to allocate resources and to progress with public policy interventions at the sub-national levels.

**Figure 2: Age-specific mortality rates estimated directly, males and females, Brazil, mesoregion Norte do Amapá, 1991-2000.**

Source: Lima et al. (2012).

**Table 1: Estimates of Adult Mortality, mesoregions of Brazil, 1991-2000 (Female and Male Separately)**

<table>
<thead>
<tr>
<th>Mesoregion</th>
<th>45q15 No mortality correction</th>
<th>DDM 45q15</th>
<th>45q15 No mortality correction</th>
<th>DDM 45q15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norte do Amapá</td>
<td>0.04</td>
<td>0.61</td>
<td>0.08</td>
<td>0.48</td>
</tr>
</tbody>
</table>

* No mortality correction: the estimates are based on age-specific mortality rates without correction. DDM: Death Distribution Method. We used an average of the 3 methods (GGB, SEG and SEG-adj), estimating the completeness of death counts using the age range 30+ to 65+. 