Maternal Mortality Estimation of Indigenous People in Brazil: a new methodological approach*

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Abstract

Reduction of maternal mortality is part of the Sustainable Development Goals, agreed by UN country members. To this day, Brazil is still present high levels of maternal mortality rates, while compared to more developed countries. Knowing that indigenous are a vulnerable population in our country, the aim of this paper is to estimate maternal mortality rates to all self-declared indigenous groups in Brazil in 2010. We use 2010 population census and vital statistics as data sources. This census was the first research that has mortality information by indigenous groups, ethnicity and languages spoken. We estimate maternal mortality in the 137 Brazilian mesoregions, by combining parametric statistical models with formal demographic methods. Our results show that indigenous maternal mortality still show high levels even in very recent periods.

Keywords: Maternal Mortality, Indigenous Population, Small Areas, Brazil

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Introduction

During the colonial period, lived in Brazil somewhat of 1,000 different indigenous groups, with an estimated population of 4 to 7 million people. This population was partly exterminated by the colonization processes, and by wars and epidemics that affected these groups from the coast (in the XVI century) towards the countryside, during the XVIII century. According to 2010 census, in the country, there are 305 indigenous groups inhabiting territories demarcated as native lands owned by the Union, with exclusive use for these communities. There are also some native peoples residing in small and large urban centers, or in lands not yet identified in the process of demarcation. In 2010, the Brazilian census accounted for 900,000 individuals who declared or considered themselves indigenous.

Over time, governmental efforts have been made to improve indigenous lives in Brazil, and the 1988 Brazilian Constitution guaranteed a number of civil rights, not only for the indigenous people, but also for implementation of public policies aimed to improve their life. However, there is a clear lack of more detailed and widely population information systems to guide, to monitor and to evaluate these public policies.

The Brazilian demographic censuses began to differentiate the indigenous people since 1991, with the self-declared information in terms of race/color. Nevertheless, many studies have already shown that this strategy has been insufficient to have a better idea of the socio-demographic situation of indigenous people.

The Brazilian Population Censuses of 1991 and 2000 captured those who self-declared or identified themselves as native people, by a new question that included in the information of race/color in the sample questionnaire. The 2010 census had an advance over its precedents, because it includes this question of self-declared ethnicity in the population questionnaire and, additionally, more questions were asked, for example "to which people or ethnicity did they belong?"; enabling the identification of 305 indigenous peoples speaking somewhat of 270 different languages. This population contingent includes people who identify themselves as: 1) "Indigenous descendants", even though they do not know to which ethnicity their ancestors belonged (generally known as maternal ancestors); 2) people living in urban dwellers and recognize themselves as belonging to a specific group/ethnicity; 3) people who live in indigenous lands and who recognize themselves as belonging to a specific ethnicities, and 4) people who recognize themselves as belonging to a specific ethnicity, and who are in the process of claiming their land and, in some cases, their ethnic identities. This inquiry has further advantage in terms of mortality studies, because it includes information related to deaths in the household in the last twelve months. That opens opportunity to explore population mortality patterns in relation to socioeconomic characteristics, not always available in administrative and vital records.

1. The challenges to estimate indigenous maternal mortality

The knowledge of the exact level and structure of mortality is essential for government agencies to establish their health policies. In the context of the millennium goals, studies relating to population health are becoming necessary, especially when the population of interest live in small locations. This knowledge is important, because they help researchers to investigate the environmental and behavioral aspects of diseases, enabling better access to health care and better understanding of the socioeconomic determinants of mortality and morbidity in these areas (Ferguson et al. 2004).

However, in developing countries, the information of mortality levels and trends are frequently limited by the quality of the data, and the most common problems faced are incomplete coverage of vital registration systems and errors in age declaration for population as well as death counts (Queiroz et al. 2017, Lima and Queiroz 2014). Concerning maternal mortality, even in the developed regions, information on maternal deaths suffers with quality issues, often due to inaccurate reporting of the main cause of death (Laurenti et al. 2000). That happens because death certificates routinely provide detailed information on the cause of death, but they do not necessarily contain information on whether death was related to pregnancy, childbirth or the puerperium (Luizaga et al. 2010).

When it comes to small populations or subgroups, such as indigenous ones, these problems are even bigger. To contour the problem of demographic estimates, we propose the use of parametric statistical models in combination with formal demographic methods to generate robust estimates of maternal mortality in different indigenous regions of the country.

The adopted estimation strategy is twofold. First, we smoothed and imputed the deaths information for indigenous women in reproductive ages, by applying a hierarchical Poisson regression model. As a second step, we analyze the mortality and birth data and check for under-registration of vital events. In other words, the number of unregistered events at certain ages can be attributed to the fact that the death and births occurred, but they were not recorded. In this case, we analyze the integrity of indigenous vital statistics based on formal demographic methods, which will be described in the next topics.

2. Methodological approach adopted

In order to estimate maternal deaths among indigenous populations in Brazil, we employ some demographic and statistical methods that will be described in this section. First, we will talk about the most common key indicators or measures for maternal mortality and, therefore, give a brief description of the data and methods used.

2.1. Maternal Mortality Indicators

Maternal mortality is an important indicator of a country's health development, as it concerns not only socioeconomic factors, but also directly reflects the access and conditions of health facilities offered to the population (McCarthy and Maine 1992). Among the main indicators of maternal mortality, Wilmoth et al. (2012) highlight,

- ✓ The Maternal Mortality Ratio (MMR), which is described as the number of maternal deaths per 100,000 live births;
- ✓ The Maternal Mortality Rate (MMRate), which represents the number of maternal deaths relative to the number of women in reproductive age or exposed to the risk of death (i.e. the total number of person-years lived by women aged 15-49), and;
- ✓ The Proportion of Maternal Deaths (PMD): the ratio of maternal deaths by the total number of deaths of women in reproductive age (15 to 49 years);

Each of these indicators has a specific representation in terms of information. MMR reflects, for example, the risk of death in a single pregnancy. This is the most common measure that indicates the intensity that maternal deaths occur in a population

(ONU, 2012). Maternal deaths can be divided into two groups, namely direct and indirect obstetric deaths. Direct obstetric death results from obstetric complications of gestational status (pregnancy, childbirth and the puerperium), interventions, omissions or direct treatment, and or a chain of events resulting from any of them.

Indirect deaths result from previously existing illnesses, or diseases that developed during pregnancy, which were not directly due to obstetric causes, but they were aggravated by the physiological effects of pregnancy (ONU, 2012). This indicator monitors deaths related to pregnancy and childbirth, and also reflects the ability of health systems to provide effective health care in preventing and treating complications that occur during pregnancy and childbirth. The values of this measure range from under 10, as in the most developed countries, to over 1,000, with an average of 290 deaths per 100,000 live births, in developing regions. However, values above 1,000 are found in a relatively small group of countries and should be considered extremely high (ONU 2012).

The MMRate contains the same information as the maternal mortality ratio, and also includes the fertility level, considering the risk of conception in its denominator. The problem with these two indicators lies in the distinct origin between the numerator (from vital statistics) and the denominator (usually demographic censuses), something that does not occur with the proportion of maternal deaths (PMD) (Hill et al. 2007).

In fact, one of the main difficulties involving the calculation of maternal mortality indicators is the source of information, especially in developing or underdeveloped countries, which lack robust and reliable birth and death registration systems (Wilmoth et al. 2012). In this paper, we will estimate and present results for MMRs in several indigenous regions of the country.

2.2. Maternal Mortality Definitions and Data Sources

Maternal death is defined by the 10th International Classification of Diseases (ICD-10) as the "death of a woman during pregnancy or up to 42 days after termination of pregnancy, regardless of the duration or location of the pregnancy, due to any cause related to or aggravated by, or due to, or related to pregnancy, but not due to accidental or incidental causes".

In Brazil, deaths are recorded by the civil registry of deaths (IBGE 2017), and maternal deaths are identified via vital statistics, provided by the Mortality Information System (SIM, in Portuguese) and Live Birth Information System (SINASC, in Portuguese) – both being part of the Department of Informatics from the Unified Health System (DATASUS, in Portuguese) from the Ministry of Health. The information of deaths and live births is compiled and released annually. DATASUS provides series of information regarding vital events, such as the place of residence that deaths and live births occurred, whether it occurred in a public or private health institution, the ethnicity/race, specific cause of death, among other information.

In some cases, maternal mortality or pregnancy-related deaths may be derived through information from demographic censored deaths (Hill et al. 2018). The origin of the idea of having population censuses as a way of collecting information on maternal mortality is not certain, although the inclusion of questions about household deaths by age and sex in the last 12 months in population censuses has a long history. It was initially limited to African countries in the 1970 (8 countries) and 1980 (22 countries) censuses. Afterwards, it was expanded to Asian and Latin American countries in the 1990s (37 countries), 2000 (53 countries) and 2010 censuses in 72 countries (Hill et al. 2018). The census has advantages as a vehicle for collecting data on pregnancy-related mortality, because its size reduces random errors and allows sub-national analyzes; its marginal cost is small, and information on household deaths also allows monitoring mortality at all ages (Hill et al. 2018). In addition, information on household deaths can also be accompanied with a verbal autopsy (WHO 2007).

In Brazil, even with the household question of deaths in the last 12 months, the 2010 census does not provide sufficient information to identify maternal deaths. In addition, vital statistics from DATASUS often suffer from under-registration, or non-event count, and inaccurate record of death cause (Silva et al. 2016, Barros et al. 2010). Luizaga et al. (2010) estimated correction factors for under-registration by region using information from capitals and metropolitan regions. It is suspected that coverage of maternal mortality in the countryside and in the less populated territories of the country should present even more problems related to death counts, given that mortality data for these areas alone still present major coverage problems in recent periods (Queiroz et al. 2017).

As strategy for estimating maternal mortality measures, we propose a combination of data sources and, therefore, we will use information on maternal deaths from vital statistics (DATASUS), and population and socioeconomic data from the 2010 census, in order to estimate the number of indigenous maternal deaths indirectly.

2.3. Strategy for Estimating Indigenous Maternal Mortality

The estimates for the calculation of maternal mortality indicators may be direct or indirect in nature. For whole Brazil, there are estimates of maternal mortality using both methods. Direct calculations are used when all necessary information is available – maternal deaths, total number of deaths of women in the reproductive period, number of females exposure to the risk of pregnancy and the number of births in the reference period – and with certain quality and, when necessary, through application of corrections to the original data (Santos et al. 2017).

Indirect estimates are usually used when information on maternal deaths is not of good quality, or when there are no population surveys measuring this type of information (Wilmoth et al. 2012). They are generally implemented through statistical models that take into account not only available maternal death information, but also other information that correlates with death during pregnancy, such as social, economic, reproductive and quality-related factors of public health, as these act as conditions for the quality of maternal health (McCarthy and Maine 1992, Hill et al. 2007, Ahmed and Hill 2011, Wilmoth et al. 2012). Therefore, these authors divide this information into three variable sets that can be described as:

- ✓ *Socioeconomic variables:* Human Development Index (HDI), Gross Domestic Product (GDP) per capita, women's education, income, etc;
- ✓ *Reproductive variables:* General Fertility Rate (GFR) or Total Fertility Rate (TFR); and,
- ✓ *Health Variables:* Number of deliveries performed in healthcare facilities, number of deliveries performed under the supervision of trained health professionals, etc.

(McCarthy and Maine 1992, Hill et al. 2007, Ahmed and Hill 2011, Wilmoth et al. 2012).

Due to the existence of information on deaths resulting from pregnancy complications, Brazilian vital statistics and, in many cases, Demographic and Health Surveys (DHS) and National Demographic and Health Survey (PNDS) are commonly used as a source of information for maternal mortality estimation in the country (Sousa et al. 2007). This information is adjusted, when necessary, by applying correction factors to the death data (Luizaga et al. 2010; Cordeiro et al. 2016).

In large Brazilian regions, on the one hand, vital information has a certain degree of quality (Queiroz et al. 2017, Lima and Queiroz, 2014). On the other hand, when considered subpopulations, as is the case of the indigenous communities of the country, the use of direct estimates becomes less appropriate due to numerous problems related to the large underreporting of deaths and the poor quality of death reporting by age, and as we move towards less populated areas, lacking adequate public health facilities (Queiroz et al. 2017). It is also not possible to identify small areas (such as indigenous lands described in the census tracts) in the DATASUS, hindering the measurement of maternal health indicators native territories, as well as the ethnicity the criteria available from these sources is deficient due to the self-declaration problems attributed to this variable (Braz et al. 2013).

The 2010 Brazilian census appears as a way to fill this gap based on the question of deaths that occurred at home in the last 12 months. Although there is no question of maternal deaths, we can use information from women exposed to the risk of pregnancy in indigenous territories, as well as other variables taken from the 2010 demographic census, and add them to the maternal death information obtained by DATASUS to build statistics models and estimate indigenous maternal deaths indirectly.

Thus, we elaborated a two-step model. In the first one, we sought to relate maternal deaths of the whole female population as a function of births and a set of contextual variables that express economic and social developments in the areas where these women live. Using these indirect estimates (Ahmed and Hill 2011, Wilmoth et al. 2012), – adapting variables and parameters and incorporating information regarding human capital such as literacy level (see Azevedo et al. 2018), access to health facilities, and reproductive information such as General Fertility Rate (GFR), see Wilmoth et al. 2012 – we built a model to predict the number of *expected* maternal deaths. As a second step, we used the same set of variables, but this time we separated the explanatory information only for women who declared themselves indigenous in the 2010 census; and with the beta coefficients from the model (step 1), we predicted among them the expected number of deaths associated with pregnancy or complications of childbirth (step 2).

The construction of this statistical model started from the idea of a hierarchical Poisson model, which we relate individual information with characteristics of the areas where the population in question lives. In analytical terms, we have a model defined in the regression equation as:

$$Maternal\ deaths_{x.ij}/log(births)_{x.ij} = \Upsilon_{00} + \Upsilon_1.Age_{ij} + \Upsilon_2.schooling_j + \Upsilon_3.GFR_j + \Upsilon_3.Preventive\ care_j + \mu_{0j} + \varepsilon_{ij}, \quad (1)$$

Where,

The response variable is the number of maternal deaths at age *x* of individuals *i* living in area *j*, and as exposure the number of births of individuals *i* aged *x* in area *j*;

- ✓ Υ_{00} is the regression intercept with information on the global average value of the regions, μ_{0j} and ε_{ij} are the residues at the macro level (level 2, or the effect of each region) and at the micro level (or level 1), respectively;
- ✓ Υ_1 is the regression coefficient for the age of a woman *i* living in mesoregion *j*;
- ✓ Υ_2 is the regression coefficient for the average level of uneducated or women with incomplete primary education in mesoregion *j*;
- ✓ Υ_3 is the regression coefficient for the General Fertility Rate in mesoregion *j.*
- ✓ Υ_4 is the regression coefficient for the number of preventive visits (Papanicolaou test), or medical and nursing visits in mesoregion residing in *j*.

The model was estimated for the 137 Brazilian mesoregions, that is, varying *j* = 1…137, first using information from all women and, therefore, a second database was generated for the indigenous population only and, based on model estimates (1), we predicted the expected number of maternal deaths in each region inhabited by indigenous population. In addition to estimates of expected number of native maternal deaths, we applied under-registration and under-enumeration corrections to both deaths and births data.

2.4. Death Record Assessment and Correction Methods

To evaluate the quality of death information, we used formal demographic methods to assess and to correct mortality information by estimating the degree of death coverage. Based on equations that describe population dynamics, some demographic methods have been developed to assess coverage of death counts (Hill et al. 2009). Among them, death distribution methods are commonly used to estimate the degree of coverage of adult mortality in non-stable populations, i.e. populations that do not have constant mortality and fertility rates over time (Hill et al. al. 2005, Hill et al., 2009). These methods compare the age distribution of deaths and population, providing the age pattern of mortality for a specific period of time.

We apply three methods for assessing death registration coverage, the General Growth Balance (GGB) (Hill 1987), the Synthetic Extinct Generation (SEG), proposed by Bennett and Horiuchi (1981), and the Adjusted Synthetic Extinct Generations (SEG-adj) (Hill et al. 2009).

It is important to mention that these methods have assumptions related to the recent demographic dynamics: 1) the population is not subject to migration; 2) the degree of death coverage and population count is constant by age; and 3) age information of the living and dead is declared without errors.

The GGB method is derived from the relationship between population entrances and exits, and how these two define a population's growth rate (Hill 1987). The growth rate is defined as the difference between the population entry rates (births) and the population exit rates (through deaths). We can state that this relationship also occurs for any age segment with open interval *x+* (people aged *x* and over). In a closed population, entries occur as birthdays at ages *x* and the difference between the entry rates at *x+* and the population growth rate at *x+* produces a residual estimate of the mortality rate at *x+*. By estimating this residue between two population censuses and comparing it with a direct mortality estimate – either collected by vital registration or census death count enumeration – the degree of coverage for the death records can be estimated from the relationship between these two quantities (Hill 1987). Importantly, the method compares the age distribution of the average deaths in the intercensal period with the population changes between censuses, and the estimate refers to the degree of coverage in the intercensal period, and not to a particular date.

The second method SEG uses age-specific growth rates to convert an age distribution of deaths into an age distribution of population, i.e. it creates a cohort from deaths (Bennett & Horiuchi 1981). Considering a population closed to migration, we can believe that the number of deaths observed from an age *x* (*x+*) is equal to the population of age *x*, adjusted by the age range growth rate, and the degree of coverage of the deaths will then be given by the ratio of estimated deaths by the population over age *x* and the population observed over age *x*.

The SEG-adj comes from the combination of the two preceding methods. It uses the estimates of the relative change in demographic censuses coverage, obtained by applying the GGB, to adjust the variation in enumeration between both inquires, and then apply the SEG-method, using the adjusted population to obtain the degree of coverage of mortality data (Hill et al. 2009).

In this work, the estimates of the degree of death coverage were produced using the three methods, using the adult coverage assessment package (DDM) developed by Riffe, Lima and Queiroz for the R-Cran (2017) software, and an average between them was taken as the final estimate. These estimates are part of the research project, funded by CNPq and developed by the research group on small area mortality assessment and estimation (Research Grants – Applied Social Sciences, N. 22/2014 and Universal, N. 14/2014).

2.5. Assessment and Correction of births records

To assess the quality of birth enumeration, we employed two combined adjustment methods, P/F (Brass 1964) and the Relational Gompertz (Brass 1978, Booth 1984, Zaba 2013).

According to Brass (1964), fertility data collected from demographic censuses (or household surveys) are generally underestimated for all age groups in the reproductive period, and some empirical evidence shows that this underestimation does not differ much between women's ages. Brass (1964) also says that this empirical finding may assist in the estimation of an adjustment factor for fertility rates, by comparing the accumulated fertility (F) of a period with the average parity distribution (P), a measure of cohort fertility (United Nations 1983). P is the average parity (cumulative lifetime fertility) of a cohort of women up to a certain age, and F measures the accumulated fertility (at the survey date) up to a certain age. The P/F ratio expresses the relationship of these two quantities for each age group (Brass 1964, Moultrie and Dorrington 2008).

The method assumes that if vital rates are constant over a long period of time, the cohort and period measures should be identical. In other words, under conditions of population stability, the cumulative fertility of a cohort of women up to a certain age will be the same as the cumulative fertility up to that same age at any given period, and if the data are without error, the P/F ratio would be equal to 1 in each age group (Brass 1964, United Nations 1983, Moultrie and Dorrington 2008, Baker et al. 2011, Hauer et al. 2013). However, if this ratio at age groups 20 to 29 years is above 1, this value indicates the percentage of births that should be added to the census or the vital register.

A second model employed is the relational Gompertz. The Gompertz model, originally proposed by Brass (1978), assumes that the cumulative proportion of fertility in a given period (*Fx*) and its ratio to total fertility rate (*TFT*) follows a linear function, derived from the equation:

$$\frac{Fx}{TFT} = e^{\alpha . e^{\beta}} \qquad (2),$$

Where:

- F(x) is the accumulated fertility up to age x;
- TFR is the total fertility Rate, and;
- Alpha and Beta are two parameters, obtained by a logit transformation, which can be defined as:

$$ln(-\,ln(\frac{Fx}{TFT})) = ln(-\,\alpha) + \beta x \qquad (3).$$

We use an equation that is quite similar to the Brass (1964) logit, because the purpose of both is to perform a linear transformation of an accumulated distribution, so that it can be compared to a standard distribution using two constants, α e β.

The parameter α is an indicator of the location of the fertility pattern in relation to the reproductive ages, while β is interpreted as a determinant of the dispersion, or the degree of fertility concentration in relation to the chosen pattern. In short, we can say that a negative value of α means a more right-skewed curve (fertility concentrated at older ages in comparison with the standard fertility), while a positive value indicates a more left-skewed curve (more concentrated fertility at younger ages). For β, a value greater than 1 is represented by a less dispersed curve; otherwise it indicates a more distributed fertility curve between female reproductive ages (Brass 1978). The common patterns used in the model can be derived from Booth (1984) and developed by Zaba (2013).

In practical terms, the Gompertz relational method seeks to correct common errors found in fertility data, associated with very few or many births reported at the interview time, under-enumeration of cohort fertility and maternal age declaration errors among older women. In addition, the method has the advantage of smoothing out specific fertility rates, an important issue when we are dealing with small populations, and it reduces errors of older women's parity data. Another important aspect is that the method requires some knowledge of the demographic patterns of the study area (Moultrie and Dorrington 2008).

Zaba (2013) proposes a refinement of the P/F method in combination with relational Gompertz. Her proposal involves finding a combination of points P and F that are internally consistent with each other, that is, the two sets of points define essentially the same lines and therefore use the equation of the line to jointly determine the alpha and beta. This last model was applied to correct the under-enumeration of births, commonly present in indigenous reproductive data.

3. Results

Table 1 brings the descriptive results for a number of demographic and socioeconomic variables that characterize the indigenous population in the study. It is important to mention that, we did not make distinction between tribes sort, but we know that they are regionally distributed.

Table 1: Population, education and fertility of women at ages 10 to 49 years old. Indigenous people and total population, Brazil and Macroregions, 2010.

	North	Northeast	Southeast	South	Midwest	Brazil
Women population (10 to 49 years old)						
Total	5206515	17474494	25974951	8734268	4714319	62104546
Indigenous people	86179	65738	32573	23132	39339	246961
Ratio indigenous/Total	1,66%	0,38%	0,13%	0,26%	0,83%	0,40%
Proportion of illiterate women						
Total	5,6%	8,5%	2,0%	1,9%	2,6%	4,2%
Indigenous people	29,0%	13,6%	5,6%	10,0%	15,5%	17,9%
Proportion without schooling or primary incomplete						
Total	49,1%	49,4%	36,8%	38,6%	39,0%	41,8%
Indigenous people	80,4%	59,6%	46,0%	67,1%	73,3%	68,0%
Proportion with primary education complete						
Total	18,9%	18,5%	20,1%	20,9%	19,5%	19,6%
Indigenous people	9,9%	17,2%	19,4%	17,7%	11,9%	14,1%
General Fertility Rates (by 1,000)						
Total	56,5	46,4	38,2	39,6	44,1	42,7
Indigenous people	105,3	65,4	45,9	70,9	89,3	81,1

Source: Brazilian Demographic Census 2010 and SIM 2017.

As we see, in comparison with the total population, most of the indigenous people are located at the Northern Amazon and Midwestern parts of the country. These regions are historically and traditionally occupied by indigenous tribes, and in many locations described as indigenous reserves. Additionally, in these two areas the most illiterate native women are living as well.

The percentage of indigenous women with low schooling is above 50% in almost all regions of the country. The highest number is located in the North, with more than 80% without schooling or incomplete primary education, followed by the Midwest with 73% in the same education category.

The native people present also higher fertility rates than the total population. In Brazil, they have almost twice as much child, as compared with the non-indigenous group. The highest levels of fertility are respectively in North, Midwest and South. In sum, this population stratum is composed by groups in vulnerable socioeconomic situations, presenting generally high levels of illiteracy and fertility. We suspect that this may affects their maternal mortality levels as well.

In table 2 and Figure 1, we present summary results for the MMRs, considering three scenarios of estimation. Due to the difficulties to apply the death distribution methods among indigenous population, we use the mortality coverage estimates for whole Brazilian women population as baseline, and establish scenarios for the amount of under-registration level for the native women. These settings were created based on other studies conducted by Hill and colleagues in Australia (Hill et al. 2007), where they specify that the degree of mortality coverage for native Australians is generally lower, while compared to the whole population. Hence, we have considered deaths correction factors the same as for the whole female population, and two additional levels with 75% and 50% from the total coverage value for the whole female population.

In Table 2 we see that there is a strong variability in terms of maternal mortality. The first scenario without mortality coverage correction, the range varies from 23 to 882 maternal deaths per 100,000 live births, and with an average of 156 indigenous maternal mortality rates. This number is somewhat close to the findings of a few studies in the country (Santos et al. 2017). Using only deaths and births data, provided by the Ministry of Health, and applying quantitative and retrospective analyses to a historical series of maternal death counts from 2005 to 2014, Santos et al (2017) found that in the state of Para the indigenous MMRs was approximate 135.8 per 100,000 live births. Combining census and vital statistics data in a predictive parametric model, our estimates (not shown here) for the same state in 2010 show a value of 133.7 indigenous maternal deaths per 100,000 live births. We can also argue that Santos et al. (2017) findings represent maternal mortality that occurred close to the mid-2009, a period not too distant from our results. In addition, when we consider corrections for under-registration of births (not shown here), our estimates for the same state increase to MMR of 176.1 per 100,000 live births.

Besides births, we also see that corrections for under-registration of death counts were not considered in Santos et al (2017) analyses. Due to this, we have also reason to believe that their MMRs might be underestimated, as empirical evidence shows that indigenous population usually present mortality coverage lower than non-indigenous ones (Choi and Smith, 2018; Hill et al. 2007; Australian Institute of Health and Welfare, 1997).

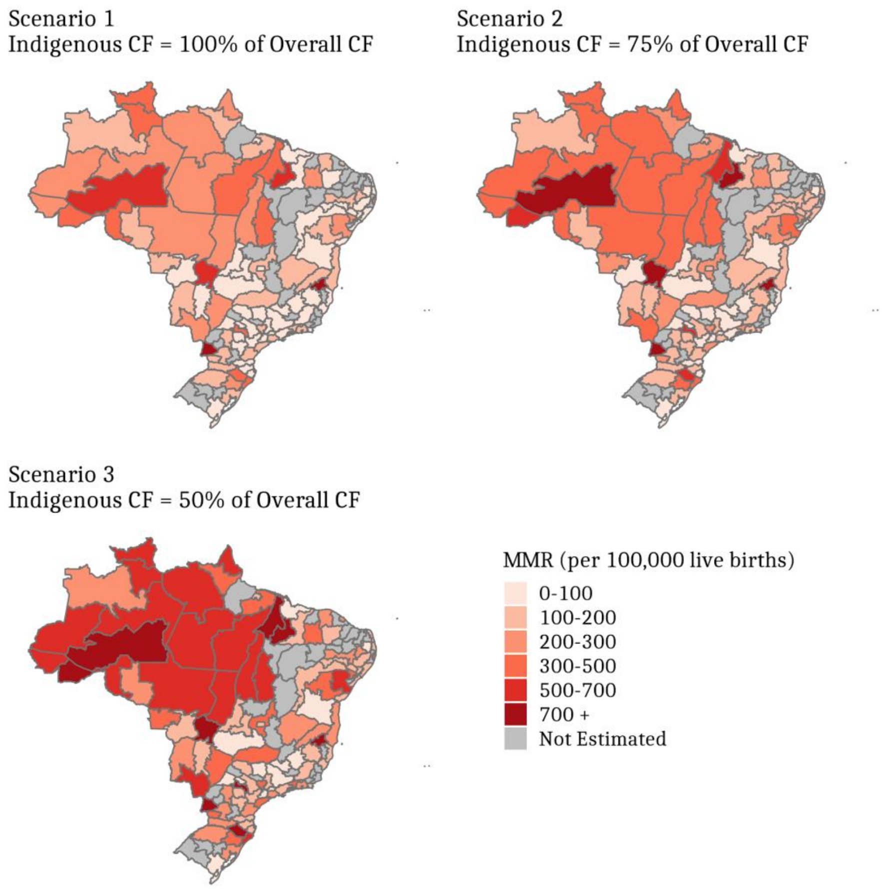
Table 2: Descriptive estimates of indigenous Maternal Mortality Ratios (MMRs) for Brazilian mesoregions in 2010, under scenarios of coverage correction.

Statistic	MMRs without coverage correction	(1) MMRs. The same correction factors applied to all female women population	(2) MMRs. Using 75% of the original value of the correction factors applied to all female population	(3) MMRs. Using 50% of the original value of the correction factors applied to all female population
Min	22,8	24,5	32,7	49,1
Average	155,7	179,4	239,2	358,7
Max	881,7	938,0	1250,7	1876,0

Source: Brazilian Demographic Census 2010 and SIM 2017.
Note: Mesoregion of Marília, in São Paulo, presents the smallest value of MMR, and the Vale do Mucuri (in Minas Gerais) show the greatest value of maternal mortality.

While we correct the mortality levels, in the worst case scenario of 50% death coverage as compared to all females, for example, the MMRs range from 49 to 1876 and with an average of 358.7 maternal deaths per 100,000 live births. Even if we consider the same correction factors used to all females, the levels of maternal mortality death are extremely high among indigenous women.

Figure 1: Maternal Mortality Ratio of indigenous women in Brazilian regions in 2010. Applied mortality data through three correction settings.



CF: death coverage correction factor

Source: Brazilian Demographic Census 2010 and SIM 2017.

Figure 1 we look at the spatial distribution of MMRs in 2010, and we confirm previous tables' findings. There are hotspots and clusters of high indigenous maternal mortality, especially encountered in Northern Amazon locations, Midwest and centered in some Northeastern parts in the state of Maranhão. This last area is well known for having the worst infant and maternal mortality levels of the country (Guarda, 2017; Seplan, 2019). There are also a few isolated spots of high maternal mortality in the South-Southeast frontier with Paraguay, occupied mainly by Guarani tribes, and some isolated mesoregions in the states of Rio Grande do Sul, Minas Gerais and São Paulo.

Discussion

Maternal mortality (MM) is still a health challenge, especially in the context of developing countries, where women's health care services are not fully effective. The MM is also an indicator of a population's quality of life, and high values of this measure can be considered a violation of human rights, mainly because it is an avoidable tragedy in about 92% of the cases. That may also result in a public health problem.

Issues related to women's health, gestational complications and maternal mortality have gaining ground in the international political scenario, especially since 2000, when the theme configured as the "fifth Millennium Development Goal (MDG) ", i.e. the goal to reduce maternal mortality to 75% by 2015 (UN, 2014).

International estimates indicate that over 1.5 million maternal deaths between 2000 and 2015 were avoided, and it was also found that during the same period the MDG achieved targets globally. For 2016 and 2030, the Sustainable Development Goal (SDG) replaced the MDG and presented new targets, among them the reduction of the global maternal mortality ratio to less than 70 maternal deaths per 100,000 live births.

In this context, indigenous population around the globe presents an extra challenge to demographers and health experts, especially because vital statistics and census data for this population are generally incomplete or scarce. In this work, we propose a new method to estimate maternal mortality among indigenous groups in Brazil by combining different data sources and applying a parametric predictive model and demographic formal methods to access quality of deaths and births records. Our estimates vary in results, according to the death correction factor employed, but in general they show that the maternal mortality among indigenous people in Brazil still presents high levels in very recent periods. For this population, it means that they still have a long way to go in the path to a low maternal mortality.

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