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ORIGINAL ARTICLE

Cardiovascular disease in Mexico 1990–2017: secondary data analysis from the global burden of disease study

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Abstract

Objectives Cardiovascular diseases (CVD) are a major cause of death and a public health threat. To report the burden of CVD in Mexico at a national and subnational scale from 1990 to 2017 as well as risk factors driving these changes.

Methods Following the 2017 global burden of disease study, mortality, disability-adjusted life-years (DALYs), and risk factors of CVD were examined according to 10 subcategories.

Results The CVD burden of disease decreased between 1990 and 2017 in Mexico as a whole and in all states, with the higher decrease located in the north and central regions. Ischemic heart disease accounted for almost two-thirds of the total number of deaths from CVD and caused the highest DALY rate. The leading CVD risk factors were high systolic blood pressure, dietary risks, high LDL cholesterol, high BMI, and high fasting plasma glucose level.

Conclusions These results allow the establishment of priorities, policy development, and implementation to decrease the CVD burden and can provide a benchmark for states to focus on key risk factors, improve the quality of health care, and reduce health care costs.

Keywords Cardiovascular diseases · Mexico · Burden of disease · Mortality

Introduction

Cardiovascular diseases (CVD) are a major cause of death worldwide and a public health threat that have reached epidemic proportions (Gupta et al. 2016). Globally, total deaths from CVD increased 21.1% between 2007 and 2017, but death rates decreased (Collaborators 2018a). Over 80% of CVD deaths occur in low- and middle-income countries (Mensah et al. 2015). Among CVD, ischemic heart disease (IHD) and stroke accounted for almost 85% of all CVD deaths in 2017. Deaths from both these causes have recently increased, while mortality rates from rheumatic heart disease decreased (Collaborators 2018a).

The United Nations General Assembly recognized the importance of CVD by including in the Sustainable Development Goals (SDG) a target to reduce premature mortality from non-communicable diseases (NCD) by one-third (Nations 2019). To improve cardiovascular health at both national and subnational levels, and to effectively reduce the CVD burden, it is necessary to provide decision makers with current information that allows them to focus resources where they are most needed (Liu et al. 2019) and areas where more targeted policy attention might be required (Gomez-Dantes et al. 2016) in order to achieve the SDG target. The main CVD risk factors include unhealthy diets, physical inactivity, heavy alcohol consumption, and tobacco use. There is evidence that these lifestyle risk factors are related to hypertension, increased levels of body mass index, cholesterol, and type-2 diabetes. These metabolic risk factors are, in turn, independent precursors of CVD (Jagannathan et al. 2019).

In Mexico, CVD have been a major cause of death since 1990, with a mortality rate of 196 deaths per 100,000 that year. The Global Burden of Disease (GBD) study estimated that CVD accounted for 22.7% of all deaths in Mexico and 10.3% of DALYs (GBD-2017 2018b). From 2007 to 2017,

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deaths from CVD increased 51.1%, while the age-standardized mortality rates increased from 145 to 153 deaths per 100,000. IHD, stroke and hypertensive heart disease accounted for 90% of all CVD deaths in 2017 (GBD-2017 2018b).

To the best of my knowledge, there is no recent comprehensive research on the national and subnational mortality and burden of CVD in Mexico. The GBD study produces comprehensive and comparable estimates of the incidence, prevalence, mortality, risk factor exposure, mortality, and morbidity attributable to these risks by cause, age, sex, across countries and over time using a highly standardized analytical approach that despite different collection methods allows deeper understanding of the countries' performance (Disease et al. 2018). In this paper, I aimed to report the findings from the GBD-2017 study on CVD in Mexico at a national and subnational scale from 1990 to 2017, and to assess the association between CVD burden and the sociodemographic index (SDI). These results may help to better understand the CVD burden in Mexico, to identify gaps between states and the interventions needed to control these diseases.

Methods

The GBD-2017 covered 195 countries, 21 regions, and seven super-regions from 1990 to 2017. The study included 359 diseases and injuries, 3484 sequelae, and 84 risks or combinations of risks factors by age and sex (Collaborators 2018a, c). Specific descriptions of the general methodological approach of the GBD-2017 and the particular methods used for CVD analysis have been presented elsewhere (Collaborators 2018a; DALYs and Collaborators 2018; Disease et al. 2018). In brief, the GBD study employs corrections made for misclassification, miscoding, and under-reporting that use evidence from medical literature, expert opinions, and statistical techniques to assign the most probable causes of death to each entry (Murray and Lopez 2017). It redistributes garbage codes and deaths with non-specific codes to the most likely causes of death using methods detailed elsewhere (Collaborators 2018a). CVD mortality data comes from surveys, sample registrations, and vital registration systems (Gomez-Dantes et al. 2016), which in Mexico had an analogous trend as official data. Non-fatal data comes from primary literature, surveys, and epidemiological surveillance, containing disease prevalence, incidence, mortality risk, duration, remission, severity (Disease et al. 2018), or risk–outcome pairs (Collaborators 2018d).

The International Classification of Diseases-10 codes used by the GBD for modeling the ten major CVD are: rheumatic heart disease (RHD) (codes I01-I01.9, I02.0, I05-I09.9), ischemic heart disease (I20-I25.9), stroke (G45-G46.8, I60-I63.9, I65-I66.9, I67.0-I67.3, I67.5-I67.6, I68.1-I68.2, I69.0-I69.3), hypertensive heart disease (HHD) (I11-I11.9), non-rheumatic valvular heart disease (NRHD) (I34-I37.8) cardiomyopathy and myocarditis (CM) (B33.2, I40-I41.9, I42.1-I42.8, I43-I43.9, I51.4), atrial fibrillation and flutter (AFF) (I48-I48.92), aortic aneurysm (I71-I71.9), peripheral vascular disease (PVD) (I70.2-I70.799, I73-I73.9), endocarditis (A39.51, I33-I33.9, I38-I39.9), other cardiovascular and circulatory diseases (OCCD) (I28-I28.8, I30-I31.1, I31.8-I32.8, I47-I47.9, I51.0-I51.3, I68.0, I72-I72.9, I77-I83.9, I86-I89.0, I89.9, I98, K75.1) (2017-GBoDS 2018).

Standard methods of the GBD-2017 study were used to estimate mortality, DALYs and the burden attributable to the main CVD risk factors for all available age groups (Collaborators 2018a; Disease et al. 2018; Foreman et al. 2018). I report the point estimates and 95% uncertainty intervals (95% UI) which account for the uncertainty accrued in the varied availability of data, model specifications, and variability of sample size within data sources (Collaborators 2018a). Differences in estimates were considered significant if 95% UIs did not overlap (Roth et al. 2018). The rates were age standardized via the direct method applying the GBD global-age structure (based on the UNPOP World-Population-Prospects) that allows comparisons over time and states regardless of the size and age structure of the Mexican population. DALYs were calculated with the information on premature death (YLL) and disability caused by CVD (YLD) (Collaborators 2018c; DALYs and Collaborators 2018). The YLL are a measure of premature death that is calculated by multiplying the number of deaths from each cause in each age group by the reference life expectancy at the average age of death of those who died in the age-group (Gomez-Dantes et al. 2016). The YLD were obtained as the product of the estimated prevalence of CVD and a comorbidity-adjusted disability weight (Collaborators 2018a). The comorbidity weights of different diseases were calculated using DisMod-MR 2.1, a meta-analysis tool that simulates 40,000 individuals to obtain the distribution of comorbid conditions on the basis of the expected distribution of each condition's sequelae in the population (Disease et al. 2018). The individual risk–outcome pairs were estimated using: the DALYs, the exposure levels for the risk factor, the theoretical minimum risk exposure level (TMREL) and the relative risk of the outcome relative to the TMREL. For the risk–outcome pairs, the estimated attributable DALYs are obtained as the DALYs for the outcome multiplied by the population attributable fraction (PAF). The PAF is the proportion by which the outcome would be reduced if the exposure to a risk factor in the past were reduced to the counterfactual level of the TMREL (Collaborators 2018d).

The SDI was used as an estimate of socioeconomic level (Nascimento et al. 2018) that is strongly correlated with health outcomes (GBD-2017 2018a). The SDI-specific methodology has been provided elsewhere (DALYs and Collaborators 2018; GBD-2017 2018a). In brief, the SDI is the weighted geometric mean of the indices of total fertility rate under the age of 25, mean education for those aged 15 and older, and income per capita. The index has a theoretical minimum level of 0 (achieved with the lowest income, fewest years of schooling, and highest fertility) and a maximum of 1 (attained with the highest income, most years of schooling, and lowest fertility). I carried out a sensitivity analysis using the state marginality index of the National Population Council (CONAPO 2019) in Mexico to compare SDI results.

Results

CVD deaths and national mortality rate

In 2017, CVD were the main cause of death in Mexico. The number of deaths from CVD increased 110% between 1990 and 2017, from 77,103 (95% UI 76,524–77,812) to 161,782 (95% UI 158,672–165,262). The largest relative growth was seen in PVD (336%), followed by NRHD (203%), AFF (186%), and IHD (136%). A significant decline was observed only in RHD, which decreased 31%. The total number of deaths from IHD in 2017 accounted for 62.6% of the total number of CVD deaths, followed by stroke (22.7%).

The CVD age-standardized mortality rate decreased 22%, from 195.7 per 100,000 in 1990 to 152.8 per 100,000 in 2017 (Table 1). This reduction was from 212.2 to 172.2 per 100,000 (18.9%) for men, and from 180.5 to 135.6 per 100,000 (24.9%) for women. However, the age-standardized mortality rate increased since 2007. The top three causes of CVD deaths in 2017 were IHD, stroke, and HHD (age-standardized mortality rates: 95.9, 34.5, and 8.8 per 100,000, respectively). A higher mortality rate among men was observed in all major CVD except in HHD, AFF, endocarditis, and PVD.

CVD mortality rate for Mexico states

Figure 1 shows the standardized CVD mortality rate for Mexican states, in 1990 and 2017 by the ten major CVD. The standardized CVD mortality rate in 2017 was highest in Yucatán, Chihuahua, Sonora, Baja California, and Mexico City (all above 175 deaths per 100,000), and it varied 1.8 times between the states; Guerrero had the lowest rate (115.6 per 100,000). CVD mortality decreased in all states, though it was not homogeneous, being higher (above 30%) in Aguascalientes, Baja California, Sinaloa, Nayarit, Colima, Nuevo León, and Durango (all located in the north and central regions). In contrast, the lowest reductions (below 15%) occurred in Campeche, Yucatan, Guerrero, Chiapas, Mexico City, Veracruz, and Quintana Roo, most of them located in the southern and southeastern regions. The top three causes of CVD deaths in all states were: IHD representing as much as a 68.9% of total CVD mortality in Sonora and as less as 54.5% in Tlaxcala; stroke, with a maximum of 27.6% in Oaxaca and minimum of 17.5% in Sonora; and HHD that varied from 2.9% (in Yucatan) to 8.8% (in Oaxaca). The other CVD causes of death represented less than 5% of total CVD mortality in all states.

National CVD DALY rate

The CVD age-standardized DALY rate per 100,000 decreased 21.4% from 3643.1 (95% UI 3544.3–3757.3) in 1990 to 2862.0 (95% UI 2755.7–2986.5) in 2017 (Table 1)—compared to a 5.7% reduction in the age-standardized DALY rate for all other NCD. However, the age-standardized DALY rate has also increased since 2007 (Online-Resource 1). The CVD age-standardized DALY rate for men was 1.45 times higher than for women in 2017, and only decreased 15.5% compared to women (28%). By cause, IHD caused the highest DALY rate both in men (2120.7 per 100,000) and women (1163.1 per 100,000), followed by stroke, HHD, OCCD, and AFF. Between 1990 and 2017, the age-standardized DALY rate from NRHD, CM, PVD, and AFF increased for both sexes; while the other CVD causes decreased.

CVD DALY rates for Mexico states

Figure 2 shows the CVD age-standardized DALY rates in Mexico's states in 2017 by sex. As shown, DALY rates were higher for men in all states. IHD burden was almost twice as great for men compared to women in most states. The age-standardized DALY rate for aortic aneurysm was at least three times as higher for men in all states. The disease burden for stroke, NRHD, CM, and endocarditis was also higher for men, while for women RHD, HHD, and PVD had higher DALY rates. The patterns of states with higher and lower rates of age-standardized CVD DALYs are similar for both sexes. For example, Tlaxcala, Aguascalientes, and Nayarit were among the states with the lower CVD DALY rate, while Yucatan, Mexico City, Chihuahua, and Sonora had the highest rates experienced by both sexes.

Table 1 Age-standardized mortality rates and disability-adjusted life years (DALYs) rates for cardiovascular disease subcategories and their percentage change in Mexico, 1990 and 2017. *Source*: Authors' elaboration based on the Institute for Health Metrics and Evaluation (2017)

Subcategory	Age-standardized mortality rate (95% UI), per 100,000			Age-standardized DALY rate (95% UI), per 100,000		
	1990	2017	%	1990	2017	%
All CVD						
Male	212.2 (210.1, 214.4)	172.2 (167.1, 177.1)	− 18.9	4048.8 (3951.0, 4162.6)	3419.6 (3297.2, 3560.7)	− 15.5
Female	180.5 (178.6, 182.4)	135.6 (132.6, 138.5)	− 24.9	3265.1 (3159.6, 3380.9)	2361.8 (2257.5, 2487.1)	− 27.7
Total	195.7 (194.3, 197.6)	152.8 (149.8, 156.2)	− 21.9	3643.1 (3544.3, 3757.3)	2862.0 (2755.7, 2986.5)	− 21.4
Rheumatic heart disease						
Male	2.6 (2.5, 2.7)	0.8 (0.8, 0.9)	− 67.9	89.6 (83.6, 96.4)	33.8 (29.6, 39.3)	− 62.2
Female	4.2 (4.0, 4.4)	1.2 (1.2, 1.4)	− 70.0	147.5 (139.4, 157.9)	47.7 (42.2, 55.1)	− 67.6
Total	3.4 (3.3, 3.5)	1.1 (1.0, 1.1)	− 69.0	119.4 (113.1, 127.2)	41.2 (36.4, 47.5)	− 65.5
Ischemic heart disease						
Male	128.9 (126.6, 131.0)	114.4 (109.8, 118.8)	− 11.2	2327.5 (2278.9, 2378.3)	2120.7 (2040.7, 2203.5)	− 8.9
Female	95.2 (93.2, 98.9)	79.6 (75.4, 82.2)	− 16.4	1480.1 (1433.4, 1537.0)	1163.1 (1104.6, 1209.4)	− 21.4
Total	111.2 (109.6, 113.6)	95.9 (92.3, 98.8)	− 13.8	1887.7 (1848.3, 1937.4)	1614.4 (1559.5, 1671.6)	− 14.5
Stroke						
Male	54.7 (53.5, 56.2)	36.6 (35.0, 37.9)	− 33.1	1030.0 (996.3, 1061.1)	738.0 (707.5, 769.2)	− 28.3
Female	52.7 (51.4, 54.7)	32.6 (30.8, 33.7)	− 38.2	1008.1 (967.8, 1047.7)	632.9 (599.3, 668.9)	− 37.2
Total	53.7 (52.8, 55.2)	34.5 (33.2, 35.4)	− 35.8	1019 (987.0, 1050.4)	683.1 (655.5, 712.8)	− 33.0
Hypertensive heart disease						
Male	10.1 (7.3, 11.1)	7.3 (5.8, 8.8)	− 28.0	158.6 (120.3, 175.6)	119.9 (97.6, 147.5)	− 24.4
Female	14.8 (9.5, 17.4)	10.0 (7.4, 14.8)	− 32.5	237.1 (157.4, 278.2)	163.2 (131.7, 233.0)	− 31.2
Total	12.7 (9.4, 14.5)	8.8 (7.2, 11.6)	− 30.7	200.2 (155.4, 225.9)	143.5 (126.9, 186.0)	− 28.3
Non-rheumatic valvular heart disease						
Male	0.9 (0.8, 1.0)	1.1 (0.8, 1.1)	16.4	23.3 (21.0, 26.3)	26.5 (20.5, 29.3)	13.9
Female	0.6 (0.5, 0.7)	0.8 (0.5, 0.8)	30.9	16.0 (13.9, 19.0)	18.7 (14.2, 21.1)	16.9
Total	0.7 (0.7, 0.8)	0.9 (0.7, 1.0)	22.3	19.5 (17.8, 22.3)	22.4 (18.0, 24.6)	14.9
Cardiomyopathy and myocarditis						
Male	1.5 (1.4, 1.9)	1.7 (1.5, 1.9)	12.5	53.3 (50.0, 68.2)	64.5 (54.8, 69.6)	21.0
Female	1.0 (1.0, 1.0)	1.1 (1.1, 1.2)	12.2	35.5 (33.7, 37.6)	42.6 (40.0, 45.4)	20.1
Total	1.2 (1.2, 1.4)	1.4 (1.3, 1.5)	11.9	44.2 (41.8, 51.1)	53.2 (49.0, 56.5)	20.4
Atrial fibrillation and flutter						
Male	4.3 (3.6, 5.1)	3.9 (3.4, 4.7)	− 8.8	103.4 (84.2, 126.3)	103.7 (83.7, 126.8)	0.3
Female	5.0 (4.8, 5.2)	5'.0 (4.8, 5.4)	0.5	102.0 (86.7, 120.9)	104.6 (88.5, 123.8)	2.5
Total	4.7 (4.4, 5.1)	4.5 (4.3, 5.0)	− 3.2	102.8 (85.6, 123.4)	104.3 (86.4, 125.3)	1.5
Aortic aneurysm						
Male	2.2 (2.2, 2.3)	1.5 (1.4, 1.6)	− 31.4	38.1 (36.8, 39.5)	27.2 (25.6, 28.7)	− 28.7
Female	0.5 (0.5, 0.5)	0.5 (0.4, 0.5)	− − 7.3	10.2 (9.8, 10.6)	8.6 (8.1, 8.9)	− 15.8
Total	1.3 (1.3, 1.4)	1.0 (0.9, 1.0)	− 26.8	23.4 (22.7, 24.1)	17.2 (16.4, 17.9)	− 26.4
Peripheral artery disease						
Male	0.5 (0.2, 0.9)	0.6 (0.3, 1.3)	23.9	15.7 (9.4, 24.8)	16.5 (9.5, 26.7)	5.3
Female	0.5 (0.2, 1.0)	0.9 (0.3, 2.4)	78.8	16.0 (8.6, 26.2)	19.5 (10.1, 37.1)	22.3
Total	0.5 (0.2, 0.8)	0.8 (0.4, 1.7)	52.7	15.8 (9.5, 24.9)	18.1 (10.5, 30.5)	14.5
Endocarditis						
Male	0.6 (0.6, 0.7)	0.7 (0.6, 0.7)	3.3	24.3 (22.9, 25.8)	23.6 (21.8, 26.0)	− 3.0

Table 1 (continued)

Subcategory	Age-standardized mortality rate (95% UI), per 100,000			Age-standardized DALY rate (95% UI), per 100,000		
	1990	2017	%	1990	2017	%
Female	0.6 (0.4, 0.9)	0.6 (0.5, 1.0)	− 5.7	22.9 (14.0, 31.9)	19.3 (15.0, 32.4)	− 15.5
Total	0.6 (0.5, 0.8)	0.6 (0.6, 0.9)	− 1.4	23.6 (18.8, 27.9)	21.4 (19.1, 29.0)	− 9.3
Other cardiovascular and circulatory diseases						
Male	5.8 (5.6, 6.1)	3.6 (3.3, 3.8)	− 39.0	185.1 (167.7, 208.4)	145.2 (124.8, 171.6)	− 21.5
Female	5.4 (5.1, 5.6)	3.3 (3.1, 3.5)	− 38.6	189.8 (166.8, 217.9)	141.6 (118.1, 172.1)	− 25.4
Total	5.6 (5.4, 5.8)	3.4 (3.2, 3.6)	− 38.7	187.5 (167.3, 213.2)	143.3 (121.8, 171.8)	− 23.5

Influence of the risk factors on CVD

In 2017, the leading risk factors that contributed to the CVD DALYs age-standardized rate (Fig. 3) were high systolic blood pressure (HSBP) (1423.8, 95% UI 1261.7–1589.1), dietary risks (1397.9, 95% UI 1249.6–1563.3), high LDL cholesterol (887.9, 95% UI 739.7–1033.0), high BMI (883.4, 95% UI 592.1–1175.3), and high fasting plasma glucose (HFPG) (824.0, 95% UI 611.8–1122.9). Other notable risks that made up smaller proportions of CVD DALYs were low physical activity, alcohol use, tobacco, air pollution, and other environmental risks. As a whole, the burden of all risk factors on CVD decreased from 1990 to 2017 (Online-Resource 2). However, this burden increased since 2007 except for alcohol and tobacco use, air pollution, and other environmental risks. While dietary risks and HSBP were the leading risk factors for CVD in all states in 1990, an elevated BMI, high LDL cholesterol, and HFPG became greater contributors in 2017, and tobacco use became a lesser contributor to CVD burden overtime.

Sociodemographic index and CVD burden

In all Mexican states, the SDI increased and the CVD age-standardized DALY rates decreased (Fig. 4). States with a higher SDI, tended to have a higher DALY rate. In 1990, there was a positive correlation between CVD DALY rates and the SDI ($r_{1990} = 0.59$; p value < 0.000), but a weaker correlation occurred in 2017 ($r_{2017} = 0.30$; p value $= 0.095$). The sensitivity analysis also shows a weak correlation between the marginality index and the CVD burden ($r_{1990} = 0.58$; p value < 0.000; $r_{2017} = 0.31$; p value $= 0.085$). Aguascalientes, Sinaloa, Baja California, and Nuevo Leon had the highest decrease in CVD burden; some of them reached the levels observed in states with the smallest burden of CVD in 1990. Despite an overall decrease in the CVD age-standardized DALY rates in all states, half of Mexico's states presented an increase since 2007. Furthermore, CVD burden has increased more than 15% since 2007 in Campeche, Quintana Roo, Yucatan (located in the Yucatan peninsula), and Morelos.

Discussion

This study presents a comprehensive analysis of the CVD burden of disease in Mexico. The number of deaths from CVD increased. IHD accounted for almost two-thirds of total deaths from CVD in 2017, followed by stroke, and HHD. The CVD mortality and DALY rates decreased nationally and in all states in the period as a whole, but they have increased since 2007. The CVD burden was higher for men and IHD caused the highest DALY rate. The leading risk factors that contributed to the CVD DALYs age-standardized rate were HSBP, dietary risks, high LDL cholesterol, high BMI, and HFPG. All states had an increase in the SDI and a decrease in the CVD age-standardized DALY rates between 1990 and 2017, but with a weak correlation between both indicators.

The CVD burden of disease decreased around 22% between 1990 and 2017, but has increased since 2007. This trend is consistent with those observed in some high-income regions (Roth et al. 2017), India (Prabhakaran et al. 2018) and the Sub-Saharan Africa, where CVD burden is no longer declining (Mensah et al. 2015). However, this trend differs from the recent reduction observed in Portuguese-speaking countries (Nascimento et al. 2018), the Eastern Mediterranean Region (Collaborators 2018b), and China (Liu et al. 2019). The initial decrease in CVD burden in Mexico could be related to high-impact strategies aimed to improve CVD medical treatments (Rosas-Peralta et al.

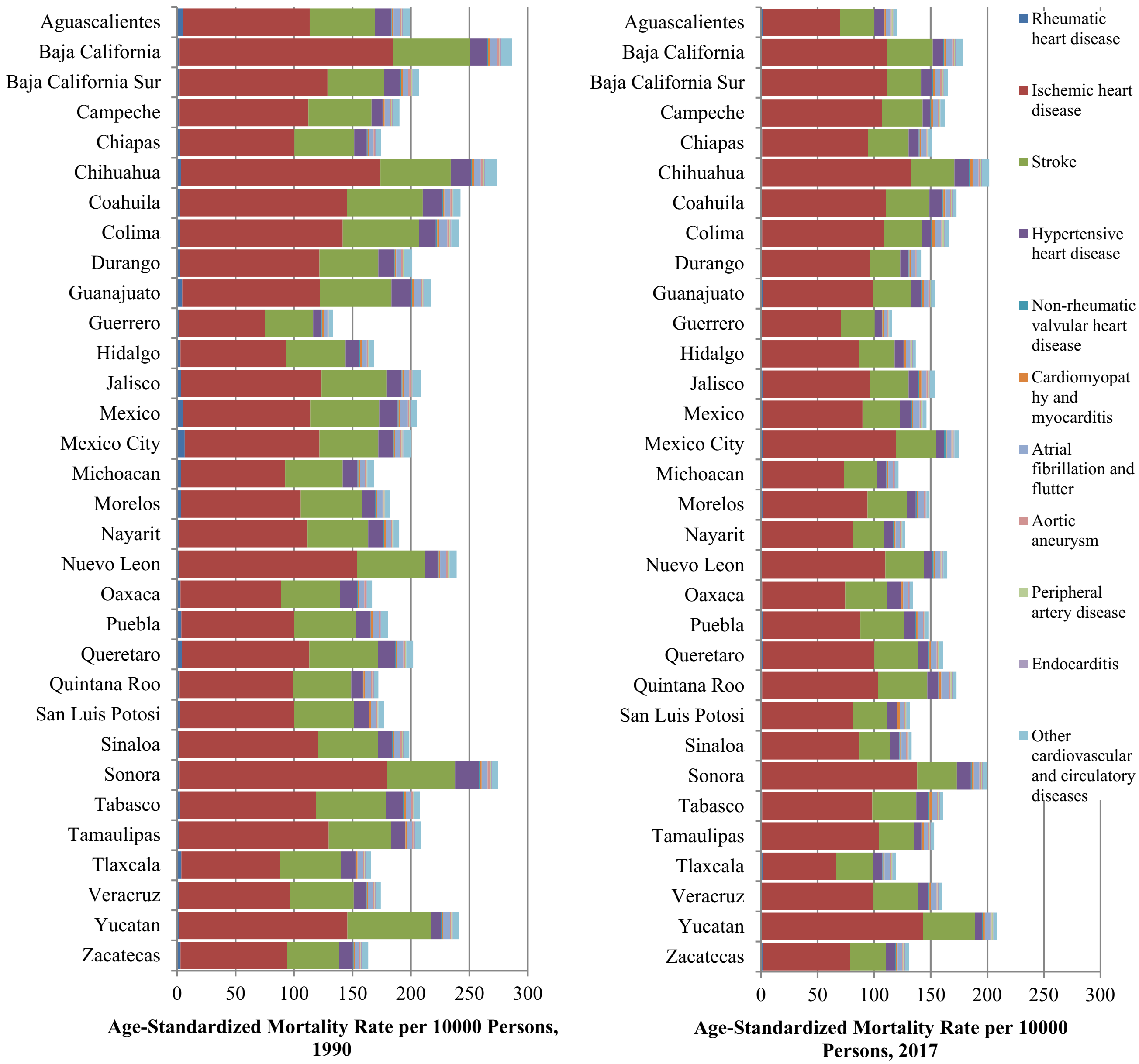

Fig. 1 Age-standardized cardiovascular disease (CVD) mortality rates per 100,000 persons by state, Mexico 1990 and 2017. *Source*: Authors' elaboration based on the Institute for Health Metrics and Evaluation (2017)

2017). But, the recent increase could be associated with sociodemographic changes such as gradual population aging (making CVD more prevalent) (Moran et al. 2014), unplanned urbanization and lifestyle changes (Gulland 2016).

IHD, stroke, HHD, and OCCD presented the highest burden of disease, as in other studies worldwide (Collaborators 2018b; Liu et al. 2019; Nascimento et al. 2018; Prabhakaran et al. 2018; Roth et al. 2018). Declines in DALY rates from IHD, stroke, and HHD accounted for most of the improvement in the CVD burden of disease from 1990 to 2007 as in other contexts (Moran et al. 2014). Yet, since 2007 the burden from IHD and HHD increased as seen in other studies (Arroyo-Quiroz et al. 2020; Pagan et al. 2017). The increase in PVD, AFF, CM, and NRHD burden, also observed in other studies (Liu et al. 2019; Mensah et al. 2015), needs better monitoring to revert the negative trend in the burden of disease from these CVD causes.

Mexico has experienced an overall improvement in living standards, but with profound social inequalities among regions (Beltran-Sanchez and Crimmins 2013) that affect health care access and hinder further health gains (Gomez-Dantes et al. 2016). Mexico also displays a mixed

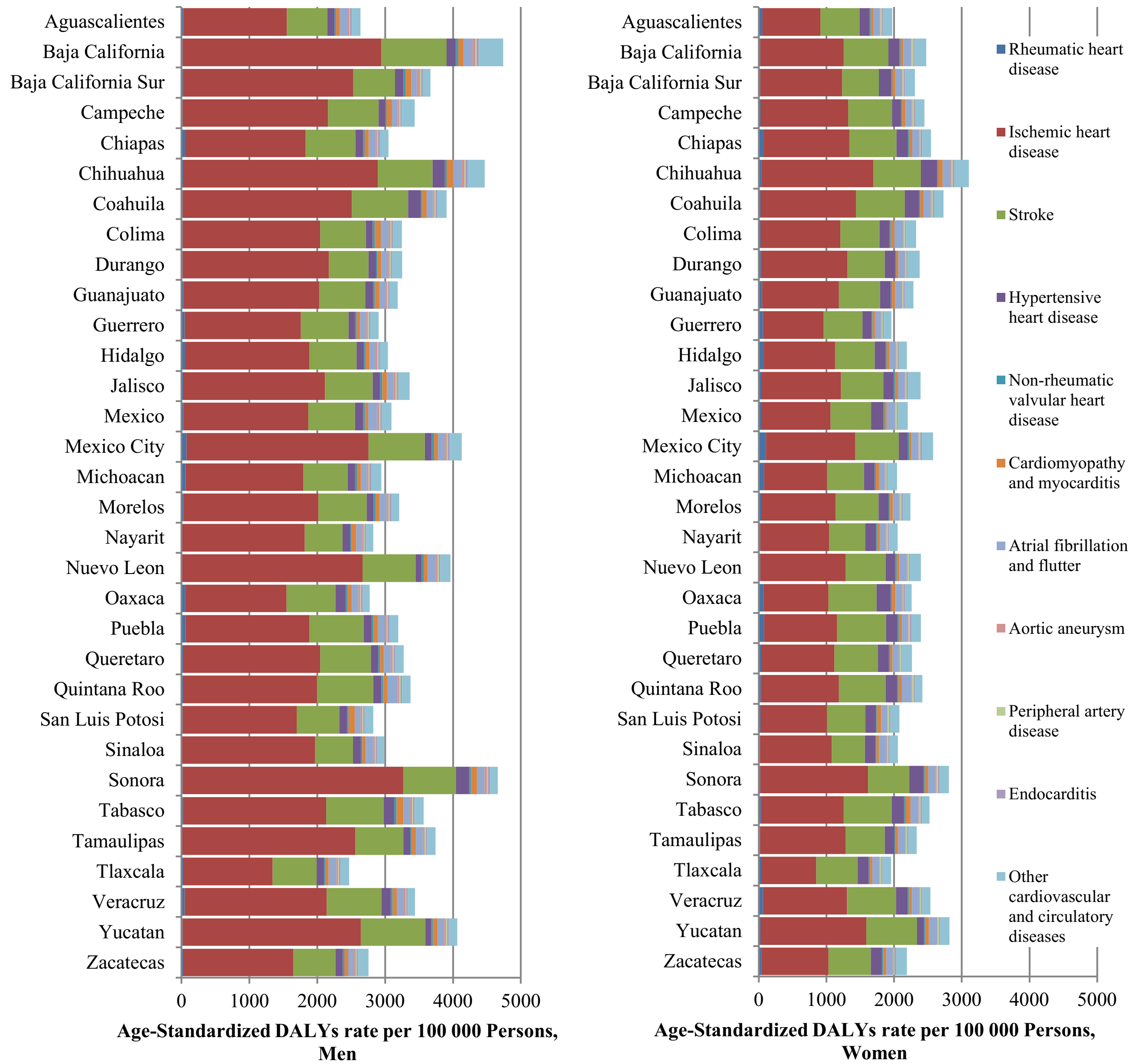

Fig. 2 Age-standardized cardiovascular disease (CVD) disability-adjusted life years (DALYs) rates per 100,000 persons by state, Mexico 2017. *Source*: Authors' elaboration based on the Institute for Health Metrics and Evaluation (2017)

epidemiological profile characterized by the coexistence of NCD, communicable diseases, and violence (Parra-Rodriguez et al. 2019), as well as a transformation in its food system implemented under the North American Free Trade Agreement (Gálvez 2018) that changed nutritional patterns, rose sugar, and saturated fat consumption, decreased the intake of fruits, vegetables, and whole grains, which contributed to an increase in NCD (Beltran-Sanchez and Crimmins 2013). This scenario is reflected in the still lingering gaps in CVD burden between states regardless of some improvements. In all states IHD, stroke, HHD, and OCCD accounted for the largest burden CVD. The results show that it has taken 27 years for states with the highest burden of CVD to achieve levels observed among those states with the smallest burden in 1990. These differences are likely the result of different exposures to CVD risk factors and access to effective health care interventions (Chow et al. 2013). It is worth noting that Mexico's health system has a high institutional fragmentation, insufficient funding, inefficient administration, segmented care provided by public and private institutions, and high out-of-pocket spending (Parra-Rodriguez et al. 2019). The increase in CVD burden observed in half of Mexico's

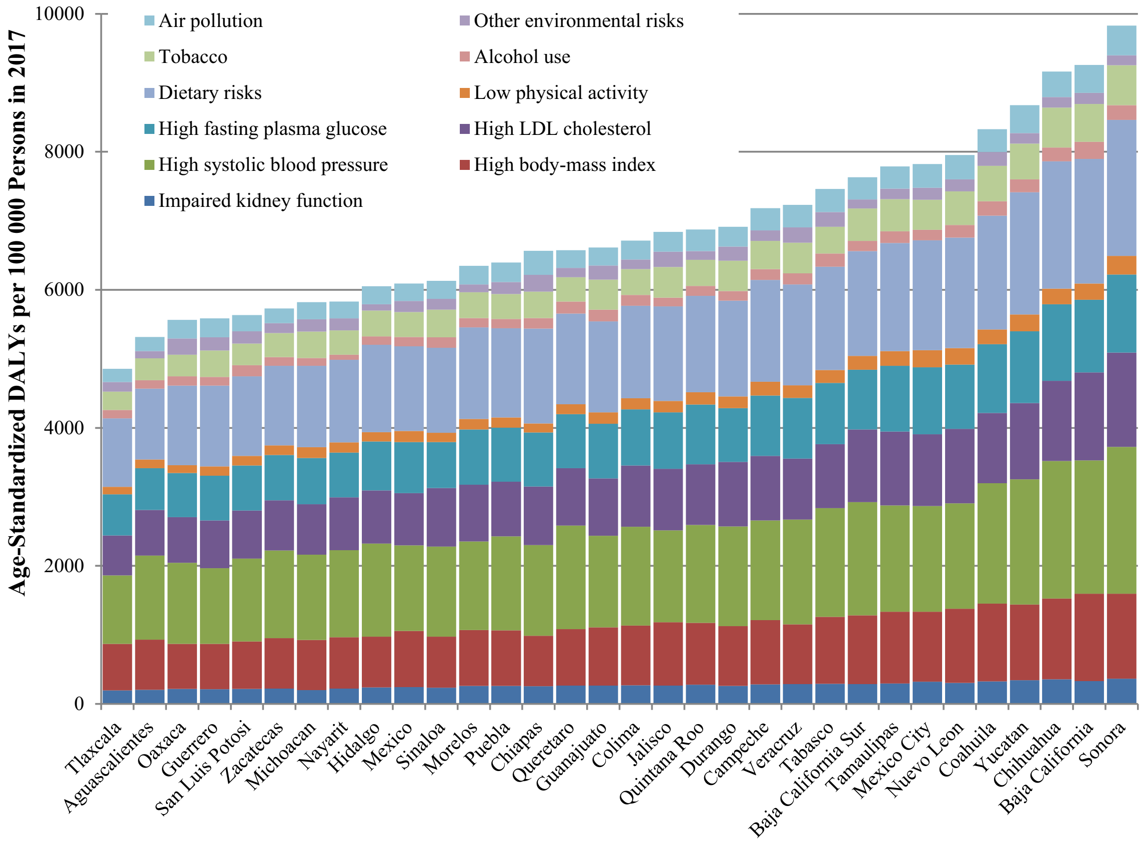

Fig. 3 Age-standardized cardiovascular disease (CVD) disability-adjusted life years (DALYs) per 100,000 persons attributable to risk factors by state, Mexico 2017. *Source*: Authors' elaboration based on the Institute for Health Metrics and Evaluation (2017)

states since 2007 is concerning and suggests that the long-term decline in CVD may be reversed.

HSBP is the most important risk factor for CVD, followed by dietary risks, high total cholesterol, HFPG, and high BMI (Collaborators 2018b; Nascimento et al. 2018; Prabhakaran et al. 2018; Roth et al. 2018). CVD DALYs attributed to HSBP decreased as in other regions (Jagannathan et al. 2019). However, since 2007, a reversal of this trend was observed. The recent data show a national self-reported prevalence of arterial hypertension of 18.4% in adults 20 years or older (Health 2019). This prevalence was 11.4% in 1993 (Villalpando et al. 2010) and 16.8% in 2000 (Gutierrez et al. 2016) which paired with poor disease control, delayed detection, and a high percentage of undiagnosed cases represents a significant challenge for the Mexican health system (Jagannathan et al. 2019). Dietary risks were the second leading CVD risk factor in Mexico as in other regions (Jagannathan et al. 2019). The results from the National Health and Nutrition Survey of 2018 (NHNS) demonstrate a high prevalence of unhealthy dietary patterns characterized by elevated intakes of processed foods and sugar-sweetened beverages, and lower intakes of healthy foods such as fruits, legumes, and vegetables (Health 2019). It has been consistently demonstrated that higher fruit and vegetable consumptions are associated with a lower CVD risk (Joseph et al. 2017). Some efforts have been implemented to address some of the dietary risks, like the sugar-sweetened beverage tax policy which is expected to reduce the impact of CVD (Basto-Abreu et al. 2019).

High blood cholesterol is one of the main CVD risk factors (Collaborators 2018b; Nascimento et al. 2018; Prabhakaran et al. 2018; Roth et al. 2018) in Mexico, with almost a third of CVD DALYs attributable to this risk factor (GBD-2017 2018b). The prevalence of high cholesterol in Mexican adults 20 years or older was 19.5% in 2018 with almost half the population being untested (Health 2019), which is an important increase from 1993 (8.9%) (Villalpando et al. 2010). This higher prevalence could be related to unhealthy dietary patterns (Acosta-Cazares and Escobedo 2010). HFPG and diabetes are other important CVD risk factors (Gutierrez et al. 2016) that in many cases go undiagnosed. Diabetes prevalence has gradually increased in Mexico for the last 20 years (6.7% in 1993 to 10.3% in 2018), ranking among the highest worldwide (Gonzalez-Villalpando et al. 2014). Thus, the CVD burden of disease could further increase unless improved management of diabetic macrovascular

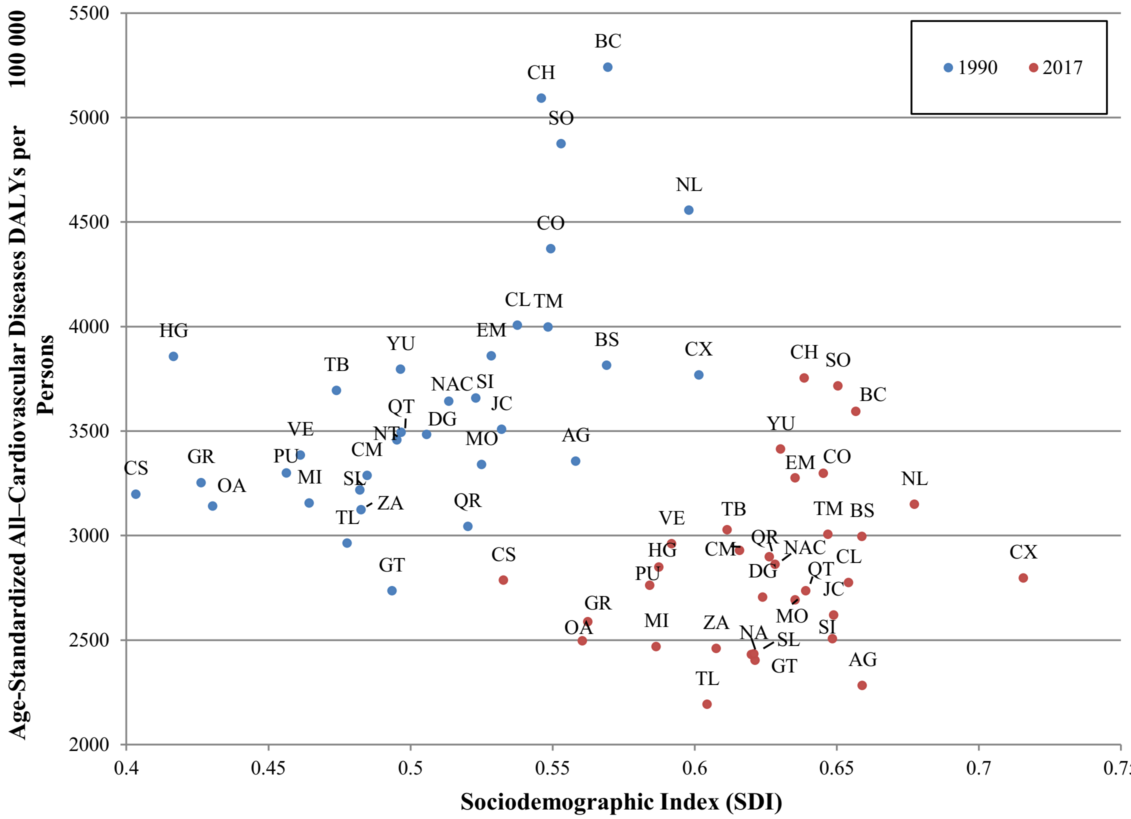

Fig. 4 Scatterplot of age-standardized cardiovascular disease disability-adjusted life years (DALYs) per 100,000 persons and sociodemographic index (SDI): Mexico's states 1990 and 2017. *AG Aguascalientes, BC Baja California, BS Baja California Sur, CM Campeche, CS Chiapas, CH Chihuahua, CO Coahuila, CL Colima, CX Ciudad de Mexico, DG Durango, GT Guanajuato, GR Guerrero, HG Hidalgo, JC Jalisco, EM Mexico, MI Michoacan, MO Morelos, NA Nayarit, NL Nuevo Leon, OA Oaxaca, PU Puebla, QT Queretaro, QR Quintana Roo, SL San Luis Potosi, SI Sinaloa, SO Sonora, TB Tabasco, TM Tamaulipas, TL Tlaxcala, VE Veracruz, YU Yucatan, ZA Zacatecas. *Source*: Authors' elaboration based on the Institute for Health Metrics and Evaluation (2017)

complications is achieved in Mexico (Jagannathan et al. 2019). Obesity is another CVD risk factor related to modifiable lifestyle behaviors such as unhealthy dietary patterns and physical inactivity (Jagannathan et al. 2019). People in Mexico are becoming more and more obese, with one of the highest prevalence worldwide. The 2018 NHNS shows that 75.2% of Mexican adults are obese or overweight; in 1993 this prevalence was 33% (Health 2019).

CVD burden of disease is also associated with behavioral risk factors such as smoking. Smoking attributable CVD burden has decreased substantially in high-income countries (Jagannathan et al. 2019). A reduction in the DALYs age-standardized rate from CVD was observed in Mexico. This reduction could be explained by the decrease in exposure to tobacco smoking after 1998 (Reynales-Shigematsu 2016). Currently, smoking prevalence is around 11.4% in adults 20 years or older (Health 2019). Tobacco control can reduce the consumption of tobacco. Thus, Mexico should implement the WHO Framework Convention for Tobacco Control within a short period (Reynales-Shigematsu 2016) to further decrease the CVD burden in Mexico.

Another intriguing finding is that the sociodemographic change over the past 28 years had a weak correlation with CVD age-standardized DALY rates in all Mexican states, with a loss of statistical significance in 2017. The reduction in the CVD disease burden has not followed the improvements in the local sociodemographic conditions. Differences in health care quality between states could explain these results or that some aspects of socioeconomic status may not be well accounted for by the GBD SDI, such as wealth (as opposed to income per capita) (Roth et al. 2018). There is no consensus on whether improvements in the CVD burden are associated with sociodemographic changes. In some studies, a positive correlation between the reduction in age-standardized burden from CVD and the SDI was found (Nascimento et al. 2018; Roth et al. 2017). However, these trends have only been observed in regions with very high SDI, and in most regions, the SDI did not explain the trends observed in the CVD burden (Roth et al. 2017).

The results from the GBD have ample relevance for the continuous reassessment of prevention policies and health promotion. These results allow the establishment of priorities, policy development, and implementation to decrease the CVD burden (Liu et al. 2019). Mexico's health care system has problems properly addressing the health needs of the Mexican population (Gomez-Dantes et al. 2011). Its low performance impairs the existing health policies, preventive programs, primary, and specialized medical services (Parra-Rodriguez et al. 2019). Thus, to improve CVD control Mexico needs an effective health system that focuses on increased investment in CVD prevention and treatment, the implementation of health policies such as the promotion of a healthy lifestyle, access to primary and secondary CVD prevention, and treatment of acute cardiovascular events is essential (Roth et al. 2017). Many CVD risk factors are treatable and are subject to lifestyle changes, which can be improved through public health and education campaigns. Delayed detection and undiagnosed risk factors, especially diabetes and hypertension, are strongly related to CVD burden. Thus, primary CVD prevention should also focus on screening, treatment, and better control of risk factors.

This study is affected by the limitations of the GBD methodology, which have been previously discussed in detail (Collaborators 2018d; DALYs and Collaborators 2018). In brief, mortality and DALY rates are subject to limitations such as the quality of the data sources for all-cause mortality, cause-specific mortality, and disability-weight derivation for CVD (Parra-Rodriguez et al. 2019). Even if Mexico has a good-quality vital registration, data for non-fatal outcomes of CVD are probably under-reported. Thus, DALY rates may be underestimated. The GBD methodology does not capture well the existent social, economic, and ethnic differences between Mexico's states which are frequently associated with health behaviors and risk factors that affect CVD burden (Nascimento et al. 2018). Nevertheless, the GBD methodology offers updated statistical approaches that reduce potential biases in estimating the CVD burden (Murray and Lopez 2017).

Conclusions

The GBD study allows for the identification of public health priorities by using unified and standard methodology, rendering these results comparable across states and time (Liu et al. 2019). The CVD burden of disease decreased, but improved heterogeneously for all states and is, at best, weakly associated with an index of sociodemographic development status. The main CDV risk factors were HSBP, dietary risks, high total cholesterol, HFPG, and high BMI. These results can provide a benchmark for states to focus on key risk factors, improve the quality of health care, and reduce costs (Roth et al. 2018). As Mexico's population is aging, the CVD burden could be expected to increase (Moran et al. 2014) unless effective preventive strategies are urgently implemented aimed mainly to reduce the prevalence of CVD main risk factors.

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Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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