**Title: The uneven state-distribution of homicides in Brazil and their effect on life expectancy, 2000-15**

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**Title: The uneven state-distribution of homicides in Brazil and their effect on life expectancy, 2000-15: A cross-sectional mortality study.**

**Keywords:** violence, demography, health inequality, avoidable/amenable mortality

**Abstract**

**Objective:** To determine cause- and age-specific contributions to life expectancy changes between 2000 and 2015, separately by state and sex in Brazil, with a focus on homicides.

**Design:** Retrospective cross-sectional demographic analysis of mortality.

**Setting and population:** Brazilian population by age, sex and state from 2000-2015.

**Main outcome measure:** Using mortality data from the Brazilian Mortality Information System and population estimates from the National Statistics Office, we used Deaths Distribution methods and the lineal integral decomposition model to estimate levels and changes in life expectancy. We also examine how multiple causes of death, including from homicides and amenable/avoidable mortality, contributed to these changes from 2000-2015.

**Results:** Between 2000 and 2015, life expectancy in Brazil increased from 71.5 to 75.1 years. Despite state-level variation in gains, life expectancy increased in almost all states over this period. However, across Brazil, homicide mortality contributed, to varying degrees, to either attenuate or decrease male life expectancy gains. In Alagoas in 2000-07 and Sergipe in 2007-15, homicides contributed to a reduction in life expectancy of 1.5 years, offsetting gains achieved through improvements due to medically amenable causes. In the period 2007-15, male life expectancy could have been improved by more than half a year in 12 of Brazil’s states if homicide mortality were remained at the levels of 2007.

**Conclusions:** Homicide mortality appears to offset life expectancy gains made through recent improvements related to mortality amenable to medical services and public health interventions, with considerable subnational heterogeneity in the extent of this phenomenon. Efforts combatting the causes of homicides can increase life expectancy beyond what has been achieved in recent decades.

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**Summary boxes:**

**What is already known on this topic:** High homicide rates can slow or reverse life expectancy gains. Although life expectancy in Brazil has increased in recent years, this masks state-level variation. We searched Google scholar and PubMed for articles in English and Portuguese using the terms “life expectancy”, “homicides”, “avoidable mortality”, “Brazil”. We found that homicide mortality may be an important contributory factor lowering longevity in Brazil, given that homicide rates are almost 10 times higher than in developed countries. An understanding of the effects of homicides on life expectancy at the state level in Brazil is required to assess the consequences of the rise of violence in some regions of the country.

**What this study adds:** We examine data from the Mortality Information System and from the National Statistics office from Brazil to assess the impact of homicides and causes of death amenable to medical services on changes to life expectancy across Brazil’s states in 2000-15. We found that in almost all states over this period, homicide mortality contributed, to varying degrees, to either attenuate life expectancy gains, or in some cases to reverse gains in life expectancy. This effect was particularly strong in Brazil’s Northern regions and was restricted to men.

**Introduction**

Violence and homicides in Brazil present a considerable public health challenge.1-3 With a risk of mortality from homicides ten times that of most developed countries and it being the leading cause of death among young adults,4-6 recent improvements in population health attributable to ongoing public health interventions and pushes towards universal health coverage are in jeopardy.7-12 On average, Brazilians live 20 years longer than half a century ago.13 These mortality advancements have been driven largely by improvements in medically amenable mortality, in particular, infant and cardiovascular disease mortality which have accompanied the introduction and expansion of a mandated universal healthcare system.14 15

However, country-level estimates of life expectancy, estimated at 74**.**7 years in 2015, mask considerable subnational heterogeneity. For instance, whereas life expectancy in Alagoas was 63**.**2 years in 2000 it was 71**.**3 years in Santa Catarina (Figure S1 in the Appendix16 presents a map of Brazil and its states).17 Moreover, gains in life expectancy have varied considerably across the country, driven in part by differential gains in average lifespan attributable to amenable mortality; improvements have ranged between 0**.**6 and 4**.**1 years between Brazil’s Southeast and Northeast regions, respectively, between 2000 and 2010.18 The high mortality risk from homicides has the potential to reverse gains in life expectancy, as has been reported in other Latin American countries.19-21 Despite this, the effect of homicides on changes to life expectancy has not been explored in the Brazilian context, a country with over 60 thousand murders reports in 2018.22 An explanation for the lack of studies investigating this could be that national statistics do not report notable changes in homicide rates in the past decade, however this could be due to the balancing effect of homicide rates increasing in some states while decreasing in others; whereas the homicide rate declined in Brasilia between 2007 and 2011, in the same period, homicides have increased by more than 40% in Bahia.22

In this study we aim to examine the impact of homicide mortality on changes in life expectancy by state for men and women separately in the period 2000-15. These results will provide information for interventions and planning aimed at reducing the burden of homicides. Specifically, they will communicate potential improvements to life expectancy gains that could be achieved through reducing homicide mortality, in addition to identifying the states in most need of public policy attention to minimize these violence and health disparities.

**Methods**

We extracted state-level mortality data by age, sex, year and cause of death from the Mortality Information System produced by the Brazilian Ministry of Health.23 We obtained state-level population estimates for the years 2000 through 2015 from the National Statistics Office (IBGE).24 Over the study period (2000-15) death counts registration improved to over 90% completeness, however, in order to correct for the lack of completeness towards the beginning of the study period, we employed Death Distribution Methods (see Appendix Section 1 for further details).25

***Cause-of-death classification***

We use the concept of amenable/avoidable mortality to form the basis of the cause of death classifications in our study to complement the analysis of homicide mortality. The concept of amenable/avoidable mortality refers to deaths that should be absent if both timely and quality healthcare is available.26 27 This concept has been successfully employed to link the progress of primary care expansion and reductions in amenable/avoidable mortality in Brazil.14 More recently the concept has included causes amenable to public health interventions that have been seen to alter health behaviours, e.g. lung cancer via smoking reduction or homicides.28

Using a cause of death classification system utilized in similar studies,20 29 30 we grouped the causes of death into the following 10 categories based on the *International Classification of Diseases* [ICD] 10th revision (Appendix Table 1):16 (1) homicides, (2) alcoholic liver disease, (3) diabetes, (4) HIV/AIDS, (5) ischemic heart diseases (IHD), (6) lung cancer, (7) road traffic accidents, (8) suicides, (9) amenable to medical service (including conditions that could be reduced by primary care, secondary intervention, and timely medical care up to age 75), and (10) all other causes (*residual causes)*.

Homicides, liver disease, diabetes, HIV/AIDS, IHD, lung cancer and suicide were analysed separately as they are amenable to both health behaviours and medical attention, and pose important public health challenges in Brazil.31 32 For instance, in 2001 Brazil featured in the top ten countries ranked by number of suicide deaths.33 The category capturing causes amenable to medical services(9) is linked to major healthcare interventions that have been implemented in the last decades in Brazil, including the Family Health Program.9 14 15 34

***Demographic Methods***

We calculated age- and sex- specific death rates for five-year age groups with an open-age interval at age 90 years for the 27 Brazilian states and constructed sex-specific period life tables for each year from 2000 to 2015.35 National results did not significantly differ from those reported by the United Nations.13 We calculated age- and cause- specific contributions to differences in life expectancy at birth following our classification for each subsequent year using the linear integral decomposition procedure (see Appendix Section 2 detailed explanation),36 and summed up single-year decompositions in order to obtain the aggregate effect for the specified period. We report results for the periods 2000-07 and 2007-15 to have two comparable points in time of the same length. Our estimates refer to the middle of the year, e.g. 2000-07 runs from middle of 2000 to middle of 2007 and 2007-15 runs from middle of 2007 to middle of 2015. The effects for the period 2000-15 are simply the sum of the effects of the two periods. All procedures were performed using the R software37 and are fully reproducible from the public repository with the data needed at <https://github.com/jmaburto/Homicides-and-life-expectancy-in-Brazil>.

**Results**

We arranged the Brazilian states within each broad region in order of the impact of homicides on male life expectancy in 2007-15 in Figures 1-4.

All states, with the exception of Pará, experienced increases in life expectancy for females and males from 2000 to 2007 (Figure 1). Relative to the period 2000-07, in 2007 to 2015, life expectancy at birth increased at a slower pace among women in 75% of states and among men in 60% of Brazil’s states. In four states, life expectancy at birth declined in the latter period among men; among women, life expectancy declined in one state. Despite this overall slowdown, all but two states (Amapá for females, and Pará and Sergipe for males) showed a continuous increase in life expectancy since 2000. Life expectancy levels for each state and total changes in 2000-15 are shown in Appendix table 2.

*Figure 1 [about here]. Changes in life Expectancy at birth in Brazil (in years), by state and period, from 2000 to 2007 and from 2007 to 2015.*

Figures 2-4 show how homicide, IHD and causes amenable to medical service, respectively, contributed to changes in life expectancy at birth in the periods 2000-07 and 2007-15 and represent the causes of death from the amenable/avoidable mortality framework that contributed the most to changes in life expectancy at birth in both periods (results for all causes of death, see Appendix Figures S2-S3).16

Homicide mortality increased in 14 states among males in 2000-07 (Figure 2), leading to declines in life expectancy at birth over the period, with especially large contributions in Alagoas state (1**.**5 years). In 2007-15 there was a clear worsening in life expectancy in 18 of Brazil’s states related to increases in homicide mortality, with three of these states losing one or more years of life expectancy at birth, and 11 losing over six months of life on average. Overall, changes in mortality due to homicide were responsible for the largest declines in life expectancy between 2000 and 2015. Over the 15-year period, the decline was most marked in least developed Northeast and North regions of Brazil (Appendix Figure S4), including the states of Sergipe, Rio Grande do Norte, Ceará and Pará. The impact of homicides on life expectancy appeared to be restricted to males. As a sensitivity check in Appendix Figure S5 we show results for the periods 2000-05, 2005-10, 2010-2015.

*Figure 2 [about here] Changes in life expectancy at birth in Brazil related to homicide mortality (in years), by state and period, from 2000 to 2007 and from 2007 to 2015*

Among females and males, 16 states and 15 states, respectively, experienced increases in mortality from IHD in the period 2000-07, leading to declines in life expectancy. Overall, increases in mortality from IHD in the period 2000-07, leading to declines in life expectancy, was observed in 16 states among women and 15 states among men.

On the other hand, in 2007-15 life expectancy due to IHD increased in most states driven by improvements in cause-specific mortality from IHD (21 and 19 states, respectively, among females and males).

*Figure 3 [about here] Changes in life expectancy at birth in Brazil related to mortality resulting from ischemic heart diseases (in years), by state and period, from 2000 to 2007 and from 2007 to 2015*

Across most states, we found increases in life expectancy due to causes amenable to medical services below age 75 in both periods. In two states (Acre and Maranhão) we found declines in female life expectancy, whilst negligible effects on male life expectancy was found in Maranhão state in the period 2000-07 (Figure 4). Notably, between 2000 and 2007, 13 states experienced an increase in female life expectancy of more than one year due to medically amenable mortality, whereas this was the case in 12 states among men. Between 2007 and 2015, improvements due to medically amenable causes persisted, albeit at a slower pace, whereby 18 and 23 states experienced an increased life expectancy by more than six months among females and males, respectively, driven by declines in mortality from causes amenable medical service. Similarly, changes in mortality due to the remaining causes also contributed to increasing life expectancy in most states during the first 15 years of the 21st century (see Appendix Figures S2-S3).16

*Figure 4 [about here] Changes in life expectancy at birth in Brazil related to mortality resulting from causes amenable to medical service (in years), by state and period, from 2000 to 2007 and from 2007 to 2015*

Although diabetes mortality had a smaller impact on changes in life expectancy relative to other causes of death between 2000-15, its impact was considerable in some regions. In the North and Northeast regions, the increase in diabetes mortality led to small decreases in life expectancy between 2000 and 2007, especially among females (Appendix Figure S3).16 This trend reversed and by 2007-15, only three states from the North region (Amapá, Amazonas and Pará) experienced decreases in female life expectancy. Among males, the impact of diabetes was smaller, however similar to females, was concentrated in the Northern regions of Brazil (Appendix Figure S2).16

Contributions to changes in life expectancy due to alcoholic liver disease, HIV/AIDS, lung cancer, suicide and traffic accidents were negligible between 2000 and 2015 (Appendix Figures S2-S3).16

**Discussion**

The period from 2000 to 2015 marked an increase in the life expectancy at birth in Brazil from 71**.**5 years to 75**.**1 years, however the extent of this increase differed between men and women and between Brazil’s diverse states. Our findings indicate that potentially large gains in state-specific life expectancy driven by mortality improvements from medically amenable causes were partially offset at times by increasing homicide, diabetes and IHD mortality (see Appendix section 3). Brazilian men in particular have experienced a disproportionately higher homicide burden when compared to women4 38. Had the homicide mortality stayed as high as at the turn of the century in Brazil’s Northern regions, male life expectancy could have increased by at least six months in 11 states during the period 2007-15.

***Violence in Brazil***

Homicides are unevenly distributed across Brazil’s states, representing in some cases a primary driver of the slower increase, and in others, decreases in male life expectancy. In some instances, increases in homicide mortality have been so drastic that it has driven declines in life expectancy by over one year in seven states from the Northeast and North regions (Ceará, Alagoas, Rio Grande do Norte, Bahia, Maranhão, Sergipe and Pará). These states contain eight of the most dangerous cities in the world (Natal, Fortaleza, Belém, Feirá de Santana, Marceió, Vitória de Conquista, Salvador and Aracaju) with homicide rates over 47 deaths per 100,000 people.39

Homicides in Brazil are primarily committed with firearms and are related to both drug trafficking, and consumption of drugs and alcohol.40 Evidence from Brazil suggests that gun control measures can be effective in reducing the burden of violence on population health through specific legislations aiming at firearm disarmament.41 Whilst we find that such legislations have been effective in some states, in others, particularly in the North and North East of Brazil, further state-level efforts aimed at disarmament is encouraged, however the implementation of firearm regulations might be more challenging in these regions, relative to the rest of the country.41 Moreover, the Brazilian government has implemented several measures aiming at reducing violence in the country, such as the National Public Security Force (Força Nacional de Segurança Pública) and the National Public Security Program (Programa Nacional de Segurança Pública com Cidadania).6 However, there is considerable regional diversity in the success of these government strategies. The most relevant example to this study is the diversity in changes to life expectancy driven by homicide mortality post strategy implementation, which started in 2004, in the period 2007-15, with declines in homicide-related life expectancy most prevalent in the North and Northeast (complementary figure from 2004 is shown in Appendix Fig. S6).

Evidence suggests that violent death varies considerably by ethnicity, whereby black males are at a higher risk of being victims of violent crime.42 43 In 2007, 55% of the total homicides among males were among mixed race individuals, while 8**.**2% were among black males. Poverty, social inequality and drug trafficking are important factors determining variation in violent mortality within Brazilian states.44-46 In this study, we were unable to disentangle the effect of changes in homicide mortality on life expectancy changes by ethnicity or socioeconomic status within states due to the lack of data disaggregated by these levels for long periods of time.

***International context with Latin America***

Latin America is currently the region with the highest homicide rates globally.22 As in Brazil, similar detrimental findings of the effect of violence in life expectancy have been reported in other Latin American contexts. In Mexico the rise in homicides has led to a stagnation in country-wide life expectancy between 2000 and 2010,47 with significant subnational variation,20 and was identified as a primary determinant of lifespan inequalities.19 Another study in Venezuela found that an increase in firearm-related deaths led to life expectancy stagnation in 1996-2013.21

***Strengths and limitations***

The analysis has several limitations. Firstly, Brazilian mortality data was still considered ‘incomplete’ according to the Pan American Health Organization’s (PAHO) criteria despite improvements in death counts coverage, particularly regarding certificate completeness and age reporting.48 To address this, we used death estimates corrected for completeness based on indirect demographic methods (see Appendix section 1).26 Additionally, we used 5-year age groups to avoid age-heaping bias and applied death distribution methods to minimize the effect of migration on our estimates.25 Secondly, causes of death could have been misclassified. To minimize chances of misclassification, we used broad cause of death categories that utilizes the concept of avoidable/amenable mortality and used data from 2000 onwards, using only the ICD-10 classification. However, the concept of amenable mortality is not able to allude to differences in the effectiveness of health care interventions over time and between states.26 49 In addition, the Brazilian Ministry of Health restricts classification of causes amenable to medical services up to age 75 years, a common practice when classifying avoidable mortality.49 To ensure comparability we did not consider causes of death amenable to medical service above age 75.

**Conclusion and future directions**

The gains made in reducing mortality attributable to causes amenable to medical services in Brazil is the primary driver of increases in life expectancy, however homicide mortality opposes this increase by over half a year in 12 states. This subnational heterogeneity within Brazil mirrors the diversity found across many Latin American countries. Homicide mortality is a local problem, however one that is a pertinent public health issue across the region, and which continues to inhibit progress towards longer and healthier lives. Better data collection is needed to accurately assess the effects of mortality from homicides on life expectancy by subpopulations, including within states.

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