Trends in avoidable mortality over the life course in Mexico, 1990-2015: A cross-sectional demographic analysis

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Abstract

Objective:To analyse average lifespan and quantify the effect of Avoidable/Amenable mortality on the dif-ference between state-specific mortality and a low-mortality benchmark in Mexico during 1990-2015.

Design: Retrospective cross-sectional demographic analysis using aggregated data.

Setting: Vital statistics from the Mexican civil registration system.

Participants: Aggregated national data (from 91.2 million people in 1995 to 119.9 in 2015) grouped in 64 populations (32 Mexican-states [including Mexico City] by sex) with cause-of-death data.

Main outcome measures: Cause-specific contributions to the gap in life expectancy with a low-mortality benchmark in three age groups (0-14, 15-49 and 50-84).

Results: Infants and children under age 15 show improvements towards maximal survival in all states. However, adult males aged 15 to 49 show deterioration after 2006 in almost every state due to increasing homicides, and a slow recovery thereafter. Out of 35 potential years, females and males live on average 34.57 (34.48 to 34.67) and 33.80 (33.34 to 34.27), respectively. Adults aged 50 to 84 show an unexpected decrease in the low mortality benchmark, indicating nationwide deterioration among older adults. Females and males in this age group show an average survival of 28.59 (27.43 to 29.75) and 26.52 (25.33 to 27.73) out of 35 potential years, respectively. State gaps from the benchmark were mainly caused by ischemic heart diseases, diabetes, cirrhosis and homi-cides. We find large health disparities between states, particularly for the adult population after 2005.

Conclusions: Mexico has succeeded in reducing mortality and between-state inequalities in children. However, adults are becoming vulnerable as they have not been able to reduce the burden of violence and conditions amenable to health services and behaviours, such as diabetes, ischemic heart diseases and cirrhosis. These trends have led to large health disparities between Mexican states in the last 25 years.

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

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 $(x_2-x_1)e_{x_1}$, and its benchmark based on minimum death rates for every age and cause of death among the Mexican states for each year as $(x_2-x_1)e_{x_1}^*$. Defined in terms of the lifetable survival function, $\ell(x)$:

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

If full survival is achieved, the life expectancy is $x_2 - x_1$. For example, if we set $x_1 = 0$ and $x_2 = 15$, and no person dies between the ages 0 and 15, on average the population lives 15 full years.

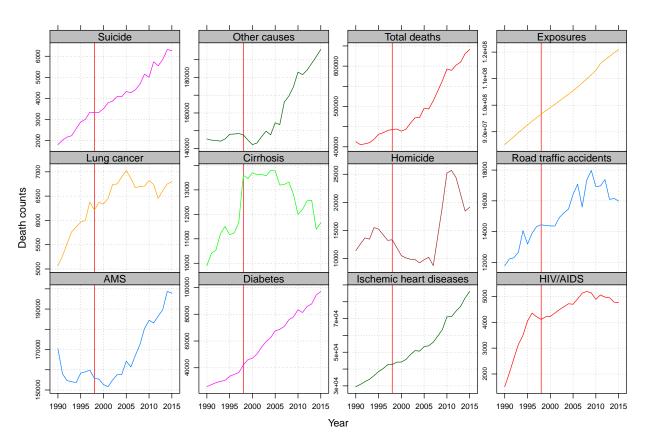
Decomposition method

The decomposition method used in this paper relies on a model of demographic functions based on continuous change (Horiuchi et al. 2008). Suppose P (e.g. temporary life expectancy between ages 15 and 49) is a differentiable function of n covariates (e.g. each age-cause specific mortality rate) denoted by the vector $\mathbf{A} = [x_1, x_2, \dots, x_n]^T$. We assume that \mathbf{A} is a differentiable function between P_1 and P_2 , then the difference in P between P_1 and P_2 can be expressed as follows:

$$P_2 - P_1 = \sum_{i=1}^n \int_{x_i(P_1)}^{x_i(P_2)} \frac{\partial P}{\partial x_i} dx_i = \sum_{i=1}^n c_i,$$
 (2)

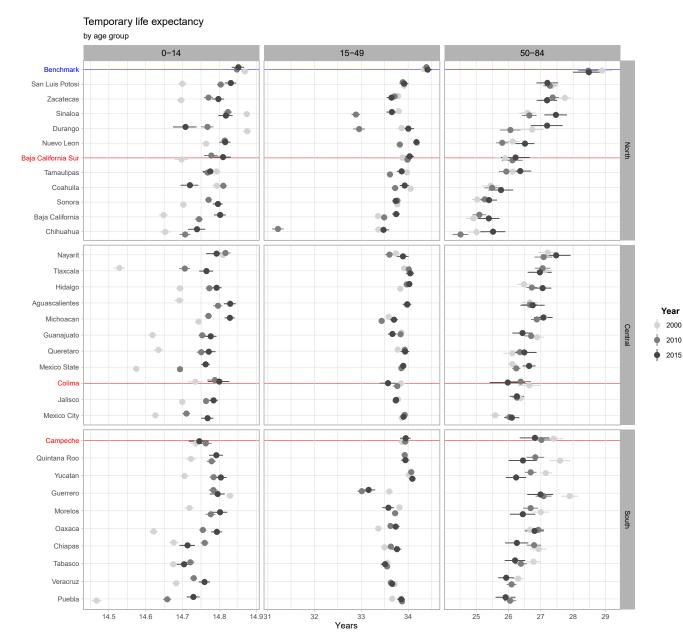
where c_i is the total change in P produced by changes in the i-th covariate, x_i . The c_i 's in equation (2) were computed by numerical integration following the algorithm suggested by Horiuchi et al. (2008). This method has the advantage of assuming that covariates change gradually along the time dimension.

Figure 1: Cause-specific death counts (different y-scale for each cause), 1990-2010.



Note: AMS "amenable to medical service". The red line indicates the change from ICD 9 to ICD 10.

Robustness check: 95% CIs for male temporary life expectancies



Note: States highlighted in red had less than 1 million population in 2010.

References

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

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.

Figure 2: Inequality in life expectancy between states for youngest (0-14), young adults (15-49), and older adults (50-84) by sex, 1990-2015.

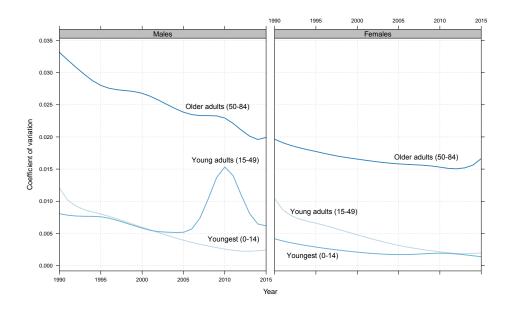
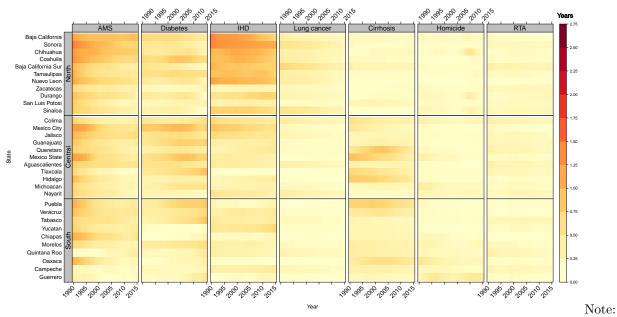


Figure 3: State ranking for average female life expectancy 2010-15 for the youngest (0-14), young adults (15-49), and older adults (50-84).

Sinaloa Si	You	ung (0–14)	Middle (15-49)	Older (50-	-84)
Nuevo Leon NL					Rank
Nayarit NA	Sinaloa	SI	NĻ	SI	1
Colima CL QR SL 4	Nuevo Leon	NL —	SI	ŅA	2
Aguascalientes AG San Luis Potosi SL Quintana Roo Michoacan MC Michoacan MC Michoacan MC Morelos MR Yucatan YU MR Baja California Sur Guerrero GR Sonora SO NA Calla CA AG	Nayarit	NA	ΥU	ĢR	3
San Luis Potosi SL	Colima	CL	QR	ŚL	4
Quintana Roo QR DU ZA 7 Michoacan MC OE OA 8 Morelos MR SL DF 9 Yucatan YU BS 10 Baja California Sur BS MR NL 11 Hidalgo HI GT CL 12 Guerrero GR DF TL 13 Sonora SO NA QE 14 Tamaulipas TM HI DU 15 Coahuila CA AG 16 AG 16 Zacatecas ZA CL GT 17 TM 18 Queretaro QE TM JA JA JA 18 19 Baja California BN MX MR 20 MX 21 Campeche CM JA MX MX 22 MX 22 Oaxaca OA CA	Aguascalientes	AG	BS	/HI	5
Michoacan Mc QE QA 8 Morelos MR SL DF 9 Yucatan YU CM BS 9 Baja California Sur BS MR NL 11 Hidalgo HI GT CL 12 Guerrero GR DF TL 13 Sonora SO NA QE 14 Tamaulipas TM HI DU 15 Coahuila CA AG AG 16 Zacatecas ZA CL GT 17 Jalisco JA ZA TM 18 Queretaro QE TM MX MR 20 Baja California BN MX MR 20 Guanajuato GT MC MX 21 Campeche CM JA CM 22 Oaxaca OA CA BN 23 Mexico City DF SO QR 24 Veracruz VE PU PU PU PU Durango <	San Luis Potosi	SL	ŢĻ	/ MC	6
Morelos MR	Quintana Roo	QR	DU	X / ZA	7
Yucatan YU CM BS 10 Baja California Sur Bs MR MR NL 11 Hidalgo HI GT CL 12 Guerrero GR DF TL 13 Sonora SO NA QE 14 Tamaulipas TM HI DU 15 Coahuila CA AG AG AG 16 Zacatecas ZA CL GT 17 Jalisco JA ZA TM 18 Queretaro QE TM JA 19 Baja California BN MX MR 20 Guanajuato GT MC MX 21 Campeche CM JA CM 22 Oaxaca OA CA BN 23 Mexico City DF SO OR 24 Veracruz VE PU PU PU PU Durango DU OA YU 26 Tlaxcala TL BN SO	Michoacan	MC X	QE V	//QA	8
Baja California Sur BS	Morelos	MR	SL	DF	9
Hidalgo HI GT CL 12 Guerrero GR DF TL 13 Sonora SO NA QE 14 Tamaulipas TM HI DU 15 Coahuila CA Zacatecas ZA CL GT 17 Jalisco JA ZA TM 18 Queretaro QE TM JA 19 Baja California BN MX MR 20 Guanajuato GT MC MX 21 Campeche CM JA CM 22 Oaxaca OA CA BN 23 Mexico City DF SO QR 24 Veracruz VE PU PU 25 Durango DU OA YU 26 Tlaxcala TL BN SO 27 Mexico State MX TB VE 28 Tabasco TB QR CP CA 31 Chiapas CP CP CA 31	Yucatan	YU	ĆW X	BS	10
Guerrero GR Sonora SO NA Tamaulipas TM Coahuila CA AG	Baja California Sur	BS	MR) NL	11
Sonora SO	Hidalgo	HI	X/X GTX	CL	12
Tamaulipas TM Coahuila CA Zacatecas ZA CL GT 17 Jalisco JA Queretaro QE Baja California BN Guanajuato GT Campeche CM Oaxaca OA Mexico City DF Veracruz VE Durango DU Tlaxcala TL Mexico State MX Chihuahua CH Tabasco TB Chiapas CP CP CA GG AG			DF	TL	13
Coahuila CA Zacatecas ZA CL GT 17 Jalisco JA Queretaro QE Baja California BN Guanajuato GT Campeche CM Oaxaca OA Mexico City DF So Durango DU Tlaxcala TL Mexico State MX Chihuahua CH Tabasco TB GR CA CA BN SO QR CA BN SO Q		so	X NA	QE	14
Zacatecas ZA		TM	HI	DU	15
Jalisco JA	Coahuila	CA	ÀG /	AG	16
Queretaro QE TM JA 19 Baja California BN MX MR 20 Guanajuato GT MC MX 21 Campeche CM JA CM 22 Oaxaca OA CA BN 23 Mexico City DF SO OR 24 PU PU PU 25 Durango DU DOA YU 26 Tlaxcala TL BN SO 27 Mexico State MX TB VE 28 Chihuahua CH VE TB 29 Tabasco TB OR CP CP CA 31	Zacatecas	ZA	CL/ /	GT	17
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Mexico City DF SO QR 24 Veracruz VE PU PU 25 Durango DU OA YU 26 Tlaxcala TL BN SO 27 Mexico State MX TB VE 28 Chihuahua CH VE TB 29 Tabasco TB GR CP 30 Chiapas CP CP CA 31			JA //	\\с`м	22
Veracruz VE PU PU PU 25 Durango DU OA YU 26 Tlaxcala TL BN SO 27 Mexico State MX TB VE 28 Chihuahua CH TB 29 TB 29 Tabasco TB GR CP 30 Chiapas CP CP CA 31		The same of the sa	CA /	BN	23
Durango DU OA YU 26 Tlaxcala TL BN SO 27 Mexico State MX TB VE 28 Chihuahua CH VE TB 29 Tabasco TB CP CA 31 Chiapas CP CA 31	Mexico City	DF //			24
Tlaxcala TL		VE	PU		25
Mexico State MX Chihuahua CH TB VE TB 29 Tabasco TB GR CP CP CA 31		DU//	\ OA /	ÝU	26
Chihuahua CH VE TB 29 Tabasco TB GR CP 30 Chiapas CP CP CA 31		TL/	BN/	so	27
Tabasco TB GR CP 30 Chiapas CP CP CA 31			TB	VE	28
Chiapas CP CP CA 31		-			
					30
Puebla PU CH 32			CP	CA	31
	Puebla	PU	_CH	——СН	32

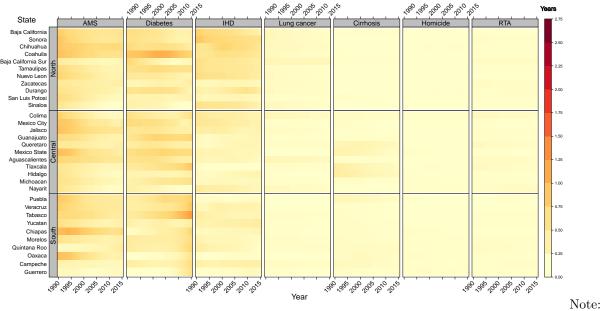
Source: calculations based on INEGI and CONAPO files.

Figure 4: Cause-specific contributions to state differences from low mortality benchmark for older male adults (ages 50-84), 1990-2015. States grouped into three regions. Reproduced from manuscript Figure 4 to have color scale comparable with other Supplementary figures. In subsequent figures 5-9 the color was rescaled to make them comparable over age groups in the supplemental material, the maximum value observed was 2.6 years caused by homicides in Chihuahua in 2010.



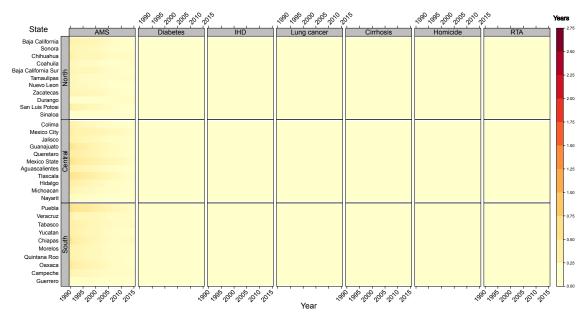
AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: own calculations.

Figure 5: Cause-specific contributions to state differences from low mortality benchmark for older female adults (ages 50-84), 1990-2015.



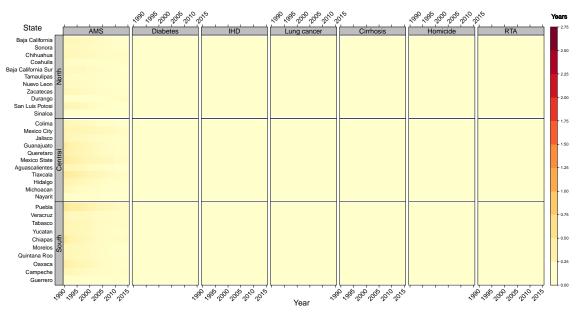
AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: own calculations.

Figure 6: Cause-specific contributions to state differences from low mortality benchmark for male youngest population (ages 0-14), 1990-2015.



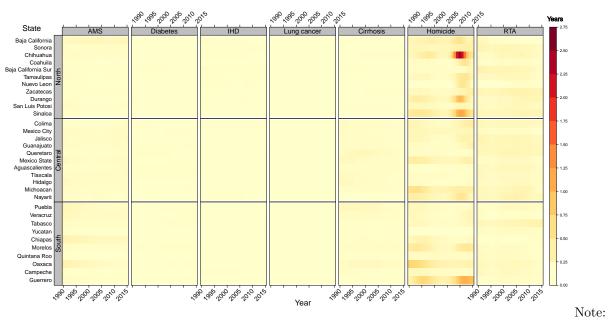
Note: AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: own calculations.

Figure 7: Cause-specific contributions to state differences from low mortality benchmark for female youngest population (ages 0-14), 1990-2015.



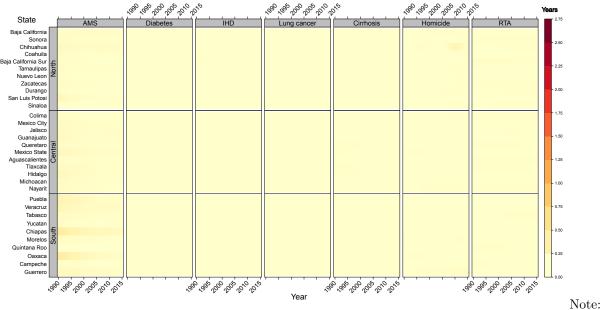
Note: AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: own calculations.

Figure 8: Cause-specific contributions to state differences from low mortality benchmark for male young adults (ages 15-49), 1990-2015.



AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: own calculations.

Figure 9: Cause-specific contributions to state differences from low mortality benchmark for female young adults (ages 15-49), 1990-2015.



AMS is "amenable to medical service", IHD is "isquemic heart diseases", and RTA is "road traffic accidents". Source: own calculations.

Figure 10: State specific gap with low mortality benchmark for selected years between ages 0-14. Source: own calculations.

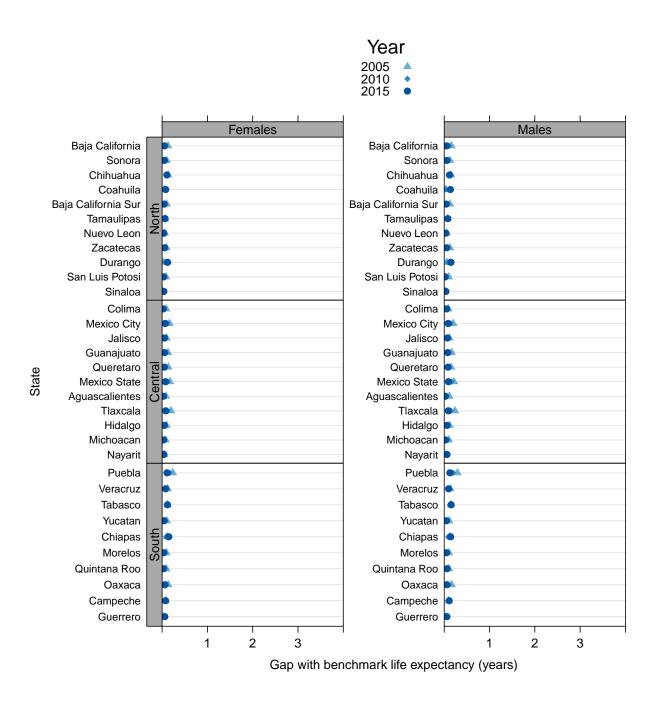


Figure 11: State specific gap with low mortality benchmark for selected years between ages 15-49. Source: own calculations.

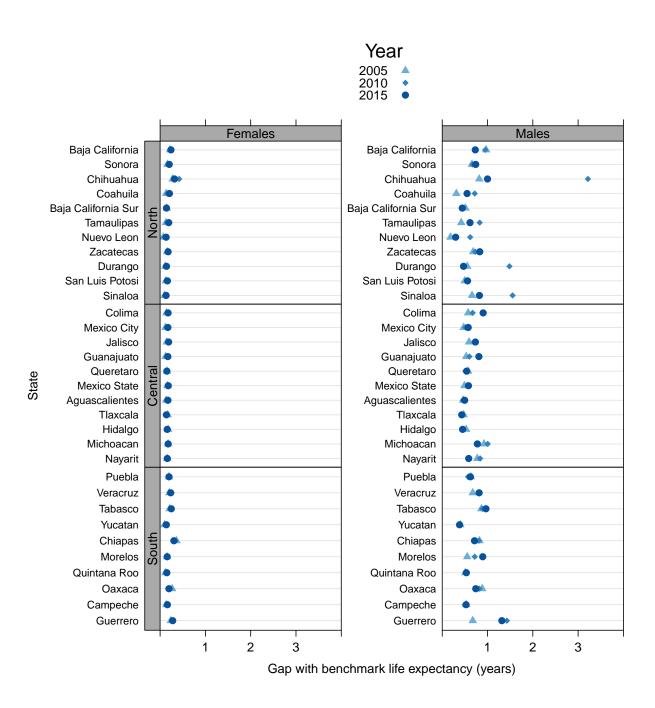


Figure 12: State specific gap with low mortality benchmark for selected years between ages 50-84. Source: own calculations.

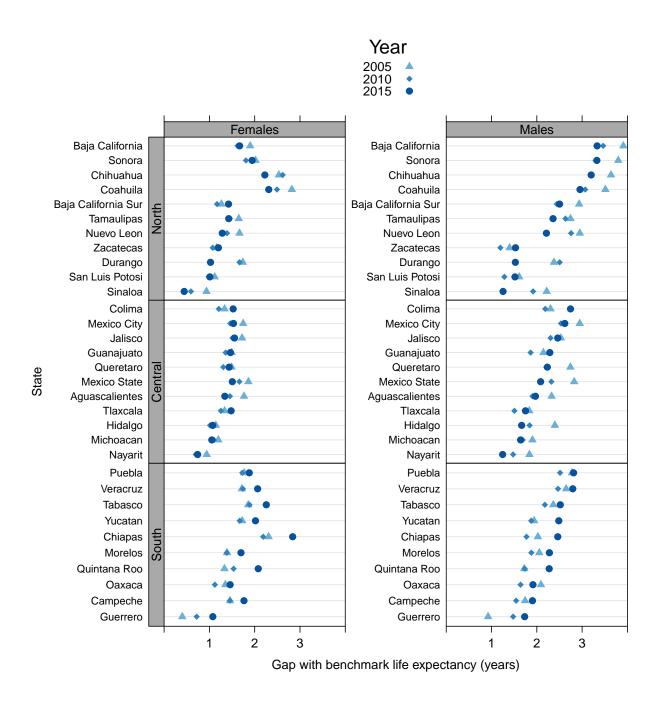


Figure 13: Proportion by cause of death from benchmark mortality for youngest females (ages 0-14). Source: own calculations.

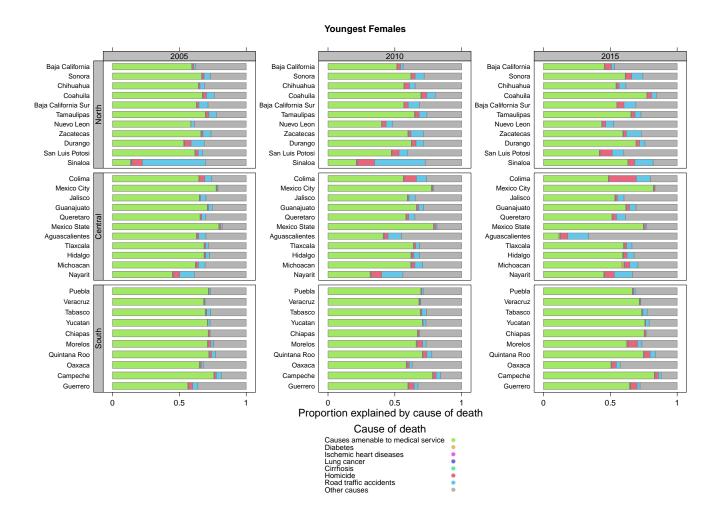


Figure 14: Proportion by cause of death from benchmark mortality for youngest males (ages 0-14). Source: own calculations.

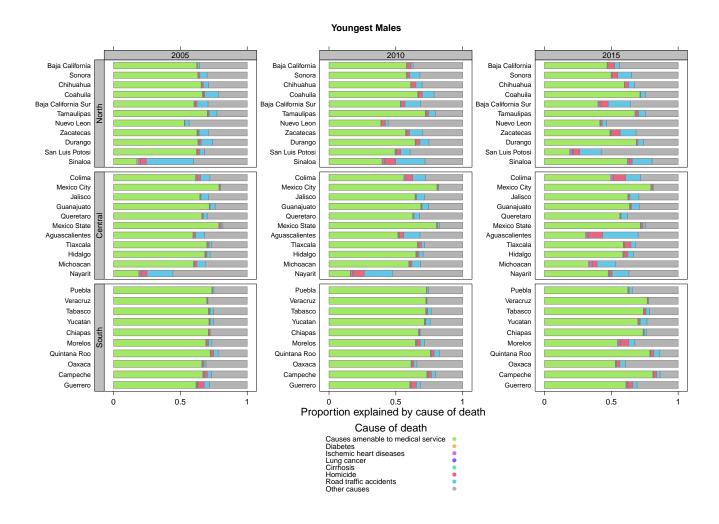


Figure 15: Proportion by cause of death from benchmark mortality for young adult females (ages 15-49). Source: own calculations.

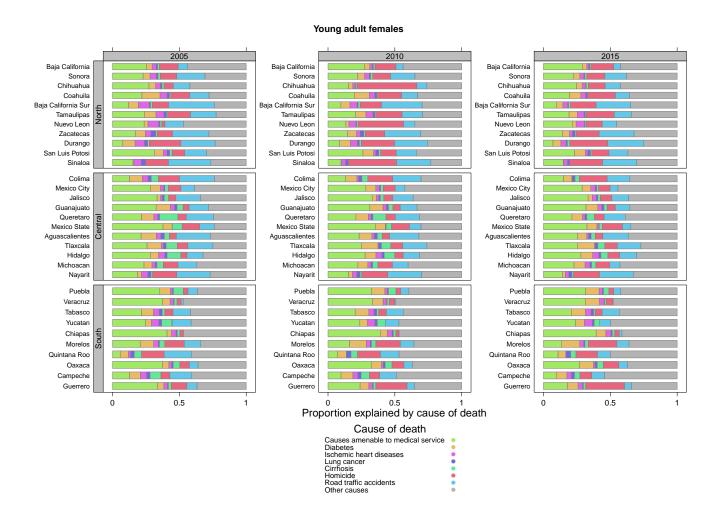


Figure 16: Proportion by cause of death from benchmark mortality for young adult males (ages 15-49). Source: own calculations.

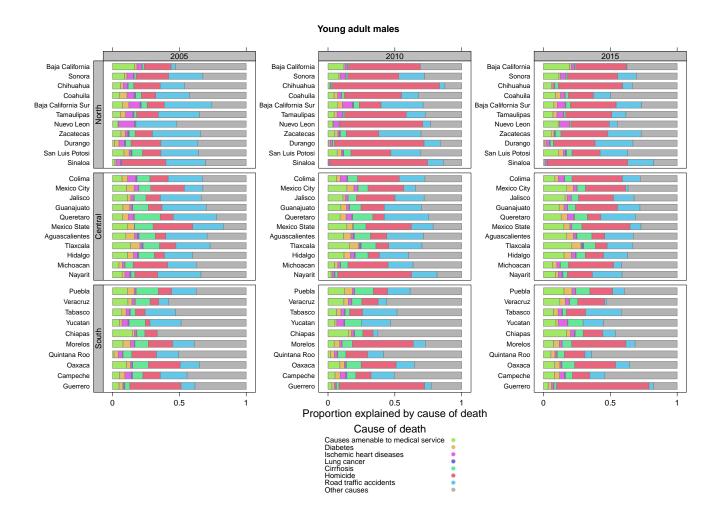


Figure 17: Proportion by cause of death from benchmark mortality for older male adults (ages 50-84). Source: own calculations.

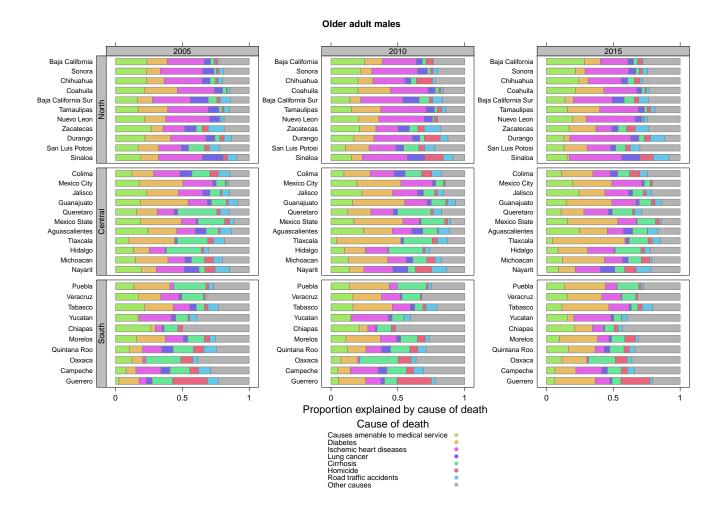


Figure 18: Proportion by cause of death from benchmark mortality for older female adults (ages 50-84). Source: own calculations.

