XVIII Jornadas Argentinas de Estudios de Población - V Congreso Internacional de Población del Cono Sur. Asociación de Estudios de Población de la Argentina, Córdoba, 2025.

# Unveiling COVID-19's Toll: How the Pandemic Reshaped Life Expectancy in Brazil and Mexico.

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# Unveiling COVID-19's Toll: How the Pandemic Reshaped Life Expectancy in Brazil and Mexico

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**Abstract**

The COVID-19 pandemic has had a significant impact on Latin American countries, with the region being identified as an epicenter due to high infection rates and excess deaths in several countries. In Brazil and Mexico, the disease spread rapidly across regions. A key factor in understanding the pandemic's full scope is its direct and indirect effects on mortality and life expectancy. This study aims to investigate how the COVID-19 pandemic affected mortality rates by age and cause of death, leading to stagnation or declines in life expectancy among subnational populations in Brazil and Mexico between 2010 and 2023. Using life table functions and the Arriaga method, we analyzed how changes in mortality rates by sex, age group, and cause of death affected life expectancy at birth in these populations. Preliminary results from national-level analyses in Brazil and Mexico indicate that the pandemic's effects on mortality and life expectancy extend beyond the period of official declaration. These findings highlight the extent to which changes in mortality rates by sex, age, and cause of death have had either negative or positive impacts on life expectancy, from the pre-pandemic period to the years overlapping with the pandemic.

**Introduction**

The COVID-19 pandemic has significantly impacted Latin American countries (Lima et al. 2021). This region has been identified as the epicenter of the pandemic given that some countries have experienced high rates of infection and excess deaths from COVID-19 (Lima et al. 2021). Brazil was one of the first countries to report the disease, which quickly spread across its regions (Castro et al., 2021). Similarly, Mexico also has a significant number of COVID-19 cases and deaths (García-Guererro and Beltrán-Sánches, 2021). Another relevant factor for understanding the extent of the pandemic includes its direct and indirect effects on mortality, such as deaths accurately registered as COVID-19 and deaths from any other health issues that occurred due to the strain placed on the healthcare system by COVID-19. This study aims to examine how the COVID-19 pandemic impacted mortality levels, leading to stagnation or a decline in life expectancy among subnational populations in Brazil and Mexico from 2010 to 2022. We analyzed how changes in mortality rates by sex, age group, and cause of death affected life expectancy at birth in these subnational populations during the period of analysis.

While several studies have examined excess mortality during the pandemic years, this measure has become the gold standard of analysis, as it relies solely on all-cause mortality and does not require additional information such as specific causes of death or age. This study contributes to the debate by investigating the impact of the pandemic alongside other causes of death, considering its effects on different age groups and subnational populations. In addition to the cases of COVID-19, an increase in the prevalence and hospitalizations due to Severe Acute Respiratory Syndrome (SARS) was observed when comparing the indicators before, during, and after the pandemic. The magnitude of the pandemic can be significantly underestimated, for several reasons. First, the unknown etiology of the disease and the need for more protocols and diagnostic tests in its early stages may result in underreporting of cases. Weak public health policies to combat the pandemic, such as a low testing rate, may have helped this process.

Given the highly age-selective nature of COVID-19, it is imperative to conduct studies that rigorously analyze and pinpoint how the pandemic has impacted mortality levels and life expectancy by age across both national and subnational populations. Multiple factors likely play a predominant role in explaining the regional disparities observed in this impact. Our analysis builds upon the work of Scholey et al. (2022); however, we advance it by decomposing mortality into specific causes of death, rather than aggregating them under 'other causes' for comparison with COVID-19.

## Data and Methods

### Data

The databases used in this study are publicly available. In Brazil, mortality and population data, disaggregated by age, sex, cause of death, and areas of interest, are provided by the Brazilian Institute of Geography and Statistics (IBGE) based on the 2010 and 2022 census and the Mortality Information System of the Ministry of Health (SIM/Datasus). In addition, IBGE has published a new revision of estimated and forecasted life tables for national and subnational areas from 2000 to 2070.

For Mexico, the same breakdowns are available from the National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and the complete life tables from the

National Population Council (CONAPO, by its acronym in Spanish). Mortality data were analyzed and corrected for coverage errors in all regions in Brazil.

Methods of Analysis

Among these decomposition methods, the Arriaga method (1984) stands out. It is used to analyze differentials in life expectancy at birth or temporary life expectancy at any age based on changes in mortality by age or differences in mortality by sex, region, or any other demographic characteristic of interest. This method estimates how changes in mortality by age contribute to changes in life expectancy, recognizing that changes in life expectancy do not necessarily indicate uniform changes in mortality rates across all ages. The extended version of the method applied here considers variations in mortality owing to a series of causes of death. Given the age-selective nature of the COVID-19 pandemic, this method is particularly suitable for analyzing its impact on life expectancy by sex and age.

The causes of death considered in this study were infectious and parasitic diseases (Chapter I), neoplasms (Chapter II), diseases of the circulatory system (Chapter IX), maternal and post-maternal (Chapter XV), and external causes of morbidity and mortality (Chapter XX). Deaths due to COVID-19, suicides, and homicides were considered separately from their respective chapters. The rationale for selecting these chapters and causes is as follows: (i) the potential impact of the COVID-19 pandemic on deaths within each chapter/cause; (ii) chapters encompassing morbidities that increased the risk of death from COVID-19 and whose treatment and follow-up were negatively affected (Mendes, 2020); (iii) the rise in maternal deaths in Brazil during the pandemic (Serra et al., 2021); and (iv) the documented increase in deaths due to homicides and suicides in contexts of health and economic crises (Banerjee et al., 2021; Viero et al., 2020).

The Arriaga method was applied to the sex- and age-specific survivorship functions of life tables for each calendar year, covering the periods before, during, and after the pandemic. When comparing abridged life tables with different mortality levels, it is observed that, in many cases, mortality varies across age groups with different magnitudes. Arriaga (1984) summarizes the following effects that changes in age-specific mortality have on life expectancy:

Effects due to exclusive changes in mortality rates within each age group:

- Direct Effect (DE): results from changes in the years of life within a given age interval because of changes in mortality within that interval.
- Indirect (IE): represents the additional years of life gained in life expectancy, given that changes in mortality within an age group can impact the number of survivors at the end of that interval.
- Interaction Effect: represents the combined impact of exclusive mortality changes in each age group on overall life expectancy:

The total contribution of changes in mortality by age groups, between year t and year *t+k*, to changes in life expectancy at birth over the same period can be determined by:

$$ {}_nC_x = \left[\frac{l_x^t}{l_0^t} \times \left(\frac{{}_nL_x^{t+k}}{l_x^{t+k}} - \frac{{}_nL_x^t}{l_x^t}\right)\right] + \left[\frac{T_{x+n}^{t+k}}{l_0^t} \times \left(\frac{l_x^t}{l_x^{t+k}} - \frac{l_{x+n}^t}{l_{x+n}^{t+k}}\right)\right] \quad (1) $$

where *l*, *L* and *T* are life table functions; *x*, *x+n* is age interval; *t* represents the initial year of observation and *t+k* is the final year of observation.

The first term on the right side of (1) refers to the Direct Effect, while the second term relates to the Indirect and Interaction Effects. The total effect of a change in mortality in the age group *x*, *x+n* between years t and *t+k* on life expectancy is given by the sum of the direct, indirect, and interaction effects. The extended version of the method applied here considers variations in mortality owing to a series of causes of death. Given the age-selective nature of the COVID-19 pandemic, this method is particularly suitable for analyzing its impact on life expectancy by sex and age.

To analyze the impact of changes in cause-specific mortality rates on the total effect and, consequently, on life expectancy at birth by age groups, the proportional contribution of the difference in cause-specific mortality rates relative to the difference in the all-cause mortality rate (envelop) between years t and *t+k* can be calculated by:

$$ {}_nC_x^i = {}_nC_x \times \left[\frac{\left({}_nR_x^{i,t} \times {}_nM_x^{i,t}\right) - \left({}_nR_x^{i,t} \times {}_nM_x^{i,t+k}\right)}{{}_nM_x^{t+k} - {}_nM_x^t}\right] \quad (2) $$

where *i* indicate the cause of death; ${}_nR_x^i$ is the proportion of deaths between age *x* and *x+n* due to cause *i*; ${}_nM_x$ is the mortality rates from life table from age *x* to *x+n*.

The Arriaga method was applied to the sex- and age-specific survivorship functions of life tables for each calendar year, covering the periods before (from 2010 to 2019), during (from 2019 to 2020 and 2021), and after the pandemic (from 2019 to 2022 and 2023), according to the final year of observation.

## Results

### Life Tables

We use estimated life tables for Brazil and Mexico for the following years: 2010, 2019, 2020, 2021, 2022 and 2023. Changes in life expectancy at birth by sex for Brazil and Mexico for each period of analysis, based on the 2010 and 2019 year as baseline, are available in Table 1. In both Brazil and Mexico, life expectancy at birth increased between 2010 and 2019, with a more pronounced rise in Brazil for both sexes during this period. In both populations, life expectancy declined from 2019 to 2020, 2021 and 2022, before resuming an upward trend in 2023. However, in Mexico, the negative impact of mortality in live expectancy at birth was significantly higher than in Brazil during pandemic years. The declines in life expectancy during the pandemic years were more significant in Mexico, particularly among men.

Figures 1 show the contributions of changes in mortality rates to increases or declines in life expectancy at birth in Brazil and Mexico, respectively, during the all period analyzed. The evolution of life expectancy at birth in both countries reflects the changes reported in Table 1 for each reference period. The figure, however, provide further insight into the extent to which shifts in mortality contributed either to gains or to setbacks in life expectancy across states in each country.

In Brazil, the impacts were predominantly positive in nearly all states and for both sexes between 2010 and 2019, resulting in consistent increases in life expectancy over this interval (see Figure 1). In contrast, in Mexico, during the same period, several states experienced adverse impacts affecting one or both sexes. The state of Colima stands out, as it exhibited particularly pronounced declines in life expectancy between 2010 and 2019.

Table 1 - Life expectancy at birth – e(0) – and absolute variation in life expectancy at birth by sex, Brazil and Mexico (2010, 2019–2022)

| Year | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | e(0) | Change relative to the year 2010 and 2019 | | e(0) | Change relative to the year 2010 and 2019 | |
| | | | *Mexico* | | | |
| 2010 | 75.6 | - | - | 80.3 | - | - |
| 2019 | 75.7 | 2010/2019 | 0.1 | 80.9 | 2010/2019 | 0.6 |
| 2020 | 67.6 | 2019/2020 | -8.1 | 76.3 | 2019/2020 | -4.6 |
| 2021 | 68.4 | 2019/2021 | -7.3 | 76.0 | 2019/2021 | -4.9 |
| 2022 | 74.4 | 2019/2022 | -1.3 | 79.9 | 2019/2022 | -1.0 |
| 2023 | 75.9 | 2019/2023 | 0.2 | 81.1 | 2019/2023 | 0.2 |
| | | | *Brazil* | | | |
| 2010 | 70.7 | - | - | 78.1 | - | - |
| 2019 | 72.8 | 2010/2019 | 2.1 | 79.6 | 2010/2019 | 1.5 |
| 2020 | 71.2 | 2019/2020 | -1.6 | 78.5 | 2019/2020 | -1.1 |
| 2021 | 69.3 | 2019/2021 | -3.5 | 76.4 | 2019/2021 | -3.2 |
| 2022 | 72.1 | 2019/2022 | -0.7 | 78.8 | 2019/2022 | -0.8 |
| 2023 | 73.1 | 2019/2023 | 0.3 | 79.7 | 2019/2023 | 0.1 |

Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

Across both countries, regions, and sexes, the evidence indicates that adverse effects on life expectancy were more pronounced in the periods 2019–2020 and 2019–2021. In Brazil, where the peak of COVID-19 cases and related mortality occurred in 2021, the most substantial negative impacts are observed in the interval 2019–2021, followed by 2019–2020, for both sexes. In Mexico, however, the most severe declines in life expectancy were not necessarily concentrated in the 2019–2021 period (see figure 1).

Figure 1 - Contributions of changes in mortality rates to increases or declines in life expectancy at birth, Brazil and Mexico (2010, 2019 to 2020, 2021, 2022 and 2023)


Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

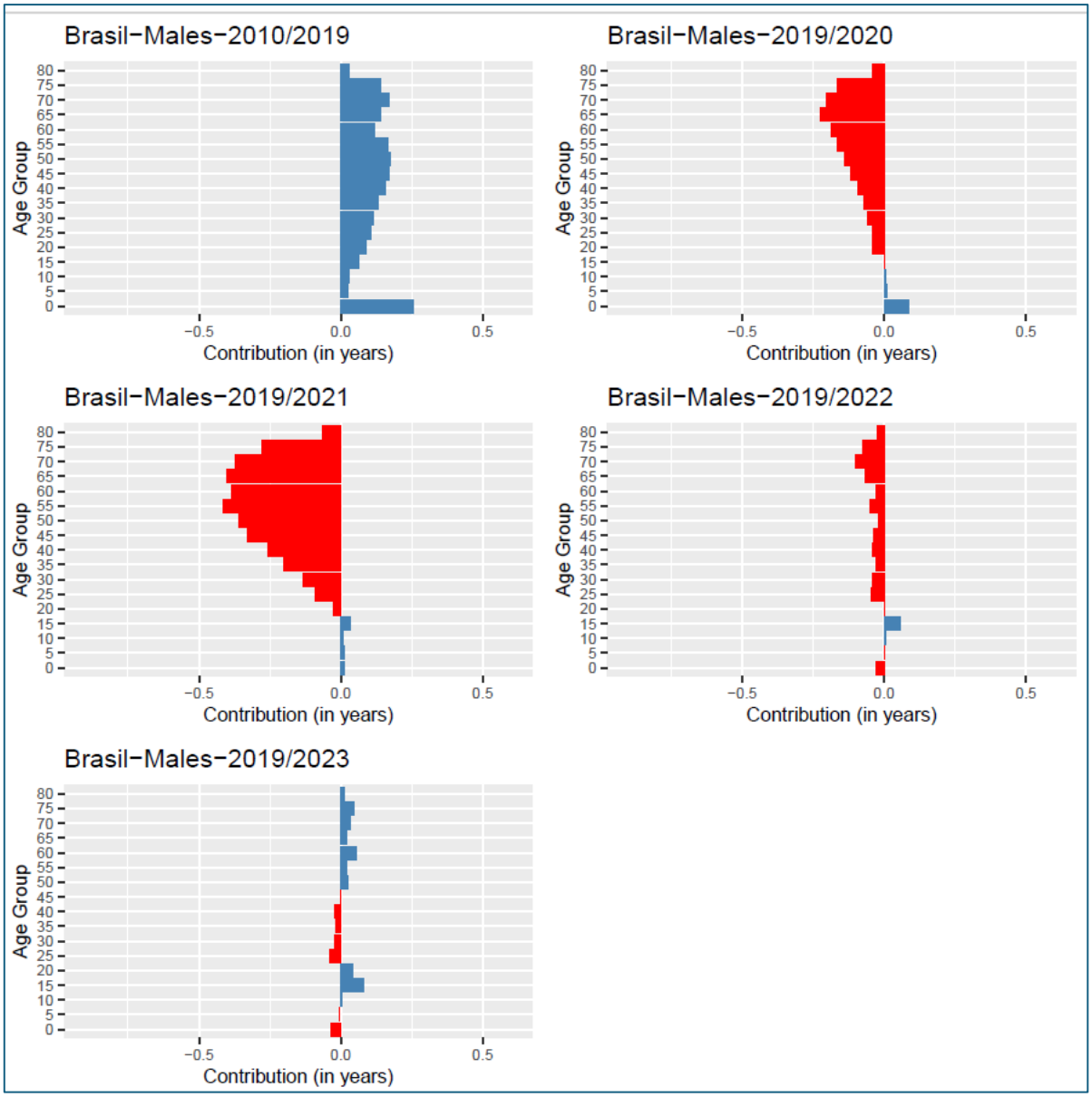
Decomposition by age

The Arriaga method was subsequently utilized to estimate the impact of changes in mortality rates by age group on life expectancy at birth across various periods from 2010 to 2023. The results of the decomposition by age for males and females in both countries are presented in Figures 2 and 3, respectively. In both figures, the black and red bars represent, respectively, the positive or negative impact that alterations in mortality rates by age groups exerted on changes in Life Expectancy at Birth (LE).

During the period from 2010 to 2019 (prior to the pandemic), in Brazil, unlike in Mexico, changes in mortality rates across nearly all age groups and for both sexes had a positive impact on the increase in life expectancy at birth. In Mexico, alterations in male mortality rates from ages 20 to 65 during this period had a significant negative effect on life expectancy at birth, resulting in only a modest increase in male life expectancy over the nine-year period, as showed in table 1.

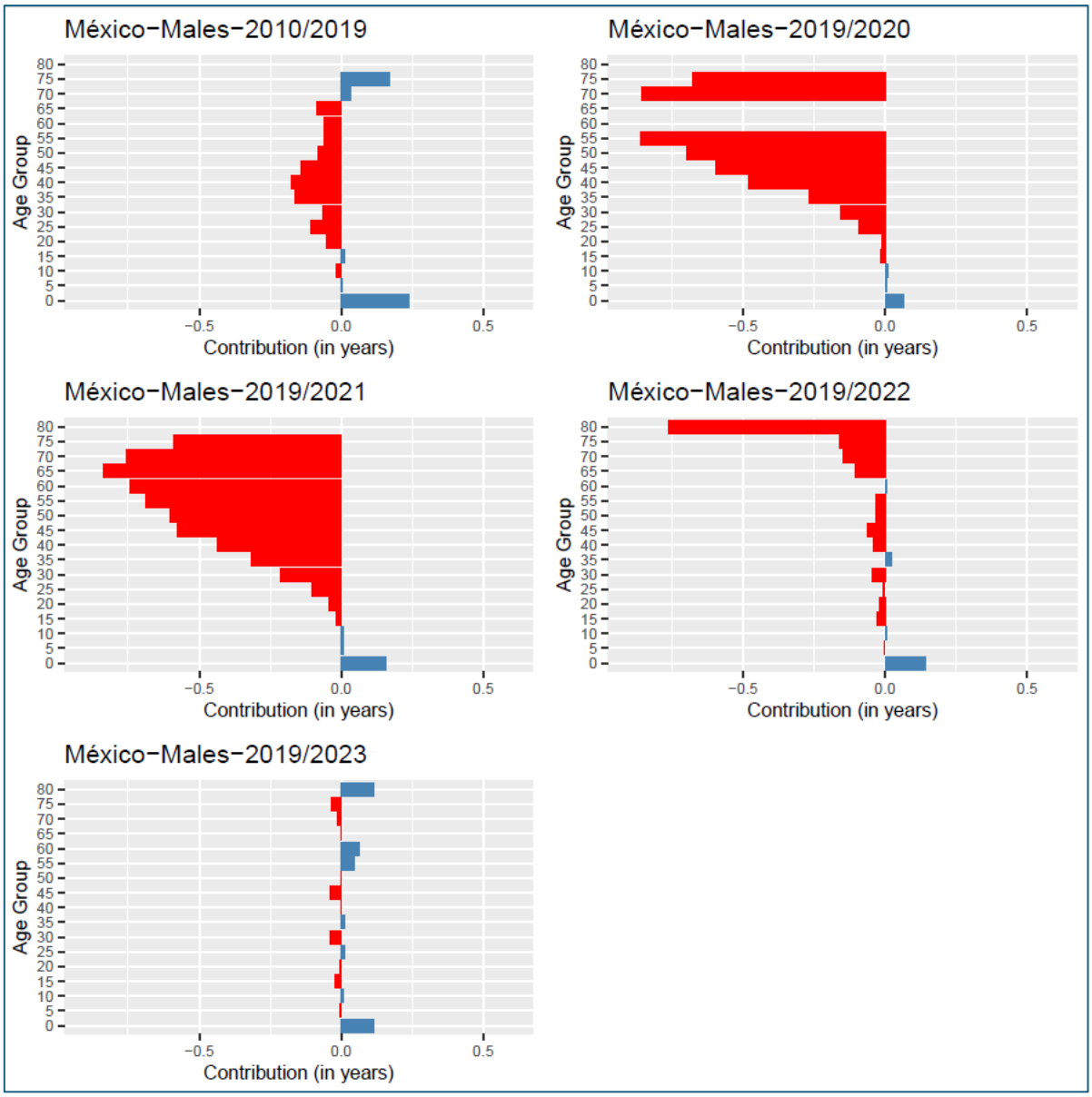
When examining the first and second years of the pandemic within the analytical periods (i.e., 2019–2020 and 2019–2022), the impact on the Mexican population was particularly severe, with pronounced declines observed across all age groups from age 25 onward, especially among males. In Brazil, the adverse effects observed from young adulthood through older ages during the periods 2019–2020 and 2019–2021 led to a regression in life expectancy at birth, with the most substantial decline occurring in the latter period (see figures 2 and 3). Furthermore, negative impacts were evident in nearly all age groups above five years during 2019–2022, and in certain age groups during 2019–2023, in both countries. These findings highlight that the effects of COVID-19 on mortality extended beyond the immediate pandemic years.

Figure 2 - Contributions of changes in mortality rates by age group to increases or declines in life expectancy at birth, **Males** - Brazil (2010, 2019 to 2020, 2021 and 2023)




Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

Figure 3 - Contributions of changes in mortality rates by age group to increases or declines in life expectancy at birth, **Males** - Mexico (2010, 2019 to 2020, 2021 and 2023)




Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

## Decomposition by cause of deaths

Figure 4 presents the contributions of COVID-19 mortality rates to changes in life expectancy at birth across different regions of Brazil and Mexico over various periods of analysis. As expected, in the period 2010–2019, the effect was null due to the absence of COVID-19 deaths. During the pandemic periods, however, COVID-19 mortality contributed negatively to life expectancy at birth in several regions of both countries and for both sexes.

In Brazil, particularly strong adverse effects were observed in the states of Rondônia, Amazonas, Roraima, and the Federal District for both sexes, as well as in Goiás, Mato Grosso do Sul, Mato Grosso, and Paraná among males. In all these states, losses in life expectancy at birth exceeded four years. In Mexico, the most severe declines were observed in Baja California Sur and Mexico City for both sexes, and in Morelos, Querétaro, Hidalgo, and Guerrero among males. In all these states, the reductions in life expectancy at birth were equal to or greater than five years.

For other causes of death (Figures 5 to 10 in Appendix 1), notable effects include the impact of male suicide mortality in Roraima (Brazil) during 2019–2023, with a loss of 0.25 years in male life expectancy, and in several Mexican states, particularly during 2010–2019, 2019–2022, and 2019–2023. In Mexico, significant adverse effects were observed among women in Quintana Roo (–0.6 years), Oaxaca (approximately –0.4 years), and Campeche (approximately –0.24 years). For Mexican men, several states recorded negative impacts during 2010–2019.

With respect to maternal causes (pregnancy, childbirth, and the puerperium), the most pronounced effects were observed in Rio Grande do Norte (–0.25 years) and Roraima (–0.21 years) during 2019–2023.

Neoplasm-related mortality also contributed negatively to life expectancy in specific regions of both countries. In Brazil, the most notable impacts were observed among women in Amapá (2010–2019) and Tocantins (2019–2020), and among men in Santa Catarina and Rondônia (2019–2023). In Mexico, severe declines were observed among women during 2019–2022, particularly in Quintana Roo (slightly over –4 years), Campeche (nearly –2.5 years), and Oaxaca (almost –2 years).

Homicide mortality also had a substantial negative impact on male life expectancy across several regions and periods in both countries.

Finally, circulatory diseases contributed significantly to declines in life expectancy in both countries, with noteworthy effects among women in Colima (Mexico) and in Rio de Janeiro (Brazil).

Figure 4 - Contributions of changes in mortality rates due to covid to changes in life expectancy at birth, Brazil and Mexico (2010, 2019 to 2020, 2021 and 2023)


Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

## Discussion and Conclusion

The results of this study highlight the profound and heterogeneous effects of the COVID-19 pandemic on mortality and life expectancy at birth in Brazil and Mexico between 2010 and 2023. While both countries experienced steady gains in life expectancy during the pre-pandemic period (2010–2019), the onset of COVID-19 triggered sharp reversals, with substantial declines particularly evident between 2019–2020 and 2019–2021. These impacts were more severe in Mexico, where reductions in life expectancy were greater than those observed in Brazil, especially among men.

The age-specific analysis confirmed the strong age-selective nature of the pandemic: most of the losses in life years were concentrated from adulthood onward, with cumulative effects at older ages. However, declines were also observed among younger adults, particularly Mexican men, underscoring how the pandemic exacerbated pre-existing vulnerabilities within this population. In Brazil, the sharpest decline occurred in 2021, coinciding with the national peak of COVID-19 cases and deaths, underscoring the close relationship between the epidemiological dynamics of the pandemic and demographic fluctuations.

Cause-of-death decomposition revealed that COVID-19 mortality was the primary driver of the decline in life expectancy, yet it did not act in isolation. Structural causes of mortality such as circulatory diseases and neoplasms also contributed, reflecting both their interaction with COVID-19 infection and the indirect effects of overwhelmed health systems. Furthermore, the rise in maternal deaths and external causes—such as homicides and suicides—demonstrates that the pandemic extended beyond health systems, deeply affecting social, economic, and behavioral dimensions of mortality.

Marked spatial heterogeneity also emerged: while some Brazilian and Mexican states experienced losses exceeding four or five years of life expectancy, others recorded less severe setbacks. These territorial disparities are linked to structural determinants such as socioeconomic inequality, health system capacity, and the effectiveness of pandemic response policies.

In summary, this study demonstrates that COVID-19 not only disrupted the trajectory of increasing longevity in Brazil and Mexico but also deepened pre-existing disparities across regions, sexes, and age groups. The partial recovery of life expectancy in 2023 points to demographic resilience but does not imply an automatic return to pre-pandemic trends, given

the long-lasting impacts of the pandemic on chronic diseases, mental health, and socioeconomic conditions.

The main contribution of this research lies in showing that life expectancy at birth, when decomposed by age, sex, and cause of death, captures not only the direct effects of COVID-19 but also its indirect consequences. These findings underscore the need for public policies aimed at strengthening health systems, reducing territorial inequalities, and mitigating social vulnerabilities that amplify the demographic impact of health crises.

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**Appendix 1**

Figure 5 - Contributions of changes in mortality rates due to suicide to changes in life expectancy at birth, Brazil and Mexico (2010, 2019 to 2020, 2021 and 2023)


Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

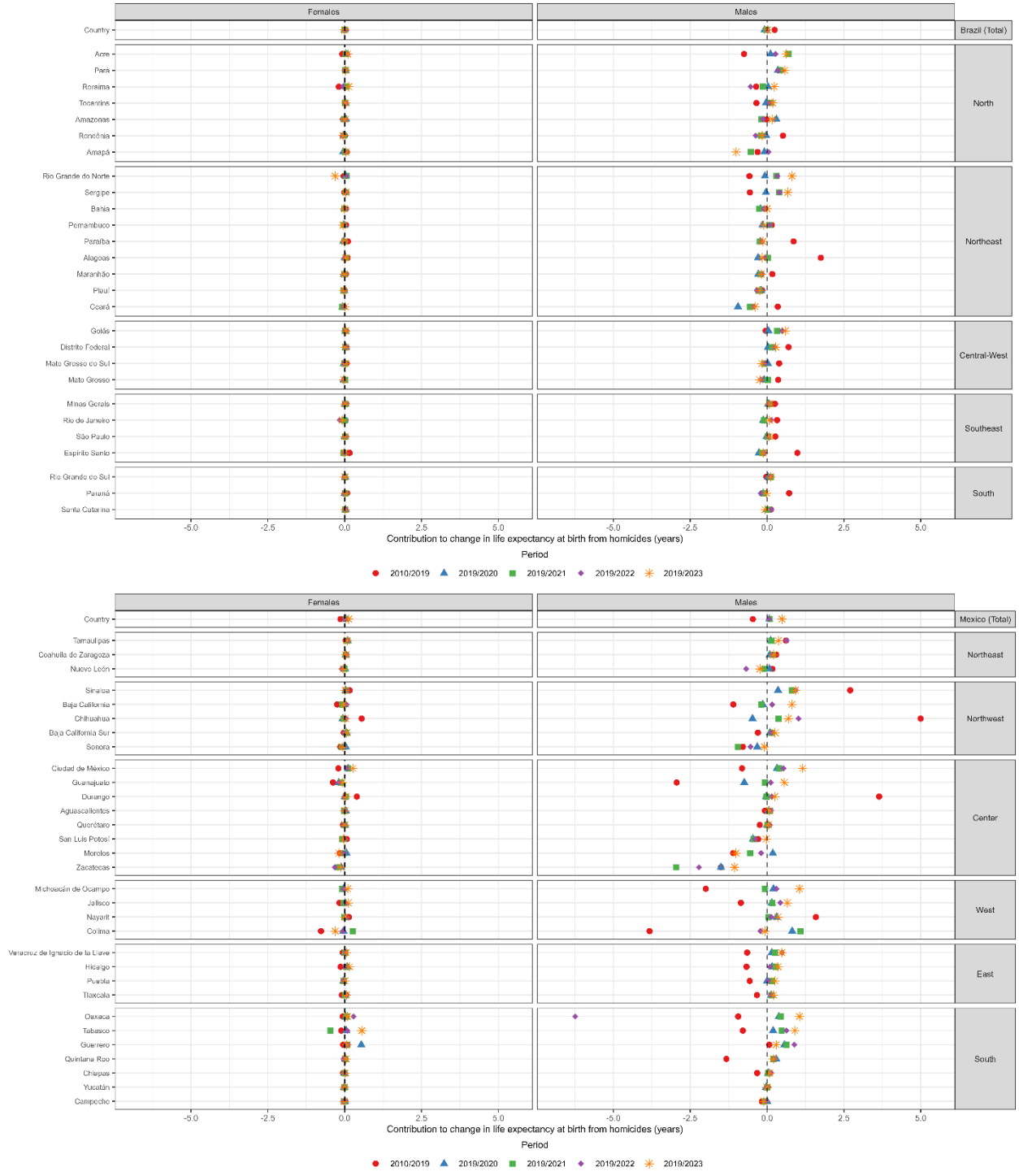
Figure 6 - Contributions of changes in mortality rates due to maternal causes (pregnancy, childbirth, and the puerperium) to changes in life expectancy at birth, Brazil and Mexico (2010, 2019 to 2020, 2021 and 2023)


Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

Figure 7 - Contributions of changes in mortality rates due to Neoplasm to changes in life expectancy at birth, Brazil and Mexico (2010, 2019 to 2020, 2021 and 2023)


Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

Figure 8 - Contributions of changes in mortality rates due to Homicide to changes in life expectancy at birth, Brazil and Mexico (2010, 2019 to 2020, 2021 and 2023)




Source: Brazilian Institute of Geography and Statistics (IBGE, by its acronym in Portuguese); Ministry of Health (SIM/DATASUS); National Institute of Statistics and Geography (INEGI, by its acronym in Spanish) and National Population Council (CONAPO, by its acronym in Spanish).

Figure 9 - Contributions of changes in mortality rates due to Circulatory to changes in life expectancy at birth, Brazil and Mexico (2010, 2019 to 2020, 2021 and 2023)

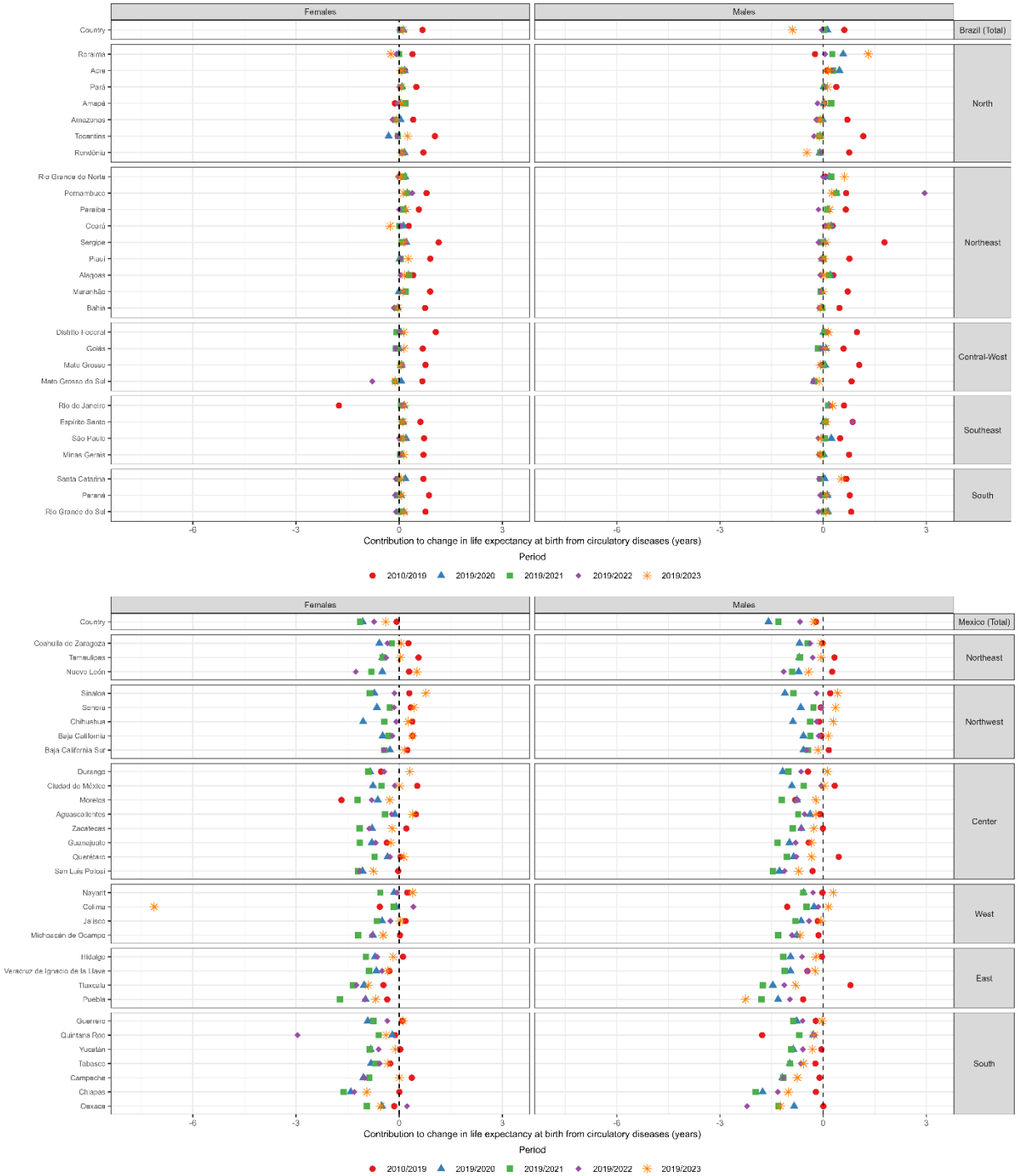



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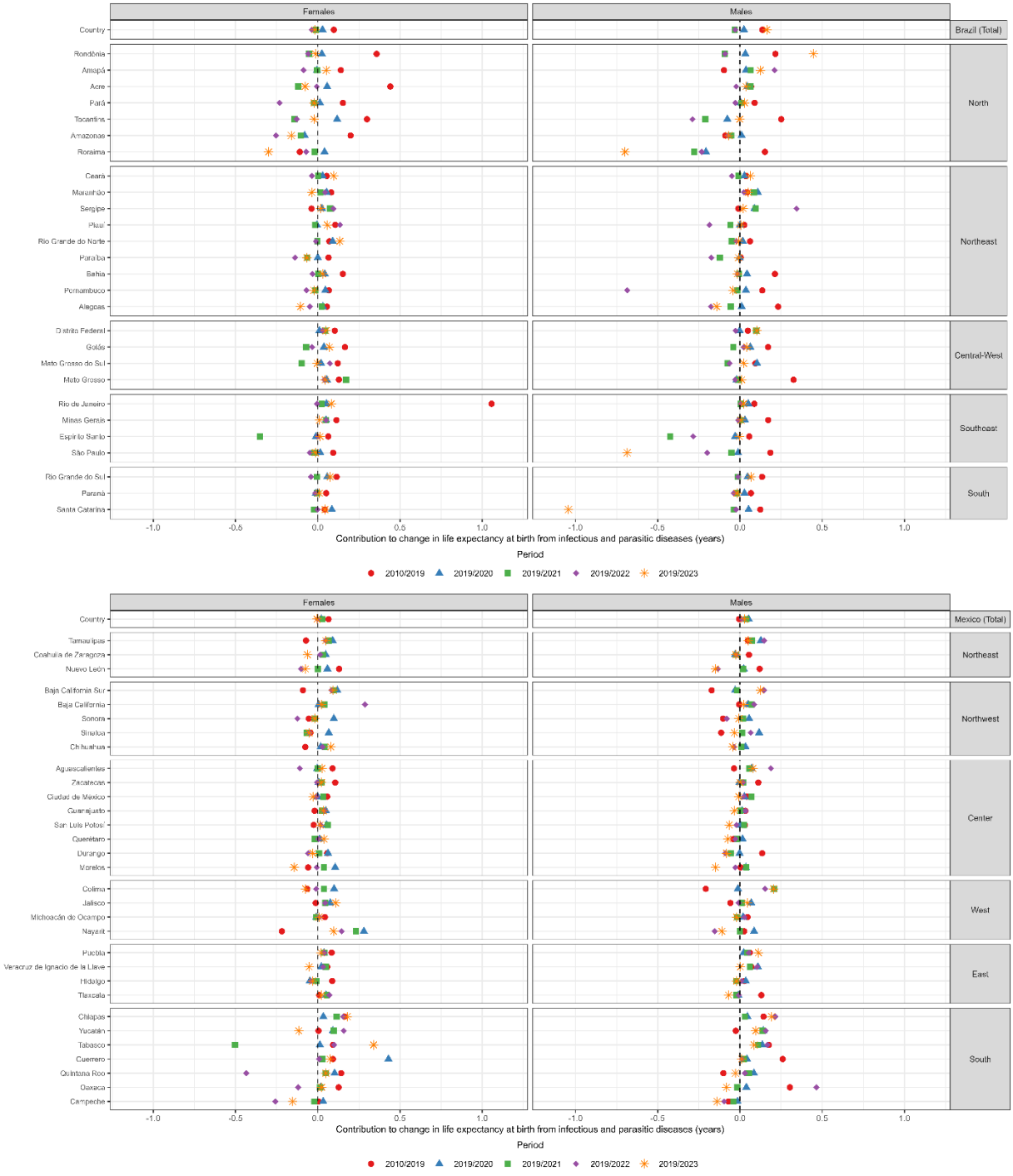
Figure 10 - Contributions of changes in mortality rates due to infectious and parasitic diseases to changes in life expectancy at birth, Brazil and Mexico (2010, 2019 to 2020, 2021 and 2023)

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