Avoidable deaths caused stagnation and reversal in adulthood survival improvements in Mexican states, 1990-2015

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Abstract

We analyze trends in mortality for three large age groups from 1990 to 2010 for all 32 Mexican states, and compare these with a low mortality benchmark. We assess the impact of avoidable mortality on survival at the state level by sex. We apply demographic measures and use standard decomposition techniques to disentangle the effects of selected causes of death on trends in state health inequality. We find improvements in survival for the population aged 0 to 14, as they continuously approached the low mortality benchmark. However, the adult population aged 15 to 39 shows deterioration among males after 2006 in almost every state. Females on the whole converged toward the low mortality benchmark in the same age group. Adults aged 40 to 74 show an unexpected decrease in the low mortality benchmark, indicating universal deterioration in temporary life expectancy for this age group, albeit with wide variation between states. These findings support the case for reforms that treat all causes of death as public health priorities, and that target regional disparities in health.

Key messages

- Improving survival among sub-populations is a goal of every developing country. Achieving such goal in the adult population in Mexico is proving to be a challenging since the 1990s.
- Geographic variation in the rise in homicide mortality and the increase of conditions amenable to medical services and policy/behavior actions are driving survival stagnation in adults.
- Young-age mortality has steadily improved, mainly due to progress made in causes amenable to public health interventions.
- Mexican states could benefit by two additional years of life if cirrhosis, homicides, diabetes and isquemic heart diseases mortality were to achieve the low mortality benchmark

Introduction (max 6000 words)

The 20th century was marked by sizable improvements in mortality, living conditions and health in most Latin American countries (Worl Health Organization 2000). 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 (Sociedad Mexicana de Demografía 2011), between 2000 and 2010, life expectancy at birth entered into a period of stagnation for males and slowed progress for females (Canudas-Romo et al. 2014).

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 (Knaul and Frenk 2005). Further, the conditional cash transfer program PROSPERA (known as Oportunidades and Progresa before 2014) was introduced to supply incentives for families to reinvest in education, health, and nutrition in 1997 (Neufeld 2012). 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 (Sepúlveda et al. 2006). 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 (Knaul et al. 2012).

These results 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. For instance, PROSPERA is 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 (Bygbjerg 2012), such as diabetes, 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) (Nolte and McKee 2004; 2008, Elo et al. 2014). 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 part 20 years (Nolte and McKee 2008). 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 (Nolte and McKee 2008).

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 (Franco-Marina et al. 2006), while it increased between 1998 and 2010 due to diabetes, circulatory diseases, perinatal and

[1]The percentage of the population aged 60 or older will go from 10% in 2015 to 15% in 2030 according to projections made by Consejo Nacional de Población (2015)

respiratory conditions (Agudelo-Botero and Dávila-Cervantes 2014). Increases in the latter causes of death were particularly concentrated in the poorest states of the country (Dávila-Cervantes and Agudelo-Botero 2014). 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 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 benchmarks 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 was first proposed by Whelpton et al. (1947) and later explored by Wunsch (1975) and Vallin and Meslé (2008). 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 (Canudas-Romo et al. 2014). On the contrary, we expect little improvements in survival for the young-adult population due to the unprecedented rise in homicide mortality, and on the older adults because of the increase in diabetes mortality along with endocrine/metabolic diseases in these ages in the country (Canudas-Romo et al. 2014). Although every state has the commitment to providing universal coverage and equitable access to health care since the early 2000's, we anticipate heterogeneity between states in mortality improvements due to state differences in epidemiological patterns and differences in how health care programs have been delivered to the population (Frenk 2006).

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 (Instituto Nacional de Estadística y Geografía 2015). 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 Society of Demography. 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 intersectoral policies (such as homicides, lung cancer) we use the concept of "Avoidable/Amenable Mortality" (AM) (Nolte and McKee 2004; 2008). We group causes of death into ten categories based on Elo et al. (2014)'s classification, recently complemented to the Mexico's case (Aburto et al. 2016), as listed in Table 1, with relative frequencies by sex for the period 2000-2015.

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

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 (Canudas-Romo et al. 2014). 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 had a sizeable impact on life expectancy recently in Mexico (Canudas-Romo et al. 2014). All causes of death were classified using the International Classification of Diseases, revision 9 for the period 1990-1997 and the tenth revision for 1998-2010 (see Appendix Table 1 for details on ICD codes for each cause). To avoid spurious results concerning the change in coding practices between the ninth and tenth revision, we performed a sensitivity analysis and did not find major changes in mortality trends by AM classification (See Appendix figure 5). Although ill-defined causes represent a small percent of the total deaths (2% in 1992 (Rivera et al. 2002)), we decided to leave them in the residual category because if we spread them proportionally, among the other causes of death could over estimate our results.

We truncated analysis at age 75 because classification of causes of deaths and age reporting are considered to be innacurate in death registration at older ages (Tobias and Jackson 2001) and most changes in life expectancy are likely due to changes in mortality patterns below the age of 75 (Aburto et al. 2016).

Age Groups

We break life expectancy into three large age groups to capture mortality differences along the lifespan based on previous research. 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) (Canudas-Romo et al. 2014). The second group, aged 15-39, is used to capture the effect of homicide mortality and external causes, which have an important impact on life expectancy in these ages (Aburto et al. 2016). Finally, the third group is for older adults aged 40-74. We focus on older adults because they are susceptible to external causes of death and likely to experience premature death due to noncommunicable conditions (Canudas-Romo et al. 2014).

Demographic Methods

We smooth cause-specific death rates over age and time for each state and sex separately using the 2-d p-spline method proposed by Camarda (2012) to avoid random variations between ages. 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 the HMD Methods Protocol (Wilmoth et al. 2007). We calculate the average years lived in each age group (temporary life expectancy) (Arriaga 1984) (See Appendix for a technical overview) and estimate cause-specific contributions to the difference between state-specific temporary life expectancy and the low mortality benchmark. We use standard decomposition methods (Horiuchi et al. 2008).

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, $e(0)^\star$. The minimum mortality schedule can be treated as the best presently achievable mortality assuming perfect diffusion of the best available practices and technologies within a given set of populations (Vallin and Meslé 2008). It is an imaginary quantity because no particular population is expected to achieve this mortality pattern. However, 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. We refer to the state with the highest life expectancy in a given year as the vanguard state.

Limitations

Mortality data from Mexico are likely to present inaccuracies in cause-of-death classification due to comorbidities, particularly at older ages (Tobias and Jackson 2001). To mitigate this, we focus on ages below 75, grouping 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 (Human Rights Watch 2011).

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 (Nolte and McKee 2008). The amount of deaths that should be considered avoidable within the avoidable classification is not clear (Beltrán-Sánchez 2011). For instance, some authors consider only 50 percent of heart diseases as avoidable (Nolte and McKee 2012)

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 the population universe, one can view any excess mortality with respect to the benchmark schedule as avoidable. Little progress has been made in advancing the concept of avoidable mortality (Holland 2003). We believe this perspective improves on the original concept by giving a directly measurable standard against which to estimate avoidable deaths.

Results

Trends in the low mortality benchmark and temporary life expectancy

Figure 1 presents the state-specific trends in temporary life expectancy for young, young-adult and older-adult populations (black lines). The red lines represent the record holder state in a given year, while the blue line represents the low mortality benchmark. Panel a) shows the trend of convergence and improvements among the young population. Since the 1990's all the states have shown improvements towards the low mortality benchmark, approaching near-complete survival between ages 0 and 14. However, both males and females have lagged behind in states such as Puebla, Tlaxcala and México.

Opposing this trend, temporary life expectancy between 15 and 39 years shows a common shift after 2005 in almost every state in Mexico (panel b)). Chihuahua and Sinaloa, in the Northern region, experienced the largest downwards trends after 2005. Over the full period Oaxaca, Baja California, and Chihuahua show the largest departures from the low mortality benchmark. Results for females show stagnation close to the maximum attainable survival. However, as in males' results, Chihuahua exhibit reductions in survival after 2005.

Temporary life expectancy for adults between 40 and 75 years shows stagnation and deterioration during the entire period (panel c)). Even the low mortality benchmark exhibits a gradual downward trend, pointing to increases in adult mortality in every state. From a potential maximum of 35 years, all the states are living on average less than 30 years for males and 32 for females. Importantly, Baja California, Chihuahua and Sonora could potentially live more than two additional years if the low mortality benchmark were achieved for males. Similar to the young-adult males, some states experienced a clear downward trend after 2005. Results for females show stagnation in this age-group.

These results allow us to identify three different patterns between the age groups and states. Mortality in ages 0-14 has been decreasing, approaching almost complete survival. Adults aged 15-39, particularly males, present a clear reversal in temporary life expectancy after 2005. Males and females aged 40-74 showed stagnation and deterioration since the 1990's. This has led to a 2-year gap for males and 1-year gap for females with benchmark survival, which itself falls short of the full 25 years by almost 3 years for males and 2.2 for females. To fully understand the underlying causes of death driving these stories, we decompose the gap between state-specific temporary life expectancy and the low mortality benchmark within each age-group.

[Figure 1 about here]

Causes of death

Of the age groups studied, adults aged 35-74 show the largest deviations from the low mortality benchmark. Figures 2 and 3 show cause-specific contributions to the gap between observed temporary life expectancy and the low mortality benchmark by state and region for females and males, respectively. 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.

As shown in figure 2, medically amenable causes of death still contribute to the gap between survival and the low mortality benchmark. However, improvements in this category throughout the period 1990-2015 helped reduce deviations in almost every state. Chihuahua, Coahuila and Baja California, in the Northern region, and Chiapas in the South exhibit the largest deviations from the low mortality benchmark as mortality due to these causes stagnated in both females and males. Opposing this, the increase of diabetes mortality among females has contributed to widening the gap between temporary life expectancy and the low mortality benchmark. Some states, like Tabasco in the South and Coahuila in the North, show a clear deterioration on the survival in the 2000's due to this cause of death. Isquemic heart diseases (IHD) is the the third most important cause of death contributing to differences with the mortality benchmark among regions. The impact of IHD on the survival of the females aged 35-74 is concentrated in the Northern region. Mortality related to cirrhosis contributes significantly to the difference with the benchmark mortality in the Central and Southern regions in female survival. Its contribution is such that in states such as Tlaxcala, Querétaro, México and Hidalgo in the central area, this cause of death accounts with more than half a year of the difference with the benchmark. The rest of AM-categories do not contribute significantly to the gap between female survival and the low mortality benchmark, which means that they are very close to the latter.

[Figure 2 about here]

Causes amenable to medical service follow a similar pattern for males (figure 3). However, diabetes, IHD and cirrhosis still contribute significantly to the difference between the observed mortality and the low mortality benchmark. The increase in diabetes has led to decreasing survival among male adults. For instance, Tamaulipas, Coahuila (Northern area); Tlaxcala, México state, Guanajuato and the Federal District in the central region; along with Veracruz, Tabasco and Puebla in the South, show clear deterioration during the study period, while other states experienced improvements that led to reducing the gap towards the low mortality benchmark due to diabetes (such as Sinaloa in the North, Nayarit in the central region, and Yucatán in the South). As in females, IHD exhibit a very different pattern between regions. Nearly every state in the North could gain more than one year of life if IHD mortality were reduced to the low mortality benchmark. On the contrary, cirrhosis affects male survival mainly in the Central and Southern regions. Querétaro, Michoacán, Jalisco, Puebla and Oaxaca show the largest deviations from the low mortality benchmark due to cirrhosis mortality. Finally, homicide mortality also affects older-adult survival in particular states, as the gaps between the low mortality benchmark and the observed life expectancy are wider after 2005. Similar to young adults patterns, Sinaloa, Durango, Chihuahua and Guerrero could potentially increase the survival in one year if homicide mortality converges to the low mortality benchmark. Nevertheless, Michoacán and Oaxaca show gradual improvements over the last 20 years. Road traffic accidents (RTA) and the rest of AM-categories do not contribute notably to the gap between the observed survival and the low mortality benchmark.

[Figure 3 about here]

Males and females in all 32 states increased survival between 0 and 14 due to reductions in causes amenable to medical service (see Appendix's figures 6 and 8). The convergence towards the low mortality benchmark was more intense in states in the Central and Southern region for males. For instance, Tlaxcala, Mexico, Puebla and Chiapas reduced the gap between the benchmark and the observed survival, gaining almost an entire additional year of life.

Among the adult population aged 15-39, deviations from the low mortality benchmark observed in males after 2005 were mainly driven by homicide mortality (see Appendix's figure 8). The unexpected increase of homicide led to widening the gap between the benchmark and the observed survival in almost every state. In the Northern region, the gap went from around a quarter of year in 2002 to more than one year by 2010 in Sinaloa (pacific coast), Durango and Chihuahua (state bordering Texas in the U.S.). Nayarit, Michoacán, in the central region, and Guerrero in the South were the states that showed the largest deviations due to homicide mortality following trend otherwise observed only in the North. Road traffic accidents contributed to the gap between the benchmark and the observed temporary life expectancy but with a minor effect. In females, the gap due to homicide mortality after 2005 is only large in the state of Chihuahua (see Appendix figure 9). The impact of the remaining AM categories in ages 0-14 and 15-39 is negligible.

Discussion

Child and young-adult mortality

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 (Sepúlveda et al. 2006). 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 calculating Gini coefficients for every year (Figure 4). Indeed, survival equality before age 15 is almost achieved paralleling improvements in mortality rates 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 (Urquieta-Salomón and Villarreal 2015). 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 (Urquieta-Salomón and Villarreal 2015). 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.

Older-adult mortality

Adults aged 15-39 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 (Aburto et al. 2016). 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 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 (Espinal-Enríquez and Larralde 2015), the effect of homicide on average survival is appalling. Between-state inequality in female survival was much smaller over the same period (figure 4), though females showed the same overall trend of convergence, followed by divergence after 2005.

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 (Glassman et al. 2010). 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 (Monteverde et al. 2010). 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 4).

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 (Castro-Rios et al. 2010). In addition, Behrman and Parker (2013) 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.

[Figure 4 about here]

Conclusion

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 (United Nations 2009). 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.

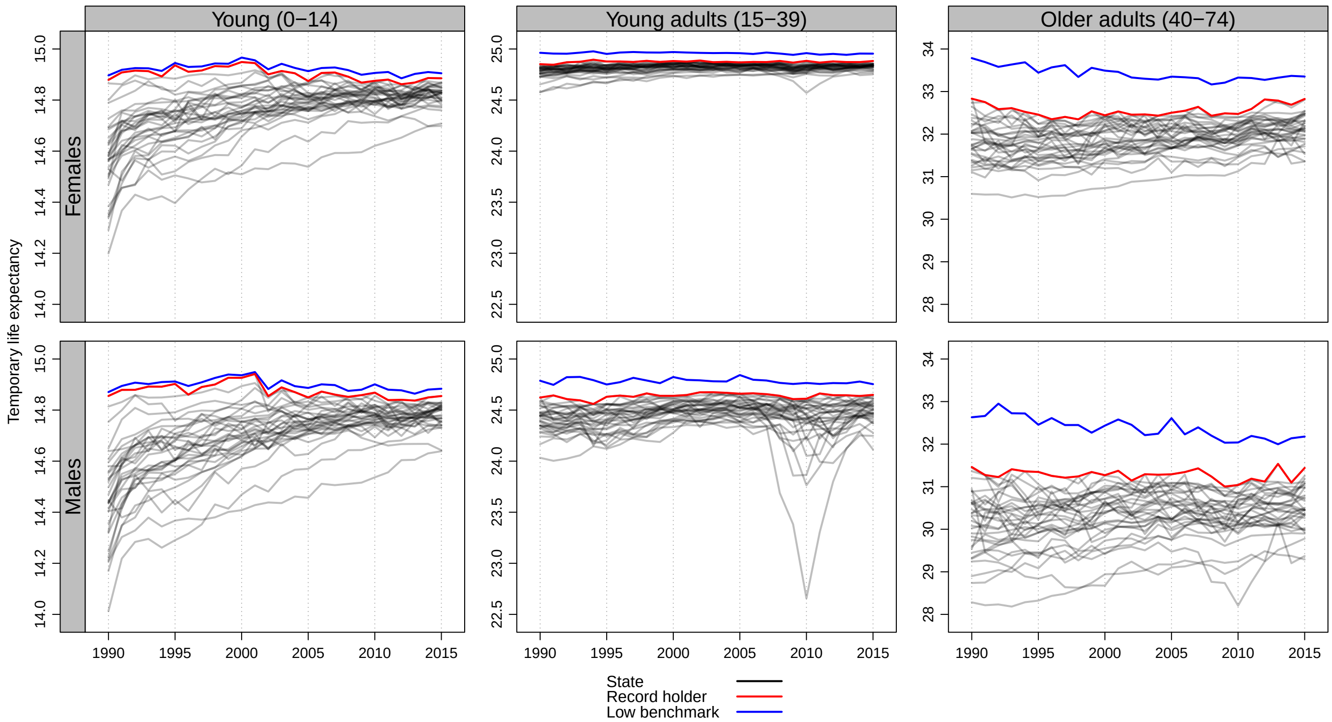
There is no simple way to lessen the impact of such conditions, but it is clear that new approaches are needed to improve survival in the adulthood and to minimize health disparities between states. Preventing diabetes and IHD implies fundamental political challenges. Therefore, public health initiatives should focus in health care for chronic conditions as recently suggested by Knaul et al. (2015), 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 interest

None to declare.

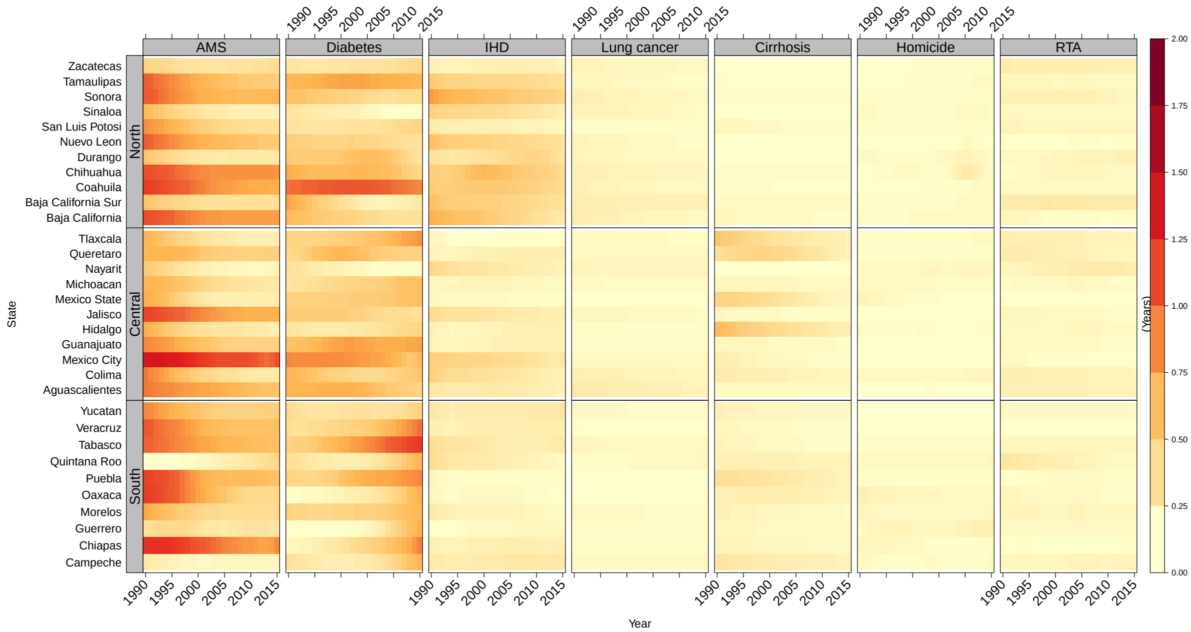
Figures

Figure 1: Temporary life expectancy for states (black line), record life expectancy (red) and low mortality benchmark by sex, 1990-2010.



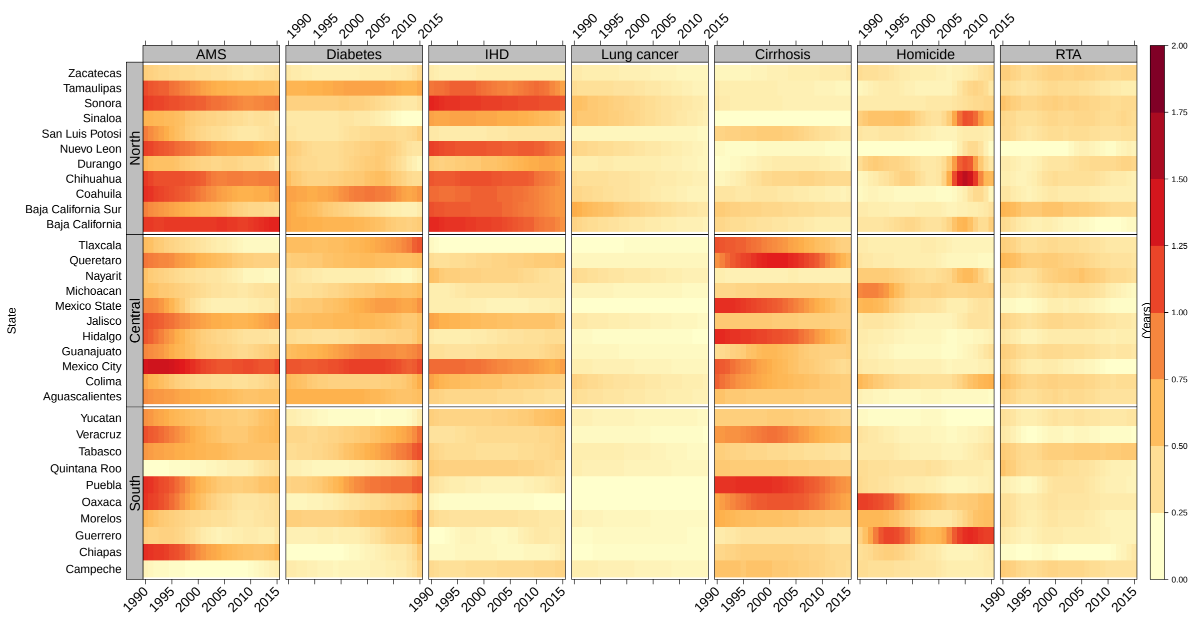
Note: Y-axis are not in the same scale in order to capture major trends over the period. Source: calculations based on INEGI and SOMEDE files.

Figure 2: Cause-specific contributions to state differences from low mortality benchmark for older female adults, 1990-2010. States grouped into three regions.)



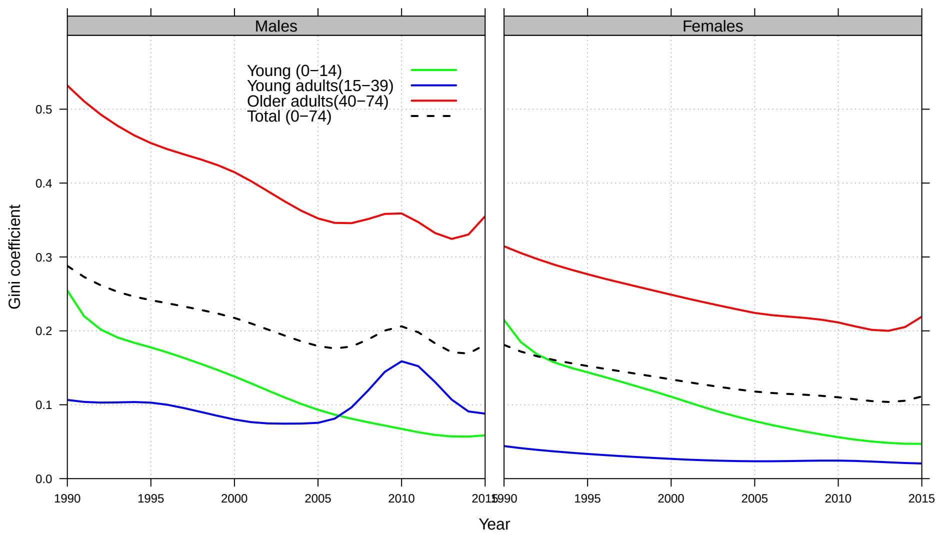
Note: AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: calculations based on INEGI and SOMEDE files.

Figure 3: Cause-specific contributions to state differences from low mortality benchmark for older male adults, 1990-2010.



Note: AMS, is the acronym for amenable to medical service, IHD for isquemic heart diseases and RTA stands for road traffic accidents. Source: own calculations based on INEGI and SOMEDE files.

Figure 4: Survival inequality by age group and sex, 1990-2010.



Source: calculations based on INEGI and SOMEDE files.

References

Aburto, J. M., Beltrán-Sánchez, H., García-Guerrero, V. M., and Canudas-Romo, V. (2016). Homicides in mexico reversed life expectancy gains for men and slowed them for women, 2000-10. *Health affairs*, 35(1):1–8.

Agudelo-Botero, M. and Dávila-Cervantes, C. A. (2014). Efecto de las muertes evitables y no evitables en la esperanza de vida en méxico, 1998–2000 y 2008–2010. *Rev Panam Salud Publica*, 35(2):121.

Arriaga, E. E. (1984). Measuring and explaining the change in life expectancies. *Demography*, 21(1):83–96.

Behrman, J. R. and Parker, S. W. (2013). Is health of the aging improved by conditional cash transfer programs? evidence from mexico. *Demography*, 50(4):1363–1386.

Beltrán-Sánchez, H. (2011). Avoidable mortality. In *International handbook of adult mortality*, pages 491–508. Springer.

Bygbjerg, I. C. (2012). Double burden of noncommunicable and infectious diseases in developing countries. *Science*, 337(6101):1499–1501.

Camarda, C. G. (2012). MortalitySmooth: An R package for smoothing Poisson counts with P-splines. *Journal of Statistical Software*, 50(1):1–24.

Canudas-Romo, V., García-Guerrero, V. M., and Echarri-Cánovas, C. J. (2014). The stagnation of the mexican male life expectancy in the first decade of the 21st century: the impact of homicides and diabetes mellitus. *Journal of epidemiology and community health*, pages jech–2014.

Castro-Rios, A., Doubova, S. V., Martínez-Valverde, S., Coria-Soto, I., and Perez-Cuevas, R. (2010). Potential savings in mexico from screening and prevention for early diabetes and hypertension. *Health Affairs*, 29(12):2171–2179.

Consejo Nacional de Población (2015). Proyecciones de poblacin 2010-2050.

Dávila-Cervantes, C. A. and Agudelo-Botero, M. (2014). Mortalidad evitable en méxico y su contribución a los años de vida perdidos: Análisis por grado de marginación estatal, 2001-2010. *Papeles de población*, 20(82):267–286.

Elo, I. T., Beltrán-Sánchez, H., and Macinko, J. (2014). The contribution of health care and other interventions to black–white disparities in life expectancy, 1980–2007. *Population research and policy review*, 33(1):97–126.

Espinal-Enríquez, J. and Larralde, H. (2015). Analysis of méxicos narco-war network (2007–2011). *PloS one*, 10(5):e0126503.

Franco-Marina, F., Lozano, R., Villa, B., and Soliz, P. (2006). La mortalidad en méxico, 2000-2004 muertes evitables: magnitud, distribución y tendencias. *Dirección General de Información en Salud, Secretaría de Salud. México*, page 2.

Frenk, J. (2006). Bridging the divide: global lessons from evidence-based health policy in mexico. *The Lancet*, 368(9539):954 – 961.

Glassman, A., Gaziano, T. A., Buendia, C. P. B., and de Aguiar, F. C. G. (2010). Confronting the chronic disease burden in latin america and the caribbean. *Health Affairs*, 29(12):2142–2148.

Holland, W. (2003). Commentary: should we not go further than descriptions of avoidable mortality? *International journal of epidemiology*, 32(3):447–448.

Horiuchi, S., Wilmoth, J. R., and Pletcher, S. D. (2008). A decomposition method based on a model of continuous change. *Demography*, 45(4):785–801.

Human Rights Watch (2011). *Neither Rights Nor Security: Killings, Torture, and Disappearances in Mexicos War on Drugs*. HRW.

Instituto Nacional de Estadística y Geografía (2015). Deaths microdata. machine readable files.

Knaul, F. M., Bhadelia, A., Atun, R., and Frenk, J. (2015). Achieving effective universal health coverage and diagonal approaches to care for chronic illnesses. *Health Affairs*, 34(9):1514–1522.

Knaul, F. M. and Frenk, J. (2005). Health insurance in mexico: achieving universal coverage through structural reform. *Health affairs*, 24(6):1467–1476.

Knaul, F. M., González-Pier, E., Gómez-Dantés, O., García-Junco, D., Arreola-Ornelas, H., Barraza-Lloréns, M., Sandoval, R., Caballero, F., Hernández-Avila, M., Juan, M., et al. (2012). The quest for universal health coverage: achieving social protection for all in mexico. *The Lancet*, 380(9849):1259–1279.

Monteverde, M., Noronha, K., Palloni, A., and Novak, B. (2010). Obesity and excess mortality among the elderly in the united states and mexico. *Demography*, 47(1):79–96.

Neufeld, L. M. (2012). The oportunidades program and child growth: Mexico perspectives. In *Handbook of Growth and Growth Monitoring in Health and Disease*, pages 1659–1671. Springer.

Nolte, E. and McKee, C. M. (2008). Measuring the health of nations: updating an earlier analysis. *Health affairs*, 27(1):58–71.

Nolte, E. and McKee, C. M. (2012). In amenable mortalitydeaths avoidable through health careprogress in the us lags that of three european countries. *Health Affairs*, pages 10–1377.

Nolte, E. and McKee, M. (2004). *Does health care save lives? Avoidable mortality revisited.* The Nuffield Trust.

Rivera, J. A., Barquera, S., Campirano, F., Campos, I., Safdie, M., and Tovar, V. (2002). Epidemiological and nutritional transition in mexico: rapid increase of non-communicable chronic diseases and obesity. *Public health nutrition*, 5(1a):113–122.

Sepúlveda, J., Bustreo, F., Tapia, R., Rivera, J., Lozano, R., Oláiz, G., Partida, V., García-García, L., and Valdespino, J. L. (2006). Improvement of child survival in mexico: the diagonal approach. *The Lancet*, 368(9551):2017–2027.

Sociedad Mexicana de Demografía (2011). Demographic conciliation of mexico and its states. [unpublished].

Tobias, M. and Jackson, G. (2001). Avoidable mortality in new zealand, 1981–97. *Australian and New Zealand journal of public health*, 25(1):12–20.

United Nations (2009). The millennium development goals report 2009.

Urquieta-Salomón, J. E. and Villarreal, H. J. (2015). Evolution of health coverage in mexico: evidence of progress and challenges in the mexican health system. *Health policy and planning*.

Vallin, J. and Meslé, F. (2008). Minimum mortality: A predictor of future progress? *Population-E*, 63(04):557–590.

Whelpton, P. K., Eldridge, H. T., and Siegel, J. S. (1947). *Forecasts of the Population of the United States, 1945-1975*. US government printing office.

Wilmoth, J. R., Andreev, K., Jdanov, D., Glei, D. A., Boe, C., Bubenheim, M., Philipov, D., Shkolnikov, V., and Vachon, P. (2007). Methods protocol for the human mortality database. Technical report, University of California, Berkeley, and Max Planck Institute for Demographic Research, Rostock.

Worl Health Organization (2000). The world health report 2000: health systems: improving performance.

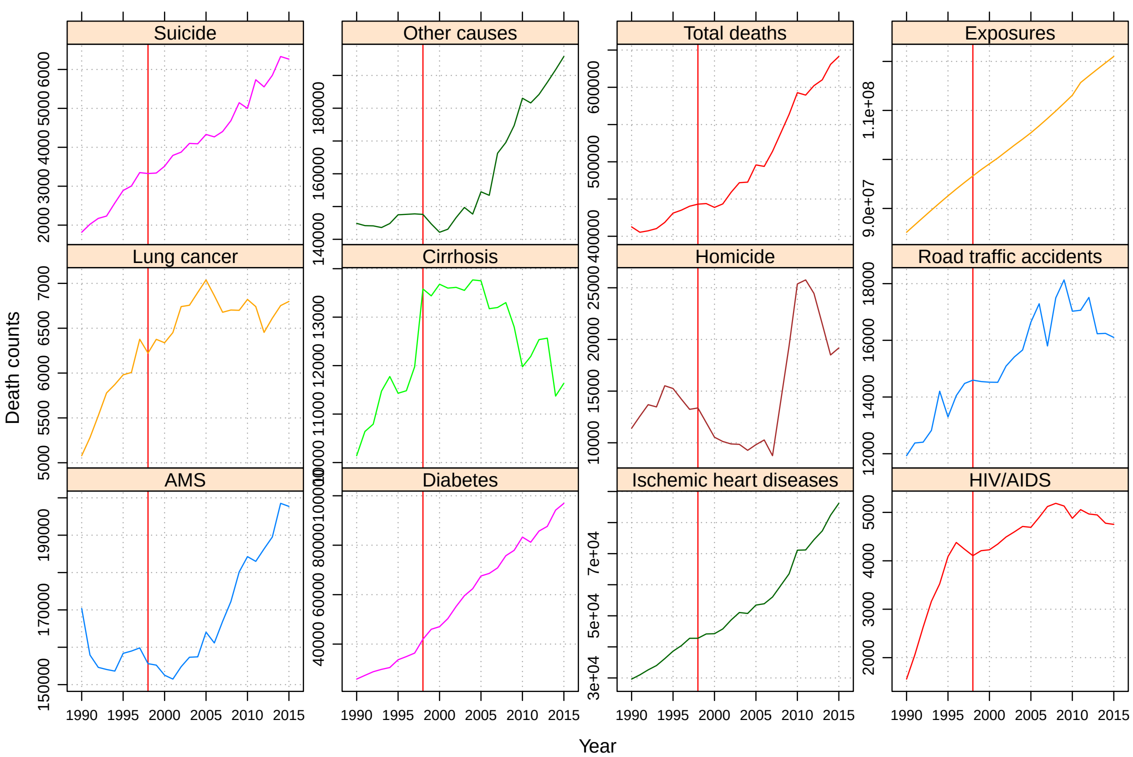
Wunsch, G. (1975). A minimum life-table for europe. *European Demographic Information Bulletin*, 5(1):2–10.

Supplemental material

Appendix Table 1. Definitions of cause-of-death categories using the 9th and 10th revision of the International Classification of Diseases.

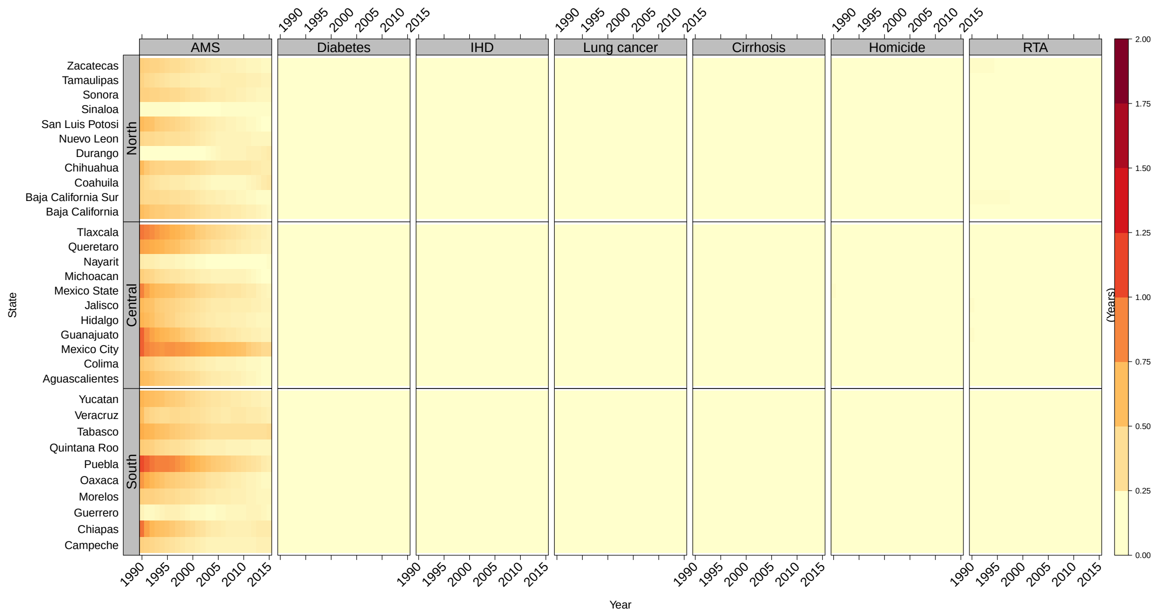
Category	ICD-10	ICD-9
I. Amenable to medical service		
I.A. AM-Infectious & respiratory diseases : intestinal infections, tuberculosis, zoonotic bacterial diseases, other bacterial diseases, septicemia, poliomyelitis, measles, rubella, infectious hepatitis, ornithosis, rickettsioses/ arthropod-borne, syphilis (all forms), yaws, respiratory diseases, influenza & pneumonia, chronic lower respiratory diseases	A00-A09, A16-A19, B90, A20-A26, A28, A32, A33, A35, A36, A37, A40-A41, A80, B05-B06, B15-B19, A70, A68, A75, A77, A50-A64, A66, J00-J08, J20-J39, J60-J99, J09-J18, J40-J47	001-009, 010-018, 32, 33, 37, 137, 020-027, 38, 45, 55-56, 70, 73, 080-082, 087, 090-099, 102, 460-479, 500-519, 480-488, 490-496
I.B. AM-Cancers: malignant neoplasm of colon, skin, breast, cervix, prostate, testis, bladder, kidney-Wilm's tumor only, eye, thyroid carcinoma, Hodgkins disease, leukemia	C16,C18-C21, C43-C44, C50, C53, C61, C62, C67, C64, C69, C73, C81, C91-C95	153-154, 172-173, 174, 180, 185, 186, 188-189, 190, 193, 201, 204-208
I.C. AM-Circulatory: active/acute rheumatic fever, chronic rheumatic heart disease, hypertensive disease, cerebrovascular disease	I00-I02, I05-I09, I10-I13, I15, I60-I69	390-392, 393-398, 401-405, 430-438
I.D. AM-Birth: maternal deaths (all), congenital cardiovascular anomalies, perinatal deaths (excluding stillbirths)	O00-O99, Q20-Q28, P00-P96	630-676, 745-747, 760-779
I.E. AM-Other: disease of thyroid, epilepsy, peptic ulcer, appendicitis, abdominal hernia, cholelithiasis & cholecystitis, nephritis, benign prostatic hyperplasia, misadventures to patients during surgical or medical care, cisticerchosis	E00-E07, 40-G41, K25-K27, K35-K38, K40-K46, K80-K81, N00-N07, N17-N19, N25-N27, N40, Y60-Y69, Y83-Y84, B69	240-246, 345, 531-533, 540-543, 550-553, 574-575.1, 580-589, 600, E870-E876, E878-E879
II. Diabetes	E10-E14	250
III. Ischemic Heart Diseases (IHD)	I20-I25	410-414, 429.2
IV. HIV/AIDS	B20-B24	279.1, 042-044
V. Lung cancer	C33-C34	162
VI. Cirrhosis	K70	571.1-571.3
VII. Homicides	X85-Y09	E960-E969
VIII. Road traffic accidents	V01-V99	E810-E819
IX. Suicide and self-inflicted injuries	U03, X60-X84, Y87.0	E950-E959
X. Residual Causes : other cancers and other heart diseases	C00-D48, I00-I99 if not listed above, R00-R99	140-239, 390-459 if not listed above, 780-799

Figure 5: Cause-specific mortality counts, 1990-2010.



Note: AMS "amenable to medical service". The red line indicates the change in ICD revision. Source: INEGI files.

Figure 6: Cause-specific contributions to state differences from low mortality benchmark for male young people, 1990-2010.



Note:

Note: AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: calculations based on INEGI and SOMEDE files.

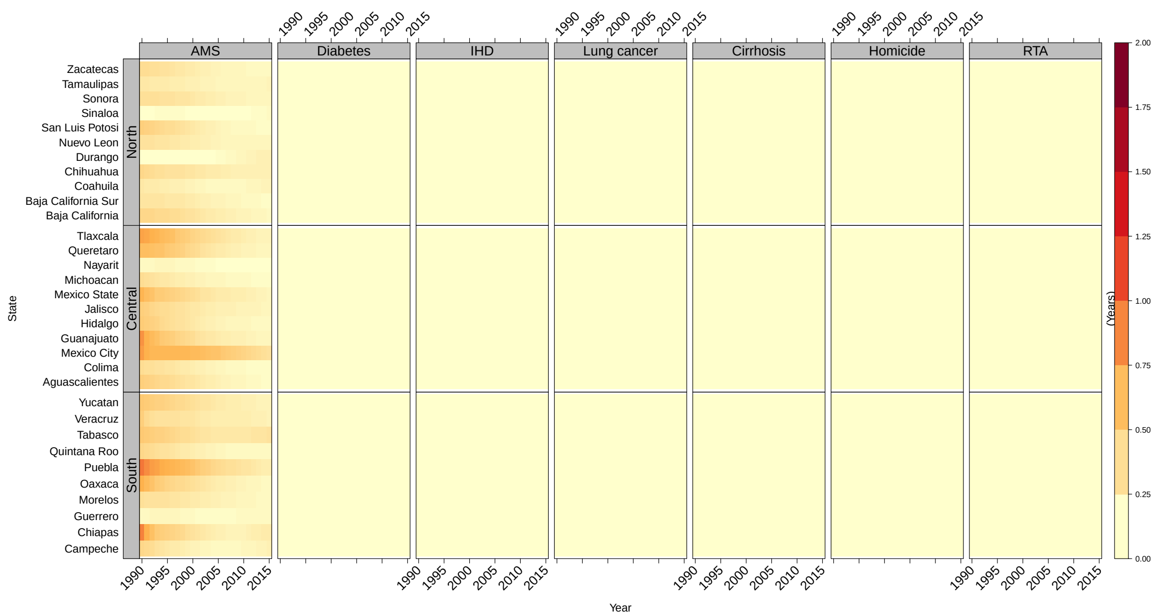
Temporary Life Expectancy

Temporary life expectancy between ages x_1 and x_2, for $x_1 < x_2$, is defined as the average years of life lived between these ages according to a given set of mortality rates (Arriaga 1984). We denote this quantity as $e(x_1, x_2)$, and its benchmark minimum as $e^\star(x_1, x_2)$. Defined in terms of lifetable survivorship, $\ell(x)$:

$$e(x_1, x_2) = \frac{\int_{x_1}^{x_2} \ell(x)\,\mathrm{d}x}{\ell(x_1)} \tag{1}$$

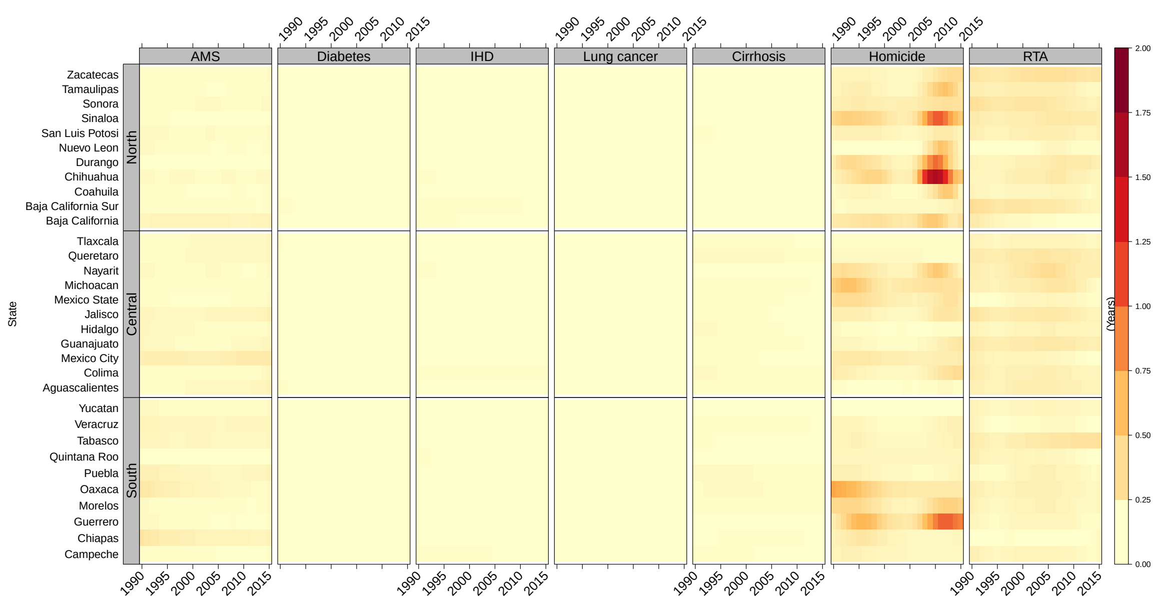
If full survival is achieved, the maximum life expectancy is $x_2 - x_1$. For example, if we set $x_1 = 0$ and $x_2 = 14$, if no person dies between the ages 0 and 14, on average the population lives 14 full years.

Figure 7: Cause-specific contributions to state differences from low mortality benchmark for female young people, 1990-2010.



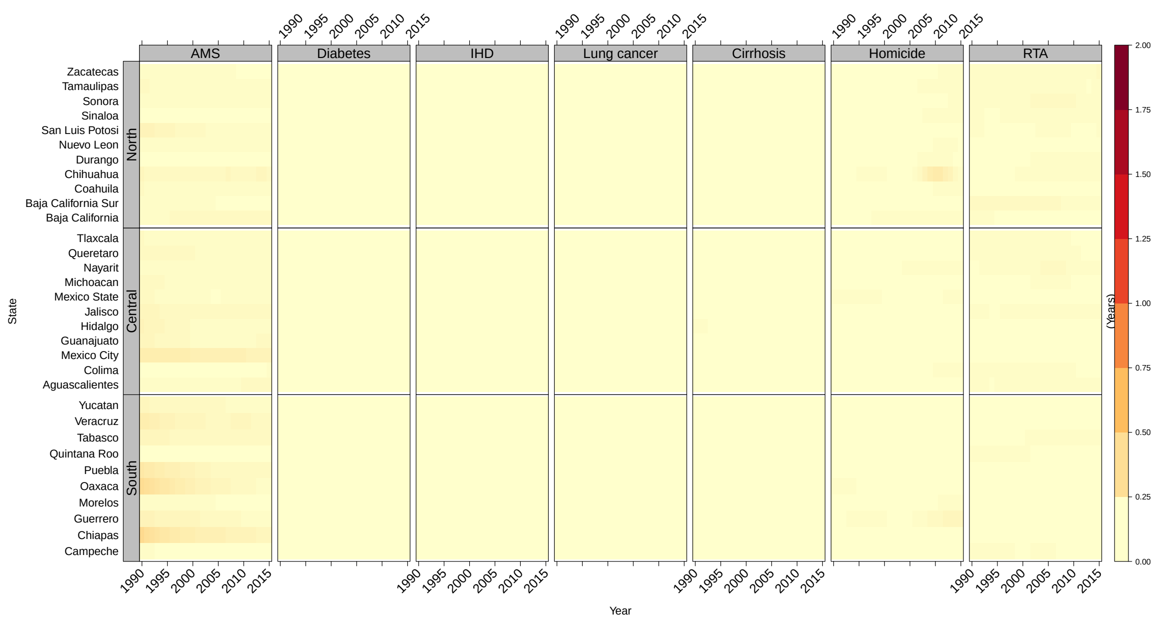
Note: AMS is “amenable to medical service”, IHD is “isquemic heart diseases”, and RTA is “road traffic accidents”. Source: calculations based on INEGI and SOMEDE files.

Figure 8: Cause-specific contributions to state differences from low mortality benchmark for male young adults, 1990-2010.



Note: AMS is “amenable to medical service”, IHD is “isquemic heart diseases”, and RTA is “road traffic accidents”. Source: calculations based on INEGI and SOMEDE files.

Figure 9: Cause-specific contributions to state differences from low mortality benchmark for female young adults, 1990-2010.



Note: AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: calculations based on INEGI and SOMEDE files.