

Avoidable mortality in the states adjacent to the Mexico-United States border; 1999-2001 and 2009-2011

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Abstract *The scope of this article is to measure the effect of avoidable mortality in changes in life expectancy in the states adjacent to both sides of the US-Mexico border between 1999-2001 and 2009-2011. The data used were the records of mortality and population censuses from official sources in each country. Standardized mortality rates were estimated and the expected years of life lost were calculated. Both in 1999-2001 and in 2009-2011 the states belonging to the southern border of the United States had lower rates of avoidable mortality rates than those observed in the northern states of Mexico. In the border region avoidable deaths have seen an average increase of 0.19 years of life for America and a loss of 0.47 years of life for Mexico. The states of the US-Mexico border have common features in their health profiles that make it necessary to address some problems on a global basis and consider the particularities of each, in order to reduce gaps and enhance social equity through strategies involving independent national actions and others by cross-border coordination.*

Key words *Mortality, Life expectancy, Border, Mexico, United States*

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Introduction

The United States (U.S.)-Mexico border is characterized by a wide variety of economic, political, social, cultural and demographic conditions, which have particular aspects in each country¹⁻³. This border has a strategic importance and unique dynamics and interrelationships due to the permanent flow of people, goods, and services⁴. However, despite the geographical proximity, the social gaps on both sides of the border are evident, mainly because they are two countries with different development degrees, which affect the demographic behavior of each population^{4,5}. Moreover, these same differences are highlighted when comparing their respective bordering territories; so that in the case of the southern U.S. border, the level indicators associated with the quality and economics are below the national average, while in the northern Mexican border these values are higher than the country's average¹⁻⁶. Although social disparities among the border states are becoming smaller in terms of environmental sanitation, employment and schooling, the Mexican side still needs to make progress on poverty indicators, maternal mortality, infant mortality and life expectancy^{7,8}. Some figures presented in 2012 by the *Pan American Health Organization* (PAHO)⁸ show that in 2009 the Gross Domestic Product (GDP) per capita was US\$ 50,871 in California (United States) while in Baja California (Mexico) was significantly lower (US\$ 7,501). In 2010, the poverty rate ranged from 21.1% to 39.4% for the northern Mexican border, and from 15.8% to 20.4% for the southern U.S. border. In that same year, the maximum life expectancy for the same Mexican region was 77.1 years and for the U.S. border region was 81 years.

In Mexico, the infant mortality (per 1 000 live births) and maternal mortality (per 100,000 live births) was from 10.6-13.4 to 30.1-62.9, respectively. In other words, they were well above that recorded in the U.S. where these values ranged from 5.1-6.3 (infant deaths) to 8.1-22.2 (maternal deaths)⁸. Meanwhile, the southern U.S. border faces a serious problem of insufficient coverage and access to health services due to a high percentage of the population has no health insurance and the lack of doctors in the first care level, which results in a notorious mobility of American people in order to search medical attention on the Mexican side.

Issues related to the health of the border population are a subject of special interest for the

two countries. Therefore, multiple joint actions have been conducted to understand and improve the health conditions of the population living in this region. Specifically, in March 2001, the United States-Mexico Border Health Commission (BHC) established the Healthy Border program (HB) 2010 as an initiative focused on disease prevention and health promotion, whose objectives are: 1.) Improve the quality and increase the years of healthy life; and 2.) Eliminate disparities in access to health. Some of the goals set out in this program include the following: Access to Health Care; Cancer; Diabetes Mellitus; Environmental Health; HIV/AIDS; Immunization and Infectious Diseases; Injury Prevention; Maternal, Infant and Child Health; Mental Health; Oral Health; and Respiratory Diseases⁹.

Most health indicators for the U.S.-Mexico border have been restricted to the use of basic indicators, such as percentages and rates to estimate the level of mortality, even though these are insufficient to measure the aspects related to the magnitude and impact of mortality in life expectancy¹⁰. However, thanks to the continuous improvement of the quality of mortality records is possible to calculate composite indices that show the relative importance of causes of death leading to the premature loss of life years^{11,12}.

This type of analysis can be conducted using the following two indicators: avoidable mortality (AM), and the years of life lost (YLL). The first concentrates on those premature deaths that should have not occurred in the presence of timely and effective health care¹³⁻¹⁶, regardless of the geographical area under study. Meanwhile, YLL measures the contribution of each cause of death and age group to the change observed in life expectancy, and they correspond to the difference between the maximum attainable life expectancy and the one actually achieved by a group of individuals¹⁷.

The objective of this work is to measure the effect of AM in life expectancy changes in the U.S.-Mexico Border States between 1999-2001 and 2009-2011.

Methods

A cross-sectional descriptive study was carried out. Mortality and population data from the *National Institute of Statistics and Geography* (INEGI)^{18,19} were used for Mexico]. Regarding the United States, mortality records were obtained from the *Centers for Disease Control and Preven-*

tion (CDC) of the *National Center for Health Statistics* (NCHS)²⁰, and the population data were obtained from the *United States Census Bureau* (USCB)²¹. The triennial deaths from 1999-2001 to 2009-2011 were considered. Statistical data were pooled into periods of three years in order to soften possible fluctuations in the records due to various causes of death. Information was divided by five-year age groups (from 0 to 74 years old), causes of AM, and states.

On the other hand, the causes proposed by Nolte and McKee²², who classified the AM depending on the relative effectiveness of various medical interventions or the health care that could prevent death in predefined ages, were used. The classification includes 33 death causes redistributed into ten major groups of causes with their respective age range (Chart 1). Note that in the case of deaths from ischemic heart diseases, only 50% of them was considered because the evidence indicates that only half of such deaths are avoidable by medical care. Most causes of AM contemplates the population under 75 years old, except for intestinal infections (1-14), pertussis (0-14), measles (1-14), malignant neoplasms of cervix and non-specified uterus parts (0-44), leukemia (0-44), diabetes (0-49) and all the respiratory diseases (except for pneumonia and influenza) (1-14)²².

Causes of death were selected considering the underlying cause of death according to the *International Statistical Classification of Diseases and Related Health Problems* 10th Revision (ICD-10)²³.

Central death rates were calculated per 100 000 people, taking as reference the U.S. population of 2010²¹, using the following method:

$$SMR = \frac{\sum_x (m_x P_x)}{\sum_x P_x}$$

Where,

SMR: standardized mortality rate

mx: age-specific mortality rate for age x

Px: population age group x to the standard population

X: age group

mx = dx/px

Where,

dx: deaths in the age group x for the population of the A area

px: population age group x

Then, *years of life lost* (YLL)¹⁷ were calculated. This index represents the difference between the maximum years that a person can live between two ages, and those that a person actually live, i.e.

the years not lived. It is based on mortality tables, as outlined below:

- (1) l_x : number of survivors at the exact age x;
- (2) ${}_n L_x$: number of person-years lived divided by the ages x, and x+n;
- (3) and e_x : life expectancy at age $x^{17,18}$; and an indirect, the temporary life expectancy divided by two ages x and x+i (e_x), which is defined as the average number of years that survivors will live at age x divided by x and x+i, and is calculated as:

$$e_x = \frac{T_x - T_{x+i}}{l_x}$$

Where, $T_x = \sum_{u=x}^{\omega} L_u$

is the number of person-years lived from the exact age x) and ω is the inferior limit of the last open age group.

Data processing for the decomposition of the change in life expectancy was done using the free software *Epidat*, version 3.1²⁴.

Results

The proportion of avoidable deaths to the total number of deaths in the Northern Mexican border in the 1999-2001 and 2009-2011 periods was of 31.0% and 26.7%, respectively. On the southern border of the United States was 25.2% (1999-2001) and 24.7% (2009-2011). The adjusted mortality rate per 100 000 population showed a decrease from 104.8 to 84.9 (- 19%) in the U.S. border states, and 160.5 to 145.9 in the Mexican border states (- 9.1%).

The adjusted mortality rate due to avoidable causes declined into all states in the analyzed periods. We found that, for both triennial periods, the U.S. Border States had AM rates lower than those observed in the Mexican Border States. For 2009-2011, Arizona was the state with the lowest AM rate, and Chihuahua had the highest AM rate (Figure 1).

The analysis of cause of avoidable death showed data evidencing the variety of mortality profiles among adjacent states, which is presented briefly in Table 1.

First, it was found that the mortality rate from infectious diseases was significantly higher in the Mexican states than in the U.S. states, although for the latter, the increased rates were found for Arizona and New Mexico.

Cancer mortality rate was similar for neighboring states, and a decreasing rate was observed in all states. This reduction was higher in the U.S. border region. Meanwhile, diabetes and ischemic

Chart 1. Classification of causes of death considered amenable.

Mortality causes	Age groups	International Classification of Diseases (ICD) 10th revision
Infectious disease		
Intestinal infections	0-14	A00-A09
Tuberculosis	0-74	A15-A19
Other infections (diphtheria, tetanus, septicaemia, poliomyelitis)	0-74	A36, A35, A80
Whooping cough	0-14	A37
Measles	1-14	B05
Tumors		
Malignant neoplasm of colon and rectum	0-74	C18-C21
Malignant neoplasm of skin	0-74	C44
Malignant neoplasm of breast	0-74	C50
Malignant neoplasm of cervix uteri	0-74	C53
Malignant neoplasm of cervix uteri and body of uterus	0-44	C54,C55
Malignant neoplasm of testis	0-74	C62
Hodgkin's disease	0-74	C81
Leukaemia	0-44	C91-C95
Diabetes	0-49	E10-E14
Ischaemic heart disease: 50% of deaths	0-74	I20-I25
Other circulatory disease		
Chronic rheumatic heart disease	0-74	I05-I09
Hypertensive disease	0-74	I10-I13, I15
Cerebrovascular disease	0-74	I60-I69
Respiratory disease		
All respiratory diseases (except pneumonia and influenza)	1-14	J00-J09, J20-J99
Influenza	0-74	J10-J11
Pneumonia	0-74	J12-J18
Surgical conditions		
Peptic ulcer	0-74	K25-K27
Appendicitis	0-74	K35-K38
Abdominal hernia	0-74	K40-K46
Cholelithiasis y cholecystitis	0-74	K80-K81
Nephritis y nephrosis	0-74	N00-N07, N19-N19, N25-N27
Benign prostatic hiperplasia	0-74	N40
Misadventures to patients	0-74	Y60-Y69, 783-Y84
Maternal, congenital and perinatal conditions		
Maternal death	0-74	O00-099
Congenital cardiovascular anomalies	0-74	Q20-Q28
Perinatal deaths, all causes, excluding stillbirths	0-74	P00-P96, A33
Other conditions		
Diseases of the thyroid	0-74	E00-E07
Epilepsy	0-74	G40-G41

Source: Nolte y Mckee, 2012²².

heart diseases highlighted in the Mexican mortality profile, with rates exceeding the values obtained for the U.S. However, the mortality rate for diabetes increased on average 23% for the U.S. and 8% for Mexico. Moreover, death rates due ischemic heart diseases declined significantly on both sides of the Border States.

Regarding other circulatory diseases, higher rates were observed in Mexico as compared to the

U.S. These differences are evident when analyzing the state of Coahuila, where a mortality rate 2.5 times higher than the one of Arizona and New Mexico (46.5 versus 17.9 per 100 000 people) for 2009-2011 was recorded. Additionally, respiratory diseases showed significant increases in their rates (more than 30%) in Coahuila (+ 51.5%), Sonora (+ 48.1%), Nuevo León (+ 42.8%) and Tamaulipas (+ 37.3%).

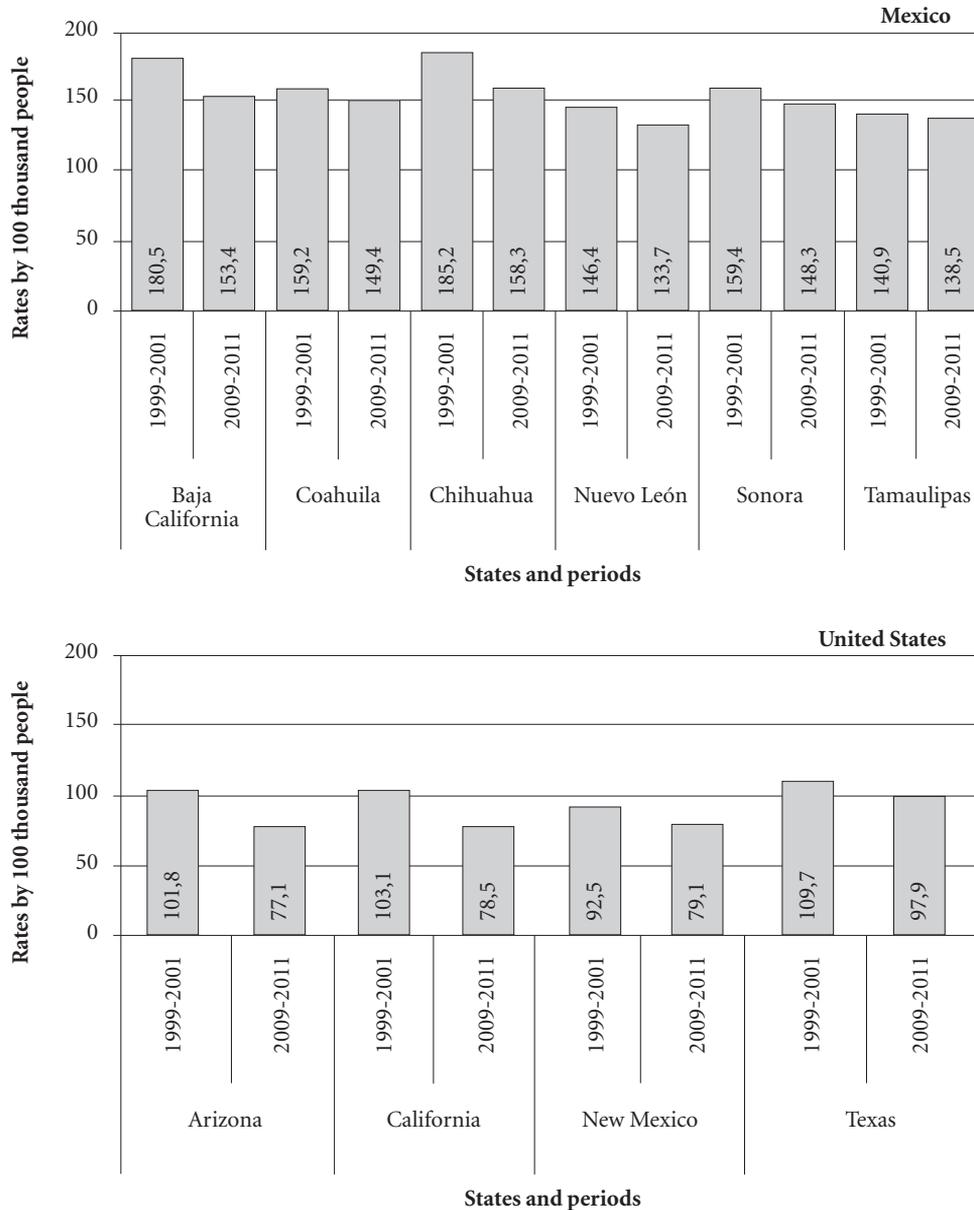


Figure 1. Adjusted mortality rates by avoidable causes on the United States-Mexico border 1999-2001 and 2009-2011.

Source: INEGI (Mexico). CDC/US Census Bureau (United States). Own elaboration.

In the group of avoidable deaths due to surgical conditions, the southern U.S. border States had relatively lower rates of mortality compared to the northern Mexican border states. However, while nearly all states shown reduced mortality rates due to this cause, New Mexico and Texas shown increased mortality rates. As for adverse medical events, mortality rates were low for both

sides of the border, although it should be noted that the number of reported cases is very small, making it impossible to see a clear trend for this cause of death.

Deaths from maternal, perinatal and congenital conditions descended on all the states of the U.S. southern border; in the case of the Northern Mexican border, both Coahuila and Tamaulipas

Table 1. Adjusted mortality rates by avoidable causes on the United States-Mexico border 1999-2001 and 2009-2011.

States	Periods	Infectious disease	Tumors	Diabetes	Ischaemic heart disease	Other circulatory disease	Respiratory disease	Surgical conditions	Misadventures to patients	Maternal, congenital and perinatal conditions	Other conditions
United States											
Arizona	1999-2001	0.3	23.8	1.7	33.9	20.5	7.3	7.1	0.6	6.1	0.5
	2009-2011	0.3	19.0	2.2	22.3	17.9	4.9	4.3	0.4	5.0	0.6
	% change	4.7	-20.1	25.9	-34.1	-12.6	-33.0	-39.2	-29.5	-18.0	36.7
California	1999-2001	0.2	24.5	1.3	33.7	27.1	5.2	4.9	0.3	5.4	0.6
	2009-2011	0.2	20.2	1.4	20.8	21.3	4.7	4.7	0.2	4.6	0.6
	% change	-21.1	-17.6	2.2	-38.3	-21.6	-9.1	-5.6	-17.7	-15.2	8.6
New Mexico	1999-2001	0.3	22.3	1.8	30.0	19.0	5.5	6.1	0.8	6.4	0.3
	2009-2011	0.4	19.4	2.5	21.1	17.9	5.6	6.4	0.5	4.8	0.6
	% change	28.9	-12.8	35.3	-29.4	-5.9	0.7	4.3	-35.1	-24.6	92.1
Texas	1999-2001	0.4	26.1	1.8	35.3	27.3	5.6	6.3	0.5	5.7	0.6
	2009-2011	0.3	21.9	2.3	29.6	24.5	5.1	8.6	0.4	5.3	0.6
	% change	-25.6	-16.2	28.6	-16.1	-10.5	-9.9	36.3	-31.0	-7.6	1.6
Mexico											
Baja California	1999-2001	12.1	25.6	6.2	46.8	45.3	11.2	16.0	0.0	15.2	2.0
	2009-2011	9.5	21.3	6.3	34.0	42.0	10.9	13.8	1.0	12.6	1.8
	% change	-21.4	-16.8	3.1	-27.3	-7.3	-3.2	-13.9	*	-17.0	-7.6
Coahuila	1999-2001	7.2	22.5	7.2	38.6	47.7	4.5	18.8	0.1	9.6	2.9
	2009-2011	3.7	20.3	7.6	37.9	46.5	6.9	14.5	0.0	10.1	2.0
	% change	-49.4	-9.7	5.5	-2.0	-2.7	51.5	-22.9	*	5.5	-32.1
Chihuahua	1999-2001	7.4	24.3	6.0	46.6	49.6	12.1	18.6	0.0	17.1	3.5
	2009-2011	4.3	23.1	6.6	38.0	41.0	10.1	17.7	0.2	14.3	2.9
	% change	-42.8	-4.7	10.8	-18.4	-17.4	-16.1	-5.0	*	-16.2	-16.5
Nuevo León	1999-2001	6.7	21.3	4.1	37.4	39.4	7.3	18.0	0.0	11.2	1.0
	2009-2011	4.6	19.4	5.3	36.1	34.3	10.5	13.0	0.0	9.0	1.4
	% change	-30.5	-8.7	27.5	-3.3	-12.8	42.8	-27.7	*	-19.4	32.1
Sonora	1999-2001	8.3	22.3	5.4	45.5	38.8	7.2	15.2	0.1	13.7	2.9
	2009-2011	5.9	21.4	5.5	42.7	35.5	10.7	12.4	0.6	11.1	2.6
	% change	-29.5	-3.9	2.6	-6.2	-8.6	48.1	-18.8	*	-19.1	-9.0
Tamaulipas	1999-2001	7.1	21.3	6.5	35.9	36.7	5.6	14.7	0.0	11.5	1.5
	2009-2011	6.2	20.0	6.6	34.4	35.0	7.7	13.9	0.3	12.7	1.6
	% change	-13.5	-6.1	1.0	-4.0	-4.5	37.3	-5.1	*	9.9	6.8

*The number of cases is too low, so that a change in rates cannot be established.

Source: INEGI (Mexico). CDC/US Census Bureau (United States). Own elaboration.

shown increased rates. The mortality rate for this cause was higher in Mexico than in the United States. Thus, Chihuahua (mortality rate of 14.3 per 100 000 people) and California (mortality rate of 4.6 per 100 000 people) shown the highest values. Finally, avoidable deaths due to other causes, such as epilepsy and thyroid disease, were lower in all states, except those states that belong to Mexico.

On average, from 1999-2001 to 2009-2011, avoidable causes represented a gain of 0.19 years of life for the southern U.S. states and a loss of

0.49 years of life for the northern Mexican states. In those same periods, the United States had a positive balance in the years of life expectancy, although with different intensity: Arizona (+ 0.70), California (+ 0.74), New Mexico (+ 0.16) and Texas (+ 0.56). In contrast, Mexico had significant fluctuations among states: Baja California (+ 0.72), Coahuila (-0.29), Chihuahua (-3.04), Nuevo León (-0.13), Sonora (+ 0.22) and Tamaulipas (-0.44) (Figure 2).

In the U.S., California was the state with fewer years of life lost, while New Mexico lost

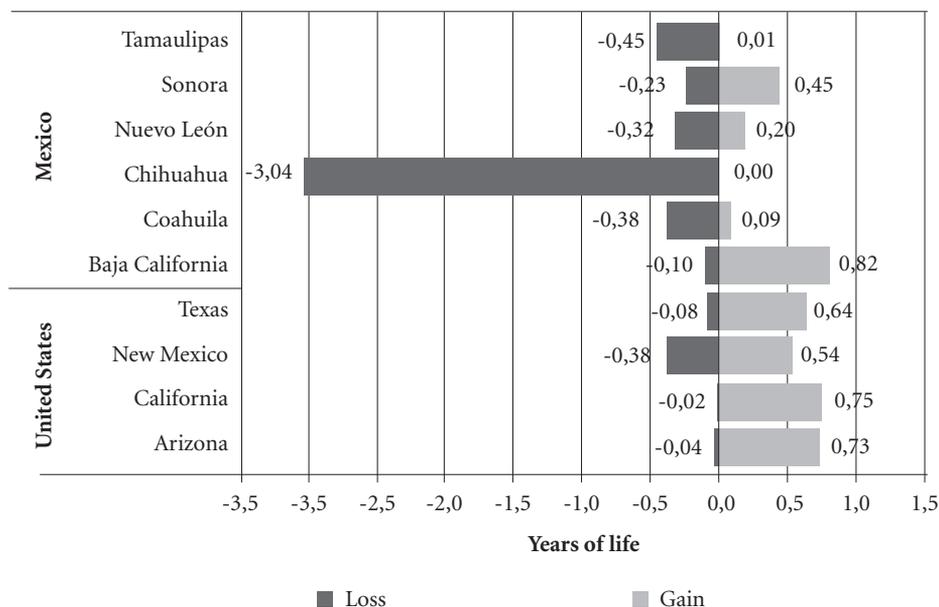


Figure 2. Life expectancy change by avoidable causes on the United States-Mexico border 1999-2001 and 2009-2011.

Source: INEGI (Mexico). CDC/US Census Bureau (United States). Own elaboration.

-0.38 years in this indicator. In the U.S. border region, years of life decreased due to the following causes: diabetes (-0.09); surgical conditions (-0.05); adverse medical events (-0.04); and infectious diseases (-0.02). In contrast, years of life increased due to the following causes: other circulatory diseases (+ 1.00); congenital and perinatal maternal conditions (+ 0.80), and respiratory diseases (+ 0.47); and others various conditions (+ 0.10). In Mexico, the state of Chihuahua showed a life expectancy highly reduced by more than three years on its inhabitants, i.e., a reduction higher than that in the other adjacent Border States. The years of life were adversely impacted by all causes in this state. In the country, eight of the ten groups of avoidable deaths had decreased life years (from highest to lowest): other circulatory diseases (-1.39); maternal, congenital and perinatal conditions (-0.65); surgical conditions (-0.45); infectious diseases (-0.29); ischemic heart diseases (-0.24); diabetes (-0.19); other conditions (-0.13) and tumors (-0.03) (Table 2).

Discussion

The U.S.-Mexico Border States show a very different picture of mortality, as mentioned in previous research²⁵⁻²⁷. This territorial heterogeneity has been explained by many factors such as the specific socio-economic and social structure that determines how people get sick and die²⁸⁻³¹; the organization and performance of each country's health systems¹³⁻¹⁶; the influence of national and local policies³²⁻³⁵, the individual and community response to health events; the distribution of the prevalence, the incidence and mortality of the diseases³⁰; and ambient environment³⁶. Regarding the U.S., the slow progress in reducing deaths in general is a matter of growing interest, especially since this phenomenon has coincided with an increase of people without social security and the stagnation in reducing deaths by ischemic heart diseases and other circulatory diseases (mainly strokes)^{8,22,37}. During 2008-2009, the population without the right to private health

Table 2. Life expectancy change by groups of avoidable causes on the United States-Mexico border, 1999-2001 and 2009-2011.

Causes	United States				Mexico					
	Arizona	California	New Mexico	Texas	Baja California	Coahuila	Chihuahua	Nuevo León	Sonora	Tamaulipas
Infectious disease	-0.01	0.00	-0.01	0.00	0.04	0.00	-0.18	-0.01	0.00	-0.13
Tumors	0.20	0.21	0.19	0.20	0.11	-0.03	-0.69	-0.04	-0.01	0.01
Diabetes	0.00	0.02	-0.10	0.03	0.04	-0.05	-0.40	-0.04	0.01	-0.01
Ischaemics heart disease	0.23	0.27	0.16	0.34	-0.10	-0.18	-0.52	-0.21	-0.23	-0.15
Other circulatory disease	0.00	0.11	-0.13	-0.01	0.16	0.08	-0.32	0.05	0.12	-0.02
Respiratory disease	0.07	-0.01	-0.08	0.01	0.07	0.02	-0.22	0.01	0.03	-0.05
Surgical conditions	0.11	0.01	0.00	-0.06	0.04	-0.01	-0.32	0.01	0.03	0.00
Misadventures to patients	0.00	0.00	0.02	0.01	0.01	0.00	-0.02	0.00	0.00	-0.01
Maternal, congenital and perinatal conditions	0.13	0.14	0.18	0.04	0.35	-0.09	-0.20	0.13	0.25	-0.09
Other conditions	-0.02	-0.01	-0.05	-0.01	0.01	-0.02	-0.17	-0.01	0.02	-0.01

Source: INEGI (Mexico). CDC/US Census Bureau (United States). Own elaboration.

services in the southern U.S. border states ranged from 19% in California to 26% in Texas (higher than the national average: 17%). In contrast, in Mexico's northern border people without social security represented 20% (Nuevo León) and 28% (Baja California) (less than the overall average of the country: 34%) in 2009⁸.

Although a decrease in rates of avoidable deaths has been observed, the level of this reduction is different on both sides of the border, creating inequalities more marked. About this point, the findings of this study are consistent, but not directly comparable, with other studies reporting slightly decreased AM. This AM decreased by 4% in the U.S. from 1997-1998 to 2002-2003²², and it decreased by 5% from 1995-1999 to 2000-2004 in Mexico²⁷. This same pattern has occurred in countries such as Spain³⁸, Canada³⁹ and Colombia³⁵.

The U.S.-Mexico border states have common features in their health profiles⁸ that make it necessary to address some problems on a global basis and others by considering their own peculiarities in order to reduce the gaps and enhance social equity through strategies that involve independent national actions and others that involve cross-border coordination^{7,8}. These efforts should be aimed at preventing and reducing AM to meet or exceed the levels observed in states with better performance in health indicators. Such actions

shall include the promotion of healthy lifestyles that encourage people to reduce the alcohol and tobacco consumption, increase physical activity on a regular basis, as well as monitoring conditions associated with the metabolic syndrome⁸.

The structure of AM in the study region is a combination of mixed epidemiological regimes, where communicable and non-communicable diseases coexist^{25-27,40}. Most causes of death analyzed are characterized by being chronic, long lasting causes and a burden of permanent disability and dependence^{41,42}, which leads to rethink the role of quality medical care, the adherence and controlled management of these conditions.

The impact of health problems on the population of the ten U.S.-Mexico Border States has not been sufficiently comparatively analyzed due to the limited sources of systematic and standardized information, among other things, and also their quality and coverage. However, U.S.-Mexico's mortality data are considered of good quality, according to previous assessments, and appropriate for the death analysis by causes, as performed in this article⁴³⁻⁴⁵.

Finally, this research provides key evidence for planning and prioritizing health interventions, but it is insufficient to explain the complexity of factors that influence the health – disease – death process of the population of the U.S.-Mexico Border States. Accordingly, we sug-

gest to incorporate other individual, social, cultural and economic variables in future analyses in order to measure the contribution of each of them for health indicators, as well as the policies influence and the organization of the health systems profiles. Another key aspect shall be the use of sex and age disaggregated data in order to identify the most vulnerable subgroups and to focus actions depending on the specific characteristics of each them.

Collaborations

MA Botero, RSG Ramírez and AML Jaramillo have also participated in each of the elaboration stages of this article.

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