Homicides in Mexico increased inequality of lifespans and slowed down life expectancy gains in 2005-2015
--Manuscript Draft--

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Abstract:	Objectives To quantify the effect of the upsurge of violence on life expectancy and lifespan inequality in Mexico after 2005. Methods Age- and cause-specific contributions to changes in life expectancy and lifespan inequality conditional on surviving to age 15 between 1995 and 2015 were calculated. Homicides, medically amenable conditions, diabetes, ischemic heart diseases, traffic accidents by state and sex were analyzed. Results Male life expectancy at age 15 increased more than twice in 1995-2005 (1.17 years) than in 2005-2015 (0.55 years). Lifespan inequality decreased by more than half a year for males in 1995-2005, while in 2005-2015, the reduction was about four times smaller. Homicides between ages 15-49 had the largest effect on slowing down male life expectancy and lifespan inequality. Between 2005 and 2015, states in the North experienced life expectancy losses, while five states increased lifespan inequality. Conclusions After ten years of the upsurge of violence, Mexico has not been able to reduce the levels homicides to those prior to 2005. Thus, males in Mexico live less, on average, and experience higher uncertainty in their eventual death.
Full Title:	Homicides in Mexico increased inequality of lifespans and slowed down life expectancy gains in 2005-2015
Manuscript Classifications:	17: Epidemiology; 33: Health Policy; 41: Human Rights; 45: Injury/Emergency Care/Violence; 50: Men's Health; 3.004: Adolescent Health
Author Comments:	
Suggested Reviewers:	Alyson van Raalte, PhD Research Scientist, Max-Planck-Institut fur Demografische Forschung vanraalte@demogr.mpg.de Dr. van Raalte is expert on lifespan inequality and, as a demographer, would be suitable to evaluate the methods used in this paper.
	Mark Hayward, PhD Professor, University of Texas at Austin mhayward@prc.utexas.edu Professor Hayward is an expert on public health and epidemiology He would be suitable to assess our manuscript since he has extensive research on health inequalities.
	Vladimir Canudas-Romo, PhD Australian National University vladimir.canudas-romo@anu.edu.au Dr. Canudas-Romo is expert on Latin American health studies, particularly in Mexico.
Response to Reviewers:	

Additional Information:	
Question	**Response**
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Title: Homicides in Mexico increased inequality of lifespans and slowed down life expectancy gains in 2005-2015

September 08, 2018

Prof Alfredo Morabia
Editor-in-Chief,
American Journal of Public Health (AJPH)

Dear Editor,

We are thankful for the opportunity to revise our manuscript entitled "**Homicides in Mexico increased inequality of lifespans and slowed down life expectancy gains in 2005-2015**" for consideration in the *American Journal of Public Health*. We thank the editors and reviewers for their useful comments and valuable recommendations which strengthened our analysis and enhanced the manuscript.

In response to the editors and reviewers' comments, we improved the manuscript as follows:

1. Simplified the presentation of results and reduced the number of figures. The manuscript has only two figures clearly labeled and added one table of results.
2. Incorporated more social and political context in relation to the rise of violence in Mexico after 2005 in the introduction and discussion sections.
3. Further elaborated on changing trends in homicide mortality before and after 2005.
4. Strengthened the discussion on social and public health implications of the impact of homicides in increasing lifespan inequality.
5. Added specific recommendations and future research to further understand the consequences of rising violence on population health on the Mexican and Latin American context.

The revised manuscript clearly shows that after 2005 life expectancy remains stagnant and it has been accompanied by increasing inequality in lifespans among young Mexicans, particularly males. Put simply, Mexican males are not only living shorter lives, on average, but are also facing more uncertainty in their age at death due to the increase in homicidal violence. We suggest that this may have resulted from policies that fail to reduce the burden of violence in Mexico.

A detailed point-by-point response to the editors' and reviewers' comments follows in the next pages.

Thank you for your time and consideration. We look forward to hearing from you.

Sincerely,

José Manuel Aburto
Hiram Beltrán-Sánchez

Reply to editors

We thank the editorial board for the opportunity to revise our manuscript. Our responses to the editors' comments are outlined below in regular font with editor's comments in bold font.

Editor-in-Chief:
Your submitted paper has undergone peer review. Even though the topic is of interest, the paper is very difficult to read for a general public health audience and will not be publishable in this journal if an effort is not made to simplify the presentation of the results. We would be interested in reconsidering a revised version for publication in AJPH that follows the guidance of the reviews provided at the end of this correspondence. Because chances of final acceptance are small, you may prefer to withdraw the paper and submit it to a more specialized journal.

EIC
You have 8 figures but can only have a maximum of 4 figures+tables. Please summarize the findings in less figures and leave the others for the web supplemental files. Make also sure that the figures are properly labeled and the interpretation of the figure is clearly provided in the text. The current figures are extremely difficult to interpret.

Following your suggestion, we reduce the number of figures. We currently have only two figures and added one table of results; the previous figures are now part of the supplemental material. The new figure is properly labeled and we believe it is easier to interpret.

Associate Editor:
This is a timely and relevant article, but it still requires some work before it can be considered for publication. As a general note, the reviewers require more attention to specific details in changing mortality rates in the studies periods, and more contextual information to help interpreting them. Reviewers #1 and #3 in particular provide helpful guidance for revising the manuscript.

We followed the reviewer's suggestions and made several changes to the manuscript. In the next sections, we show our point-by-point reply to reviewers and the steps we took to incorporate those suggestions. We added more context for the upsurge of violence in Mexico during the study period, given the space limitation we kept additional text short and to the point.

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Reply to reviewers

We appreciate the reviewers' comments; their detailed reading of the manuscript and many suggestions that have greatly improved the article. Our responses to the reviewers' comments are outlined below in regular font with reviewer's comments in bold font.

Reviewer #1

The effect of homicide on life expectancy and lifespan inequality is an important public health topic, particularly in the fields of injury prevention and global health. I think this issue is of interest for readers of the American Journal of Public Health, but the data could use some more context. I think describing some of the policies and social context contributing to the increasing homicide rate would help further frame this public health issue.

We thank the reviewer for the valuable suggestions that helped improved the manuscript. Below, we explain how we incorporated more context regarding the data during the period that we study. In addition, we further described some of the policies and social context that had contributed to the increasing homicide mortality.

I also recommend expanding on the discussion, particularly to describe some of the limitations of the study and describing more specific policy recommendations and/or future research that these study results suggest.

We added a subsection where we explain the limitations in our study. We also added specific policy recommendations and future research that would help us understand the several consequences that violence has had on the Mexican population. Below we provide a point-by-point description of our answers.

-Introduction

Although the authors provide more details later in the paper, I would suggest adding at least a sentence in the first few paragraphs about the specific social/political context that contributed to homicide rates doubling between 2007 and 2012 in Mexico, to provide this context upfront.

We thank the reviewer for this suggestion. We have added more context in the introduction. For example, previous evidence has shown that Mexico's wave of violence was triggered by the interactions of competitions between drug cartels, enforcement operations trying to mitigate drug trafficking operations after 2005, and the increased profitability in the flow of drug-trade with United States (Rios, 2013; Dell, 2015; Castillo et al. 2014). This interaction led to a cycle of violence and the spillover onto civilians which by 2017, with the newest available data just released by the Mexican Census Bureau (INEGI), has not ended and has even increased in the last couple of years (Hienle et al. 2017).

We have included in the first paragraph the next sentences:

"…In Mexico, homicides rates declined from 1995 to 2006 but these trends were reversed and homicides more than doubled between 2007 and 2012 (Supplementary Material [SM] figure S1). This increase has been associated with more enforcement operations trying to mitigate drug cartel activities, increased territorial competition, and higher profitability in the drug-trade flow with the United States.[3-5] This led to a cycle of violence- the so-called war on drugs- and the spillover onto civilians which,[6] along with an increasing burden of diabetes, led to stagnating male life expectancy in the period 2000-10.[7]"

References:
Ríos, Viridiana. "Why did Mexico become so violent? A self-reinforcing violent equilibrium caused by competition and enforcement." *Trends in organized crime* 16.2 (2013): 138-155.

Dell, Melissa. "Trafficking networks and the Mexican drug war." *American Economic Review* 105.6 (2015): 1738-79.

Castillo, Juan, Daniel Mejía, and Pascual Restrepo. "Scarcity without leviathan: The violent effects of cocaine supply shortages in the mexican drug war." (2014).

Heinle, Kimberly, Octavio Rodríguez Ferrerira and David A. Shirk. "Drug violence in Mexico: Data and analysis through 2016." *Trans-Border Institute, University of San Diego, San Diego* (2017).

The authors write, "Studying both life expectancy and lifespan inequality adds an important dimension to the study of population health because these indicators represent individuals' decisions based not only on their expected lifetime, but also on the uncertainty in their timing of death." I'm not sure I am correctly understanding what decisions means in this context. Are the authors arguing that these indicators are the consequence of individual decisions?

Thank you for this observation. We clarified those sentences, in particular we noted the difference between the two indicators we used in the paper. For example, life expectancy represents the average age at death if everyone experiences the prevailing deaths rates throughout their lifetime; while lifespan inequality is an indicator of how similar ages at death are. We believe that analyzing both indicators is important because increases in life expectancy are not necessarily accompanied by reductions in lifespan inequality (Sasson 2016). For instance, large inequality of lifespans implies greater uncertainty in the timing of death at the individual level, and thus have implications for the planning of life's events (van Raalte et al. 2011, Sasson 2016). We have rephrased the sentence to make it clearer that we do not mean that these indicators are the consequence of individuals' decisions, but rather individuals consider these indicators when making decisions. It now reads (from line 45):

"…However, life expectancy masks inequality of lifespans or lifespan variation.[10] Variability in age at death (lifespan) is important because it addresses the growing interest in health inequalities[11] and because larger variation in lifespans implies greater uncertainty in the timing of death at the individual level, and has implications for the planning of life's events.[12,13] From a public health perspective…"

References:

Van Raalte, Alyson A., et al. "More variation in lifespan in lower educated groups: evidence from 10 European countries." *International Journal of Epidemiology* 40.6 (2011): 1703-1714.

Sasson I. Trends in life expectancy and lifespan variation by educational attainment: United States,1990–2010. *Demography.* 2016;53(2):269-293.

The authors contrast their focus on "the role of violence" with other literature that "focuses on social determinants of health (e.g., socioeconomic status and health risk factors). Could violence be considered a social determinant of health? I would be interested to hear more about the social context of violence, and the social implications of lifespan inequality, as a public health issue.

We agree with the reviewer that the 'role of violence' and the 'social determinants of health' are not completely contrasting but rather complementing. However, the current manuscript aims at describing the observed changes in homicide mortality and their link with lifespan variation and life expectancy. Our goal is not to explain why there are differences in lifespan variation and life expectancy by sex, or by region. Such an analysis requires the inclusion of additional factors, as those mentioned by the reviewer, and would also require different analytic techniques to identify the sources of variation in life expectancy and lifespan.

We made the following changes to the manuscript to address this issue:
Replaced "Most literature in this area focuses on social determinants of health (e.g., socioeconomic status and health risk factors) as proximate determinants of lifespan variation and health inequality.[11] In contrast, our paper highlights the role of violence, and its ultimate consequence in the form of homicides, among young adults on increasing lifespan inequality."

With "Most literature in this area focuses on the social determinants of health such as socioeconomic status or educational attainment as proximate determinants of lifespan variation and health inequality.[12,14] Our paper highlights the role of violence, and its ultimate consequence in the form of homicides, among young adults on increasing lifespan inequality. We describe the observed changes in homicide mortality and their link with lifespan variation and life expectancy by sex and by region in Mexico."

Discussion; line 242: "Moreover, homicides are the ultimate form of violence but they do not fully represent its burden on population health. As a social determinant of health, exposure to violence can increase the likelihood that young people will perpetrate gun violence,[31] and increases the risk of depression, alcohol abuse, suicidal behavior, and psychological problems, among other detrimental consequences over the life course.[32] Even witnessing violence can affect the wellbeing of the population by increasing rates of post-traumatic stress disorder and depression.[33]"

We also expanded our discussion regarding lifespan inequality and its social implications from a public health perspective. As noted in the paper, lifespan inequality is a marker of heterogeneity at the population level that highlights a primary health indicator: age at death. At the societal level, larger lifespan variation has been linked with increasing vulnerability, which suggest ineffectiveness of policies aiming to protect individuals against life's vicissitudes such as social

safety nets (van Raalte et al. 2011, Bartley et al. 1997). In the context of rising violence, it implies lack of effectiveness of social protection policies aiming at decreasing homicide/crime rates and increasing vulnerability at the population level beyond homicides. For example, in 2016, 66.5% of the population with children under age 18 reported that they did not let them go out because of fear to be a victim of some crime, while 43.6% reported to stop going out at night for the same reason (ENVIPE 2017). Moreover, larger inequality of lifespans underlies greater heterogeneity in population health. This is important because previous evidence highlighted inequalities in adult health between states in Mexico (Aburto et al. 2018); our paper complements this by showing how homicides also increased inequalities in population health within states. Therefore, preventing homicides will contribute significantly to increases in life expectancy as well as greater equality of individual lifespans in Mexico.

We added the next sentences discussing further the social implications of increasing lifespan inequality:

Introduction, from line 48: "From a public health perspective, larger lifespan variation implies increasing vulnerability at the societal level, which suggest ineffectiveness of policies aiming to protect individuals against life's vicissitudes.[12] In the context of rising violence, it implies a failure of social protection policies aiming at decreasing homicide/crime rates and increasing vulnerability at the population level."

Discussion, line 222: "Larger variation in lifespans underlies greater vulnerability at the population level. For example, in Mexico the expected years lived vulnerable of becoming victim of violence increased by 30.5 million person-years between 2005 and 2014.[29] Moreover, increasing inequality of lifespans means larger heterogeneity in population health which translates into the need for more resources to optimize health over the life course.[13]…"

Discussion, line 239: "These results complement previous evidence on adult health inequalities between states[9,22] by identifying homicides as a direct contributor to inequalities in population health between and within states".

Conclusion, line : "Therefore, preventing homicides will contribute significantly to increases in life expectancy as well as greater equality of individual lifespans in Mexico"

References:
Braveman, Paula, and Laura Gottlieb. "The social determinants of health: it's time to consider the causes of the causes." *Public health reports* 129.1_suppl2 (2014): 19-31.

Van Raalte, Alyson A., et al. "More variation in lifespan in lower educated groups: evidence from 10 European countries." *International Journal of Epidemiology* 40.6 (2011): 1703-1714.

Bartley, Mel, David Blane, and Scott Montgomery. "Socioeconomic determinants of health: Health and the life course: why safety nets matter." *BMJ* 314.7088 (1997): 1194.

Canudas-Romo V, Aburto JM, García-Guerrero VM, Beltrán-Sánchez H. Mexico's epidemic of violence and its public health significance on average length of life. *Journal of epidemiology and community health.* 2017;71(2):188-193.

Koh, Howard K., et al. "Healthy people: a 2020 vision for the social determinants approach." *Health Education & Behavior*38.6 (2011): 551-557.

Mikton CR, Butchart A, Dahlberg LL, Krug EG. Global status report on violence prevention 2014. *American journal of preventive medicine*. 2016;50(5):652-9

Davidson JR, Hughes DC, George LK, Blazer DG. The association of sexual assault and attempted suicide within the community. *Archives of general psychiatry*. 1996;53(6):550-5.

Buka SL, Stichick TL, Birdthistle I, Earls FJ. Youth exposure to violence: Prevalence, risks, and consequences. *American Journal of Orthopsychiatry*. 2001;71(3):298-310.

Aburto, José Manuel, Tim Riffe, and Vladimir Canudas-Romo. "Trends in avoidable mortality over the life course in Mexico, 1990–2015: a cross-sectional demographic analysis." *BMJ open* 8.7 (2018): e022350.

Sasson I. Trends in life expectancy and lifespan variation by educational attainment: United States, 1990–2010. *Demography.* 2016;53(2):269-293.

Mexican National Institute of Statistics and Geography (INEGI). Mexican National Survey of Victimization and Perception of Public Safety [In spanish: Encuesta Nacional de Victimización y Percepción sobre Seguridad Pública] (ENVIPE 2017).
http://www.inegi.org.mx/est/contenidos/proyectos/encuestas/hogares/regulares/envipe/

Does the phrase "working ages" refer to a specific age range, or does it mean any age at which a person might work (which could be a very broad age range)?

We clarify this in the text. We now refer to specific ages: people between ages 20 and 65 years. We have replaced the term "working ages" and "middle ages" with "between 20 and 65 years" in the manuscript.

-Methods

If there is supporting literature available, I would recommend adding a citation to focusing on deaths below age 95 "since cause-specific coding practices above that age are less reliable."

We thank the reviewer for this suggestion. We have added Rosenberg's (1999) reference that shows that cause of death classification at older ages is difficult to ascertain due to multi-morbidities. More specifically, to address the reviewer's concern, we re-analyzed the data using cause-of-death data below age 85; this is the standard age cutoff used in the World Health

organization and in the United Nations Population Division cause-of-death and mortality data, respectively. Moreover, about 99% of homicides are concentrated in ages below age 85 in 2017 (INEGI, 2017), thus our estimates do not change in major ways when we change the age in the upper bound. We have updated the results accordingly and found no major changes from the earlier version.

We have added the next sentence in the methods section:
"To mitigate biases due to misclassification of causes of death, we focused on deaths occurring below age 85 since cause-specific coding practices above that age are less reliable due to the presence of comorbidities[22]and about 99% of homicide occurred below this age in the study period."

References
Rosenberg, Harry M. "Cause of death as a contemporary problem." *Journal of the history of medicine and allied sciences* 54.2 (1999): 133-153.

World Health Organization. "WHO mortality database: Tables." *Geneva: WHO* (2018).

United Nations. "World Population Prospects; 2017." *United Nations: Department of Economic and Social Affairs.* (2017).

-Results
"Importantly, homicides declined in 1995-2005 and this contributed to about one-fourth (0.44 years) of the overall gain in life expectancy in this period." Since the authors report that the 1995-2005 gain in life expectancy among men was 1.17 years, I believe they could say about one-third. I think 0.44/1.17=0.376 is closer to one-third than one-fourth.

We have adjusted as suggested. It now reads:
Line 150: "Importantly, homicides declined in 1995-2005 and this contributed to about 38.5% (0.45 years) of the overall gain in life expectancy in this period."

"Life expectancy among males had a larger increase in 1995-2005 than in 2005-2015 across all states (panel A)" Is it possible that Yucatan is an exception to this overall statement? It appears from figure 3, panel A that there was a greater increase in 2005-2015 in Yucatan.

We have made the changes accordingly. It now reads:
"Life expectancy among males had a larger increase in 1995-2005 than in 2005-2015 across all states (panel A) except for Yucatán, some states even experienced reductions in life expectancy in 2005-2015 particularly in the North (e.g., Chihuahua, Nuevo León and Sinaloa)."

pg. 10: "For example conditions amendable to medical service contributed to reductions in lifespan inequality in most states" Looking at Figure 4, in the region of the south it appears that AMS may be contributing to small increases in lifespan inequality in most states of the south in 2005-2015, and some states of the north and central regions as well. It might be worth noting this apparent contrast with 1995-2005.

We thank the reviewer for this observation. Indeed, while for the period 1995-2005 all but two states reduced inequality of lifespan due to medically amenable conditions, by 2005-2015 in nine states these conditions increased lifespan variation. We have adjusted the text accordingly and highlighted this contrast.

We have made the changes accordingly. It now reads:
"In the same period, all but two states for males, Baja California Sur in the North and Tlaxcala in the central region decreased lifespan variation attributed to improvements in medically amenable conditions (SM figures 4 and 5)."

-Discussion

"After 10 years of the beginning of the War on Drugs" I would recommend providing more context for the War on Drugs, describing in at least an additional sentence or two more specifically how it started, the policies and social/political impact. Not all readers of AJPH might be familiar with this important context.

We have followed this suggestion and added more context in the first paragraph of the introduction, as previously suggested by the reviewer:

"…In Mexico, homicides rates declined from 1995 to 2006 but these trends were reversed and homicides more than doubled between 2007 and 2012 (Supplementary Material [SM] figure S1). This increase has been associated with more enforcement operations trying to mitigate drug cartel activities, increased territorial competition, and higher profitability in the drug-trade flow with the United States.[3-5] This led to a cycle of violence- the so-called war on drugs- and the spillover onto civilians which,[6] along with an increasing burden of diabetes, led to stagnating male life expectancy in the period 2000-10.[7]"

Pg. 12 "Rising inequality of lifespans underlies increasing flustered population" I am not quite sure I understand what this means. Might it be possible to re-phrase? I think this point and more generally the discussion of lifespan inequality needs to be made clear and expanded, particularly because this paper's primary contribution seems to be its examination of lifespan inequality, as opposed to how homicides in Mexico have reversed life expectancy gains for men and slowed them for women (as has been previously described in, for example, Aburto et al. 2016, reference #5). So I would be interested to hear more about the public health implications of the lifespan inequality findings and what this suggests about policy and future research.

We have rephrased the sentence. It now reads:
Line 258: "...Larger variation in lifespans underlies greater vulnerability at the population level."

In this revised version, we put more emphasis on the importance of lifespan inequality in the context of rising violence and its public health implications. At the individual level, we found that the most violent states showed grater increases in lifespan inequality through homicides, which can affect long-term decision for individuals. This greater uncertainty could well be one of the determinants of the increase of perceived vulnerability of the population between 2005 and 2014.

Future research should examine if indeed individuals living in states with higher increases in lifespan inequality do perceive higher vulnerability. These studies should focus on women since there exists a sex paradox between being victim of a crime and perceived vulnerability (Canudas-Romo et al. 2017), i.e. males are more likely to experience a crime but they perceived lower vulnerability. In addition, more research is needed to quantify the long-lasting consequences of rising violence in the context of the war on drugs to anticipate and intervene the pathways through which the current violence might affect future health outcomes, as those mentioned in previous points (e.g. depression, suicide, more violence).

In addition to the sentences added in the previous points, we added s small paragraph on future research and policy:

Line 248: "Here, we quantified the effect of rising homicides on longevity and on increasing lifespan inequality as additional consequences of the upsurge of violence in Mexico. However, our understanding of the consequences of violence would benefit from research examining if indeed individuals living in states with increases in lifespan inequality do perceive higher vulnerability and how this might affect their long-term decisions. These studies should also focus on women since females are less likely to experience a crime but they perceived greater vulnerability.[29] In addition, more research is needed to quantify the long-lasting consequences of rising violence in the context of the war on drugs to anticipate and intervene in the pathways through which the current violence might affect future health outcomes. For example, the health system might need to be prepared for mental health issues such as depression, suicidal behavior and post-traumatic stress disorder."

And added in line 258:
"In an international context, Mexico's levels of violence are not even the highest around the globe, nor in the region. Countries in central America, such as El Salvador and Honduras, and Venezuela, Colombia and Brazil in south America have higher homicide rates. It is likely that these countries experience higher variation in lifespans which, along with the existence of high levels of homicides, points to possible failure of policies to reduce the burden of violence. These policies should pay more attention to social determinants of premature mortality, psychosocial factors and get to the root of violence to prevent its diffusion towards the young population"

References:
Canudas-Romo V, Aburto JM, García-Guerrero VM, Beltrán-Sánchez H. Mexico's epidemic of violence and its public health significance on average length of life. *Journal of epidemiology and community health.* 2017;71(2):188-193.

The discussion section needs a brief discussion of some limitations of the paper, for example, the paper does not address means of homicide, or other potential variables beyond gender that may be relevant, such as socio-economic status

We followed this suggestion and added a subsection of limitations:

"First, inaccuracies in cause-of-death practices are likely to be present in the data that we used.[8] To reduce these inaccuracies, we used broad causes of death and adjusted them with a smoothing

process over age to have reliable cause-of-death distributions.[24] Second, our estimated effects of homicides could be a lower bound due to undercounting, underreporting, and the large number of missing individuals.[8] Third, we were not able to disentangle whether a homicide is drug-related (i.e., a homicide resulting from altercations between drug cartels and army operations).Thus, our results provide an upper bound for the possible impact of the war on drugs at the population level. Finally, we were not able to disaggregate deaths by socioeconomic status and other social factors that are closely linked with homicides given that the data is at the aggregate national-level. Future research should try to shed light into the individual-level pathways of violence and its effects on life expectancy and lifespan inequality.[31] This illustrates the need of reliable estimates of mortality by cause of death and population by socioeconomic status and other social factors in Mexico."

References:
Aburto JM, Beltrán-Sánchez H, García-Guerrero VM, Canudas-Romo V. Homicides in Mexico reversed life expectancy gains for men and slowed them for women, 2000–10. *Health Affairs.* 2016;35(1):88-95.

Camarda CG. MortalitySmooth: An R Package for Smoothing Poisson Counts with P-Splines. *Journal of Statistical Software.* 2012;50:1-24.

Braveman P, Gottlieb L. The social determinants of health: it's time to consider the causes of the causes. *Public health reports.* 2014;129(1_suppl2):19-31.

I would like to see more detail and elaboration in the concluding recommendation "Our results from Mexico underscore the need to comprehensively reduce, through public policies and strategies, the impact of violence on population health and in the uncertainty surrounding the age of death" Are there any specific policies or strategies worth mentioning?

We thank the reviewer for this suggestion.

We elaborated further. We note that violence prevention should focus at the individual, family, community and, as we show, at the state level. Previous evidence suggests that school-based efforts; mental health and child welfare programs, educational programs and placement of graduates in jobs, self-employment, and continuing education, together with programs aimed at reducing alcohol consumption have been successful to mitigate violence diffusion (Hoffman et al 2011, Pinker, 2011, Viner et al, 2012). In the Mexican context, political will is essential since it has been shown that policies pursuing drug prohibition or severe suppression have not worked (Csete et al. 2016). Moreover, Mexico has failed to recognize and correct the health and human rights harms that these policies have caused. In this sense, it has been suggested that military forces' participations should be phased out as much as possible since it exacerbates violence with drug traffickers.

We have added the next concluding paragraph:
"Mexico has failed to recognize and correct the detrimental consequences in health and human rights that suppressive and drug-prohibition policies have had on the population.[34] There is an urgent need to stop these policies and complement them with policies that are less focus on military actions against drug cartels. For example, programs on improving regional and schooling

outcomes and educational and community programs to reduce the risk factors of violence (e.g. alcohol consumption)[35] among others. This will prevent homicides and contribute significantly to increases in life expectancy as well as greater equality of individual lifespans in Mexico."

References
Hoffman, Joan Serra, Lyndee M. Knox, and Robert Cohen. *Beyond suppression: Global perspectives on youth violence*. ABC-CLIO, 2011.

Pinker, Steven. "Decline of violence: Taming the devil within us." *Nature* 478.7369 (2011): 309.

Viner, Russell M., et al. "Adolescence and the social determinants of health." *The lancet* 379.9826 (2012): 1641-1652.

Csete, Joanne, et al. "Public health and international drug policy." *The Lancet* 387.10026 (2016): 1427-1480.

Reviewer #2

The article was interesting and well-developed. A few conceptual questions to help strengthen the presentation of the data further:

*When using the lifespan inequality or lifespan variation the cut-off was age 15--surviving to age 15 to capture the onset of homicides. Why is this the threshold set-point? Can the paper describe why this selection was made since the presentation of the data is defined by this choice?

We clarified our choice for age 15 as the cut-off. The main reason for the cut-off is that homicides in Mexico during the study period are concentrated in ages above 15, for example, over 95% of homicides occurred above this age over the period of study 1995-2015 (see table below).

% of homicide deaths	1995	2000	2005	2010	2015
Ages 15+	95.4 %	95.1%	95.4%	98.0%	98.7%

Source: Own estimates from INEGI data.

We added the next sentence to the manuscript:
"We condition on surviving to age 15 because over 95% of homicides occur above that age and because including infant mortality conceals dynamics of mortality at adult ages."

*How does the distribution of poverty connect with these analysis/findings or not? The introduction mentions that historically poor states concentrated in the south but is very brief. I kept wondering if it too was a driver of the picture that this paper presents but it was never mentioned, controlled for or discussed.

We concur with the reviewer that poverty is likely linked with homicides. We included additional information about this. However, the current manuscript aims at describing the observed changes in homicide mortality and their link with lifespan variation and life expectancy. Our goal is not to explain why there are differences in lifespan variation and life expectancy by sex, or by region. Such an analysis requires the inclusion of additional factors, as those mentioned by the reviewer, and would also require different analytic techniques to identify the sources of variation in life expectancy and lifespan.

*What does flustered mean in line 232?

We have rephrased the sentence. It now reads:
Line 258: "...Larger variation in lifespans underlies greater vulnerability at the population level."

*The discussion could be developed more and connected with the data presented. Why is drug trafficking more violent in Mexico than other countries? The article mentioned that establishment of a single payer health system was not enough to change these trends--what are some of the policy approaches that could be adopted (educational, social, justice, etc.)?

We thank the reviewer for these suggestions. We have added more context in the introduction. For example, previous evidence has shown that Mexico's wave of violence was triggered by the interactions of competitions between drug cartels, enforcement operations trying to mitigate drug trafficking operations after 2005, and the increased profitability in the flow of drug-trade with United States (Rios, 2013; Dell, 2015; Castillo et al. 2014). This interaction led to a cycle of violence and the spillover onto civilians which by 2017, with the newest available data just released by INEGI, has not end, and has even increased in the last couple of years (Hienle et al. 2017).

We have included in the first paragraph the next sentences:

"…In Mexico, homicides rates declined from 1995 to 2006 but these trends were reversed and homicides more than doubled between 2007 and 2012 (Supplementary Material [SM] figure S1). This increase has been associated with more enforcement operations trying to mitigate drug cartel activities, increased territorial competition, and higher profitability in the drug-trade flow with the United States.[3-5] This led to a cycle of violence- the so-called war on drugs- and the spillover onto civilians which,[6] along with an increasing burden of diabetes, led to stagnating male life expectancy in the period 2000-10.[7]"

References:
Ríos, Viridiana. "Why did Mexico become so violent? A self-reinforcing violent equilibrium caused by competition and enforcement." *Trends in organized crime* 16.2 (2013): 138-155.

Dell, Melissa. "Trafficking networks and the Mexican drug war." *American Economic Review* 105.6 (2015): 1738-79.

Castillo, Juan, Daniel Mejía, and Pascual Restrepo. "Scarcity without leviathan: The violent effects of cocaine supply shortages in the mexican drug war." (2014).

Heinle, Kimberly, Octavio Rodríguez Ferrerira and David A. Shirk. "Drug violence in Mexico: Data and analysis through 2016." *Trans-Border Institute, University of San Diego, San Diego* (2017).

Regarding policy approaches we elaborated further. We note that violence prevention should focus at the individual, family, community and, as we show, at the state level. Previous evidence suggests that school-based efforts; mental health and child welfare programs, educational programs and placement of graduates in jobs, self-employment, and continuing education, together with programs aimed at reducing alcohol consumption have been successful to mitigate violence diffusion (Hoffman et al 2011, Pinker, 2011, Viner et al, 2012). In the Mexican context, political will is essential since it has been shown that policies pursuing drug prohibition or severe suppression have not worked (Csete et al. 2016). Moreover, Mexico has failed to recognize and correct the health and human rights harms that these policies have caused. In this sense, it has been suggested that military forces' participations should be phased out as much as possible since it exacerbates violence with drug traffickers.

We added in line 258:
"In an international context, Mexico's levels of violence are not even the highest around the globe, nor in the region. Countries in central America, such as El Salvador and Honduras, and Venezuela, Colombia and Brazil in south America have higher homicide rates. It is likely that these countries experience higher variation in lifespans which, along with the existence of high levels of homicides, points to possible failure of policies to reduce the burden of violence. These policies should pay more attention to social determinants of premature mortality, psychosocial factors and get to the root of violence to prevent its diffusion towards the young population"

We have added the next concluding paragraph:
"Mexico has failed to recognize and correct the detrimental consequences in health and human rights that suppressive and drug-prohibition policies have had on the population[.34] There is an urgent need to stop these policies and complement them with policies that are less focus on military actions against drug cartels. For example, programs on improving regional and schooling outcomes and educational and community programs to reduce the risk factors of violence (e.g. alcohol consumption)[35] among others. This will prevent homicides and contribute significantly to increases in life expectancy as well as greater equality of individual lifespans in Mexico."

References
Hoffman, Joan Serra, Lyndee M. Knox, and Robert Cohen. *Beyond suppression: Global perspectives on youth violence*. ABC-CLIO, 2011.

Pinker, Steven. "Decline of violence: Taming the devil within us." *Nature* 478.7369 (2011): 309.

Viner, Russell M., et al. "Adolescence and the social determinants of health." *The lancet* 379.9826 (2012): 1641-1652.

Csete, Joanne, et al. "Public health and international drug policy." *The Lancet* 387.10026 (2016): 1427-1480.

Reviewer #3

This is a well-written manuscript describing a life expectancy in the context of severe violence related to death, using an inequity framework. In epidemiological perspective, it may not be novel the result that increasing homicide rate is associated with reducing life expectancy in population level. However, the quantification of homicide in life expectancy is still important. This study has significant policy implication as it providing alternative indicator for population impacts of severe violence.

I was therefore a bit disappointed to see some conceptual and logical limitations in the manuscripts. First, the manuscript does not properly address changing patterns of homicide in Mexico especially the period between 1995 and 2015. In particular, few details are provided regarding dividing panel A (1995-2005) and panel B (2005-2015). This manuscript is based on comparison of life expectancy between these two periods. This division should be justified with significant difference of homicide rate between them.

We clarify this issues in the manuscript. We previously indicated in the methods section that homicide rates declined among young adults between 1995 and 2005, but they increased between 2005 and 2015:

"We study two comparable 10-year periods, between 1995 and 2005, and from 2005 to 2015. This allowed us to identify a period of mortality improvements (1995-2005) in which life expectancy increased by 2.1 and 4.3 years for males and females, respectively, and homicide rates declined among young adults. The second period (2005-2015) is characterized by the upsurge of violence and homicides in Mexico."

We now provide more context in the introduction and in the methods section. As suggested by the reviewer, we include a figure with time trends in age-standardized homicide rates. Given the space limitations, the figure (below) is shown in the supplemental material but we refer to it in the text. The introduction now states:

Age-standardized homicide rate by sex

"…In Mexico, homicides rates declined from 1995 to 2006 but these trends were reversed and homicides more than doubled between 2007 and 2012 (Supplementary Material [SM] figure S1). This increase has been associated with more enforcement operations trying to mitigate drug cartel activities, increased territorial competition, and higher profitability in the drug-trade flow with the United States.[3-5] This led to a cycle of violence- the so-called war on drugs- and the spillover onto civilians which,[6] along with an increasing burden of diabetes, led to stagnating male life expectancy in the period 2000-10.[7]"

The methods section reads (in the subsection on *cause-of-death classification*):

"We study two comparable 10-year periods, between 1995 and 2005, and from 2005 to 2015 that represent periods of major changes in homicides (SM figure S1). The first period corresponds to mortality improvements (1995-2005) in which life expectancy increased by 2.1 and 4.3 years for males and females, respectively, and homicide rates declined among young adults; while the second period (2005-2015) is characterized by the upsurge of violence and homicides in Mexico."

In discussion section, the author attempts to explain the contextual reason of reductions in life expectancy with homicide patterns in the regions. However, the paper fails to provide key difference on patterns and magnitude of homicide between 1995-2005 and 2005-2015. I think the added value of this study is measuring quantified impacts of homicide on life expectancy. Therefore, it is critical to provide more details on a changing patterns of homicide rate especially before and after 2005 which led changes in life expectancy. Again, the causal association between homicide and life expectancy is not new.

As shown above, we now include a figure showing time trends in age-standardized homicide rates. This figure shows a clear downward trend in homicides among males prior to 2005 and an increase

thereafter. Additional evidence of changing trends in homicides by States in Mexico is shown in Espinal-Enriquez and Larralde (2015) and Flores et al. (2015). These papers analyze the extent of the diffusion of violence from to 2005 to 2010. They found that despite army operations being executed in some states, violence displaced to other localities. In addition, Aburto et al. (2016) found that while homicides contributed to increasing life expectancy between 2000 and 2005, they reduced life expectancy in the period 2005-2010, with a large magnitude in the state of Chihuahua.

In addition to the sentences included in the previous point, we included these references to the paper and it reads in the manuscript:

'We also expect uneven variability across states in the country due to the changing dynamics of violence and homicides in Mexico.[16] For instance, states in the Northern part of Mexico (e.g., Chihuahua, Durango and Sinaloa) experienced the largest losses in life expectancy between 2005 and 2010[8]… although this impact may now be larger in other states as homicides spread throughout the country in recent years.[17]'

"For instance, in 2010 males aged 15-50 in Chihuahua had three times higher mortality than the US-troops in Iraq between 2003 and 2006."

References
Flores, Miguel, and Amado Villarreal. "Exploring the spatial diffusion of homicides in Mexican municipalities through exploratory spatial data analysis." *Cityscape* 17.1 (2015): 35-50.

Espinal-Enríquez, Jesús, and Hernán Larralde. "Analysis of Mexico's narco-war network (2007–2011)." *PloS one* 10.5 (2015): e0126503.

Aburto, José Manuel, et al. "Homicides in Mexico reversed life expectancy gains for men and slowed them for women, 2000–10." *Health Affairs* 35.1 (2016): 88-95.

In addition, similarly, the authors attempted to address regional difference of lifespans using the inequality framework. The lifespan inequality is simply epidemiological results of unequal patterns of violence across the regions. So, here, unequal distribution of homicide is key underlying factors. But its description is also missing in this manuscript.

We thank the reviewer for this suggestion. We address this comment in two steps. Firs, we clarify in the manuscript that lifespan inequality is an indicator that in itself represents unequal ages at death in the population. For example, large values in lifespan implies greater uncertainty in the timing of death at the individual level which implies an unequal age at death. This approach is different from the inequality framework in public health that addresses inequalities in health arising as a result of socioeconomic and/or racial/ethnic differences. Second, the analytic method we use (decomposition method) takes into account the unequal distribution of homicides by age, sex, and region. This method attributes changes in lifespan inequality and in life expectancy due to changes in homicide mortality every year; thus, regions that experience larger changes in homicide mortality (i.e., those with more unequal distribution of homicides --either increases or decreases) will consequently contribute more to the observed changes in the lifespan and life expectancy.

We thus believe our methods are inherently taking into account the reviewer's concern.

Lastly, I would like to suggest the authors to consider that violence rate is highly associated with underlying socioeconomic and political inequalities between regions and between individuals. And, beyond homicide, these factors are significant determinants of premature death due to diverse medical conditions. I do not think the authors have adequately conceptualized the population health impacts of violence using appropriate concept of inequality, although they attempted to measure the most severe form of violence - homicide on population health.

We agree with the reviewer's view about the association of homicides with socioeconomic and political factors. Although this link is indeed interesting, we feel it is out of the scope of the current manuscript. The current manuscript attempts to describe the observed changes in homicide mortality and their link with lifespan variation and life expectancy. Our goal is not to explain why there are differences in lifespan variation and life expectancy by sex, or by region. Such an analysis requires the inclusion of additional factors, as those mentioned by the reviewer, and would also require different analytic techniques to identify the sources of variation in life expectancy and lifespan. We included this issue in the discussion as future area of research.

"… Future research should try to shed light into the individual-level pathways of violence and its effects on life expectancy and lifespan inequality.[31] This illustrates the need of reliable estimates of mortality by cause of death and population by socioeconomic status and other social factors in Mexico."

It is difficult to present a complex study such as this in limited words, as required by AJPH. I would like to make these recommendations in full understanding that it will be difficult to respond to all of them within this constraint, but I do hope the authors at least think about some of the conceptual difficulties I find with the paper.

We thank you for your suggestions. We took them into consideration as we revised the manuscript. We have made every effort to include them in the text and when space was a limitation, we added figures/text to the supplemental material.

1   **Title: Homicides in Mexico increased inequality of lifespans and slowed down life expec-**
2   **tancy gains in 2005-2015**
3

4 **Abstract**
5 **Objectives** To quantify the effect of the upsurge of violence on life expectancy and lifespan ine-
6 quality in Mexico after 2005.
7 **Methods** Age- and cause-specific contributions to changes in life expectancy and lifespan ine-
8 quality conditional on surviving to age 15 between 1995 and 2015 were calculated. Homicides,
9 medically amenable conditions, diabetes, ischemic heart diseases, traffic accidents by state and
10 sex were analyzed.
11 **Results** Male life expectancy at age 15 increased by more than twice as many years in 1995-2005
12 (1.17 years) than in 2005-2015 (0.55 years). Lifespan inequality decreased by more than half a
13 year for males in 1995-2005, while in 2005-2015, the reduction was about four times smaller.
14 Homicides between ages 15-49 had the largest effect in slowing down male life expectancy and
15 lifespan inequality. Between 2005 and 2015, states in the North experienced life expectancy losses,
16 while five states increased lifespan inequality.
17 **Conclusions** Ten years into the upsurge of violence, Mexico has not been able to reduce the hom-
18 icide levels to those prior to 2005. Thus, males live less, on average, and experience higher uncer-
19 tainty in their eventual death.
20
21 **Keywords:** violence, lifespan variation, premature mortality, public health, vulnerability.
22
23
24 Word count: 3347
25 References: 35
26
27 *Up to 3500 words in the text, a structured abstract, up to 4 tables & figures combined, and no*
28 *more than 35 references. The structured abstract must provide the date(s) and location(s) of the*
29 *study. The text must have an introduction and separate sections for Methods, Results, Discussion,*
30 *and, Public Health Implications*

Introduction

Violence has become a major public health issue in Latin America.[1] This region experiences the highest homicide rate in the world (over 16.3 per 100,000 people), with some countries in Central America undergoing a recent upsurge in homicides.[2] In Mexico, homicides rates declined from 1995 to 2006 but these trends were reversed and homicides more than doubled between 2007 and 2012 (Supplementary Material [SM] figure S1). This increase has been associated with more enforcement operations trying to mitigate drug cartel activities, increased territorial competition, and higher profitability in the drug-trade flow with the United States.[3-5] This led to a cycle of violence- the so-called war on drugs- and the spillover onto civilians which,[6] along with an increasing burden of diabetes, led to stagnating male life expectancy in the period 2000-10.[7] At the subnational level, gains in life expectancy due to medically amenable causes, such as infectious, respiratory diseases and birth conditions, were wiped out by the increase of homicides after 2005 in each of the 32 states in Mexico, with large regional variation.[8]

Trends in life expectancy are important and have been studied in Mexico and its states.[7-9] However, life expectancy masks inequality of lifespans or lifespan variation.[10] Variability in age at death (lifespan) is important because it addresses the growing interest in health inequalities[11] and because larger variation in lifespans implies greater uncertainty in the timing of death at the individual level, and has implications for the planning of life's events.[12,13] From a public health perspective, larger lifespan inequality implies increasing vulnerability at the societal level, which suggest ineffectiveness of policies aiming to protect individuals against life's vicissitudes.[12] In the context of rising violence, it implies a failure of social protection policies aiming at decreasing homicide/crime rates and increasing vulnerability at the population level. Previous studies have found a negative association between life expectancy and lifespan variation, suggesting that as life

54 expectancy increases, inequality in lifespans decreases.[12,14] However, at the subnational level and

55 during periods of life expectancy fluctuation, increases in lifespan variation may simultaneously

56 occur with increases in life expectancy, mostly due to a slowdown in mortality improvements over

57 ages between 20 and 65.[13,15] This is particularly relevant for countries that have experienced an

58 upsurge in homicides, since this increase has mainly affected young individuals.

59   In Mexico, homicides are concentrated between ages 15 and 50, affecting mainly males.[8]

60 It is unclear what their net effect is on lifespan inequality but it certainly had an effect on premature

61 mortality. We thus hypothesize that Mexican males may be experiencing increases in lifespan in-

62 equality in tandem with declines in life expectancy. We also expect uneven variability across states

63 in the country due to the changing dynamics of violence and homicides in Mexico.[16] For instance,

64 states in the Northern part of Mexico (e.g., Chihuahua, Durango and Sinaloa) experienced the

65 largest losses in life expectancy between 2005 and 2010[8] and it is likely they also exhibited large

66 lifespan inequality during that period, although this impact may now be larger in other states as

67 homicides spread throughout the country in recent years.[17] On the other hand, medically amenable

68 mortality improvements, which have been Mexico's priority since the 1990s,[18] could have had a

69 substantial effect on reducing inequality in lifespans, particularly in the poorer states, which are

70 mostly concentrated in the South.

71   This paper makes three main contributions. First, it contributes to the literature on lifespan

72 variation and inequalities in health in the context of rising homicides. Most literature in this area

73 focuses on the social determinants of health such as socioeconomic status or educational attain-

74 ment as proximate determinants of lifespan variation and health inequality.[12,13] Our paper high-

75 lights the role of violence, and its ultimate consequence in the form of homicides, among young

76 adults on increasing lifespan inequality. We describe the observed changes in homicide mortality

77 and their link with lifespan inequality and life expectancy by sex and by region in Mexico. A

78 second contribution is its focus on Mexico with the growing violence associated with the war on

79 drugs making it a serious health policy concern.[7,8] Understanding the consequences of violence on

80 population health is important for policy makers in Mexico and other countries experiencing sim-

81 ilar increases in homicides such as Honduras in Central America, and Venezuela in South Amer-

82 ica.[2] Finally, this analysis contributes to our knowledge of regional inequality in lifespans.

83 We analyzed how life expectancy and lifespan inequality for the young population changed

84 over the period from 1990 to 2015 for females and males in Mexico. This framework allows us to

85 thoroughly analyze premature mortality and to determine the ages and causes of death that con-

86 tributed the most to the observed changes.

87

88 **Methods**

89 We used data on deaths from vital statistics files available through the Mexican Institute of

90 Statistics[19] that includes information on cause of death by age, sex, and place of occurrence from

91 1995 to 2015. Additionally, we used population estimates corrected for completeness, age mis-

92 statement, and international migration from the Mexican Population Council to construct age-spe-

93 cific death rates by age, sex and state.[20]

94 *Cause-of-death classification*

95 We classified deaths into eight categories representing the main causes of death in Mexico

96 using the concept of Amenable/Avoidable mortality (SM Table 1).[21,22] This concept assumes that

97 some conditions should not cause death in the presence of timely and effective medical care, and

98   are used as a proxy for the performance of health care systems.[21] To mitigate biases due to mis-

99   classification of causes of death, we focused on deaths occurring below age 85 since cause-specific

100 coding practices above that age are less reliable due to the presence of comorbidities[23] and about

101 99% of homicide occurred below this age in the study period.

102 We study two comparable 10-year periods, between 1995 and 2005, and from 2005 to 2015

103 that represent periods of major changes in homicides (SM figure S1). The first period corresponds

104 to mortality improvements (1995-2005) in which life expectancy increased by 2.1 and 4.3 years

105 for males and females, respectively,[20] and homicide rates declined among young adults;[19] while

106 the second period (2005-2015) is characterized by the upsurge of violence and homicides in Mex-

107 ico.[8]

108 *Lifespan inequality indicator*

109 We use 'years of life lost' as a dispersion indicator and refer to it as "lifespan inequality"

110 or "lifespan variation" from age 15. It is defined as the average remaining life expectancy at death,

111 or life years lost due to death (see SM for a summary).[14] For example, if in a cohort of newborns

112 all die at the same age then the value of lifespan inequality is zero; to the extent that death occurs

113 at different ages, those who die "prematurely" will contribute years to lifespan variation. We con-

114 dition on surviving to age 15 because over 95% of homicides occur above that age and because

115 including infant mortality conceals dynamics of mortality at adult ages.[10]

116 This indicator is easy to understand, to interpret, and to decompose thereby allowing us

117 to quantify the impact of age and cause-specific mortality on changes in lifespan variation over

118　time.[14] Moreover, the high correlation between our preferred indicator and other measures of var-

119　iability in lifespans (e.g., variance, Gini coefficient) suggests that our main results would be con-

120　sistent with those obtained with any of these additional measures.[14]

121

122　*Demographic methods*

123　　　To mitigate random variation in cause-of-death classification, we smoothed cause-specific

124　death rates over age using a 1-d p-spline separately by year, sex and state, and rescaled them to

125　all-cause death rates to maintain the overall mortality level.[24] Using these mortality rates we com-

126　puted period life tables for each year (1995 to 2015), state and sex following standard demographic

127　methods.[25] Finally, we computed life expectancies and lifespan variation conditioned on surviving

128　to age 15 and estimated the age- and cause-specific contributions to yearly differences between

129　the study periods using standard decomposition techniques (see SM).[26] All analyses were carried

130　out using R[27] and are reproducible (see SM). In addition, we created an interactive app to perform

131　sensitivity analyses available here.

132　**Results**

133　　　Table 1 shows cause-specific contributions to changes in life expectancy and lifespan ine-

134　quality at age 15 between 1995 and 2015 and between 2005 and 2015. Among men, life expectancy

135　increased more than twice as fast in 1995-2005 (1.17 years) than in 2005-2015 (0.55 years). Most

136　causes of death contributed to life expectancy's improvement in 1995-2005 (except for diabetes

137　and accidents). Importantly, homicides declined in 1995-2005 which accounted for about 38.5%

138　(0.45 years) of the overall gain in life expectancy in this period. About 80% (0.36 years) of the

139　homicide reduction was concentrated between ages 15-49 (red bars in SM figure S2, panel A). In

140   contrast, the slowed-down improvement in life expectancy in 2005-2015 was mainly the result of

141   rising homicides and heart diseases, hence their negative contributions. Female life expectancy

142   increased by 0.58 year in 1995-2005 and 0.57 year in 2005-2015. These gains resulted from mor-

143   tality improvements in most causes of death with a negative impact of diabetes and a negligible

144   impact of homicides, traffic accidents and heart diseases.

145

146   [Table 1]

147

148   Lifespan inequality declined by more than half a year between 1995 (14.31) and 2005

149   (13.77) for males. This means that, on average, Mexican males were losing six months of life less

150   at their time of death in 2005 than in 1995. Although lifespan inequality also declined between

151   2005 and 2015 (-0.15), the reduction in 1995-2005 was about four times larger. In other words,

152   male lifespan inequality was stagnant in recent times. Nonetheless, improvements in other causes

153   of death contributed to a reduction in lifespan inequality in both periods; for example, mortality

154   declines in accidents and cirrhosis at younger ages (figure S1). Importantly, homicides (about 0.19

155   years) had the largest effect on increasing lifespan variation in 2005-2015 (i.e., positive contribu-

156   tion). For females, lifespan inequality decreased since 1995 due to improvements in most causes

157   of death. However, in 1995-2005 increased mortality from diabetes and traffic accidents increased

158   lifespan inequality, while in 2005-2015 homicides were the major contributor to slowing down

159   improvements in variation of lifespans. These results underscore the major role of rising homicide

160   rates among young adults in recent times and the consequent slow improvement in reducing

161   lifespan inequality.

162

163   In figures 1-2 we focus on results for males because the impact of homicides is larger

164   among them, results for females are in SM figures S3-S4. Figure 1 shows changes in life expec-

165   tancy (panel A) and in lifespan inequality (panel B) for males in each of the 32 states in Mexico

166   between 1995 and 2005 (blue dots) and between 2005 and 2015 (red triangles). We grouped states

167   into three broad regions: North, Central and South.

168   Life expectancy among males had a larger increase in 1995-2005 than in 2005-2015 across

169   all states (panel A) except for Yucatán, some states even experienced reductions in life expectancy

170   in 2005-2015 particularly in the North (e.g., Chihuahua, Nuevo León and Sinaloa). Lifespan ine-

171   quality (panel B) was reduced in most states over the two decades, 1995-2015, except for those in

172   the North and Nayarit. For example, almost every state between 1995 and 2005 had major reduc-

173   tions in lifespan inequality of at least 0.4 years, but between 2005 and 2015, all states in the north

174   had negligible reductions in lifespan inequality with five states having a large increase (Chihuahua,

175   Nuevo León and Tamaulipas --all bordering with Texas in the US, Sinaloa and Durango).

176   [Figure 1]

177

178

179   Figure 2 shows the contribution of homicides to changes in lifespan inequality between

180   1995 and 2005 and between 2005 and 2015 by state. For contributions from all cause-of-death

181   categories and for females see Supplementary Material figures S4-S5.

182   Every state decreased lifespan inequality due to reductions in homicide mortality between

183   1995 and 2005. In the same period, all but two states for males, Baja California Sur in the North

184   and Tlaxcala in the central region decreased lifespan variation attributed to improvements in med-

185   ically amenable conditions (SM figures 5 and 6). As we hypothesized, the states showing the larger

186 reductions were mostly concentrated in the southern region of Mexico (e.g., Chiapas, Oaxaca,

187 Puebla, Guerrero and Morelos). A decade later (2005-2015), however, there is more heterogeneity

188 in the contribution of causes of death to lifespan inequality. For example, conditions amenable to

189 medical service contributed to reductions in lifespan inequality in some states but small increases

190 in nine states for males distributed across the country, while cirrhosis decreased variation in

191 lifespans in the central and northern regions. Homicides increased variation in lifespans. Although

192 the increase in homicides affected lifespan inequality in all states after 2005, one state in the South

193 was affected the most (about a 1 year increase for males and about two months for females in

194 Guerrero), followed by some states in the North (increase of about 0.75 and 0.5 years in Chihuahua

195 and Sinaloa) and in the central part of the country (e.g. Colima). Mortality due to diabetes showed

196 negligible contributions to lifespan inequality in both periods. Results for females indicate sub-

197 stantial reductions in lifespan inequality from medically amenable conditions and diabetes in the

198 period 1995-2015.

199   [Figure 2]

200

201 **Discussion**

202 Ten years after the beginning of the war on drugs, Mexico has not been able to reduce homicides

203 and their effect on longevity, at least to the levels observed back in 2005. As violence spread

204 throughout the country,[17] life expectancy gains slowed down between 2005 and 2015, with a tem-

205 porary reversal in average lifespan in 2005-10.[7,8] Despite recent efforts from the Mexican govern-

206 ment to contain the upsurge of violence in the country,[5,28] data up to 2015 shows that life circum-

207 stances among young adults have not improved and are actually deteriorating. For example, almost

208 every state experienced a reduction in life expectancy at age 15 across all regions in Mexico due

209 to homicides (SM figure S7). The strongest effect occurred in Guerrero, a state in the Southern

210 region, where life expectancy was reduced by almost 2 years between 2005 and 2015, followed by

211 Chihuahua and Sinaloa in the North, with life expectancy losses of one year each, three additional

212 states in the North (Zacatecas, Baja California Sur and Nuevo León), one in the Central region

213 (Colima), and one in the South (Morelos), experienced losses of half a year in life expectancy.

214 These detrimental consequences offset increases in life expectancy due to ongoing public health

215 interventions, such as the enactment of a universal health insurance program (*Seguro Popu-*

216 *lar*).[8,9,18]

217   Furthermore, homicides have slowed down the progress in reducing lifespan inequality

218 among young adults in Mexico. While lifespan inequality declined by more than half a year be-

219 tween 1995 and 2005, a decade later this progress was stagnant and barely reached a reduction of

220 less than two months. Increase in homicide mortality, concentrated in the young population (be-

221 tween ages 15 and 50), accounted for most of this outcome. Thus, males in Mexico not only live

222 less on average, as shown by life expectancy, but they also face more uncertainty in their time of

223 death due to the increase in homicides. Larger inequality in lifespans underlies greater vulnerabil-

224 ity at the population level. For example, in Mexico the expected years lived vulnerable of becom-

225 ing victim of violence increased by 30.5 million person-years between 2005 and 2014.[29] Moreover,

226 increasing inequality of lifespans means larger heterogeneity in population health which translates

227 into the need for more resources to optimize health over the life course.[13]

228   At the subnational level, the states that experienced reductions in life expectancy after 2005

229 also showed increases in lifespan inequality due to homicides. These results are consistent with

230 the upsurge in violence in these parts of the country. Although homicides have spread across Mex-

231 ico,[16] they are not evenly shared between states and over time. By 2010, the North of Mexico was

232   the region most affected by homicide mortality.[8] In contrast, by 2015 all regions showed similar

233   patterns of the effects of homicides on lifespan inequality. Moreover, while in 2010 Chihuahua

234   (Northern region) was the state affected the most by homicides relative to the 2005 level, in 2015

235   Guerrero (Southern region) had overtaken this place. The impact of violence in the population in

236   these states is staggering. For instance, in 2010 males aged 15-50 in Chihuahua had three times

237   higher mortality than the US-troops in Iraq between 2003 and 2006.[8] Recent evidence suggests

238   that the second and fifth most dangerous cities in the world are located in the state of Guerrero,

239   along with cities in countries with higher homicide rates than Mexico.[30] As a result, young males

240   in Guerrero experienced an increase in lifespan inequality of almost an additional year. These

241   results complement previous evidence on adult health inequalities between states[9,22] by identifying

242   homicides as a direct contributor to inequalities in population health between and within states.

243   Moreover, homicides are the ultimate form of violence but they do not fully represent its burden

244   on population health. As a social determinant of health, exposure to violence can increase the

245   likelihood that young people will perpetrate gun violence,[31]and increases the risk of depression,

246   alcohol abuse, suicidal behavior, and psychological problems, among other detrimental conse-

247   quences over the life course.[32] Even witnessing violence can affect the wellbeing of the population

248   by increasing rates of post-traumatic stress disorder and depression.[33]

249   Here, we quantified the effect of rising homicides on longevity and on lifespan inequality.

250   However, our understanding of the consequences of violence would benefit from future research

251   examining if indeed individuals living in states with increases in lifespan inequality do perceive

252   higher vulnerability and how this might affect their long-term decisions. These studies should also

253   focus on women since females are less likely to experience a crime but they perceived greater

254   vulnerability.[29] In addition, more research is needed to quantify the long-lasting consequences of

255 rising violence in the context of the war on drugs to anticipate and intervene in the pathways

256 through which the current violence might affect future health outcomes. For example, the health

257 system might need to be prepared for mental health issues such as depression, suicidal behavior

258 and post-traumatic stress disorder.

259   In an international context, Mexico's level of violence is not even the highest in the region.

260 Countries in central America, such as El Salvador and Honduras, and Venezuela, Colombia and

261 Brazil in south America have higher homicide rates.[1,2] It is likely that these countries experience

262 higher variation in lifespans which, along with the existence of high levels of homicides, points to

263 possible failure of policies to reduce the burden of violence. These policies should pay more at-

264 tention to social determinants of premature mortality, psychosocial factors and get to the root of

265 violence to prevent its diffusion towards the young population.

266 *Limitations*

267 This study has some limitations. First, inaccuracies in cause-of-death practices are likely to be

268 present in the data that we used.[8] To reduce these inaccuracies, we used broad causes of death and

269 adjusted them with a smoothing process over age to have reliable cause-of-death distributions.[24]

270 Second, our estimated effects of homicides could be a lower bound due to undercounting, underre-

271 porting, and the large number of missing individuals.[8] Third, we were not able to disentangle

272 whether a homicide is drug-related (i.e., a homicide resulting from altercations between drug car-

273 tels and army operations).Thus, our results provide an upper bound for the possible impact of the

274 war on drugs at the population level. Finally, we were not able to disaggregate deaths by socioec-

275 onomic status and other social factors that are closely linked with homicides given that the data is

276 at the aggregate national-level. Future research should try to shed light into the individual-level

277 pathways of violence and its effects on life expectancy and lifespan inequality.[31] This illustrates

278   the need of reliable estimates of mortality by cause of death and population by socioeconomic

279   status and other social factors in Mexico.

280   *Conclusion*

281   Mexico has failed to recognize and correct the detrimental consequences in health and human

282   rights that suppressive and drug-prohibition policies have had on the population.[34] There is an

283   urgent need to stop these policies and complement them with policies that are less focus on military

284   actions against drug cartels. For example, programs on improving schooling outcomes and educa-

285   tional and community programs to reduce the risk factors of violence (e.g. alcohol consumption)[35]

286   among others. This will prevent homicides and contribute significantly to increases in life expec-

287   tancy as well as greater equality of individual lifespans in Mexico.

288

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371
372
373 **Figures & Tables**
374
375 **Table 1. Contribution to the change in life expectancy and lifespan inequality at age 15 in the peri-**
376 **ods 1995-2005 and 2005-2015 at the National level by cause of death below age 85.**
377
378 **Figure 1. Changes in male life expectancy at age 15 (panel A) and male lifespan inequality at age 15**
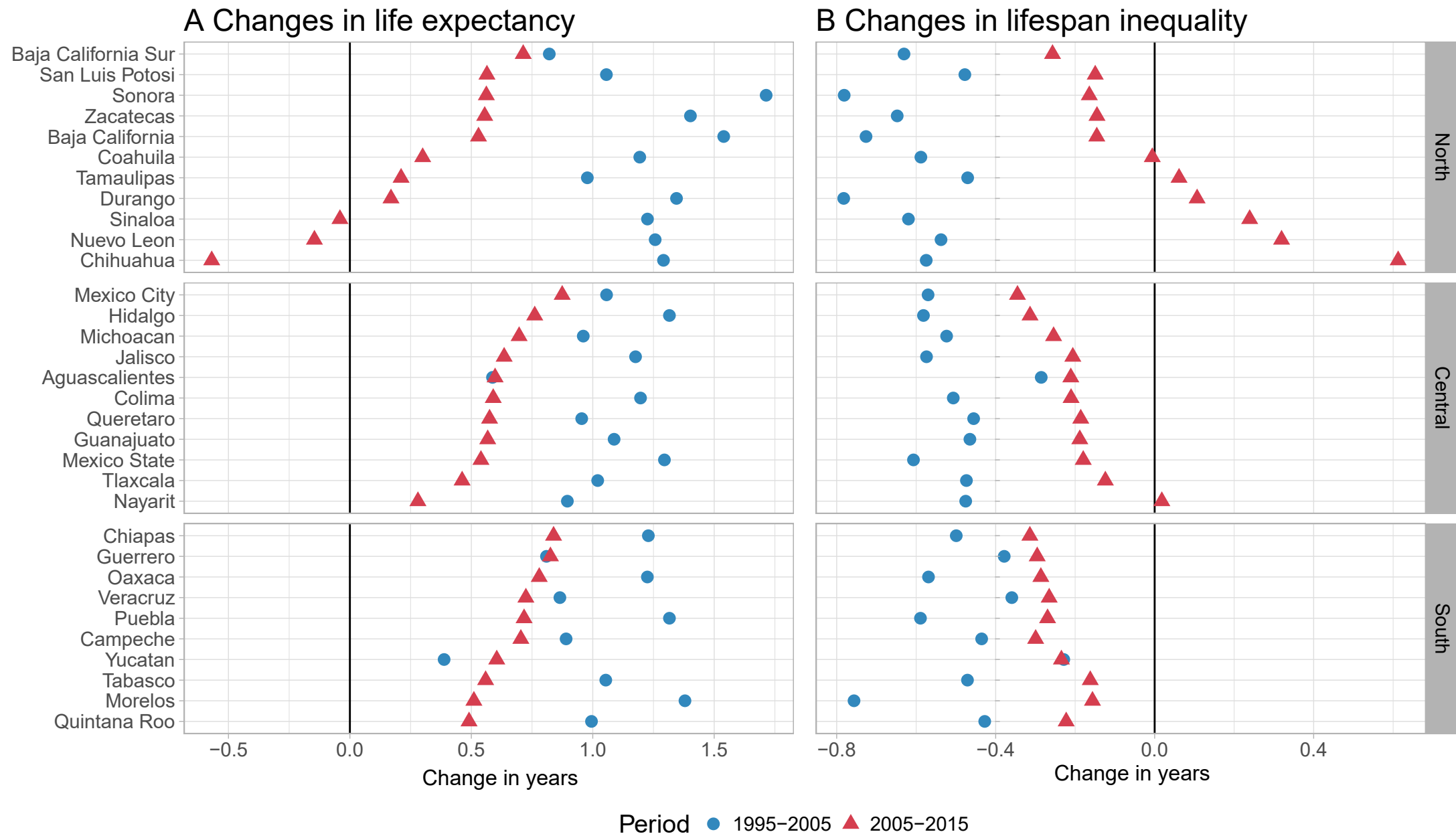379 **(panel B) by state for the periods 1995-2005 and 2005-2015.**
380
381 **Figure 2. Contribution of homicide mortality to changes in male lifespan inequality by state for the**
382 **periods 1995-2005 and 2005-2015.**
383

Table 1

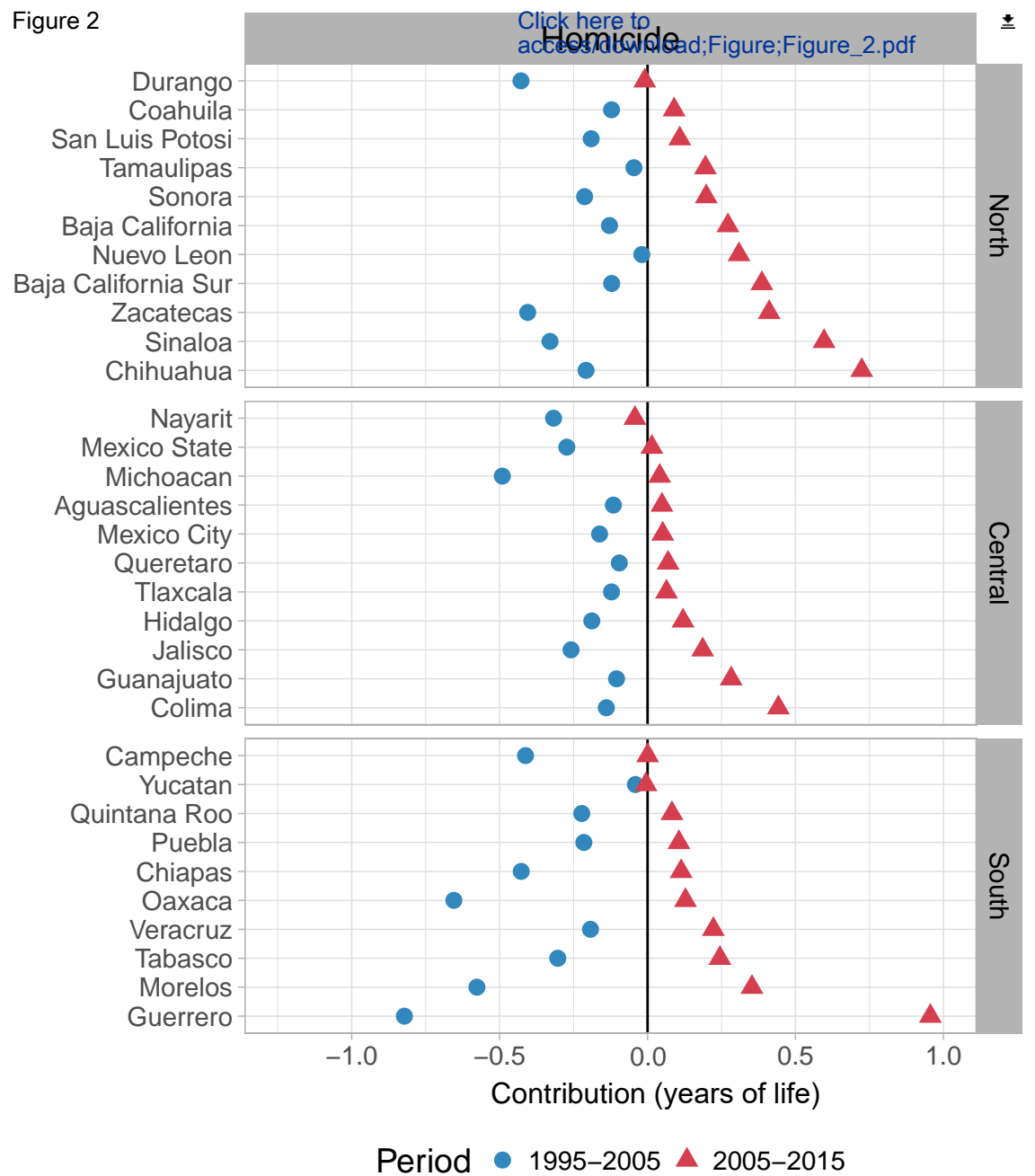Click here to access/download;Table;Table 1.docx ⬇

Table 1. Contribution to the change in life expectancy and lifespan inequality at age 15 in the periods 1995-2005 and

2005-2015 at the National level by cause of death below age 85.

Sex	Cause of death	Contribution to life expectancy		Contribution to lifespan inequality	
		Period		Period	
		1995-2005	2005-2015	1995-2005	2005-2015
Males	Amenable to medical service	0.508	0.169	-0.073	0.005
	Diabetes	-0.572	-0.076	0.028	-0.029
	IHD	0.007	-0.116	-0.023	0.003
	Lung Cancer	0.048	0.099	-0.004	-0.003
	Cirrhosis	0.041	0.280	-0.026	-0.105
	Homicide	0.447	-0.290	-0.265	0.186
	Traffic accidents	-0.069	0.180	0.048	-0.097
	Rest	0.767	0.303	-0.193	-0.107
	Total Change	1.17 From 57.08 to 58.25	0.55 From 58.25 to 58.80	-0.54 From 14.31 to 13.77	-0.15 From 13.77 to 13.62
Females	Amenable to medical service	0.630	0.393	-0.236	-0.144
	Diabetes	-0.612	0.106	0.100	-0.060
	IHD	0.074	-0.048	-0.023	-0.012
	Lung Cancer	0.017	0.021	-0.005	-0.002
	Cirrhosis	0.032	0.060	-0.017	-0.028
	Homicide	0.023	-0.039	-0.014	0.029
	Traffic accidents	-0.021	0.044	0.015	-0.024
	Rest	0.443	0.030	-0.156	0.030
	Total Change	0.58 From 62.75 to 63.33	0.57 From 63.33 to 63.90	-0.34 From 12.40 to 12.06	-0.21 From 12.06 to 11.85

Figure 1

Figure 1. A Changes in life expectancy. B Changes in lifespan inequality. Period: 1995–2005, 2005–2015.

Figure 2

Supplemental material for the paper 'Homicides in Mexico increased inequality of lifespans and slowed down life expectancy gains in 2005-2015'

Authors: Redacted

Author affiliations: Redacted

Corresponding author: Redacted

Table 1. Classification of causes of death based on Aburto et al 2016

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 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 I.C. AM-Circulatory: active/acute rheumatic fever, chronic rheumatic heart disease, hypertensive disease, cerebrovascular disease I.D. AM-Birth: maternal deaths (all), congenital cardiovascular anomalies, perinatal deaths (excluding stillbirths) I.E. AM-Other: disease of thyroid, epilepsy, peptic ulcer, appendicitis, abdominal hernia, cholelithiasis & cholecystitis, nephritis, benign prostatic hyperplasia, misadventures to patients during surgical or medical care, cisticerchosis.	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-C50, C53, C61, C62, J39, J60-J99, J09-J18, J40-J47 C16,C18-C21, C43-C44, C67, C64, C69, C73, C81, C91-C95 I00-I02, I05-I09, I10-I13, I15, I60-I69, O00-O99, Q20-Q28, P00-P96 E00-E07, 40-G41, K25-K27, K35-K38, K40-K46, K80-K81, N00-N07, N17-N19, N25-N27, N40, Y60-Y69, Y83-Y84, B69	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, 490-496 153-154, 172-173, 174, 180, 185, 186, 188-189, 190, 193, 201, 204-208 390-392, 393-398, 401-405, 430-438, 630-676, 745-747, 760-779, 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. 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. Residual Causes : HIV/AIDS; suicide and self-inflicted injuries; other cancers and other heart diseases	B20-B24, U03; X60-X84, Y87.0; C00-D48; I00-I99 if not listed above; R00-R99	042-044; E950-E959; 140-239; 390-459 if not listed above; 780-799

1. Lifespan inequality indicator

In lifetable notation, $e_{15}^{\dagger}$ is defined as:

$$e_{15}^{\dagger} = \frac{\int_{15}^{\omega} \ell(x)\mu(x)e(x)dx}{\ell(15)} = \frac{\int_{15}^{\omega} d(x)e(x)dx}{\ell(15)}, \qquad (1)$$

where $\ell(x)$, $\mu(x)$, $e(x)$, $d(x)$ and ω are the survival function, the force of mortality, life expectancy, the age at death distribution at age x, and the open-aged interval, respectively.

2. Decomposition method summary

The decomposition method used in this paper is based on the line integral model (Horiuchi et al 2008). Suppose f (e.g. $e^{\dagger}$ or life expectancy) is a differentiable function of n covariates (e.g. each age-cause specific mortality rate) denoted by the vector $\boldsymbol{A} = [x_1, x_2, \ldots, x_n]^T$. Assume that f and $\boldsymbol{A}$ depend on the underlying dimension t, which is time in this case, and that we have observations available in two time points t_1 and t_2. Assuming that $\boldsymbol{A}$ is a differentiable function of t between t_1 and t_2, the difference in f between t_1 and t_2 can be expressed as follows:

$$f_2 - f_1 = \sum_{i=1}^{n} \int_{x_i(t_1)}^{x_i(t_2)} \frac{\partial f}{\partial x_i} dx_i = \sum_{i=1}^{n} c_i, \qquad (2)$$

where c_i is the total change in f (e.g. $e^{\dagger}$ or life expectancy) produced by changes in the i-th covariate, x_i. The c_i's in equation (2) were computed with 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

Code and data to reproduce results

Available at *(redacted to avoid identification)*
Shinny app for sensitivity and state specific analysis

Results with starting age 0, available at *(redacted to avoid identification)*
Results with starting age 15, available at https://demographs.shinyapps.io/LVMx_15_App/

Supplemental figures. All figures are own calculations based on CONAPO (2017) and INEGI (2017) data.

Figure S1. Age standardized homicide rates by sex 1995-2015.

Age-standardized homicide rate by sex
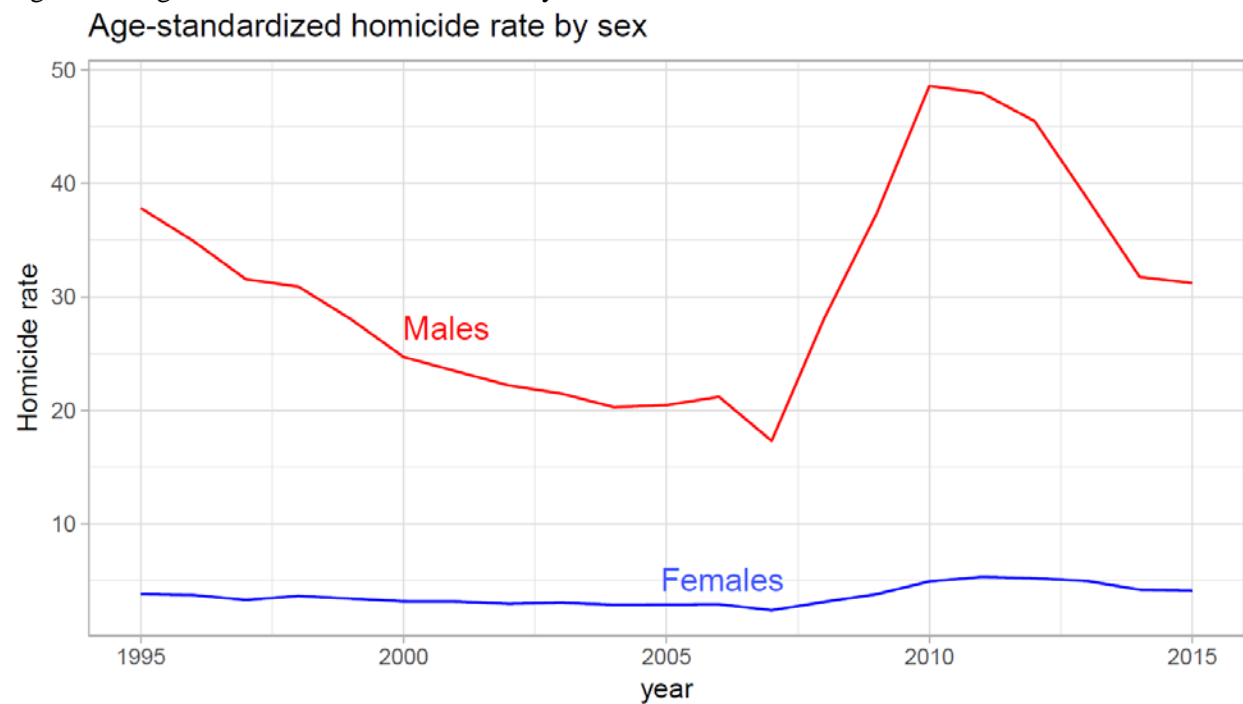
Figures S2 and S3 shows age- and cause-specific contributions (in years) to life expectancy and lifespan inequality's changes at age 15 between 1995 and 2005 (Panels A) and between 2005 and 2015 (Panels B). Vertical values in rectangles next to the y-axis represent age-specific contributions, while bars' length correspond to cause-specific contributions by age. Overall cause-specific contributions across all ages are shown in the panel's legend in parenthesis (also in years).

Figure S2 A. Age-cause specific contributions to the changes in national life at age 15 for Males. Panel A refers to 1995-2005 and panel B to 2005-2015. Note: Numbers in boxes are age-specific contributions.
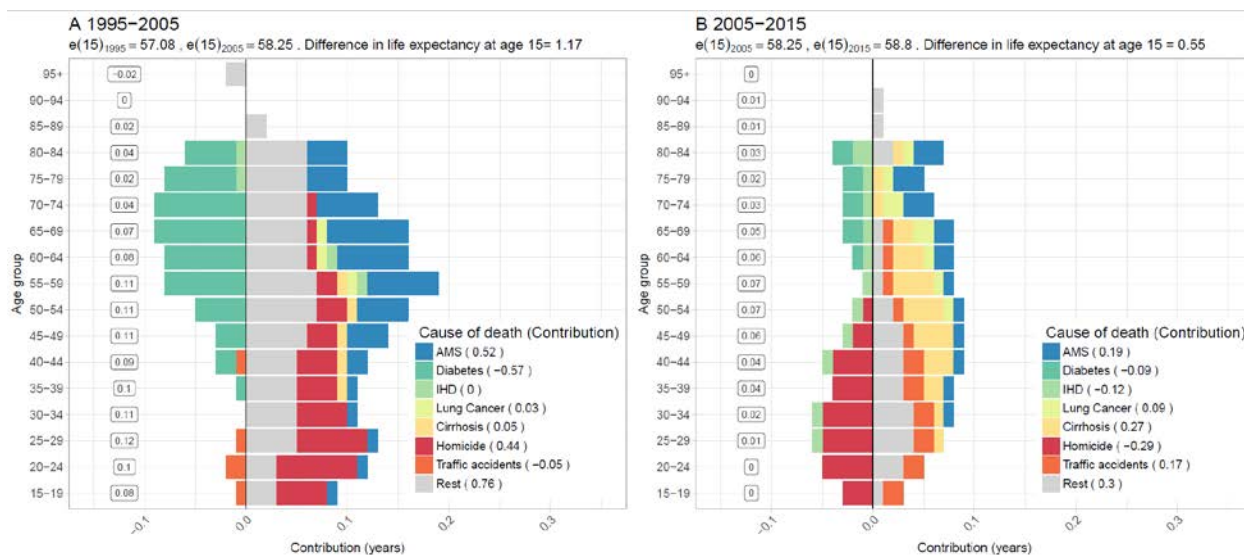
Figure S2 B. Age-cause specific contributions to the changes in national lifespan inequality at age 15 for Males. Panel A refers to 1995-2005 and panel B to 2005-2015. Note: Numbers in boxes are age-specific contributions.
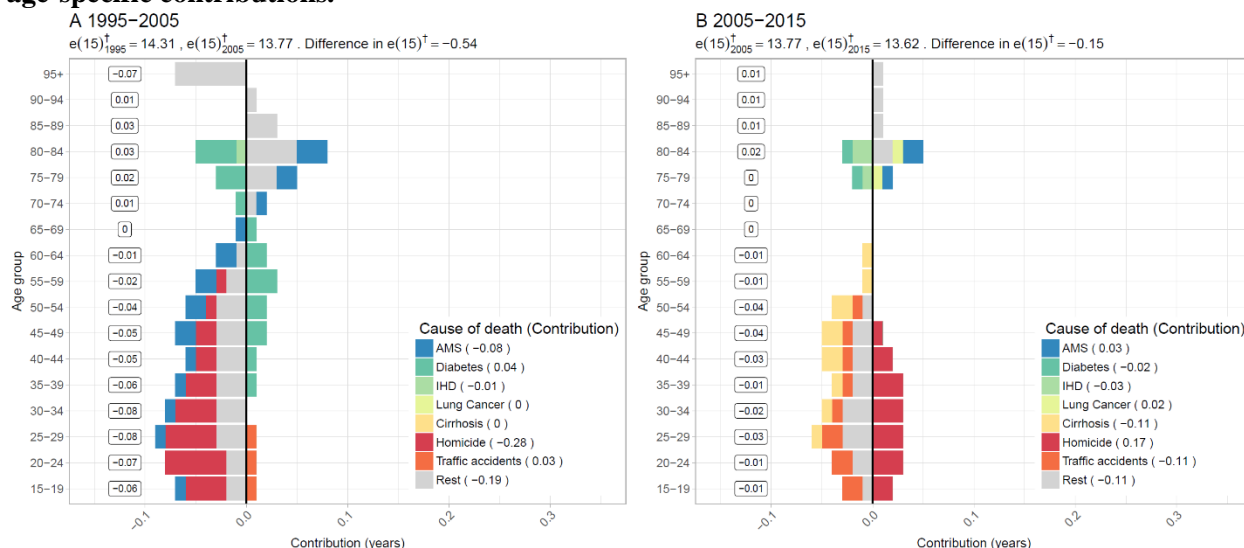
Figure S3 A. Age-cause specific contributions to the changes in national life expectancy for females. Panel A refers to 1995-2005 and panel B to 2005-2015. Note: Numbers in boxes are age-specific contributions.
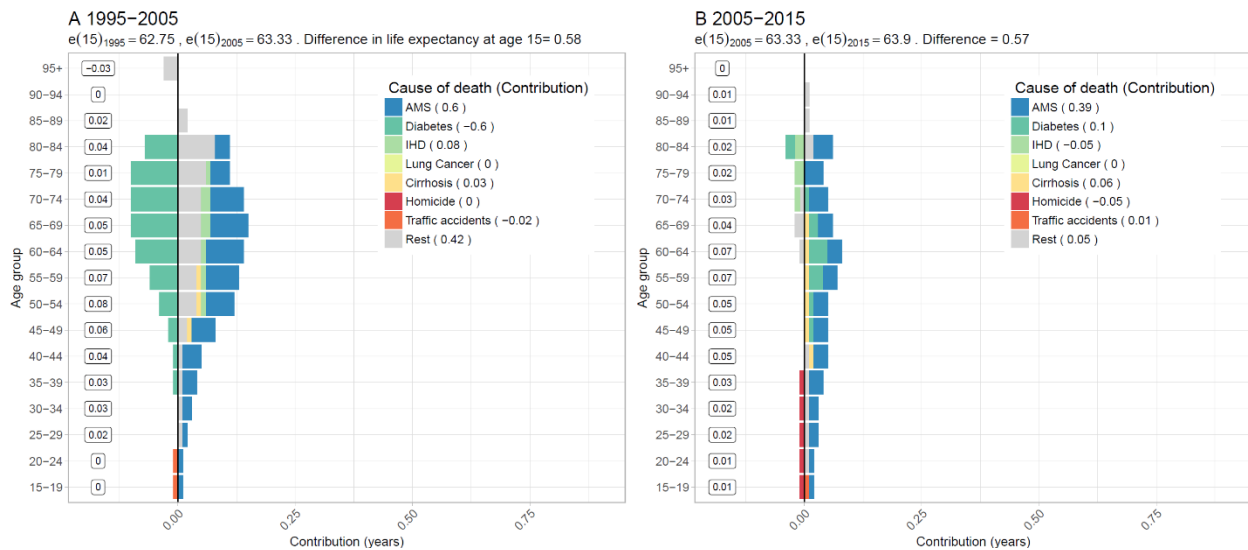

Figure S3 B. Age-cause specific contributions to the changes in national lifespan inequality for females. Panel A refers to 1995-2005 and panel B to 2005-2015. Note: Numbers in boxes are age-specific contributions.
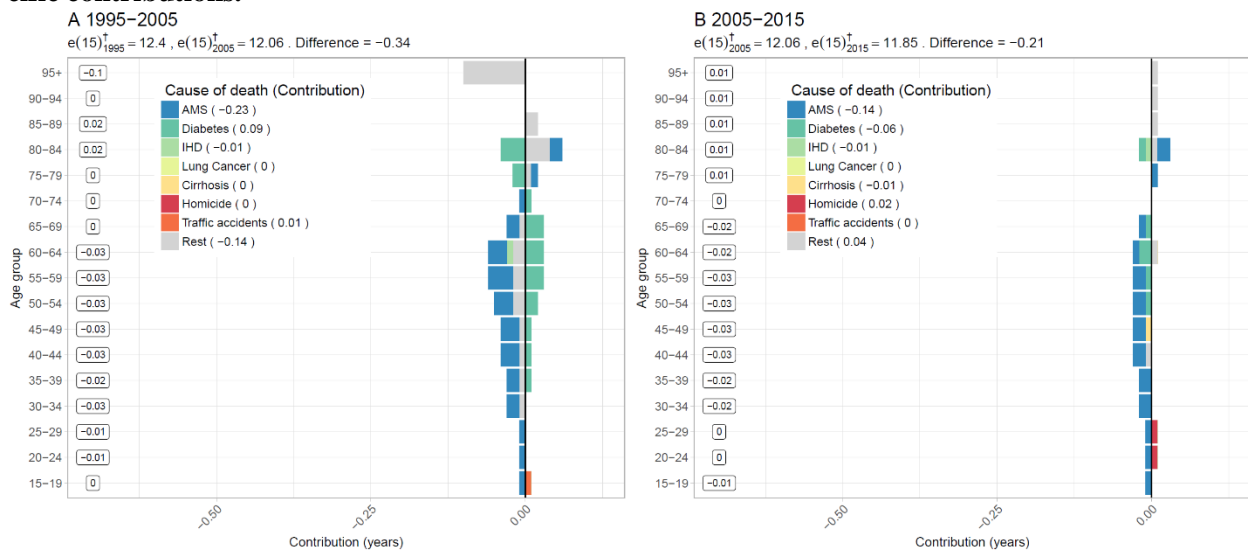
Figure S4. Changes in female life expectancy (panel A) and male lifespan inequality (panel B) by state for the periods 1995-2005 and 2005-2015.

A Changes in state female life expectancy (e_{15})
by period

B Changes in state female lifespan variation ($e_{15}^{\dagger}$)
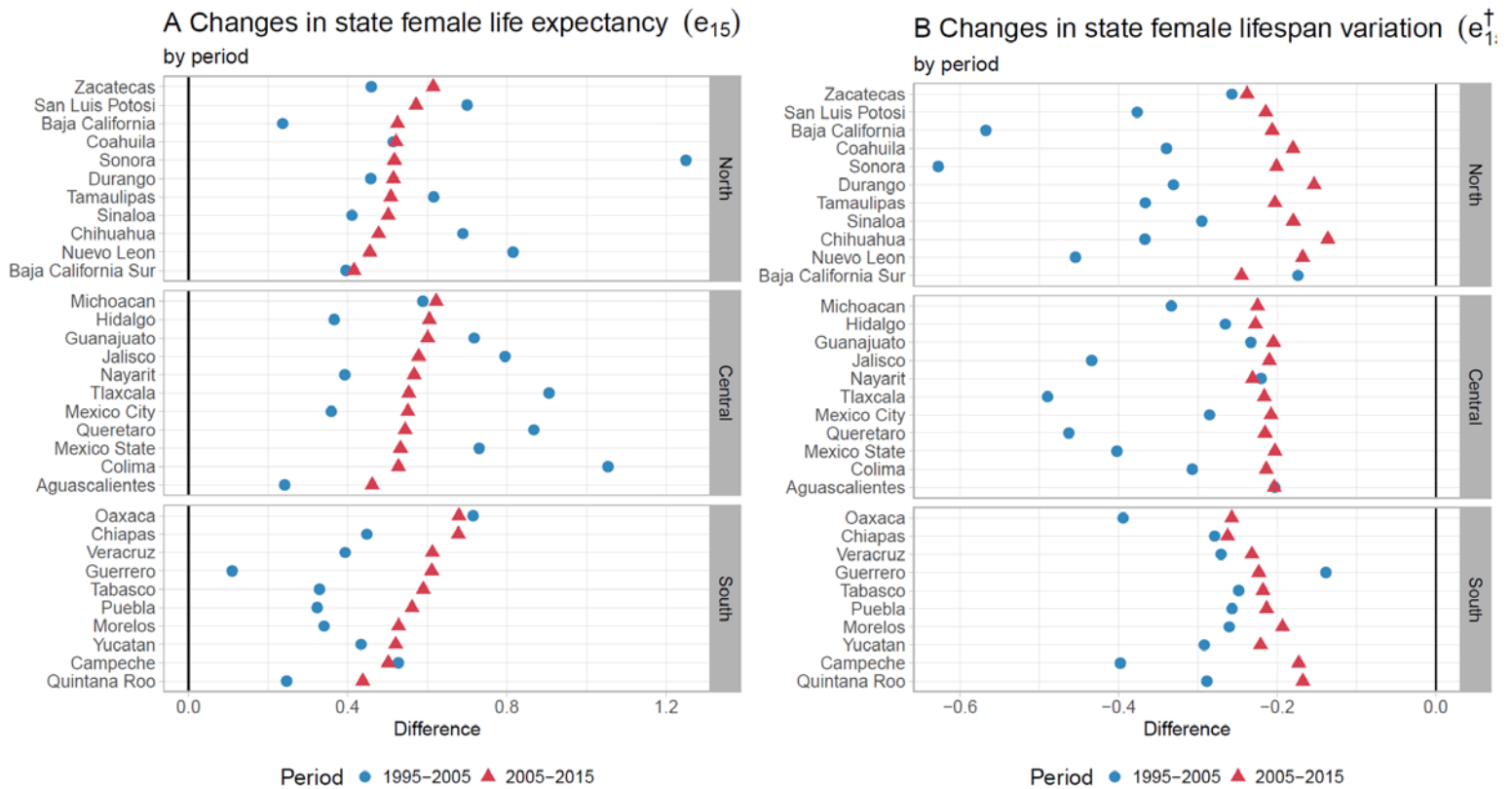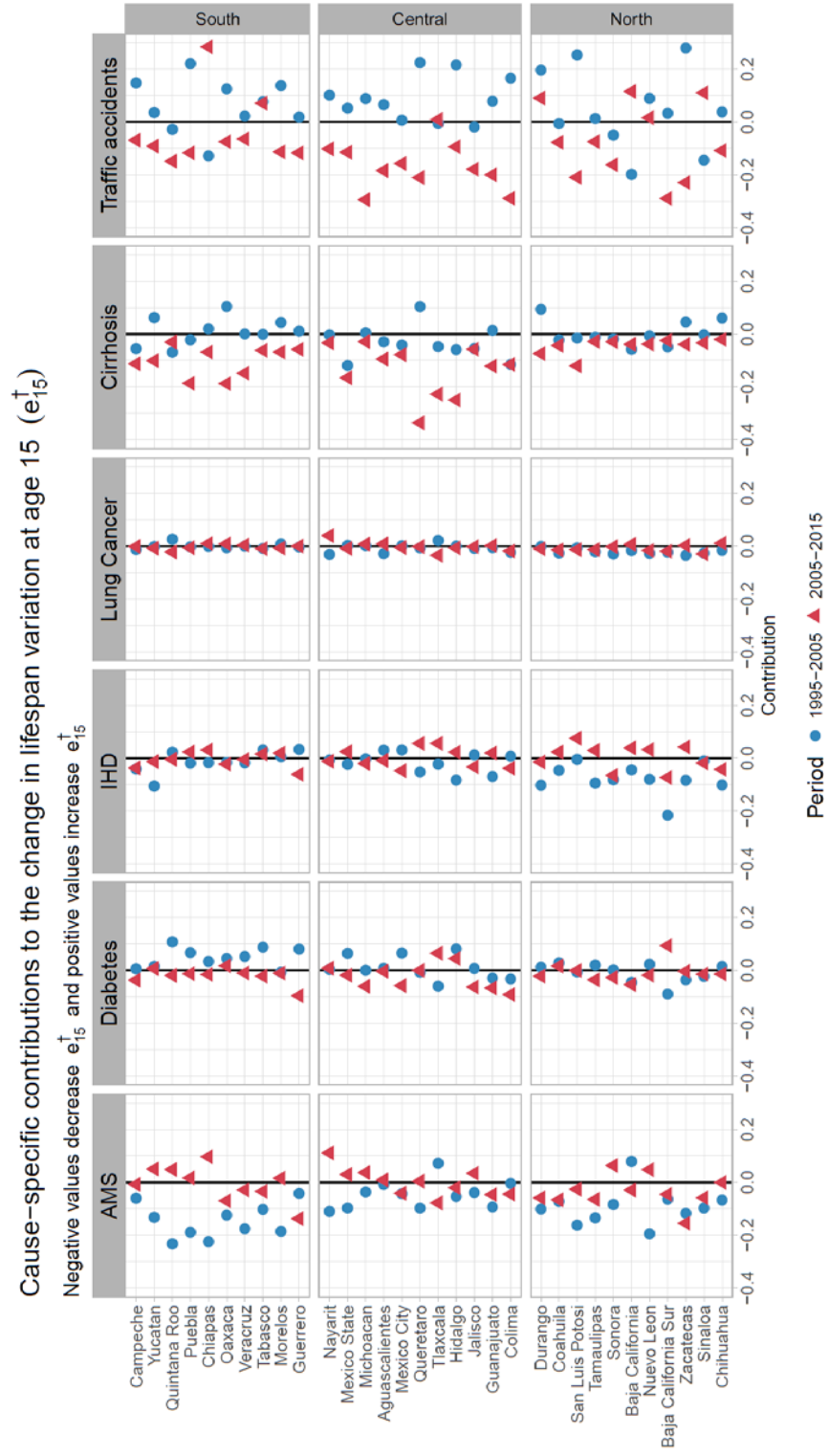by period

Period ● 1995–2005 ▲ 2005–2015

Figure S5. Cause-specific contributions to changes in male lifespan inequality at age 15 by state for the periods 1995-2005 and 2005-2015 (x-axis in different scale than the paper).

Figure S6. Cause-specific contributions to changes in female lifespan inequality at age 15 by state for the periods 1995-2005 and 2005-2015.
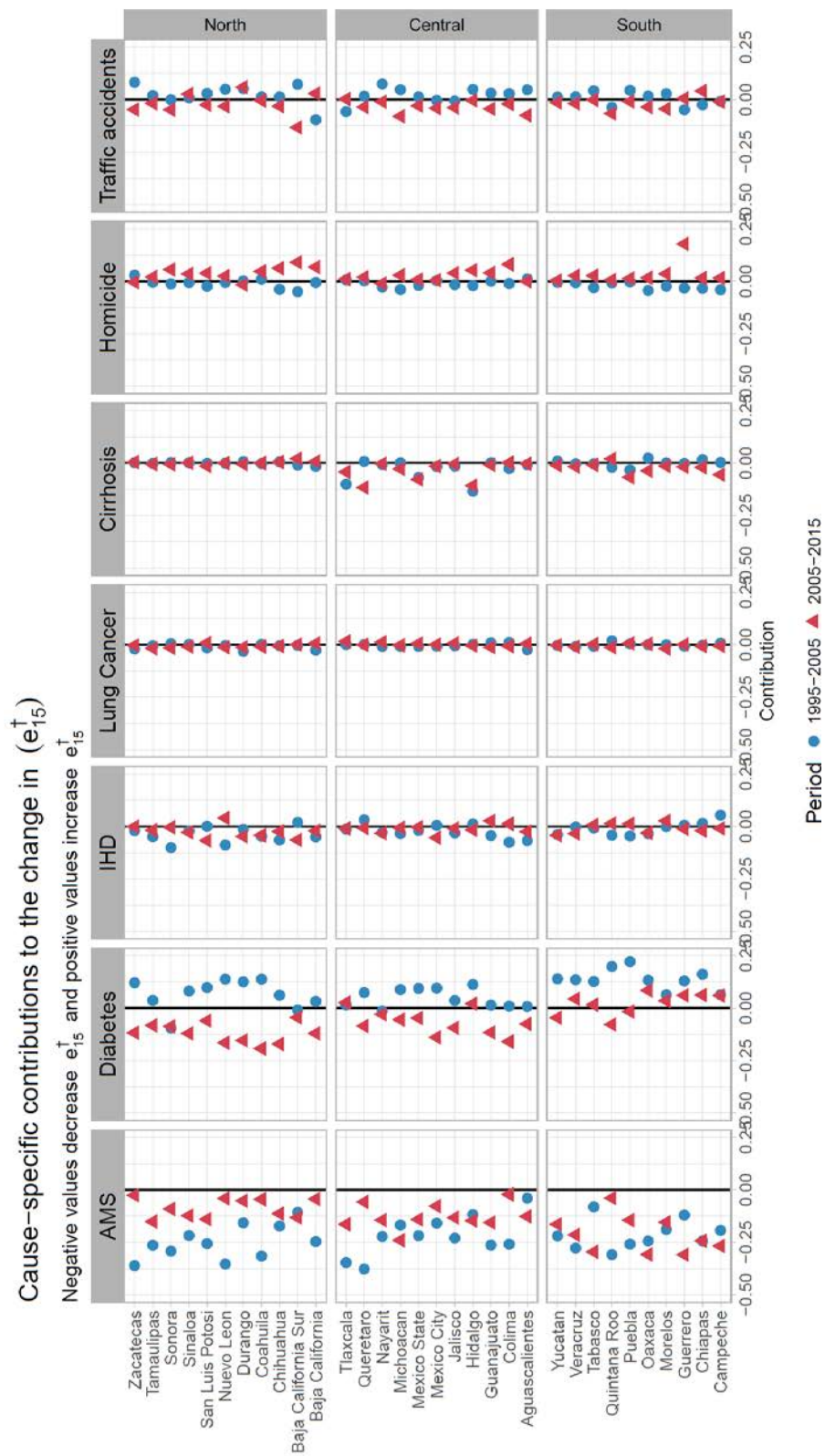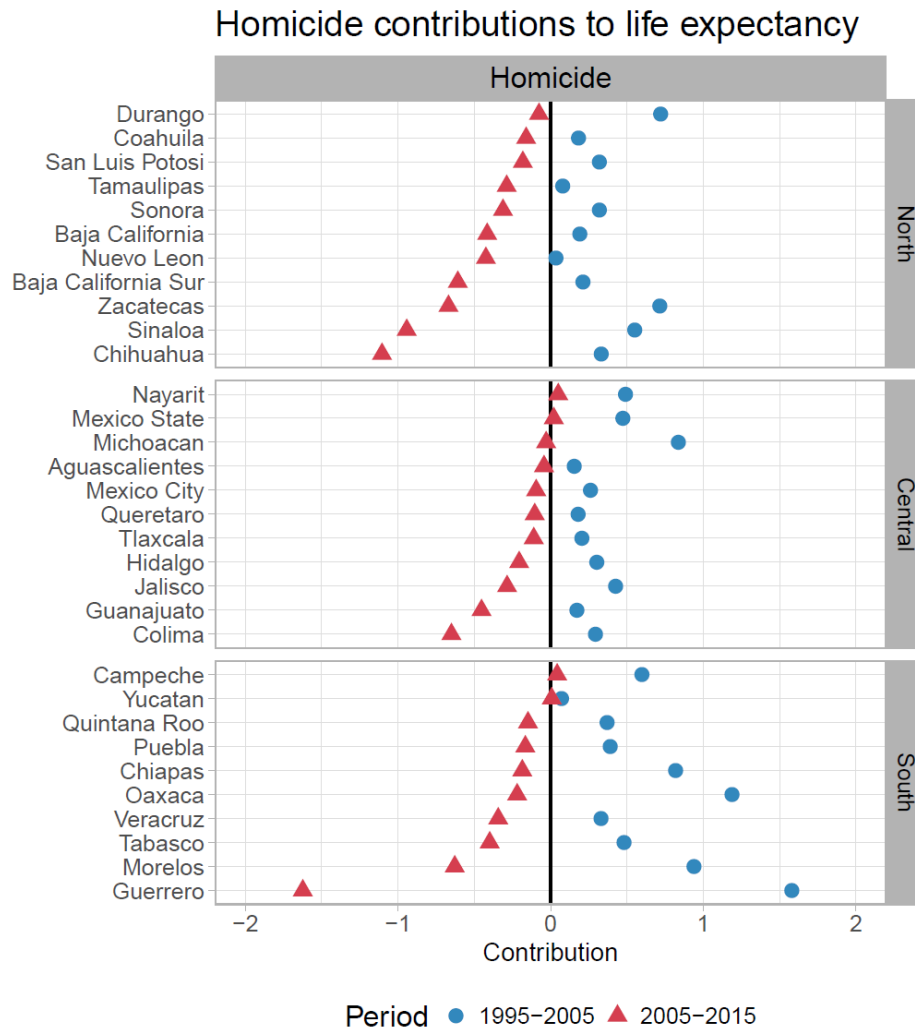
Figure S7. Homicide contributions to changes in male life expectancy at age 15 by state for the periods 1995-2005 and 2005-2015.

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