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José Manuel Aburto[1*†], Tim Riffe[2†] and Vladimir Canudas-Romo[1]

*Correspondence:
jmaburto@health.sdu.dk
[1]Department of Public Health & Max Planck Odense Center on the Biodemography of Aging at University of Southern Denmark, J.B. Winsløws Vej 9, 5000 Odense, Denmark
Full list of author information is available at the end of the article
†Equal contributor

Abstract

Background: The second half of the 20th century was marked by sizable improvements in mortality, living conditions and health in most Latin American countries. In Mexico, these improvements have slowed down recently as a result of opposing trends in particular causes of death. We aim to extend these findings by age groups to the 32 Mexican states by measuring the potential gains in life expectancy due to avoidable causes of death.

Methods: We use mortality data from 1990 to 2015 for all states and calculate temporary life expectancies for three large age groups, and compare these with a low mortality benchmark. We use the concept of avoidable mortality and use standard decomposition techniques to disentangle age-cause-specific effects on survival.

Results: We find improvements in survival for the population below age 15. However, the adult population aged 15 to 39 shows deterioration among males after 2006 in almost every state as a result of an increase in homicide mortality. Adults aged 40 to 74 show an unexpected decrease in the low mortality benchmark, indicating universal deterioration in both males and females. State-specific departures from this benchmark was caused by ischemic heart diseases, diabetes, cirrhosis and homicide mortality, mainly. We find large health disparities between states, particularly for the adult population and specially after 2005.

Conclusions: Mexico has succeeded in reducing mortality and between-states inequalities in children and the young population. However, the adult population is becoming vulnerable as they have not been able to reduce the burden of conditions amenable to health services and some related to public policies (e.g. homicides). This has led to large health disparities between states in the last 25 years.

Keywords: health inequalities; adult health; causes of death; homicides; ischemic heart diseases; diabetes; cirrhosis

Background

The second half of the 20th century was marked by sizable improvements in mortality, living conditions and health in most Latin American countries [1]. In Mexico, these improvements have slowed down recently as a result of opposing trends in particular causes of death. For instance, homicide and diabetes increased during the first decade of the 2000's, even as infectious and respiratory diseases continued to fall over the same period. While life expectancy at birth increased by 4.3 years for males (from 67.6 to 71.9) and 3.4 for females (from 73.8 to 77.2) between 1990 and 2000 [2], between 2000 and 2010, life expectancy at birth entered into a period of stagnation for males and slowed progress for females [3].

This period coincides with ongoing public health interventions, such as the Universal Vaccination Program, and with the implementation of Seguro Popular, which aim to provide primary and secondary health care to the uninsured population and allocate funds to cover catastrophic health expenditures [4]. Further, conditional cash transfer programs were introduced to supply incentives for families to reinvest in education, health, and nutrition in 1997 [5]. Some evidence suggests that Mexico experienced substantial decreases in infant and child mortality, along with improvements that contributed to the reduction of mortality and in the prevalence of acute malnutrition between 1980 and 2000 because of these interventions [6]. Similarly, by 2012 Seguro Popular had provided health insurance coverage to an additional 52 million people in Mexico that previously did not have any access to public health care and, as a result, there has been a reduction in catastrophic health expenditures [7].

Conditional cash transfers are focused on the poorest states, and Seguro Popular was introduced at different times in different states. In addition, Mexico faces a rapid aging process in which we can anticipate the interaction between infectious diseases and noncommunicable conditions [8] on the adult population.[1] Although these actions underscore broad progress in public health interventions, they mask disparities between Mexican states and the epidemiological patterns for different age groups. Therefore, it is necessary to assess the varied impacts that these interventions may have had on mortality in Mexican states [10].

One approach to approximate the impact of health care and other interventions, and to reveal potential areas of improvement is by operationalizing the concept of Avoidable or Amenable Mortality (hereafter abbreviated AM) [11, 12, 13]. This categorization of mortality aims to measure the quality of health service systems by selecting certain causes of death that should not occur in the presence of effective and timely health care. Among industrialized countries, such as United States, Australia, France, Japan, a reduction in AM rates was observed over the past 20 years [12]. Avoidable mortality rates fell, on average, by 17% for males and 14% for females in these countries. Despite mortality reductions from cancers and circulatory diseases for both sexes, heterogeneity between countries persists, with the United States showing the smallest reductions (around 5%) for both sexes [12].

In Mexico, the components of avoidable mortality had different trends since the late 1990's. Mortality from infectious diseases and nutrition-related conditions decreased between 2000 and 2004 [14], while deaths related to diabetes and circulatory diseases increased in the same period [15]. Importantly, increases in the latter causes of death were concentrated in the poorest states of the country [16].

We extend previous analyses by using the most recent available data to study mortality trends by cause of death for all 32 states, by sex, and over the full period from 1990 to 2015. This choice of period covers several public health interventions and captures several major trends in state and cause-of-death variation. We further segment AM into health intervention-related AM and behavior-related AM causes that capture the epidemiological patterns of Mexico [17]. In addition, our work differentiates from earlier studies by comparing state mortality patterns with an

[1]The percentage of the population aged 60 or older is projected to go from 10% in 2015 to 15% in 2030 [9].

easy-to-understand low-mortality benchmark calculated for large age groups (i.e. 0-14, 15-49, 50-84). This concept has been previously used in mortality studies [18], and further developed elsewhere [19, 20]. Deviations from the low-mortality benchmark indicate a strong potential for improvement.

We hypothesize age-dependent variations in mortality outcomes. In particular, we expect convergence between states and improvement in survival for young people, since public health interventions are mainly focused on infant and child health. For instance, the vaccination program and Seguro Popular aim to fully cover children in the entire country, and recent evidence suggests a decrease in mortality below age 15 due to a decline in infectious and respiratory diseases [21]. On the contrary, we expect little improvement in survival for the young-adult population due to the sudden and egregious rise in homicide mortality, and among older adults because of the increase in diabetes along with endocrine/metabolic diseases in these ages in the country [22, 21]. Although every state has the commitment to provide universal coverage and equitable access to health care, we anticipate disparities between states in mortality improvements due to state differences in epidemiological patterns [23] and differences in how health care programs have been delivered to the population [24].

Data & Methods

Our analyses are based on publicly available anonymized datasets. We used microdata death files produced by the Mexican Statistical Office (INEGI) from 1990 to 2015 [25]. From these data, information on causes of death by single age, sex, and state of residence at the time of death was extracted. Population estimates from 1990 to 2015 came from the Mexican Population Council (CONAPO) [9]. These estimates adjust for age misstatement, undercounting, and interstate and international migration. Death counts and estimated of the population exposed to risk were used to calculate cause-age-specific death rates by sex and state from 1990 to 2015.

Classification of Causes of Death

To classify deaths we use the concept of "Avoidable/Amenable Mortality" (AM) [11, 12]. We group causes of death into ten categories based on a previous classification [13] that has recently been adapted to the case of Mexico [17]. The first category refers to those conditions that are susceptible to medical intervention, such as infectious and respiratory diseases, and it is labeled "Causes amenable to medical service". We separate diabetes, ischemic heart diseases (IHD), HIV/AIDS, lung cancer, and cirrhosis because these causes are susceptible to both health behavior and medical service, and because the first two represent major causes of death in Mexican adults [23]. We also separate homicide, road traffic accidents, and suicide because they have emerged as leading causes of death among young people, and the first two recently had a sizeable impact on life expectancy in Mexico [17]. Remaining causes were grouped into a single category labeled "Other causes".

Death data was originally classified according to the International Classification of Diseases (ICD), revision 9 for years 1990 to 1997 and revision 10 for 1998 to 2015 (see Additional file 1 Table 1 for details on ICD codes for each category). For the sake

of a consistent cause-of-death classification over studied period, we grouped specific causes using codes from a previous study on avoidable mortality in the US [13]. To check the validity of these cause-of-death bridge codes in Mexico, we performed a sensitivity analysis and did not find major ruptures in mortality trends by AM classification (See Additional file 1 figure 1). Although ill-defined causes represent a small percentage of the total deaths (2% in 1992 [26]), we decided to leave them in the residual category rather than redistribute over other causes of death. We suspect that ill-defined causes could be related to specific conditions, such as homicides, in Mexico.

We truncate analysis at age 85 because cause of death classification and age reporting are considered to be inaccurate in death registration at older ages [27]. Further, age 85 is higher than both the mean and modal lifespan in Mexico, and most important changes in survival are captured below it.

Age Groups

We calculate life expectancy in three large age groups to capture mortality differences along the lifespan. Life expectancy in each age group simply refers to the average years of life lived between two ages conditional on survival to the lower age bound. The first age group refers to people aged 0-14. This group is likely to represent improvements in causes amenable to medical service (e.g. infectious diseases and conditions of perinatal period) [3]. The second group, aged 15-49, is used to capture the effect of homicide mortality and external causes historically related to the young-adult mortality hump. This age group had an important impact on changes in state life expectancy in the first decade of the 2000s [17]. The third group covers older adults aged 50-84. We focus on adults because they likely represent a vulnerable group due to deterioration in non-communicable diseases and injury-related mortality in recent years [22, 23].

Statistical & demographic Methods

We smooth cause-specific death rates over age and time for each state and sex separately using a 2-d p-spline to mitigate random variations between ages [28]. We then calculate period life tables up to age 74 for males and females from 1990 to 2015 following standard demographic methods [29]. We calculate the temporary life expectancy [30] (See Additional file 1 for a technical overview) and estimate cause-specific contributions to the difference between each state and the low mortality benchmark using standard decomposition techniques [31]. Finally, to measure the level of disparities between states over time, we estimate the coefficient of variation and the Gini coefficient on temporary life expectancy within each age-group and year. In addition, we perform a two way ANOVA and post hoc tests to analyze disparities in temporary life expectancy between states and age groups in Mexico.

Low mortality benchmark

Our low-mortality benchmark is calculated in the basis of the lowest observed mortality rates by age, cause of death, from among all states for a given sex and year.

The resulting minimum mortality rate schedule has a unique age profile, and it determines our benchmark temporary life expectancy. The minimum mortality

schedule can be treated as the best presently achievable mortality assuming perfect diffusion of the best available practices and technologies in Mexico [20]. This value is a practical reference because it is based neither on a projection of improvements into the future nor on an arbitrary and likely dissimilar population.

Limitations

Mortality data from Mexico are likely to present inaccuracies in cause-of-death classification due to comorbidities, particularly at older ages [27]. To mitigate this, we focus on ages below 85 and grouped causes of death using ICD codes. Our estimates regarding homicide mortality are likely to be underestimated due to inaccurate practices regarding counting, reporting, and due to the large number of missing individuals in Mexico [32].

Avoidable mortality should be understood as an indicator of potential weaknesses with respect to health care and some public health policies and not as a definitive assessment [12]. The amount of deaths that should be considered avoidable within the avoidable classification is not clear [33]. For instance, some researchers consider only 50 percent of heart disease mortality to be avoidable [34, 35]. We do not have information to precisely measure percentages of avoidable mortality within cause groups in Mexico. Nonetheless, the difference between a given mortality schedule and the best mortality schedule of the same year can be conceived of as a minimal definition of avoidable mortality. The benchmark mortality schedule sets a lower bound to how much mortality could have been avoided. Certainly, even the best mortality schedule will contain elements of mortality that most would consider avoidable. To the extent that the components of the benchmark schedule were indeed attained somewhere in Mexico, one can view any excess mortality with respect to the benchmark schedule as avoidable. We believe this perspective improves on the AM concept by giving a directly measurable standard against which to estimate avoidable deaths.

Results

Trends in mean survival for Mexican states by age-groups

Figure 1 presents life expectancy between two ages (temporary life expectancy) by state for three large age groups, young (ages 0-14), young adults (15-49) and older adults (50-84), over the period 1990-2015. Grey lines refer to each one of the 32 states; and the blue lines represent the low mortality benchmark. The black line at the top of each panel indicates the maximum survival in each age group. For example, the young group has a maximum of 15 livable years, while young and older adults have up to 35 years conditional on surviving to 15 and 50, respectively. Any gap between a state line and the blue line represents potential years of life that could be gained if mortality were to achieve the low mortality benchmark.

All states show improvements in the young age group since 1990, approaching the low mortality benchmark, which itself is very close to maximum survival below age 15. In contrast, Mexico City (former Federal District) has lagged behind in reducing mortality at these ages; and some southern states, such as Tabasco, Puebla and Chiapas, show the lowest levels of life expectancy below age 15 throughout the entire period.

Life expectancy between ages 15 and 49 shows a common shift after 2005 among males in almost every state in Mexico. In 2005, young males in this age group had a temporary life expectancy of 33.8 years averaged over states. By 2010, the number of states below this level had increased from 12 to 21. Chihuahua, Sinaloa and Durango, in the northern region, experienced a substantial mortality shock in 2010 in this age group, and consequently recorded the largest departures from the low mortality benchmark. In 2015, the states with the lowest mid-life expectancy were Guerrero and Tabasco from the southern region, and Chihuahua, which borders the US state of Texas. By this time the state average had recovered to its 2005 level of 33.8. Trends for females are closer to the low mortality benchmark. However, Chihuahua also shows a clear downward since 2005.

Among older adults, life expectancy between ages 50 and 84 shows stagnation and deterioration over the entire period of observation. Even the low mortality benchmark exhibits a gradual downward trend, pointing to a generalized mortality increase. Of a maximum of 35 years, females state average life expectancy declined from 28.8 years in 1990 to 28.3 years in 2010. By 2015, this average only managed to recover to 28.6 years. Among males, the average over states decreased from 26.8 in 1990 to 26.5 in 2015. As with young adult males, some states experienced a deterioration after 2005, with a minor recovery since 2010.

[Figure 1 about here]

Health disparities between states and age groups

Figure 2 shows the trends in inequalities between states in Mexico for three large age groups, as measured by the coefficient of variation (results for the Gini coefficient are reported in Additional file 1 figure 2). These indicators measure the variation in temporary life expectancy between states in different age groups. Larger values are related to higher disparities between states. Both indicators are relative and have the property that even if temporary life expectancy refers to different range of ages, e.g. 0-14 and 15-49, the values are still comparable over age groups and time.

Since 1990, inequality in life expectancy for the young population has been decreasing. Young adults show even lower values than the population at younger ages in females. However males show a crossover in the beginning of the 2000s and after 2005 the level of disparities begun to increase leading to higher inequality. The highest values are observed in the period 2009-2011. By 2015 the level has not yet recovered, and still is higher than that of the young population.

Older adults show substantially higher inequality than the other age groups in the entire period. Similar to young male adults, after 2005 they experienced an upturn, and a slowly recovery until 2012. From 2013, both males and females show a rise in disparities between states. Importantly, women show less inequality in every age group at any year.

We further performed a two-way ANOVA on temporary life expectancy by state and age-groups controlling by year. There was a statistically significance interaction between the effects of states and age groups [$F = 19.62, p < .001$]. There were statistically significant differences in temporary life expectancy between age groups [$p < .001$] and states [$p < .001$]. Tukey's HSD post hoc tests were carried out.

Results show that 74.9% of 4,560 possible pairs of comparisons were significantly different at the level of $p < .001$. To illustrate these results, Figure 2 shows...

[Figure 2 about here]

Causes-decomposition analysis

In figures 3 and 4, the Mexican states in each region are arranged according to potential gains in survival for older adults in 2015, i.e. departure of each state from the low mortality benchmark.

Figure 3 shows how causes amenable to medical service, diabetes, ischemic heart diseases (IHD), lung cancer, cirrhosis, homicide and road traffic accidents contributed to the gap between each state and the low mortality benchmark from 1990 to 2015 for male older adults (ages 40-84). These are the causes of death that contributed the most to impeding the states from achieving the low mortality benchmark. Light-yellow colors indicate no contributions to the gap, which means that are very close to the low mortality benchmark within each category. Darker red hues indicate larger contributions to the gap. If a particular state is improving during the period, it shows a transition from red to light-yellow.

Medically amenable causes of death show gradual improvements in most states from 1990 to 2015, leading to decreasing the gap with the benchmark in this category. However, large disparities between states and large room for improvements remain. For example, Baja California, Chihuahua, Sonora and Coahuila from the northern region; along with Mexico City in the central region; and most states in the south show substantial contributions to the gap with the low mortality benchmark. Mortality caused by diabetes has increasingly contributed to the gap with the benchmark in some states. Coahuila and Tamaulipas in the north; Mexico City, Guanajuato and Tlaxcala in the central region; and Puebla, Veracruz and Tabasco in the south, show deterioration in diabetes mortality in the last decade, leading to widening the gap with the benchmark. Similarly, IHD affects significantly the north part of the country, while cirrhosis is mostly concentrated in the south. Although lung cancer and road traffic accidents do not have the same magnitude as these previous causes, in every state these conditions contribute to the gap with the benchmark. Cause specific mortality for homicides increased the gap with the low mortality benchmark in some states affecting ages 50-84. In particular, Chihuahua, Durango and Sinaloa in the north; Colima, Michoacan and Nayarit in the central region; and Morelos and Guerrero in the southern part of the country were affected.

[Figure 3 about here]

Causes amenable to medical service, diabetes and IHD are the causes of death that mostly contributed to the gap with the low mortality benchmark among older adult females (see Additional file 1 figure 3). Although almost every state shows improvements in causes medically amenable, these conditions still represent potential years of life if the low mortality benchmark were achieved in this age group. Diabetes shows deterioration in recent years in several states, such as Coahuila, Tamaulipas in the north; Guanajuato and Tlaxcala in the central area; and Puebla, Veracruz and Tabasco in the south, among others, widening the gap with the low

mortality benchmark. Moreover, IHD contributes significantly to the gap, particularly in the northern region, and there are not clear improvements throughout the entire period 1990-2015.

Among the young population below age 15, improvements in survival and in reducing the gap with the low mortality benchmark were mainly driven by causes amenable to medical service in both females and males. However, Mexico, Tlaxcala, Mexico City in the central region, along with almost every state from the south could improve in this set of conditions (see Additional file 1 figures 4 and 5). Finally, homicide mortality and road traffic accidents mainly explain the trends in the gap with the benchmark among young male adults (ages 15-49) (see Additional file 1 figures 6 and 7). Homicides contributed more than 2.5 years to the gap with the low mortality benchmark in 2010 in Chihuahua, other states in the north like Baja California, Coahuila, Tamaulipas, Nuevo León, Durango and Sinaloa experienced substantial increases in this cause of death after 2005 explaining most of the gap with the benchmark. States were also affected in the central and southern regions. Importantly, some states still show high impact of homicides with respect to the benchmark, such as Guerrero and Morelos in the south; Colima and Guanajuato in the central region. The impact of the remaining AM categories in ages 0-14 and 15-49 is negligible.

Potential gains and causes of death in 2015

Figure 4 shows the potential gains in survival for male older adults (ages 50-84) if the low mortality benchmark were achieved in 2015 in the left panel (Results for previous years and other age groups are shown in the Additional file 1). The right-hand panel shows the proportion of potential gains explained by specific causes of death for 2015.

Every state in Mexico could increase survival by at least one year in older adult ages if they were to achieve the low mortality benchmark. However, for 17 of them the gap with the benchmark is higher than 2 years, and for 3 states in the northern region is greater than 3 years. In females, with the exception of Sinaloa and Nayarit, all the states show a gap greater than one year of life between ages 50-84 (see Additional file 1 figure 9). Since 2005, no major improvements were observed, and in some states the potential gains even increased in 2015 compared to 2010, for example San Luis Potosí and Zacatecas in the north; Colima, Guanajuato, Mexico City in the central region; and all the southern region, with the exception of Guerrero.

More than half of these potential gains in life expectancy between 50 and 84 years are due to avoidable causes of death in every state of Mexico (right-hand panel), and in more than 60% of the sates these causes account for more than 75% of potential years. The three main causes of death explaining these differences with respect to the low mortality benchmark are conditions amenable to medical service (AMS) (green bar), diabetes (yellow) and IHD (purple). This is true also for females (see Additional file 1 figure 10). Cirrhosis explains a considerable proportion mainly in states in the central and southern region, and the effect of homicide mortality is present in almost every state, particularly in Guerrero, Morelos (south), Nayarit, Colima (center) and Sinaloa in the north.

[Figure 4 about here]

Discussion

Young survival

This analysis demonstrates the potential contribution of achieving the low mortality benchmark to improvements in survival. However, it is concerning that the low mortality benchmarks have not been steadily increasing over the period studied. Trends were flat for children, they are experiencing almost full survival before age 15. More worrisome is the common shift after 2005 in adults aged 15-39 and decreasing survival among older adults aged 35-74.

Despite the flattening pattern of the low mortality benchmark in children, our results show that all states in Mexico have improved survival towards this benchmark and to the maximum survival. Causes amenable to medical service are at the heart of such improvements, consistent with decreases in infectious and respiratory diseases associated with public health interventions targeted to children in Mexico previously documented [6]. For example, Puebla and Tlaxcala improved survival over half a year since the 1990's. By 2010 survival was improved so that all states' temporary life expectancy ranged between 14.6 and 14.8 years. We further estimated survival inequalities between states by age group for every year. Indeed, survival inequality below age 15 was reduced paralleling improvements in survival during the period. In addition, our results are also consistent with advances in coverage for skilled attendance at delivery, which by 2012 remained above 90% and more than 78% of children under age one visited the doctor to monitor their development and growth [10]. Moreover, vaccination coverage has been achieved for the entire young population, the success of such public health interventions are in line with our results, underscoring the improvements in survival in the population younger than 15 years associated to the progress detected in health insurance coverage due to vaccination programs and the implementation of the Seguro Popular [10]. Although average years lived below 15 has improved, there still exist areas of opportunity to achieve full-survival under age 15 in causes amenable to medical service, mainly in states in the Central and Southern regions of the country.

Young adults

Young adults (ages between 15 and 39) show a converging pattern towards the low mortality benchmark in all states just until 2005. A sudden increase in homicide rates widened the gap with the low mortality benchmark by almost four times on average in 2010, relative to the level observed in 2005. Previous research documented losses in the overall life expectancy up to three years in the state of Chihuahua (the bordering state with Texas, USA) and almost two years in Sinaloa, Durango (North) and Guerrero (South) between 2005 and 2010 due to homicides [17]. Our findings show that the trend towards the low mortality benchmark was reversed after 2005 due to the increase in homicide mortality, with a peak in 2010-2011. Although homicide rates decreased after 2011, they still are the main cause of death contributing to the gap between the observed survival and the low mortality benchmark in particular states, such as Sinaloa, Durango in the North, Nayarit and Michoacán in the cetral region, and Guerrero in the South. These findings underscore the need for effective interventions to reduce homicide mortality, as it still contributes the most to survival shortcomings among the young-adult population and mortality

inequality among states. Even ten years after the national security strategy that aimed at reducing drug cartels' operations started and homicides begun to spread all over the country [36], the effect of homicide on average survival is appalling. Between-state inequality in female survival was much smaller over the same period.

Older adults

In Mexico, since the beginning of the 1990's, adult survival in ages 40-74 deteriorate for males and stagnate for females. Our results help explain on this pattern showing that the low mortality benchmark decreased as a result of state-specific mortality trends and the interaction between specific causes of death. In particular, there are offsetting effects between improvements in causes amenable to medical service, such as infectious and respiratory diseases, and deterioration in diabetes, isquemic heart diseases (IHD), and behavior-related mortality through cirrhosis and homicides.

Out of 35 potential years, adult females in Mexico are living less than 33 and males less than 31 since the 1990's. The increase in diabetes, IHD and cirrhosis mortality is at the heart of survival's deterioration, with clear regional variations. Although improvements in causes amenable to medical service were witnessed, almost every state still has potential to improve in this ages, in particular the Northern states of Sonora, Chihuahua and Baja California. Diabetes mortality increased over the period and contributed to increases in the gap to achieve the low mortality benchmark. Diabetes-related mortality increased 23% from 1998 to 2002, and the prevalence of diabetes was estimated at 14.4% in the adult population in 2006. These figures underscore the emerging epidemic of diabetes [37]. To put this in perspective, Coahuila, the state of Mexico, Guanajuato, the Federal District, Tabasco and Puebla could increase survival by almost one year if diabetes mortality were to achieve the low mortality benchmark. Similarly, mortality related to IHD contributes to lowering life expectancy in adults. There is a clear regional pattern in the country. Almost all the states in the Northern region could potentially benefit with one additional year in life expectancy if the low mortality benchmark were reached, where as the Central and Southern regions present a lower impact of IHD. Cirrhosis-related mortality shows a higher impact in the Southern and Central states of the country, particularly in Querétaro, México state, Hidalgo (central area) and Puebla and Oaxaca in the South. Both diabetes and IHD mortality are closely related to obesity prevalence, previous research anticipated that the increasing levels of obesity in Mexico could compromise gains in life expectancy [38]. These regional differences on cause-specific mortality led to increases in health inequalities in adults aged 30-74 after 2006 for males and stagnation among females (figure **??**).

There is still potential for improvements to reduce state-mortality differences and improve the survival among the adult population in Mexico. Several screening and prevention strategies (e.g. PREVENIMSS) for early diabetes and hypertension have been implemented in the country. However, as previous research has found, they are far from achieving the ultimate goal and including the entire population [39]. In addition, [40] show that the conditional cash transfer program PROSPERA improves health significantly for adult women older than 50. The authors also noted that the effect on men's health is much lower. They argue that this could be the result of the lack of inclusion of men in the program and the main role of women in the

program's requirements. Women are recipients of the monetary transfers and they are more likely to attend clinic visits and follow health measures given by doctors in these clinics than men.

Conclusion

Health inequalities have been previously identified as a current challenge for Mexico [23, 41], here we give cause and age-specific targets to improve longevity and at the same time reduce inequalities between states. Since different risk factors are present at different ages for different causes of death in each state, we quantify potential gains in survival of achieving a low mortality benchmark conditioned to surviving at different ages in all 32 states by sex. This allowed us to identify three main stories over the last 25 years. Firstly, improvements in causes amenable to medical service, such as infectious & respiratory diseases and birth conditions, led to achieve almost full survival below age 15 for the 32 states.

The increase in homicide mortality reversed gains in male life expectancy, particularly between ages 15-50. These results are consistent with previous studies quantifying the effect of homicide mortality on the stagnation of national life expectancy in the first decade of the 21st century [3], and with the reversal experienced in average length of life in most states between 2005 and 2010 [17]. Our results extend such studies by adding five years of information. We found that after ten years of the unexpected rise in homicide mortality, most states have experienced a slow recovery after 2010. However, the impact of homicide is still higher than the levels observed in 2005. Between 2010 and 2015, this cause of death accounted for most departures in life expectancy between ages 15 and 50 with the low mortality benchmark. The states that show higher impact in 2015 are Baja California, Chihuahua and Sinaloa in the northern region; Colima, Jalisco, Guanajuato, Mexico state and Michoacán in the central region show a recent increase in homicides that led to widening the gap with the low mortality benchmark; and Guerrero is the most affected in the southern region. To put these recent wave of homicides in perspective, Guerrero would achieve an extra year of life between ages 15 and 49 if they get to the lowest level of homicide mortality observed in the country. Importantly, these figures are likely to be underestimates caused by miss-registration of homicides and all missing individuals in the country, particularly in Guerrero [32, 42].The disproportionate number of homicides witnessed in the last ten years, along with the increased perceived vulnerability associated to violence, has affected the Mexican population beyond survival. For instance, women are expected to live over 70% of their remaining life expectancy at age 20 with fear if the perception of vulnerability remains at the 2014 level [43]. There is no simple way to lessen the impact of homicide mortality, but it is clear that the government has not been able to reduce its burden on the population over the last ten years.

and the stagnation and worsening in mortality on ages above 50

and identify the varied impact of different causes of death over the life course conditional on survival

We showed that conditions amenable to health behavior and healthcare, such as diabetes, IHD and lung cancer, are having a sizable impact in determining why

mexican states are not improving life expectancy after age 50 in the last 25 years. As a consequence of the very variety of epidemiological patterns between states and over the life course, there are discordant patterns of mortality over age groups and regions. These results point towards strengthening preventive care among the adult population to improve healthy behaviors...

Identifying specific opportunities to improve and put forward solutions to reduce the gap of the unequal impact of public health interventions on health is a necessary step to promote equitable increases in survival among the Mexican population.In addition, given the improvements in health care coverage, the strong role

Improving health is a priority for governments of many developing countries. In part to reduce child mortality, improve maternal health and lessen the impact of other infectious diseases, such as HIV/AIDS, to achieve the Millennium Development Goals established for 2015 [44]. Mexico has succeeded in reducing mortality and inequalities in children and the young population. Nevertheless, our results show that older adults are becoming a vulnerable group, and more efforts are required to reduce the burden of conditions amenable to health services and policy-related conditions. In particular, this group lacks comprehensive interventions to reduce the burden of violence through homicides, chronic-degenerative causes of death, such as diabetes and IHD, and behavior-related conditions such as cirrhosis.

There is no simple way to lessen the impact of such conditions, but it is clear that new approaches are needed to improve survival in the adulthood and to minimize health disparities between states. Preventing diabetes and IHD implies fundamental political challenges. Therefore, public health initiatives should focus in health care for chronic conditions as recently suggested by [45], but they should also influence the population towards improving health behavior. Our results reinforce the need of such, among others public health interventions, with an special focus on older adults in the Mexico.

Competing interests
The authors declare that they have no competing interests.

Author's contributions
TR and JMA conceptualized the study and performed the demographic and statistical analyses. JMA, TR and VCR helped to interpret the results. JMA and TR wrote the first manuscript and VCR reviewed and revised the manuscript. All authors approved of the final version.

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Author details
[1]Department of Public Health & Max Planck Odense Center on the Biodemography of Aging at University of Southern Denmark, J.B. Winsløws Vej 9, 5000 Odense, Denmark. [2]Max Planck Institute for Demographic Research, Konrad-Zuse-Straße 1, 18057 Rostock, Germany.

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Figures

Figure 1 State-specific average survival (grey lines) and low mortality benchmark (blue line) for young (0-14), young adults (15-39) and older adults (40-74) by sex, 1990-2015.
Note: Y-axis are not in the same scale in order to capture major trends over the period. Source: calculations based on INEGI files.

Figure 2 Survival inequality (coefficient of variation) by age group and sex, 1990-2010.
Source: calculations based on INEGI files.

Figure 3 Cause-specific contributions to the gap between state survival and low mortality benchmark for older male adults, 1990-2015.
Source: calculations based on INEGI files.

Figure 4 Left panel: Potential years gained if benchmark were achieved for older adult males in 2005,2010,2015. Right panel: Proportion of potential years explained by cause of death in 2015
Source: calculations based on INEGI files.

Additional Files
Additional file 1 — Supplemental material
This might refer to a multi-page table or a figure.

Additional file 2 — Results
Rdata file with all results.