RESEARCH

Avoidable mortality caused stagnation and reversal in survival improvements among adults in Mexican states, 1990-2015

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 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.

Methods: We analyze trends in mortality for three large age groups from 1990 to 2015 for all 32 Mexican states, and compare these with a low mortality benchmark. We use the concept of avoidable mortality and apply demographic measures 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. State-specific departures from this benchmark was caused by ischemic heart diseases, diabetes, cirrhosis and homicide mortality. We find large health disparities between states, particularly for the adult population and specially after 2005.

Conclusions: 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.

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

Background

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 the implementation of different public health interventions, such as the Universal Vaccination Program and 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].

These actions underscore broad progress in public health interventions, but they mask heterogeneity 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 [8]. For instance, 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 [9] on the adult population.[1] 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.

One approach to assess the impact of health care and other interventions 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. Between 2000 and 2004 AM decreased, particularly from infectious diseases and nutrition-related conditions [14], while it increased between 1998 and 2010 due to diabetes, circulatory diseases, perinatal and respiratory conditions [15]. Increases in the latter causes of death were particularly concentrated in the poorest states of the country [16]. We aim to extend these studies by a more focused segmentation of AM into health intervention-related AM and behavior-related AM. Also, we extend analysis to all 32 states, by sex, and over the full 26-year period

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

from 1990 to 2015. Finally, we compare state mortality patterns with an easy-to-understand low-mortality benchmark calculated for large age groups (e.g., 0-14, 15-39, 40-75). This low mortality benchmark is calculated on the basis of the lowest observed mortality within ages and causes, selected from the full set of 32 Mexican states. This concept has been previously used in mortality studies [17], and further developed elsewhere [18, 19]. Deviations from the low-mortality benchmark indicate a strong potential for improvement. We apply demographic measures and standard decomposition techniques to isolate the cause and age-specific deviations between states and the low mortality optimal lifetable for each year.

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 in infant mortality and child health. For instance, the vaccination program and the health reform aim to fully cover children in the entire country, and recent evidence suggests a decrease in mortality between ages 0 to 14 due to a decline in infectious and respiratory diseases [20]. On the contrary, we expect little improvements in survival for the young-adult population due to the unprecedented 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 [21, 20]. 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 [22] and differences in how health care programs have been delivered to the population [23].

Data & Methods

Our analyses are based on publicly available anonymized datasets. We used deaths microdata available from official files produced by the Mexican Statistical Office from 1990 to 2015 [24]. These data contain information on causes of death by single age, sex, and state of residence at the time of death. Population estimates from 1990 to 2015 came from the Mexican Statistical Office as well [24]. 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 separate causes of death that are susceptible to medical intervention (such as infectious and respiratory diseases) and those related to health behaviors and specific public policies (such as homicides, lung cancer) 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 [25]. Table 1 lists the cause of death categories we use with relative frequencies by sex for the period 2000-2015.

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 [22]. 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 recently in Mexico [25]. All causes of death were classified using the International Classification of Diseases, revision 9 for the period 1990-1997 and the tenth revision for 1998-2015 (see SI Table 1 for details on ICD codes for each cause). For the sake of a continuous cause of death series from ICD-9 to ICD-10, 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 changes in mortality trends by AM classification (See SI 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 redistributing over other causes of death. We suspect that ill-defined causes could be related to specific conditions, such as homicides, in Mexico.

We truncated analysis at age 75 because cause of death classification and age reporting are considered to be inaccurate in death registration at older ages [27] and most changes in life expectancy are likely due to changes in mortality patterns below the age of 75 [25]. This does not mean that the population above age 75 should not be included in public health priorities.

Age Groups

We break life expectancy into three large age groups to capture mortality differences along the lifespan. The first 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 15-39, is used to capture the effect of homicide mortality and external causes, historically related to the young-adult mortality jump. This age group had an important impact on changes in state life expectancy in the first decade of the 2000s [25]. The third group covers older adults aged 40-74. We focus on older adults because they likely represent a vulnerable group since mortality rates at adult ages deteriorated in recent years from non-communicable diseases and injury-related mortality [21, 22].

Demographic Methods

We smooth cause-specific death rates over age and time for each state and sex separately using the 2-d p-spline to avoid random variations between ages [28]. Smoothed death rates are then constrained to sum to the unsmoothed all-cause death rates. We then calculate period life tables up to age 74 for males and females from 1990 to 2015 following standard demographic methods [**?**]. We calculate the average years lived in each age group (temporary life expectancy) [30] (See SI for a technical overview) and estimate cause-specific contributions to the difference between state-specific temporary life expectancy 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 average survival for each age-group in each year.

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 [19]. 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 75 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 average survival (temporary life expectancy) by state for three large age groups, young (ages 0-14), young adults (15-39) and older adults (40-74), 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 25 and 35, respectively. Any gap between a state line and the blue line represents a potential gain in survival if mortality were to achieve the low mortality benchmark.

All states show improvements in the young age group from 1990 to the early 2000s approaching the low mortality benchmark, which is very close to full survival below age 15. In contrast, Mexico City (former Federal District) has lagged behind in reducing mortality at these ages; and some states, such as Tabasco and Chiapas, even experienced a downward in survival in both sexes in recent years.

Survival among young male adults shows a common shift after 2005 in almost every state in Mexico. In 2005 the male mean survival between states was 24.5 years; by 2010, twenty states were below this number. Chihuahua, Sinaloa and Durango, in the Northern region, experienced substantial losses in 2010, and consequently the largest departures from the low mortality benchmark. In 2015, the states with the lowest survival were Guerrero, Chihuahua and Tabasco. Trend for females were similar, albeit with lower magnitude, with the exception of Chihuaha, which clearly shows a shift after 2005 in survival, comparable to those observed in males.

In older adults, survival shows stagnation and deterioration during the entire period. Even the low mortality benchmark exhibits a gradual downward trend, pointing to small increases in adult mortality in every state. Of a maximum of 35 years, females in the Mexican states were living on average around 32, and men 30.5 in 2015. These values are very close to those observed 10 years earlier, 31.9 and 30.4 respectively. Similar to the young adults, in some states males experienced a clear downward trend after 2005. Throughout the entire period, the most disadvantaged states were Baja California, Chihuahua and Mexico City.

[Figure 1 about here]

Inequalities in survival by age-groups

Figure 2 shows survival inequalities for the Mexican states, as measured by the coefficient of variation, by age group (results for the Gini coefficient are reported in SI figure 2). Larger values are related to higher disparities between states.

Since 1990, survival inequality among the young population has been decreasing. Young adults show even lower inequality than the population at younger ages in both females and males. However, after 2005 the level of disparities begun to increase in males, and by 2007 there was a crossover 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. Survival below age 75 (dotted line) shows a similar trend, although with lower levels. Importantly, women show less inequality in every age group at any year.

[Figure 2 about here]

Causes of death

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 2 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 40-74). 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; and most states in the south would significantly increase survival by reducing the mortality associated to this category. 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, every state would reduce the gap by lowering mortality related to these conditions. Cause specific mortality for homicides shows a clear reversal in improvement trends around 2010. Particularly, Baja California, 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. Importantly, Oaxaca, Guerrero, Morelos, and other states in the north point towards an upsurge of homicide mortality in 2015.

[Figure 3 about here]

Causes amenable to medical service, diabetes and IHD are the causes of death that mostly contribute to the gap with the low mortality benchmark among older adult females (see SI 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 still could improve (see SI figures 4 and 5). Finally, the causes of death that mainly explain the trends in the gap with the benchmark on the young male adults (ages 14-39) are homicides and road traffic accidents (see SI figures 6 and 7). States like Chihuahua, Durango, Sinaloa and Guerrero would benefit with an additional year of life in these ages by reducing homicide mortality to the low mortality benchmark.

The impact of the remaining AM categories in ages 0-14 and 15-39 is negligible.

Potential gains and causes of death in 2015

Figure 4 shows the potential gains in survival for male older adults if the low mortality benchmark were achieved for the years 2005 (light blue triangles), 2010 (rhombus) and 2015 (dark blue dot) in the left panel. 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 one year in older adult ages if they were to achieve the low mortality benchmark, with the exception of Nayarit, in 2015. Since 2005, no major improvements are clear, 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.

Importantly, in every state more than half of the potential gain is explained by avoidable causes of death, and in some states more than 75% (righ-hand panel). In particular, causes amenable to medical service, along with mortality related to health behavior, such as diabetes, IHD, cirrhosis, homicide and traffic accidents play an important role in explaining the gap with the low mortality benchmark. Moreover, their relative importance has not changed since 2005 (see SI figure 8).

[Figure 4 about here]

Females show similar results than males but with lower magnitude (see SI figures 9 and 10). However, Baja California, Chihuahua, Sonora, and Coahuila in the northern region; Mexico City in the center; and Puebla, Veracruz, Tabasco, Yucatán, Morelos, Chiapas and Quintana Roo in the south show potential gains larger than one year. The respective results for young and younger adults are shown in SI figures 11-16

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 [8]. 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 [8]. 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 [25]. 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

Conclusion

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

Author's contributions
JMA and TR conceptualized the study, performed the analyses and wrote the manuscript.

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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.

Tables

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.

Table 1 Avoidable Mortality classification, with crude percentages below age 75, years 1990-2015. Source: INEGI files.

	Category	%	Males (1,000's)	%	Females (1,000's)
1	Causes amenable to medical service	30.9 %	127.5	28.2 %	114.4
2	Diabetes	4.5 %	18.7	4.9 %	19.9
3	Ischemic heart diseases	4 %	16.4	4.2 %	17
4	HIV/AIDS	0.4 %	1.5	0.5 %	2.1
5	Lung cancer	0.9 %	3.7	0.9 %	3.8
6	Cirrhosis	2.3 %	9.5	2.5 %	10
7	Homicide	2.7 %	11.2	3 %	12.4
8	Road traffic accidents	2.8 %	11.4	2.9 %	11.8
9	Suicide	0.4 %	1.7	0.5 %	1.9
10	Other causes	24.8 %	102.4	25 %	101.2