**Title: Homicides in Mexico increased inequality of lifespans and slowed down life expectancy gains in 2005-2015**

**Abstract**

**Objectives** To quantify the effect of the upsurge of violence on life expectancy and lifespan inequality in Mexico after 2005.

**Methods** Age- and cause-specific contributions to changes in life expectancy and lifespan inequality conditional on surviving to age 15 between 1995 and 2015 were calculated. Homicides, medically amenable conditions, diabetes, ischemic heart diseases, traffic accidents by state and sex were analyzed.

**Results** Male life expectancy at age 15 increased more than twice in 1995-2005 (1.17 years) than in 2005-2015 (0.55 years). Lifespan inequality decreased by more than half a year for males in 1995-2005, while in 2005-2015, the reduction was about four times smaller. Homicides between ages 15-49 had the largest effect on slowing down male life expectancy and lifespan inequality. Between 2005 and 2015, states in the North experienced life expectancy losses, while five states increased lifespan inequality.

**Conclusions** After ten years of the upsurge of violence, Mexico has not been able to reduce the levels homicides to those prior to 2005. Thus, males in Mexico live less, on average, and experience higher uncertainty in their eventual death.

**Keywords:** violence, lifespan variation, avoidable mortality, causes of death, public health.

Word count: 3048

**Introduction**

Violence has become a major public health issue in Latin America.1 This region currently experiences the highest homicide rate in the world (over 16.3 per 100,000 people), with some countries in Central America, including Mexico, undergoing an upsurge in homicides since the first years of the 21st century.2 In Mexico, for example, homicide rates doubled between 2007 and 2012 (from 9.3 to 18.6).3 As a result of this increase, along with an increasing burden of diabetes, male life expectancy in Mexico stagnated in the period 2000-10.4 At the subnational level, gains in life expectancy due to causes amenable to medical service, such as infectious, respiratory diseases and birth conditions, were wiped out by the increase of homicides after 2005 in each of the 32 states in Mexico, with large regional variations.5

Trends in life expectancy are important and have been studied in Mexico and its states.4-6 However, life expectancy masks inequality of lifespans or lifespan variation.7. Variability in ages-at-death has arisen as an important topic since it addresses the growing interest in health inequalities8, and because it is a marker of heterogeneity at the population level, while it expresses the uncertainty in time of death at the individual level. Studying both life expectancy and lifespan inequality adds an important dimension to the study of population health because these indicators represent individuals’ decisions based not only on their expected lifetime, but also on the uncertainty in their timing of death.9 Most studies have found a negative association between these two measures, suggesting that as life expectancy increases, inequality in lifespans decreases.10-12 However, at the subnational level increases in lifespan variation may simultaneously occur with increases in life expectancy, mostly due to a slowdown in mortality improvements in working ages (e.g., premature mortality).13,14 This is particularly relevant for countries that have experienced an upsurge in homicides, since this increase has mainly affected working age individuals.

In Mexico, homicide mortality is concentrated between ages 15 and 50, affecting mainly males.3 We thus hypothesize that the Mexican population may be experiencing increases in lifespan inequality due to the rise in homicides in tandem with declines in overall life expectancy at the subnational level. We also expect larger changes in lifespan inequality among men and uneven variability across states in the country due to the changing dynamics of violence and homicides in Mexico.15 For instance, states in the Northern part of Mexico (e.g., Chihuahua, Durango and Sinaloa) experienced the largest losses in life expectancy due to homicides between 2005 and 20105 and it is likely they also exhibited large lifespan variation during that period, although this impact may now be larger in other states as homicides spread throughout the entire country in recent years.16 However, since the more pronounced fluctuation in age-specific mortality occurred over working ages,5 it is unclear what the net effect would be on lifespan inequality but it certainly had an effect on premature mortality. On the other hand, medically amenable mortality improvements (which have been Mexico’s priority since the 1990s).17,18 could have substantial effect on reducing variation in lifespans, particularly in historically poor states, which are mostly concentrated in the South.

This paper makes three main contributions. First, it contributes to the literature on lifespan variation and inequalities in health in the context of rising homicides. Most literature in this area focuses on social determinants of health (e.g., socioeconomic status and health risk factors) as proximate determinants of lifespan variation and health inequality.19 In contrast, our paper highlights the role of violence, and its ultimate consequence in the form of homicides, among young adults on increasing lifespan inequality. A second contribution is its focus on Mexico. Mexico is experiencing a growing violence associated with the war on drugs that started in the last decade, making the increase in homicides a serious health policy concern.5,16 Understanding the consequences that homicides have on population health is important for policy makers in Mexico and in other countries that are experiencing similar increases in homicides such as Honduras in Central America, and Venezuela in South America.2 Finally, this analysis contributes to our knowledge of regional inequality in lifespans.

Here, we analyzed how life expectancy and lifespan inequality for the young population changed over a 20-year period, from 1990 to 2015 for females and males in Mexico. This framework allows us to thoroughly analyze premature mortality and determined the ages and causes of death that contributed the most to the observed changes.

**Methods**

We used data on deaths from vital statistics files publicly available through the Mexican Institute of Statistics20 that includes information on cause-of-death by age, sex, and place of occurrence from 1995 to 2015. Additionally, we used population estimates corrected for completeness, age misstatement, and international migration from the Mexican Population Council to construct age-specific death rates by age, sex and state.21

*Cause-of-death classification*

We classified deaths into eight categories representing the main causes of death in Mexico 5 using the concept of Amenable/Avoidable mortality (Table 1). 22 This concept assumes that there are some conditions that should not cause death in the presence of timely and effective medical care, and are used as a proxy for the performance of health care systems.22 To mitigate biases due to misclassification of causes of death, we focused on deaths occurring below age 95 since cause-specific coding practices above that age are less reliable due to the presence of comorbidities.

We study two comparable 10-year periods, between 1995 and 2005, and from 2005 to 2015. This allowed us to identify a period of mortality improvements (1995-2005) in which life expectancy increased by 2.1 and 4.3 years for males and females, respectively,21 and homicide rates declined among young adults.20 The second period (2005-2015) is characterized by the upsurge of violence and homicides in Mexico.5

*Lifespan inequality indicator*

We use ‘years of life lost’ as a dispersion indicator and we refer to it as “lifespan inequality” or “lifespan variation” from age 15. It is defined as the average remaining life expectancy when death occurs above age 15, or life years lost due to death (see Supplementary Material for a summary).10 For example, if in a cohort of newborns all die at the same age then the value of lifespan inequality is zero; to the extent that death occurs at different ages, those who die “prematurely” will die before their expected lifetime contributing lost years to lifespan variation. We condition on surviving to age 15 to capture the onset of homicides.

This indicator has three main properties: it is easy to understand, to interpret, and to decompose thereby allowing us to quantify the impact of age and cause-specific mortality on changes in lifespan variation over time.23 Moreover, there is a high correlation between our preferred indicator and other measures of variability in ages at death (e.g., variance, or the Gini coefficient) suggesting that our main results would be consistent with those obtained with any of these additional measures.24

*Demographic methods*

To mitigate random variations in cause-of-death classification, we smoothed cause-specific death rates over age using a 1-d p-spline separately by year, sex and state.25 We then rescaled the smoothed cause-specific deaths to all-cause death rates to maintain the overall mortality level. Using these mortality rates we computed period life tables for each year (1995 to 2015), state and sex following standard demographic methods.26 Finally, we computed life expectancies and lifespan variation conditioned on surviving to age 15 and estimated the age- and cause-specific contributions to differences between the study periods using standard decomposition techniques (see Supplementary Material).27 All analyses were carried out using R28. In addition, we created an interactive app to perform sensitivity analyses available [here](https://demographs.shinyapps.io/LVMx_15_App/).

**Results**

*Results at the national level*

As expected, results for males show the largest impact of homicides on life expectancy and lifespan variation for both time periods (Figures 1-4). We thus focus on these results (females’ results are shown in Supplementary Material, figures S1-S4).

Figure 1 shows age- and cause-specific contributions (in years) to male life expectancy’s changes at age 15 between 1995 and 2005 (Panel A) and between 2005 and 2015 (Panel B). Vertical values in rectangles next to the y-axis represent age-specific contributions, while bars’ length correspond to cause-specific contributions by age. Overall cause-specific contributions across all ages are shown in the panel’s legend in parenthesis (also in years).

Among men, life expectancy at age 15 increased more than twice as fast in 1995-2005 (1.17 years) than in 2005-2015 (0.55 years). Most causes of death contributed to life expectancy’s improvement in 1995-2005 (except for diabetes, heart disease and accidents). Importantly, homicides declined in 1995-2005 and this contributed to about one-fourth (0.44 years) of the overall gain in life expectancy in this period. About 80% (0.36 years) of this contribution was concentrated between ages 15-49 (red bars in Figure 1, panel A). In contrast, the slowed down improvement in life expectancy in 2005-2015 was mainly the result of rising homicides (mostly between ages 15-49) and heart diseases (panel B), hence their negative contributions. Results for women suggest continuous improvement in life expectancy over time with a negligible impact of homicides. (Supplementary Material, figures S1-S4). Female life expectancy increased by 0.58 year in 1995-2005 and by an additional half year of life in 2005-2015; all these resulted from mortality improvements in most causes of death, except for diabetes and medically amenable.

[Figure 1]

Figure 2 shows results for lifespan inequality in both periods. This figure depicts information in a similar format to that in Figure 1. Panel A of Figure 2, for example, shows that lifespan inequality reduced by more than half a year between 1995 (14.31) and 2005 (13.77). This means that, on average, Mexican males were losing six months of life less at their time of death in 2005 than in 1995. Although lifespan inequality also declined between 2005 and 2015 (-0.15), the reduction in 1995-2005 was about four times larger. In other words, male lifespan inequality was stagnant in recent times. Nonetheless, improvements in other causes of death contributed to a reduction in lifespan inequality in both periods; for example, mortality declines in accidents and cirrhosis at younger ages. Importantly, homicides (about 0.17 years at ages below 60) and amenable causes of death had the largest effect on increasing lifespan variation in 2005-2015 (e.g., positive contribution). For females, lifespan variation decreased since 1995. There is a tipping point at around age 70 indicating the importance of cardiovascular disease, diabetes and medical services at older ages in reducing lifespan inequality, while accidents, homicides and cirrhosis play a larger role at younger ages. These results underscore the major role of rising homicide rates among young adults in recent times and the consequent slow improvement in reducing lifespan inequality.

[Figure 2]

*Results at the state level*

Figure 3 shows changes in life expectancy (panel A) and in lifespan inequality (panel B) for males in each of the 32 states in Mexico between 1995 and 2005 (blue dots) and between 2005 and 2015 (red triangles). We grouped states into three broad regions: North, Central and South.

Life expectancy among males had a larger increase in 1995-2005 than in 2005-2015 across all states (panel A), but some states experienced reductions in life expectancy in 2005-2015 particularly in the North (e.g., Chihuahua, Nuevo León and Sinaloa). Lifespan inequality (panel B) was reduced in most states over the two decades, 1995-2015, except for states in the North. For example, every state between 1995 and 2005 had major reductions in lifespan inequality of at least 0.4 years, particularly those in the South (e.g., Chiapas, Oaxaca and Puebla), but between 2005 and 2015, all states in the north had negligible reductions in lifespan variation with five states having a large increase (Chihuahua, Nuevo León and Tamaulipas --all bordering with Texas in the US, Sinaloa and Durango).

[Figure 3]

We further assess the cause-of-death contributions by state to changes in lifespan inequality (Figure 4). We focus on the main causes of death, for contributions from all cause-of-death categories and females’ results see Supplementary Material figures S4-S7.

Except for one state in the North (Baja California Sur) and one in the central part (Tlaxcala), every state decreased lifespan inequality due to improvements in medically amenable causes of death and homicides between 1995 and 2005. As we hypothesized, the states showing the larger reductions were mostly concentrated in the southern region of Mexico (e.g., Chiapas, Oaxaca, Puebla, Guerrero and Morelos). A decade later (2005-2015), however, there is more heterogeneity on the contribution of causes of death to lifespan inequality. For example conditions amenable to medical service contributed to reductions in lifespan inequality in most states, while homicides increased variation of lifespans. Although the increase in homicides affected lifespan inequality in all states after 2005, one state in the South was affected the most (about 1 year increase for males and about two months for females in Guerrero), followed by some states in the North (increase of about 0.75 and 0.5 year in Chihuahua and Sinaloa) and in the central part of the country (e.g. Colima). Mortality due to diabetes shows negligible contributions to lifespan inequality in both periods. Results for females indicate substantial reductions in lifespan inequality from medically amenable conditions, diabetes and IHD in the period 1995-2015.

[Figure 4]

**Discussion**

After 10 years of the beginning of the War on Drugs, the Mexican government has not been able to reduce homicides and its effects, at least to the levels observed back in 2005. Due to the strong impact of homicides in 2005-2015, improvements in male life expectancy and lifespan inequality at age 15 slowed down relative to the trend observed in the previous decade, during which young males experienced an increase of more than one year in life expectancy and a decrease of more than half a year in lifespan inequality.

Despite major public health interventions between 2005 and 2015, such as the enactment of a universal health-insurance program (*Seguro Popular*),29 every state in the country experienced less progress in life expectancy at age 15 than in the previous decade due to the spread of homicides throughout the country after 200516. This is consistent with previous research documenting the impact of homicides between 2000 and 2010.4,5 Despite recent efforts from the Mexican government to contain the upsurge of violence in the country,30,31 data up to 2015 shows that life circumstances among young adults have not improved and are actually deteriorating. For example, almost every state experienced a reduction in life expectancy at age 15 across all regions in Mexico due to homicides (Fig S7). The strongest effect occurred in Guerrero, a state in the Southern region, were life expectancy was reduced by almost 2 years between 2005 and 2015, followed by Chihuahua and Sinaloa in the North, with life expectancy losses of one year each, three additional states in the North (Zacatecas, Baja California Sur and Nuevo León), one in the Central region (Colima), and one in the South (Morelos), experienced losses of half a year in life expectancy over the same period due exclusively to increasing homicides (Fig S7).

Furthermore, homicides have slowed down the progress on reducing lifespan inequality among young adults in Mexico. While lifespan inequality declined by more than half a year between 1995 and 2005, a decade later this progress was stagnant and barely reached a reduction of less than two months. Increase in homicide mortality, concentrated in the young population (between ages 15 and 50), accounted for most this outcome. Which is consistent with the high sensitivity of lifespan variation to premature mortality.10,32. Thus, males in Mexico not only live less on average, as shown by life expectancy, but they also face more uncertainty in their time of death due to the increase in homicides.

The same states that experienced reductions in life expectancy after 2005 also showed increase in lifespan inequality due to homicides. Rising inequality of lifespans underlies increasing flustered population. These results are consistent with the upsurge in violence in these parts of the country. Although homicides have spread across the country,15 they are not evenly shared between states and over time. By 2010, the North of Mexico was the region most affected by homicide mortality.5 In contrast, by 2015 all regions show similar patterns of the effects of homicides on lifespan inequality. Moreover, while in 2010 Chihuahua (Northern region) was the state affected the most by homicides relative to the 2005 level, in 2015 Guerrero (Southern region) has overtaken this place. The impact of violence in the population in these states is staggering. For instance, in 2010 males aged 15-50 in Chihuahua had three times higher mortality than the US-troops in Iraq between 2003 and 2006.5 Recent evidence suggests that the second and fifth most dangerous cities in the world are located in the state of Guerrero, along with cities in countries with higher homicide rates than Mexico.33 As a result, young males in Guerrero experienced an increase in lifespan inequality of almost an additional year due exclusively to homicides. These results indicate that homicides are an additional contributor to health inequalities in the country, which complement previous evidence identifying rising health inequalities between states as a challenge for Mexico.6

The consequences of the ongoing violence in Mexico represent an urgent priority for comprehensive strategies to mitigate the impact on population health; importantly, new policies cannot continue to be dismissive of the extensive evidence documenting negative health impacts of the war on drugs on the population.34 For example, the increase in homicide mortality after 2005 suggests a rapid deterioration in life expectancy,5 in perceived vulnerability and psychosocial outcomes,35 and, as we show, in lifespan inequality in the Mexican population.

In an international context, Mexico’s levels of violence are not even the highest around the globe, nor the region. Countries in central America, such as El Salvador and Honduras, and Venezuela, Colombia and Brazil in south America have higher homicide rates. Given the great level of lifespan variation and life expectancy losses in Mexico, it is likely that countries in the region experience higher variation in lifespans and reductions in average life due to homicides. Our results from Mexico underscore the need to comprehensively reduce, through public policies and strategies, the impact of violence on population health and in the uncertainty surrounding the age at death in other countries from Latin America and the world.

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**Figures**

**Figure 1. Age-cause specific contributions to the changes in national life expectancy for males. Panel A refers to 1995-2005 and panel B to 2005-2015. Note: Numbers in boxes are age-specific contributions.**

**Figure 2. Age-cause specific contributions to the changes in national lifespan inequality for males. Panel A refers to 1995-2005 and panel B to 2005-2015. Note: Numbers in boxes are age-specific contributions.**

**Figure 3. Changes in male life expectancy (panel A) and male lifespan inequality (panel B)**

**by state for the periods 1995-2005 and 2005-2015.**

**Figure 4. Cause-specific contributions to changes in male lifespan inequality by state for the periods 1995-2005 and 2005-2015.**