

Adult mortality drives deviations from best practices mortality: the role of avoidable causes of death in Mexican states, 1990-2015

Jose Manuel Aburto¹ and Tim Riffe²

¹European Doctoral School of Demography

^{1,2}Max Planck Institute for Demographic Research

February 4, 2016

Abstract

We analyze trends in temporary life expectancy for three large age groups from 1990 to 2015 for all 32 Mexican states, and compare these with a synthetic best practices trend. We assess the impact of avoidable/amenable mortality on temporary life expectancy at the state level by sex. We apply demographic measures and use standard decomposition techniques to disentangle the effects of selected causes of death. We find improvements in temporary life expectancy for the population aged 0 to 14, as they continuously approached the best practices trend. However, the adult population aged 15 to 39 shows deterioration among males after 2006 in almost every state. Opposing this trend, females show a convergence trend toward the best practices benchmark between ages 15 and 39. Adults aged 40 to 74 show an unexpected decrease in the best practices indicator, and major variation among states in temporary life expectancy. These findings might strengthen the case for reforms that will enable all the Mexicans to improve in their health status.

Key messages

- Reducing health inequalities among sub-populations is a goal of every developing country. Addressing such inequalities in older adult populations is proving to be a challenge to reaching this goal.
- We hypothesize age-dependent variations in temporary life expectancy. Particularly due to the rise in homicide mortality and the increase of conditions amenable to medical services and policy/behavior actions.
- Our results show that deviations from the best practices mortality are mainly driven by old-age mortality. While young-age mortality has been constantly approaching the best practices trend pointing towards the success of public health interventions.
- Cirrhosis, homicide, diabetes and ischemic heart diseases contribute the most to the persistence of health inequalities within the states in Mexico. Importantly, some of them could potentially live two additional years if best practices were achieved.

Introduction (max 6000 words)

The 20th century was marked by sizable improvements in mortality, living conditions and health in most Latin American countries (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 dramatically, even as infectious and respiratory diseases continued to fall. 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 Oportunidades program was introduced to supply incentives for families to invest in themselves and benefit from education, health, and nutrition in the late 1990's (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, some evidence suggests that by 2012 Seguro Popular had covered an additional 52 million people in Mexico that 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).

Although these results are important and underscore the progress in public health interventions, they do not reveal heterogeneity between Mexican states and epidemiological patterns for adult mortality. Which is an important task given the high degree of social and health inequalities in Mexico (Frenk 2006), and the expected accelerated process of aging in the country. The percentage of the population aged 60 or older will go from 10% in 2015 to 15% in 2030 (Consejo Nacional de Población 2015). Therefore, given the improvements in health care coverage, the strong role of institutions, and ongoing public health interventions, it is necessary to assess the varied impacts that these health interventions may have had on particular causes of death in states populations and across the country. Moreover, it is important to identify specific potential opportunities to improve and put forward solutions to reduce the gap of the unequal impact of public health interventions caused by the heterogeneity in how these interventions have taken place within the states (e.g., Oportunidades is focused on the poorest states and Seguro Popular did not started at the same time in the states).

One approach to assess the impact of health services is by operationalizing the concept of Avoidable/Amenable Mortality (hereafter abbreviated AM) (Nolte and McKee 2004; 2008). This construct 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 (e.g., United States, Australia, France, Japan), a reduction in AM rates was observed from the late 1990's into the 21st Century (Nolte and McKee 2008). Avoidable mortality rates fell, on average, by 17% for males and 14% for females in these countries. Despite mortality reductions for both sexes, heterogeneity between countries was identified, with the United States showing the smallest reductions (around 5%) for both sexes. However, each country showed progress in mortality from treatable cancers and circulatory diseases except for ischemic heart diseases.

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 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 improve on 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 best-practice benchmarks for large age groups (e.g., 0-14, 15-39, 40-75). These best practice benchmarks are calculated on the basis of the lowest observed mortality within ages and causes, among the full set of 32 Mexican states. This concept was first proposed by Whelpton et al. (1947), later explored by Wunsch (1975) and Vallin and Meslé (2008), and more recently applied under a different definition by Eikemo et al. (2014). We apply demographic measures and standard decomposition techniques to isolate the cause and age-specific shortcomings between states and the corresponding best-practices lifetable.

We hypothesize age-dependent variations in temporary life expectancy outcomes. In particular, we expect convergence between states in temporary life expectancy 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 temporary life expectancy for the adult and older adult population due to the unprecedented rise in homicide mortality and 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 the differential in how benefits of health care programs have been delivered to the population. (Frenk 2006).

Data & Methods

This project was done using secondary data of public sources, which did not have any individual identifiers. Therefore, ethical approval for human subject research from the Institutional Review Board of the respective institutions was exempted.

We used death counts available from official microdata 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 place of residence at the time of death. In addition, we used population estimates (Exposures) corrected for age misstatement, undercounting, and migration— both internal and international— available from the Mexican Society of Demography to construct cause-age-specific death rates by sex and state from 1990 to 2010 (Sociedad Mexicana de Demografía 2011). Additionally, we performed

an inter-census estimation of exposures for the period 2011-2014 using the most recent inter-census survey that took place in 2015 (Instituto Nacional de Estadística y Geografía 2015).

Classification of Causes of Death

To separate causes of death that are susceptible to medical intervention (e.g., infectious and respiratory diseases) and those related to health behaviors and intersectoral policies (e.g., homicides, lung cancer) we use the concept of 'Avoidable/Amenable Mortality' (AM) (Nolte and McKee 2004; 2008). This concept assumes a list of conditions that should not occur with the availability of timely medical care. Recently, this concept has also been used to gauge the effect of causes that can be influenced by public policy (e.g., cirrhosis) (Elo et al. 2014). We classified causes of death into ten groups based on prior studies (Elo et al. 2014, Aburto et al. 2016).

We grouped the causes of death in ten categories: 1) amenable to medical service, 2) diabetes, 3) ischemic heart diseases (IHD), 4) HIV/AIDS, 5) lung cancer, 6) cirrhosis, 7) homicide, 8) road traffic accidents, 9) suicide and 10) other causes. We separate diabetes, ischemic heart diseases (IHD), HIV/AIDS, lung cancer, and cirrhosis because all of them are amenable to both health behavior and medical service, and because the first two represent major causes of death in Mexico (Canudas-Romo et al. 2014). In addition to these causes, we also isolate 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 1998-2015 (see Appendix Table 1 for details on ICD codes for each cause).

We truncated analysis at age 75 because classification of causes of deaths and age reporting are considered to be inaccurate in death registration at older ages (Tobias and Jackson 2001) and because most changes in life expectancy are likely due to changes in mortality patterns below the age of 75 (Aburto et al. 2016). In addition, health care and policy/behavior interventions are more likely to be effective at younger ages (Elo et al. 2014).

Age dimension

We break life expectancy in three large age groups to capture mortality differences along the lifespan based on previous research. The first group, young people, refers to people younger than 15 years. This group (0-14) 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, young adults, allude to the population aged 15-39. We use this interval in order 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, older-adults, makes reference to the population older than 40 years up to 75. The population in this group represents the core of this article and they are susceptible of experiencing a premature death due

to chronic diseases (Canudas-Romo et al. 2014).

Demographic Methods

We first 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). This helps eliminate stochastic zeros, which otherwise would accumulate in the best-practices mortality schedule, and artificially inflate the best practices life expectancy. Smoothed death rates are then constrained to sum to the unsmoothed all-cause death rates. There are no zeros in all-cause death rates. We then calculate period life tables up to age 74 for males and females from 1990 to 2010 following the HMD Methods Protocol (Wilmoth et al. 2007). Second, we estimated temporary life expectancy to capture differential effects of all-cause mortality among three large age groups: children (ages 0-14), young adults (ages 15-40) and older adults (40-74). We do this following the formulas of Arriaga (1984), as defined below.

We then construct the best practices lifetables (BP) for every year and sex and estimated cause-specific contributions to the difference between state-specific temporary life expectancy and BP temporary life expectancy (e^*) applying standard decomposition methods (Horiuchi et al. 2008). Decomposition techniques are a suitable method for comparing life expectancies across populations and analyzing age and cause-specific contributions to their differences (Preston et al. 2001). All the analyses were carried out using R.

Best Practices Lifetable

This approach was first proposed by Whelpton et al. (1947), and we summarize it briefly here. The synthetic best practices (BP) lifetable is a composite of the lowest observed mortality rates by age, cause, and state for a given sex and year. In continuous terms, we define life expectancy, $e(0)$, as:

$$\int_0^\infty \ell(x) dx \quad , \quad (1)$$

where $\ell(x)$ is the survivorship function defined with radix of one, or as a function of the force of mortality, $\mu(x)$ as:

$$\ell(x) = e^{-\int_0^x \mu(a) da} \quad (2)$$

In general, $\mu(x)$ can be treated as the sum of I cause-specific mortality rates at age x assuming that causes of death are independent of one another:

$$\mu(x)^* = \sum_1^I \min(\mu_i(x)) \quad (3)$$

This BP mortality rate schedule ($\mu^*(x)$) has a unique age profile, and it determines a pattern of $\ell(x)^*$, per (2), that corresponds with a best practices life expectancy, $e(0)^*$. Thus, $e(0)^*$ can be treated as a maximum presently achievable life expectancy given the best available practices and technologies within a given set of

populations and assuming perfect diffusion (Vallin and Meslé 2008). It is an imaginary quantity because no particular population ever achieves this mortality pattern.. However, this value is a real referent not based on a projection of improvements into the future, and so it bounds our optimism in a practical way. This definition of best practices is different from other uses found in the literature, and it is important to notice that it is not the same as the vanguard, or record-holder life expectancy. Vanguard life expectancy is the notion that was treated by Oeppen and Vaupel (2002), and it is different from our definition of best practices in that the vanguard life expectancy of a given year is based on all-cause mortality and refers to a single population.

Temporary Life Expectancy

We require an estimate of temporary life expectancy between ages x_1 and x_2 , for $x_1 < x_2$, or the average years of life lived between these ages according to a given set of period mortality rates (Arriaga 1984). We denote this quantity as $e(x_1, x_2)$, and its best practices maximum as $e^*(x_1, x_2)$. Defined in terms of $\ell(x)^*$:

$$e^*(x_1, x_2) = \frac{\int_{x_1}^{x_2} \ell(x)^* dx}{\ell(x_1)^*} \quad (4)$$

The interpretation of temporary life expectancy has the advantage, that if nobody dies between the starting and ending age, then 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, which means that the temporary life expectancy between these ages, $e(0, 14)$, is fourteen. Which sets a maximum achievable and, therefore, measurable.

Limitations

The limitations of our study should be mentioned. First, mortality data 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 according to the avoidable mortality concept. Second, our estimates regarding homicide mortality are likely to be underestimated because of inaccurate practices regarding counting, reporting, and due to the large number of missing individuals in Mexico (Human Rights Watch 2011). Third, 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). Fourth, the amount of deaths that should be considered avoidable within the avoidable classification is not clear (Beltrán-Sánchez 2011). For instance, Nolte and McKee (2012) consider only 50 percent of heart disease amenable in industrialized countries, based on a previous review of evidence.

We do not have information to precisely measure percentages of avoidable mortality within cause groups. Nonetheless, the difference between a given mortality schedule and the best practices schedule of the same

year can be conceived of as a minimal definition of avoidable mortality, a sort of lower bound to how much mortality could have been avoided. Certainly, even a best practices schedule will contain elements of mortality most would consider avoidable. To the extent that the components of the BP schedule were indeed attained somewhere in the population universe, one can view any excess mortality with respect to the BP 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 and gauge better the avoidable deaths.

Results

Trends in best practices life expectancy

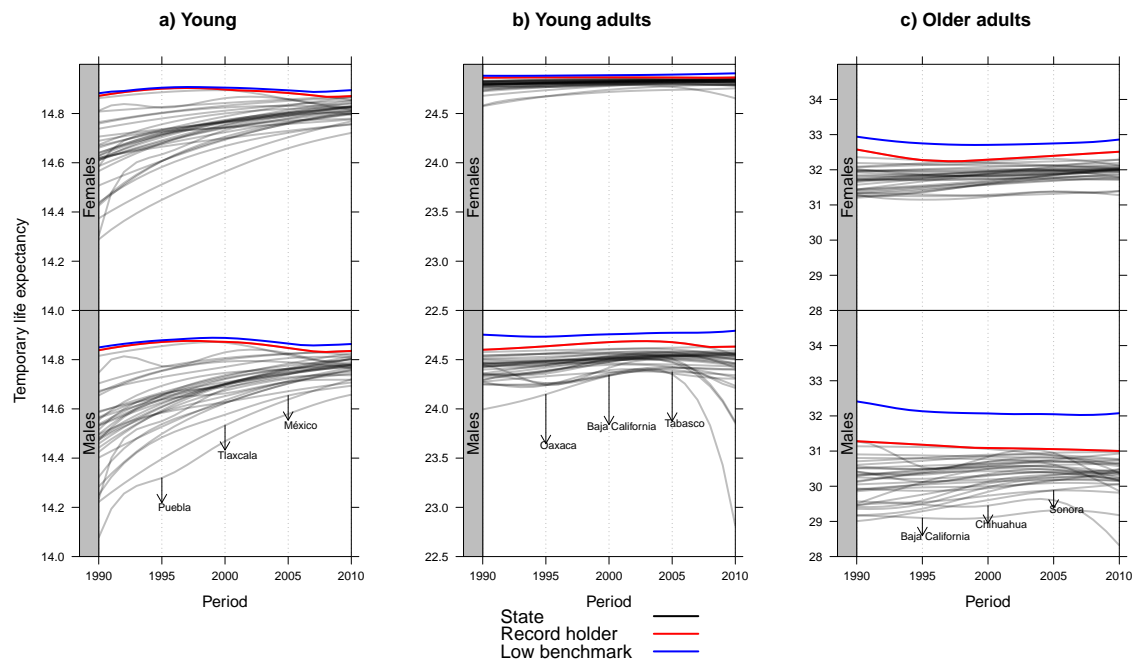
Figure 1 shows state-specific (black lines), vanguard (red lines) and BP (blue lines) remaining life expectancies for ages 0-14 (??), 15-39 (??) and 40-74 (??). The red line represents the vanguard life expectancy out of the 32 states within each year and the blue line represents the maximum potentially achievable for the Mexican population under the best practices definition. The figures clearly shows a convergence pattern among the states toward the BP expectancy through at least the year 2000; however the latter period shows stagnation and even decreases for some states. Particularly, improvements and a trend to achieve BP is seen between ages 0 and 14. Opposing this trend, male temporary life expectancy between 15 and 39 years shows a clear downward after 2005, with some states experiencing a dramatic deterioration in temporary life expectancy. Results for females show stagnation in achieving BP temporary life expectancy. As in males' results, some states experienced losses of life after 2005, leading to widening the gap between states and BP line. Importantly, temporary life expectancy for adults between 40 and 75 years shows stagnation and deterioration during the 20-year period. Even the BP life expectancy exhibits a downward trend, pointing to increases in adult mortality. Furthermore, also the BP line has been moving further from the maximum temporary life expectancy, which means that the survival in this population group is not following the rectangularization hypothesis (Wilmoth and Horiuchi 1999).

Cause-decomposition analysis ¹

Recent deviations from the low mortality benchmark in the new century

¹This section will be completed at a later date and updated to 2015. Preliminary results are shown.

Figure 1: Temporary life expectancy for states (black line), record life expectancy (red) and low mortality benchmark life expectancy by sex, 1990-2015.



Source: own calculations based on INEGI and SOMEDE files.

Table 1: Selected cause-specific contributions to deviations from low mortality benchmark, male older-adults by state and years, 2000, 2005 and 2010

Region	State	Amenable to M.S			Diabetes			IHD			Lung cancer			Cirrhosis			Homicide		
		2000	2005	2010	2000	2005	2010	2000	2005	2010	2000	2005	2010	2000	2005	2010	2000	2005	2010
North	Baja California	0.59	0.6	0.64	0.3	0.29	0.28	0.62	0.55	0.47	0.1	0.08	0.06	0.12	0.1	0.09	0.16	0.12	0.44
	Baja California Sur	0.26	0.22	0.21	0.22	0.19	0.16	0.46	0.45	0.42	0.22	0.18	0.14	0.18	0.17	0.16	0.08	0.07	0.06
	Coahuila	0.4	0.32	0.3	0.38	0.48	0.42	0.49	0.47	0.49	0.11	0.09	0.07	0.1	0.09	0.09	0.03	0.02	0.08
	Chihuahua	0.47	0.4	0.45	0.22	0.25	0.3	0.57	0.54	0.49	0.12	0.1	0.09	0.2	0.18	0.17	0.17	0.13	1.3
	Durango	0.22	0.2	0.16	0.2	0.23	0.23	0.24	0.3	0.41	0.09	0.08	0.06	0.09	0.1	0.08	0.14	0.13	0.65
Central	Nuevo León	0.32	0.28	0.31	0.17	0.2	0.26	0.52	0.48	0.53	0.12	0.09	0.07	0.02	0.03	0.03	0	0	0.09
	San Luis Potosí	0.16	0.1	0.08	0.12	0.17	0.23	0.09	0.1	0.11	0.04	0.04	0.04	0.23	0.21	0.16	0.1	0.06	0.09
	Sinaloa	0.17	0.14	0.14	0.12	0.1	0.02	0.34	0.35	0.32	0.2	0.15	0.1	0	0	0	0.22	0.14	0.73
	Sonora	0.46	0.39	0.39	0.21	0.19	0.17	0.64	0.61	0.59	0.19	0.14	0.1	0.08	0.07	0.08	0.09	0.09	0.18
	Tamaulipas	0.28	0.23	0.29	0.31	0.33	0.37	0.46	0.44	0.43	0.13	0.1	0.07	0.07	0.06	0.05	0.06	0.06	0.18
South	Zacatecas	0.16	0.14	0.16	0.08	0.11	0.15	0.09	0.08	0.1	0.07	0.06	0.05	0.08	0.08	0.08	0.1	0.08	0.06
	Aguascalientes	0.21	0.19	0.2	0.3	0.3	0.28	0.15	0.17	0.17	0.1	0.08	0.07	0.22	0.21	0.21	0.04	0.04	0.06
	Colima	0.12	0.1	0.14	0.19	0.19	0.21	0.23	0.22	0.21	0.12	0.11	0.09	0.31	0.27	0.24	0.16	0.14	0.18
	Distrito Federal	0.34	0.24	0.37	0.48	0.52	0.51	0.34	0.31	0.29	0.04	0.03	0.02	0.27	0.21	0.16	0.06	0.04	0.06
	Guanajuato	0.2	0.16	0.19	0.38	0.44	0.46	0.13	0.15	0.16	0.03	0.03	0.03	0.31	0.26	0.19	0.03	0.02	0.04
	Hidalgo	0.25	0.17	0.17	0.16	0.2	0.25	0.07	0.13	0.17	0.02	0.02	0.01	0.61	0.51	0.42	0.06	0.03	0.03
	Jalisco	0.3	0.27	0.29	0.29	0.3	0.3	0.25	0.24	0.22	0.07	0.06	0.04	0.24	0.22	0.2	0.07	0.04	0.09
	México	0.25	0.2	0.25	0.39	0.47	0.51	0.14	0.12	0.13	0.01	0.01	0.01	0.59	0.47	0.34	0.15	0.11	0.1
	Michoacán	0.16	0.13	0.15	0.2	0.26	0.32	0.11	0.13	0.15	0.05	0.04	0.03	0.21	0.22	0.23	0.2	0.2	0.19
	Nayarit	0.14	0.11	0.1	0.08	0.08	0.07	0.19	0.19	0.17	0.12	0.09	0.06	0.07	0.08	0.08	0.16	0.15	0.37
	Querétaro	0.23	0.16	0.14	0.23	0.26	0.33	0.16	0.2	0.24	0.04	0.04	0.04	0.76	0.7	0.46	0.08	0.05	0.03
	Tlaxcala	0.14	0.07	0.04	0.32	0.37	0.43	0.01	0.01	0	0.01	0.02	0.02	0.42	0.36	0.3	0.09	0.07	0.04
	Campeche	0.03	0.03	0.06	0.08	0.1	0.13	0.15	0.15	0.14	0.07	0.06	0.05	0.25	0.24	0.24	0.12	0.09	0.07
	Chiapas	0.39	0.3	0.28	0.02	0.06	0.12	0.04	0.04	0.04	0.02	0.02	0.01	0.23	0.21	0.18	0.15	0.07	0.05
	Guerrero	0.1	0.04	0.1	0.09	0.13	0.23	0.03	0.03	0.11	0.02	0.03	0.03	0.13	0.13	0.14	0.41	0.31	0.7
	Morelos	0.14	0.1	0.1	0.21	0.27	0.34	0.11	0.11	0.1	0.04	0.03	0.02	0.26	0.25	0.25	0.18	0.1	0.17
	Oaxaca	0.26	0.15	0.18	0.09	0.15	0.23	0.01	0.01	0.04	0.01	0.01	0.01	0.56	0.54	0.47	0.34	0.24	0.24
	Puebla	0.28	0.19	0.26	0.33	0.46	0.46	0.04	0.03	0.09	0	0	0	0.73	0.63	0.49	0.1	0.06	0.04
	Quintana Roo	0	0.04	0.13	0.05	0.1	0.18	0.12	0.11	0.1	0.07	0.06	0.06	0.23	0.24	0.25	0.13	0.12	0.1
	Tabasco	0.23	0.21	0.2	0.22	0.32	0.44	0.14	0.12	0.17	0.07	0.06	0.04	0.17	0.16	0.14	0.07	0.06	0.07
	Veracruz	0.28	0.22	0.29	0.21	0.27	0.36	0.17	0.16	0.17	0.03	0.02	0.02	0.48	0.42	0.3	0.06	0.04	0.04
	Yucatán	0.15	0.12	0.14	0.01	0.01	0.01	0.18	0.2	0.21	0.03	0.03	0.02	0.21	0.22	0.23	0.02	0.01	0

Table 2: Selected cause-specific contributions to deviations from low mortality benchmark, female older-adults by state and years, 2000, 2005 and 2010

Region	State	Amenable to M:I.S			Diabetes			IHD			Lung cancer			Cirrhosis			Homicide		
		2000	2005	2010	2000	2005	2010	2000	2005	2010	2000	2005	2010	2000	2005	2010	2000	2005	2010
North	Baja California	0.31	0.31	0.33	0.19	0.17	0.15	0.22	0.19	0.15	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.05
	Baja California Sur	0.1	0.11	0.15	0.13	0.08	0.08	0.21	0.2	0.17	0.07	0.07	0.08	0.03	0.02	0.02	0.02	0.02	0.02
	Coahuila	0.36	0.31	0.34	0.52	0.55	0.5	0.22	0.22	0.22	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.02
	Chihuahua	0.39	0.35	0.38	0.28	0.28	0.28	0.28	0.26	0.23	0.05	0.05	0.04	0.02	0.02	0.02	0.03	0.02	0.14
	Durango	0.13	0.1	0.17	0.25	0.26	0.32	0.14	0.17	0.2	0.04	0.03	0.03	0	0.01	0.01	0.02	0.03	0.07
	Nuevo León	0.2	0.17	0.18	0.17	0.18	0.15	0.18	0.16	0.15	0.03	0.02	0.02	0	0.01	0.01	0	0	0.02
	San Luis Potosí	0.17	0.13	0.12	0.1	0.12	0.18	0.07	0.07	0.06	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02
	Sinaloa	0.07	0.04	0.05	0.07	0.05	0	0.16	0.15	0.14	0.04	0.04	0.03	0	0	0	0.02	0.02	0.04
	Sonora	0.28	0.24	0.24	0.19	0.16	0.14	0.26	0.23	0.2	0.05	0.04	0.04	0.01	0.01	0.01	0.02	0.02	0.02
	Tamaulipas	0.22	0.19	0.22	0.31	0.31	0.28	0.17	0.16	0.15	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.02	0.02
Central	Zacatecas	0.12	0.12	0.16	0.13	0.16	0.17	0.07	0.08	0.09	0.04	0.04	0.04	0.01	0.01	0.01	0.02	0.01	0.01
	Aguascalientes	0.23	0.24	0.27	0.25	0.24	0.24	0.07	0.08	0.09	0.07	0.07	0.06	0.03	0.03	0.03	0.01	0.01	0.01
	Colima	0.13	0.06	0.03	0.18	0.16	0.16	0.15	0.13	0.1	0.07	0.06	0.05	0.07	0.06	0.06	0.03	0.02	0.02
	Distrito Federal	0.29	0.23	0.26	0.26	0.23	0.17	0.12	0.11	0.1	0.01	0.01	0.01	0.03	0.02	0.01	0.01	0.01	0.01
	Guanajuato	0.22	0.17	0.18	0.35	0.36	0.33	0.04	0.06	0.07	0.02	0.02	0.01	0.04	0.03	0.03	0.01	0.01	0.01
	Hidalgo	0.15	0.13	0.14	0.08	0.1	0.18	0.05	0.07	0.08	0.02	0.02	0.02	0.18	0.14	0.11	0.02	0.01	0.01
	Jalisco	0.34	0.29	0.26	0.21	0.18	0.13	0.1	0.09	0.07	0.03	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.01
	México	0.3	0.24	0.27	0.32	0.33	0.34	0.06	0.05	0.05	0.01	0	0	0.15	0.11	0.06	0.02	0.01	0.01
	Michoacán	0.19	0.15	0.15	0.18	0.2	0.23	0.05	0.05	0.05	0.02	0.02	0.02	0.04	0.04	0.04	0.03	0.02	0.02
	Nayarit	0.1	0.08	0.09	0.06	0.04	0.06	0.12	0.11	0.09	0.05	0.04	0.04	0.01	0.01	0.01	0.03	0.03	0.05
South	Querétaro	0.14	0.14	0.19	0.24	0.22	0.19	0.06	0.08	0.08	0.03	0.03	0.03	0.17	0.15	0.11	0.01	0.01	0.01
	Tlaxcala	0.15	0.12	0.12	0.21	0.26	0.36	0.01	0.01	0	0.03	0.03	0.03	0.15	0.12	0.09	0.02	0.02	0.02
	Campeche	0.05	0.06	0.09	0.11	0.13	0.21	0.09	0.1	0.1	0.04	0.04	0.04	0.1	0.09	0.09	0.02	0.02	0.02
	Chiapas	0.53	0.41	0.41	0.12	0.18	0.26	0.06	0.07	0.08	0.02	0.01	0.01	0.05	0.04	0.04	0.03	0.02	0.01
	Guerrero	0.13	0.1	0.17	0.02	0.04	0.17	0.02	0.04	0.07	0.02	0.01	0.02	0.04	0.03	0.03	0.05	0.04	0.05
	Morelos	0.17	0.15	0.17	0.16	0.19	0.27	0.05	0.06	0.05	0.02	0.02	0.02	0.05	0.04	0.04	0.03	0.03	0.02
	Oaxaca	0.35	0.24	0.17	0.06	0.1	0.16	0.03	0.03	0.03	0	0	0	0.08	0.08	0.07	0.05	0.03	0.03
	Puebla	0.31	0.24	0.26	0.24	0.33	0.33	0.01	0.01	0.05	0	0	0	0.12	0.1	0.08	0.02	0.01	0.01
	Quintana Roo	0.03	0.07	0.13	0.09	0.11	0.18	0.07	0.05	0.03	0.03	0.04	0.04	0.06	0.06	0.07	0.03	0.03	0.03
	Tabasco	0.27	0.23	0.23	0.28	0.37	0.5	0.08	0.08	0.07	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02
	Veracruz	0.3	0.25	0.27	0.19	0.23	0.31	0.08	0.09	0.09	0.01	0.01	0	0.03	0.03	0.02	0.01	0.01	0.01
	Yucatán	0.12	0.09	0.11	0.09	0.1	0.11	0.08	0.09	0.1	0.02	0.02	0.02	0.05	0.04	0.03	0	0	0

Trends in cause-specific contributions to the gap between temporary life expectancy and low mortality benchmark

Figure 2, 3 and 4 show cause-specific contributions of avoidable mortality to the gap between temporary life expectancy and the BP life expectancy for males (panels (a)) and females (panels (b)) between 0 and 14, 15 and 39, and 40 and 74 years respectively. Results near 0 mean that they are very close to the minimum observed among all the states, results greater than zero mean deterioration in mortality relative to the minimum observed.

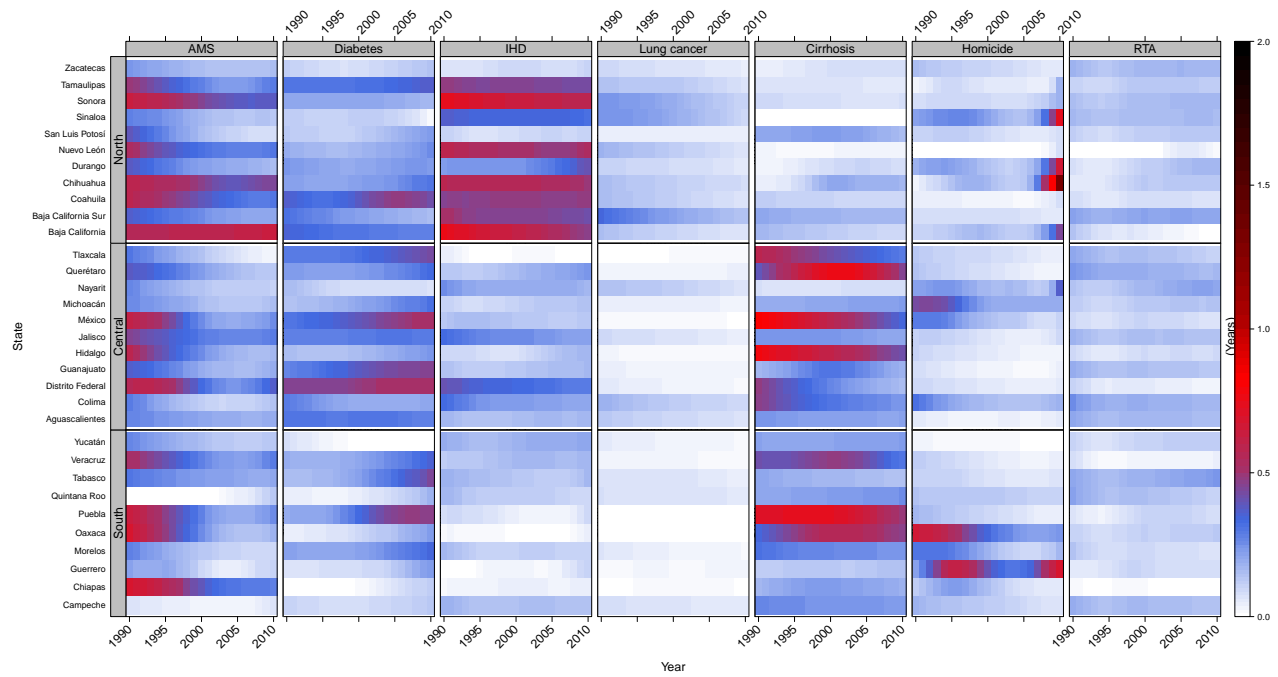
Reductions in the gap between the observed life expectancy and the best practices between 0 and 14 years are mainly driven by the causes amenable to medical service (??). Since the 1990's, reductions in mortality of these articular conditions had led to convergence among the states and reducing health disparities. In some states, the gap went from half a year to less than a quarter of year. The results are similar for men and women (??). Contributions of the other avoidable categories are negligible.

Among the young-adult population (15-39), the deviation of the states from BP life expectancy is, almost entirely, explained by homicide mortality and road traffic accidents for males (??). In the 1990's, some states were more than a quarter of year far from the BP line. This trend was reversed as the 1990's ended and the 2000's begun, almost all the states were less than 0.05 years (blue line) from achieving the minimum homicide-mortality observed in the country. Nevertheless, after 2005, an upward trend is documented, with some states experiencing deviations from the best practices over half a year (first red line). Similar trends are observed in women (??) but with lower magnitude. The impact of the rest of AM categories is negligible.

Adult mortality shows the largest deviations from the best practices life expectancy (Figure 4) in both males (??) and females (??). Specifically, among men, conditions amenable to medical services, diabetes, IHD, cirrhosis and homicides have the largest toll on mortality, leading to the largest gap between the BP line and contributing to disparities among the states. For instance 12 of the 32 states are more than a quarter of life far from the best practices mortality, one of them with almost 0.75 years lagging behind. Similarly, diabetes and IHD show little improvements in the full period. Cirrhosis and homicide are at the heart of health deterioration among the adults. Both of them show large disparities within the states, ranging from values very close to zero in some states, to deviations over 1.25 years from the BP observed. After 2005, homicide shows an important increase in the gap from the minimum mortality observed.

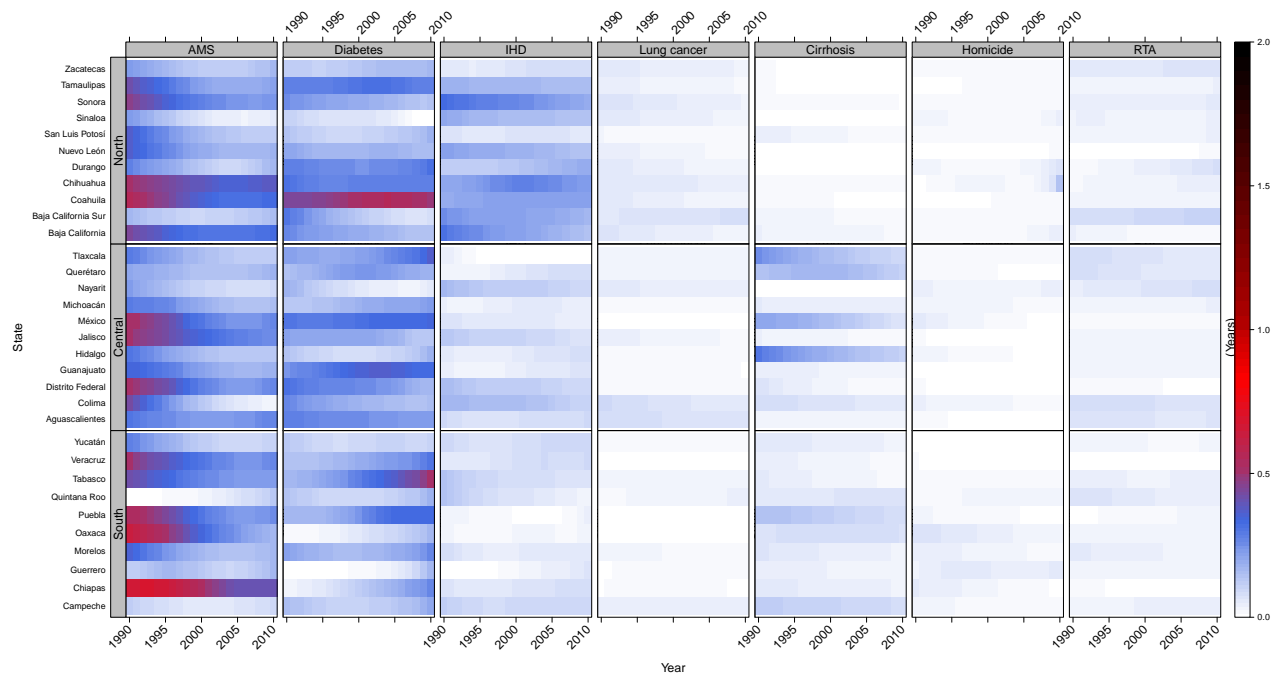
Results for women (??) are different. Deviations from the BP line are mainly explained by the high mortality of conditions amenable to medical service, diabetes and IHD. These three categories show a steady pattern far from the BP mortality. On the contrary, Cirrhosis shows convergence to the minimum observed. The rest of conditions are very close to the BP line.

Figure 2: Cause-specific contributions to state differences from low mortality benchmark for older male adults, 1990-2015.



Source: own calculations based on INEGI and SOMEDE files.

Figure 3: Cause-specific contributions to state differences from low mortality benchmark for older female adults, 1990-2015.



Source: own calculations based on INEGI and SOMEDE files.

Discussion

Trends in best practices life expectancy

It is both curious and concerning that the best practices trends have not been steadily increasing over the period studied. Rather, trends were irregular for children, flat for adults, and decreasing for older adults. We expected that the geographic diversity in Mexico would offset the recent mortality setbacks known from states such as Chihuahua and Durango. If the best practices trend determines our expectations for future mortality, we can conclude that our expectations ought to have been stagnant or deflating over time, depending on the age group considered. It would still represent a great success if mortality were to drop to the best practices level in all states, as unrealistic as this may seem, but at the same time we expect the best practices trend to increase given a mix of new technologies, reforms, and improved material wellbeing.

Child and young-age mortality

Despite this pessimistic finding about the best practices trend, all states have converged toward the best practices temporary life expectancy for the age group from 0 to 14 over the 21 years studied. Our results show that this has been due to improvements in causes amenable to medical service. Which is consistent with previous studies highlighting decreases in infectious and respiratory diseases in these ages (Canudas-Romo et al. 2014). Moreover, major health care reforms and programs, such as Seguro Popular and Oportunidades (now Progresa) have focused efforts in reducing inequalities and improving health services for children. In fact, in 2012 78.3% of children under age one visited a doctor to monitor their development and growth; however, children with social security showed a significantly greater effective access coverage than those with Seguro Popular or no health insurance (Urquieta-Salomón and Villarreal 2015). Our results reinforce the success of such programs by bringing life expectancy up and narrowing the gap between the best practices trend and the state-specific life expectancy in these ages.

Males experienced the same positive trend of convergence in the age group 15 to 39 until the year 2006, when a sudden and sizeable excess in homicide mortality began in particular states, especially on the Northern border with the U.S.A. The surge in violent deaths overlapped with a more widespread and earlier trend in increasing diabetes mortality. It is important to note that the so-called accident hump grew manifold in size due to violent deaths in particular states. Our results show that deviations from the best practices mortality in this age-group is mainly driven by the unprecedented rise in homicide mortality after 2005, which is consistent with previous research that highlight the burden of violence on population health between 2005-2010 (Aburto et al. 2016). We extended this previous analysis by adding information from 2011 to 2015. Our results show that the high prevalence of homicide mortality in these ages remain, which highlight the failure of the Mexican government to bring down the levels of violence that started rising after 2005. In fact, states like xxx are still experiencing high mortality rates provoking losses of life of xx years relative to the best practices mortality. Between-state variance in temporary life expectancy was much smaller for females

over the same period, though females showed the same overall trend of convergence, followed by divergence after 2006.

Old age mortality

The main results of our study are the trends in older adult mortality. For older adults in the 39 to 74 age group, all states except for Chihuahua and Baja California converged, albeit not toward the best practices trend. Instead, the best practices trend decreased toward the state trends. Males experienced no notable improvements in these age groups over the period, while females only experienced minor improvements, excepting Chihuahua and Baja California.

Improving health is a priority for governments of many developing countries, in part to achieve the Millennium Development Goals established for 2015. Great improvements have been accomplished 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 efforts on attending the burden of violence, through homicides; chronic-degenerative causes of death, such as diabetes and ischemic heart diseases; and behavior-related conditions like homicide and cirrhosis. Of the three age groups considered, the older adult age group has the most potential for gains in the future. All age groups considered have room to improve, and many states have much potential for recovery.

After ten years of the implementation of the Popular Insurance program and more than 15 years after conditional transfers programs took place in Mexico, health disparities remain in the country with high, but achievable, challenges for the post-2015 agenda. As Biosca and Brown (2015) pointed out, these programs should also focus in the awareness of enrollment in health insurance programs to 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 country. Nevertheless, the health component of the conditional transfers program Oportunidades targets women between 20 and 59 years old. We argue that such programs must be more inclusive and reach older population since, as we showed, a high number of years is being lost due to the lack of presence of effective and opportune health care service.

In addition, previous research emphasized the need of public health interventions to lessen the burden of homicides on population's health observed in the first decade of the 21st century (Canudas-Romo et al. 2014, Aburto et al. 2016). We extend the period five years and found that the toll of homicides on the population is still high and it is highly contributing to health inequalities in the young population, consistent with the previous trend observed (Canudas-Romo et al. 2014). Moreover, our results underscore the impact of violence also in the older adult population reaching unprecedented levels after 2005 making the best practices trend decrease.

Competing interest

None to declare.

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.
- Beltrán-Sánchez, H. (2011). Avoidable mortality. In *International handbook of adult mortality*, pages 491-508. Springer.
- Biosca, O. and Brown, H. (2015). Boosting health insurance coverage in developing countries: do conditional cash transfer programmes matter in Mexico? *Health policy and planning*, 30(2):155-162.
- 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.
- Consejo Nacional de Población (2015). Proyecciones de población 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.
- Eikemo, T. A., Hoffmann, R., Kulik, M. C., Kulhrov, I., Toch-Marquardt, M., Menvielle, G., Looman, C., Jasilionis, D., Martikainen, P., Lundberg, O., Mackenbach, J. P., and for the EURO-GBD-SE consortium (2014). How can inequalities in mortality be reduced? a quantitative analysis of 6 risk factors in 21 European populations. *PLoS ONE*, 9(11):e110952.
- 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.
- 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.
- 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 Mexico's War on Drugs*. HRW.
- Instituto Nacional de Estadística y Geografía (2015). Deaths microdata. machine readable files.
- Knauth, F. M. and Frenk, J. (2005). Health insurance in Mexico: achieving universal coverage through structural reform. *Health affairs*, 24(6):1467-1476.

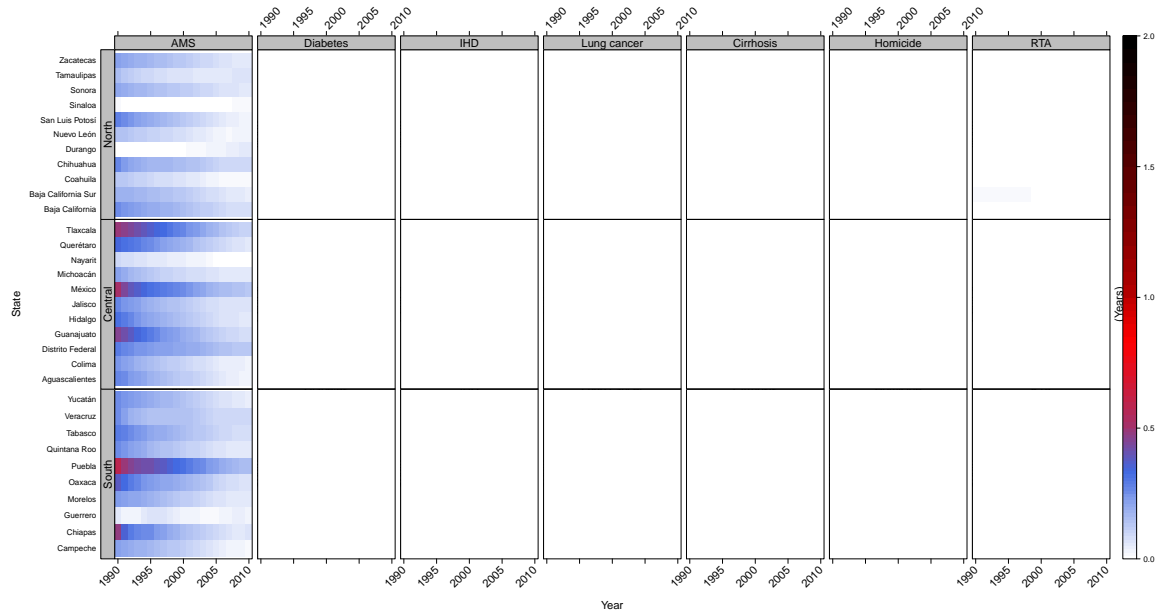
- Knaul, F. M., González-Pier, E., Gómez-Dantés, O., García-Junco, D., Arreola-Ornelas, H., Barraza-Lloréns, M., Sandoval, R., Caballero, F., Hernández-Avila, M., Juan, M., et al. (2012). The quest for universal health coverage: achieving social protection for all in mexico. *The Lancet*, 380(9849):1259–1279.
- 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 mortality deaths avoidable through health care progress 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.
- Oeppen, J. and Vaupel, J. W. (2002). Broken limits to life expectancy. *Science*, 296(5570):1029–1031.
- Organization, W. H. (2000). *The world health report 2000: health systems: improving performance*. WHO.
- Preston, S. H., Heuveline, P., and Guillot, M. (2001). *Demography: measuring and modeling population processes*. Blackwell Publishers, Malden, MA.
- 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.
- 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.
- Wilmoth, J. R. and Horiuchi, S. (1999). Rectangularization revisited: Variability of age at death within human populations*. *Demography*, 36(4):475–495.
- 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, cisticercosis	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

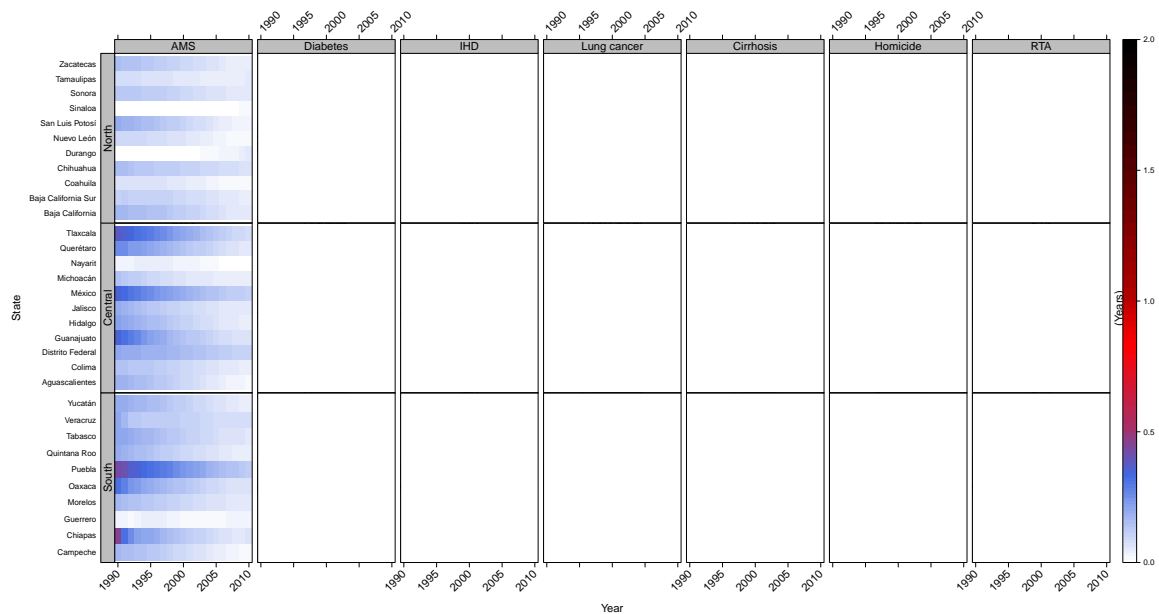
Figure 4: Cause-specific contributions to state differences from low mortality benchmark for male young people, 1990-2015.



Source:

own calculations based on INEGI and SOMEDE files.

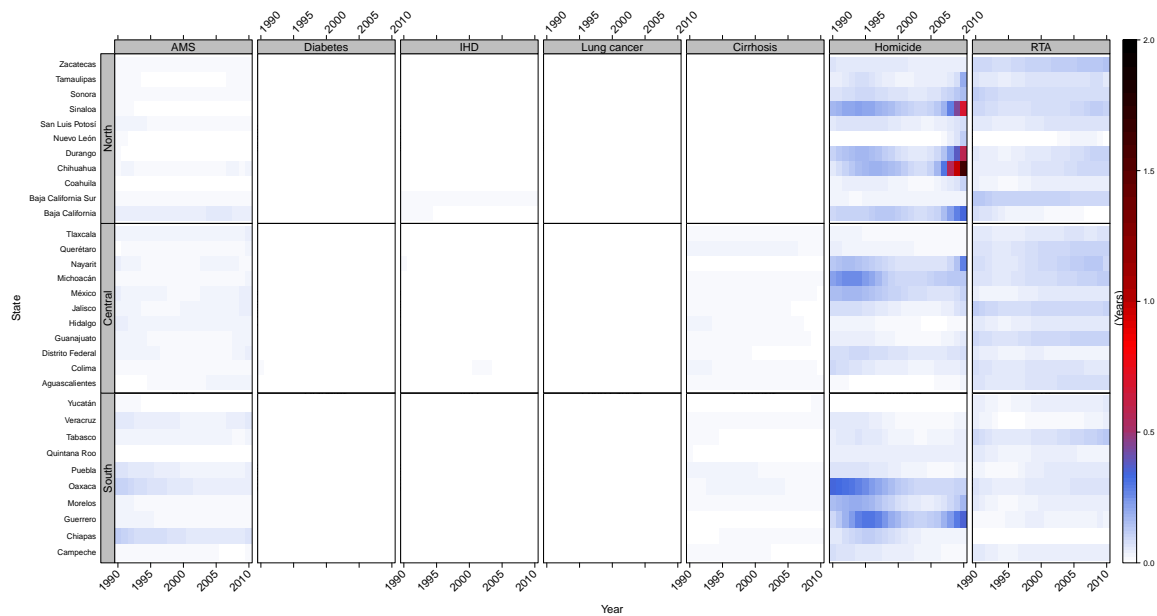
Figure 5: Cause-specific contributions to state differences from low mortality benchmark for female young people, 1990-2015.



Source:

own calculations based on INEGI and SOMEDE files.

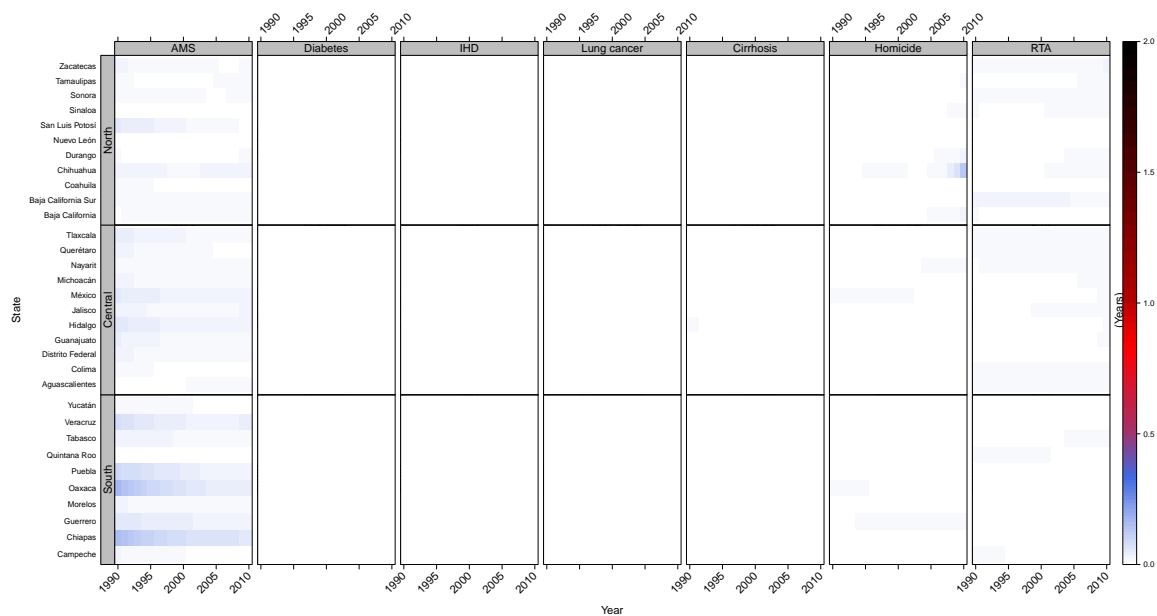
Figure 6: Cause-specific contributions to state differences from low mortality benchmark for male young adults, 1990-2015.



Source:

own calculations based on INEGI and SOMEDE files.

Figure 7: Cause-specific contributions to state differences from low mortality benchmark for female young adults, 1990-2015.



Source:

own calculations based on INEGI and SOMEDE files.