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Marginalization and life expectancy loss during the Covid-19 pandemic in Mexico, 2020

Marginalización y años esperanza de vida perdidos durante la pandemia por Covid-19 en México, 2020

Felipe J. Uribe Salas[1] y Gerardo Núñez Medina[2]

Abstract: Introduction: Studies have been conducted in Mexico on indicators of socioeconomic status in relation to morbidity, incidence, survival, mortality, and lethality due to Covid-19, with the exception of life expectancy (LE). This study proposes to examine LE for the year 2020 in the context of the Covid-19 pandemic and to analyze its relationship with indicators of marginalization in Mexican municipalities. **Methodology:** LE was calculated using the standard actuarial method based on death information from the Mexican Ministry of Health. Demographic information and indicators of marginalization were obtained from the National Population Council. Correlations and risk analyses were performed to evaluate the relationship between LE and marginalization indicators. A multiple correspondence analysis (MCA) was performed with indicators of education, income, housing, population size and LE. **Results:** The effect of marginalization indicators on LE indicate that the higher the percentage of marginalization, the higher the effect on LE. The population size of the municipalities had a positive relationship with LE, that is, the larger the population size, the greater the loss in years of LE. MCA reveals clear territorial polarization of well-being and longevity in Mexican municipalities, with educational attainment, income and population size remaining key determinants of LE. **Conclusion:** These results suggest that the impact of the Covid-19 pandemic on LE was greater in populations with larger communities and, at the same time, the highest percentage of marginalization indicators was found in populations with smaller size.

Keywords: Covid-19; life expectancy; marginalization indicators; municipalities.

Resumen: Introducción: En México se han realizado estudios sobre indicadores de nivel socioeconómico en relación con morbilidad, incidencia, supervivencia, mortalidad y letalidad por Covid-19, con excepción de la esperanza de vida (EV). Este estudio propone examinar la EV para el año 2020 en el contexto de la pandemia por Covid-19 y analizar su relación con indicadores de marginación en municipios mexicanos. **Metodología:** La EV se calculó por el método actuarial estándar con información sobre defunciones de la Secretaría de Salud de México. La información demográfica y los indicadores de marginación se obtuvieron del Consejo Nacional de Población. Se realizaron correlaciones y análisis de riesgo para evaluar la relación entre la EV e indicadores de marginación. Se realizó un análisis de correspondencias múltiple (ACM) con indicadores de educación, ingreso, vivienda y EV. **Resultados:** El efecto de los indicadores de marginación sobre la EV indicó que, a mayor porcentaje de marginación, mayor fue el efecto sobre la EV. Por el contrario, el tamaño de la población de los municipios tuvo una relación positiva con la EV. A mayor tamaño de la población, mayor la pérdida en años de la EV. El ACM mostró una polarización territorial bienestar-marginación-EV, siendo la educación, el ingreso y el tamaño de la población determinantes clave sobre la EV. **Conclusiones:** Los resultados sugieren que el impacto de la pandemia por Covid-19 sobre la EV fue mayor en las poblaciones con mayor tamaño de los municipios y, al mismo tiempo, el mayor porcentaje de los indicadores de marginación se encontró en las poblaciones con menor tamaño.

Palabras clave: Covid-19, esperanza de vida, indicadores de marginación, municipios.

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1. Introduction

The Covid-19 pandemic, which began in Wuham, China, in late 2019 (WHO, 2020), had a significant impact on life expectancy (LE) in various countries, especially in 2020. Internationally, by region, LE decreased by 1.73 years in North America, 2.09 years in Europe, 0.7 years in Oceania, 2.89 years in Latin America and

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the Caribbean, 1.66 years in Asia, and 1.03 years in Africa (Mo *et al*, 2023). Globally, LE declined by 1.8 years (Cao *et al*, 2023). It can be seen that Latin America and the Caribbean has the highest number of years of life lost. It was found that the impact of Covid-19 mortality in Latin America resulted in a decrease in life expectancy of 2.42 years for Brazil, 1.94 for Chile, 7.91 for Ecuador, 2.26 for Guatemala, 5.54 for Mexico, and 10.91 for Peru (Lima *et al*, 2021). Thus, Peru, Ecuador, and Mexico had the greatest impact of Covid-19 mortality on life expectancy in Latin America.

The excess mortality caused by Covid-19 in Mexico had an important impact on LE. In 2019, the three leading causes of death were cardiovascular diseases (26.3%), diabetes mellitus (14.3%), and malignant neoplasms (12.1%). However, by 2020, Covid-19 deaths will be second only to cardiovascular diseases, accounting for 18.6% of total deaths (Palacio-Mejía *et al,* 2022). The first work done in Mexico on the impact of Covid-19 mortality in LE showed a reduction of 2.5 and 3.6 years for women and men, respectively (García-Guerrero y Beltrán-Sánchez, 2021). These results are lower than those reported by Lima et al (2021), who calculated a total reduction of 5.54 years. Another study conducted in Mexico found an average reduction in LE of 4.7 years (Uribe-Salas *et al*, 2023). From a demographic point of view, premature mortality due to Covid-19 in Mexico had a large impact on LE. It has been pointed out that LE is a function of age at death (Martinez *et al*, 2019). Mortality from Covid-19 in the 45-64 age group in Mexico was 40.2%, compared with 25.6% for other causes in this age group in 2020 (Palacio-Mejía *et al*, 2022). In other words, this is an age group that is likely to account for a significant number of years lost, which would explain its impact on life expectancy.

LE is a widely used health indicator to assess changes in the direction and magnitude of mortality in a population and is closely related to demographic, socioeconomic and health conditions (Wirayuda y Chan, 2021). From a health perspective, the Covid-19 pandemic has had a major impact on LE in different populations and countries (Lima *et al*, 2021; Islam *et al*, 2021; Heuveline, 2022), but little research has been done on the relationship between LE and socioeconomic characteristics of the population.

In Mexico, studies have been carried out using indicators of socioeconomic position that, on the one hand, articulate a theoretical framework that makes it possible to relate the social world to the health of the population and, on the other hand, provide methodological elements to operationalize the variables for their analysis in terms of research (Ribet *et al*, 2007). These studies have linked indicators of marginalization and poverty to health outcomes related to the Covid-19 pandemic, such as morbidity (Chávez-Almazán *et al*, 2022), incidence rates (Contreras-Manzano *et al,* 2022), survival (Millán-Guerrero *et al*, 2021), mortality (Lozano y Ramírez-García, 2023; Bancet y Sosa-Sanchez, 2022; Contreras-Manzano *et al*, 2022), and lethality (Mendoza-González, 2020; Muñíz-Montero *et al*, 2022; Chávez-Almazán *et al*, 2022). To date, however, there are no studies that relate LE to socioeconomic indicators at the community level in the context of the Covid-19 pandemic.

The question of this paper is whether LE is sensitive to changes in the magnitude of social marginalization indicators at the level of Mexican municipalities. Using updated information from the Marginalization Index by Municipality for 2020 (National Population Council, 2020), this paper aims to calculate life

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expectancy comparing that of 2019 (non-pandemic year) with that of 2020 (pandemic year), and to analyze its relationship with indicators of the Marginalization Index in Mexican municipalities.

2. Conceptual framework

The conceptual framework for interpreting the results goes beyond the epidemiological analysis of risk factors based on the "black box" paradigm, where exposure risks that cause disease, can be identified, but not the internal (biological processes at the sub individual level) or external (socially produced differences) mechanisms that produced them (Schwartz *et al*, 1999). Krieger *et al* (1997) approach socially produced differences in health from two streams, that of social class from a Marxist approach and that of socioeconomic position from a Weberian approach. The second approach includes resource-based and prestige-based measures of social class position. These measures refer to material and social resources and assets, including income, wealth, and educational attainment. The terms used to describe a lack of economic position are "poverty" or "deprivation". This second approach is utilized in this work.

3. Methodology

3.1 Approach

This ecological, quantitative and correlative study proposes to evaluate LE in the context of the Covid-19 pandemic and to analyze its relationship with indicators of marginalization along Mexican municipalities.

3.2 Study population and variables

Life expectancy was calculated using information registered deaths for 2019 and 2020 from the Mexican Ministry of Health (2022). Demographic information was obtained from the population projections of the National Population Council (2018). Life expectancy was calculated comparing 2019 and 2020 according to the standard actuarial method (Pagano y Gauvreau, 1993), whose procedure has been published (Uribe-Salas *et al*, 2023). The procedure started with age distribution (x). The central Death rate, represented by the "$_nm_x$" notation, is calculated by the ndx/nLx quotient, which represent the number of deaths and the population in the middle of the period between x and x + n. The hazard function "nqx" indicates the proportion of individuals alive at the beginning of the x to x + n interval who die at some point of the interval. The "lx" notation indicates the number of people from the original cohort who are alive on their x^{th} anniversary. The "ndx" notation represents the number of lx at the beginning of the x to x + n interval who die at some point during the interval. The "nLx" notation is known as the stationary population. It represents the number of person-years lived by the original cohort of the synthetic table within the x to x + 1 age interval. The "Tx" notation indicates the total number of person-years lived beyond their x^{th} birthday by lx individuals alive on that birthday. Finaly, the "ex" notation represents the average number of years of life remaining for an individual who is alive at age x.

The indicators developed by the National Population Council (2020) were used to construct the marginalization index by state and municipality in 2020. The indicators used in this study were: ANALF: Percentage of the population aged 15 and above illiterate; SBASC: Percentage of the population aged 15

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and above without basic education; OVSDE: Percentage of the population living in private dwellings with or without drainage or toilet; OVSEE: Percentage of the population living in private dwellings without electricity; OVSAE: Percentage of the population living in private dwellings without piped water; OVPT: Percentage of the population living in private dwellings with dirt floor; VHAC: Percentage of population living in private dwellings with overcrowding; PO2SM: Percentage of employed population with income below 2 minimum wages; POP_TOT: Total population by municipality.

3.3 Analysis and processing

Since the variables studied were numerical, a descriptive and normality analysis was performed using the Kolmogorv-Smirnov test. The results showed that the variables did not have a normal distribution, so they were subjected to a Spearman correlation analysis with the variable life expectancy. Next, the dependent variable (LE) was transformed from numerical into quartiles, resulting in four categories of loss in years of LE. Marginalization indicators were also transformed from numeric to categorical variables, using the quartiles of their distribution as cut-off points. These transformations were used to test hypotheses of independence between the dependent variable (LE) and the independent variables (indicators of marginalization), and to obtain measures of association by calculating odds ratio (OR). In addition, nonparametric correlation tests were calculated between population size and indicators of marginalization.

A multiple correspondence analysis (MCA) was performed using information from the bivariate analysis of loss of years of LE and the marginalization index indicators categorized by quartiles. This analysis aimed to reduce dimensionality of a data set comprising multiple categorical variables in order to evaluate the relationships and associations between their categories withing a two-dimensional space. A reduced set of factors represented on axes can be used to capture the inertia o variance of the association in the data set. The results are used to create a geographic dimension map, in which each category of variable is represented by a dot. Dots that are close together indicate that the categories are strongly associated, while dots that are far apart indicate that they are mutually exclusive. Since there are independent variables related to education (ANALF and SBASC), variables related to housing (OVSDE, OVSEE, OVPT, and VHAC), and a variable related to income (PO2SM), only one variable related to education, housing, and income was selected for the analysis to avoid redundancy or the use of proxy variables.

4. Results

The analysis included 2 469 municipalities in Mexico. Table 1 shows negative and significant correlations between the dependent variable and all indicators of marginalization, except for OVSAE and POB_TOT. For the latter, the correlation was positive and significant. Table 2 shows the results of the bivariate analysis of the relationship between categories of life years lost and quartile distributions of marginalization indicators. Taking the category with the lowest LE year loss (≤1.6) and the lowest school marginalization category (ANAF ≤4.4) as reference, the corresponding magnitudes of association were 0.5 (95%CI: 0.3-0.7), 0.3 (95%CI: 0.2-0.4), and 0.2 (95%CI: 0.1-0.3), respectively, compared with the categories in the column with the highest LE years loss (>7.8). These categories of reference where then

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contrasted with the categories in columns 4.7-7.8 and 1.6-4.7 of loss in LE years. Similarly, SBASC variable and housing variables such as OVSAE, OVSDE, OVSEE and OVSAE showed a decreasing trend of association with respect to the categories of loss in years of LE variable. However, the strength of the association was less clear for OBSDE y OVSAE. Table 3 shows that the OVPT and VHAC variables relating to housing characteristics continue to exhibit a downward trend in terms of the strength of the association when their categories are compared with those of the lost LE years variable. Conversely, the POP_TOT variable had a positive effect on the dependent variable. A positive trend was found in the magnitude of the association between loss of LE and population size categories. Finally, the PO2SM variable follows the same pattern as the other marginalization indicators: it shows decreasing measures of association as the magnitude of the variable increases, and as the categories if the dependent variable change.

Table 1

Correlation coefficients between the loss in years of life expectancy and the natural logarithm of the indicators of marginalization.

Dependent variable	Independent variables	Spearman´s correlation coefficients
perdidaev	ANALF	-0.249 *
	SBASC	-0.284 *
	OBSDE	-0.086 *
	OVSEE	-0.179 *
	OVSAE	-0.027 †
	OVPT	-0.186 *
	VHAC	-0.132 *
	PO2SM	-0.240 *
	POB_TOT	0.321 *

* P<0.001; † NS.

perdidaev = loss in years of life expectancy; POB_TOT = total population of the municipalities ANALF = percentage of illiterate population 15 years of age or older; SBASC = percentage of population 15 years of age or older without basic education; OVSDE = percentage of occupants in private dwellings without drainage or toilet; OVSEE = percentage of occupants in private dwellings without electricity; OVSAE = percentage of occupants in private dwellings without piped water; OVPT = percentage of occupants in private dwellings with dirt floors; VHAL = percentage of private dwellings with overcrowding; PO2SM = Percentage of employed population with income below 2 minimum wages. Source: Registered deaths for 2019 and 2020 from the Mexican Ministry of Health (2022), Demographic information was obtained from the population projections of the National Population Council (2018), Marginalization Indicators developed by the National Population Council (2020).

Figure 1 shows the scatterplots of the log of POP_TOT against the variables ANALF, SBASC, OVSDE y OVSEE. The respective spearman´s rank correlation coefficients were -0.306, -0.487, -0.142 and -0.242, all of which were highly significant. The other half of figure 1 shows the distribution of points between the logarithm of the variable POP_TOT and OVSAE, OVPT, VHAL and PO2SM variables, for which the Spearman correlation coefficients were -0.067, -0.218, -0.115 and -0.490, respectively. These were all statistically significant except for the correlation between OVSAE and POB_TOT.

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Table 2

Relationship between the loss in years of life expectancy and indicators of social marginalization in Mexico's municipalities, 2020

Variables	≤1.6 n (%)	1.6-4.7 n (%)	4.7-7.8 n (%)	>7.8 n (%)	>7.8 vs ≤1.6 OR (95%CI)	4.7-7.8 vs ≤1.6 OR (95%CI)	1.6-4.7 vs ≤1.6 OR (95%CI)
ANALF							
≤ 4.4	80 (13.0)	135 (21.9)	198 (32.1)	204 (33.1)	1	1	1
4.41-8.2	121 (19.6)	168 (27.2)	172 (27.9)	156 (25.3)	0.5 (0.3-0.7)**	0.5 (0.4-0.8)**	0.5 (0.5-1.1)†
8.21-13.7	165 (26.7)	174 (28.2)	136 (22.0)	142 (23.0)	0.3 (0.2-0.4)**	0.3 (2.0-4.0)**	0.6 (0.4-0.8)**
> 13.7	251 (40.7)	141 (22.9)	112 (18.2)	112 (18.2)	0.2 (0.1-0.3)**	0.1 (0.1-0.2)**	0.3 (0.2-0.4)**
SBASC							
≤35,7	45 (7.3)	146 (23.7)	205 (33.2)	221 (35.8)	1	1	1
35.71-46.3	142 (23.0)	167 (27.1)	155 (25.1)	153 (24.8)	0.2 (0.1-0.3)**	0.2 (0.1-0.3)**	0.3 (0.2-0.5)**
46.31-55.8	188 (30.5)	172 (27.9)	130 (21.1)	127 (20.6)	0.1 (0.09-0.2)**	0.15 (0.1-0.2)**	0.2 (0.1-0.4)**
>55,8	242 (39.3)	133 (21.6)	128 (20.8)	113 (18.3)	0.09 (0.06-0.1)**	0.1 (0.07-0.2)**	0.16 (0.1-0.2)
OVSDE							
≤ 0.65	109 (17.7)	145 (23.5)	162 (26.3)	201 (32.6)	1	1	1
0.66-1.42	174 (28.2)	154 (24.9)	170 (27.5)	120 (19.4)	0.3 (0.2-0.5)**	0.6 (0.4-0.9)*	0.6 (0.4-0.9)*
1.43-3.34	163 (26.5)	150 (24.4)	159 (25.9)	143 (23.3)	0.4 (0.3-0.6)**	0.6 (0.4-0.9)*	1.0 (0.7-1.4)†
>3.34	171 (27.7)	169 (27.4)	127 (20.6)	150 (24.3)	0.4 (0.3-0.6)**	0.4 (0.3-0.6)**	0.7 (0.5-1.0)†
OVSEE							
≤ 0.36	111 (18.0)	137 (22.3)	176 (28.6)	191 (31.1)	1	1	1
0.37-0.82	125 (20.2)	156 (25.2)	161 (26.0)	177 (28.6)	0.8 (0.5-1.1)†	0.8 (0.5-1.1)†	1.0 (0.7-1.4)†
0.83-1.68	157 (25.5)	173 (28.1)	172 (27.9)	114 (18.5)	0.4 (0.3-0.5)**	0.6 (0.5-0.9)*	0.8 (0.6-1.2)†
> 1.68	224 (36.3)	152 (24.6)	109 (17.7)	132 (21.4)	0.3 (0.2-0.4)**	0.3 (0.2-0.4)**	0.5 (0.3-0.7)**
OVSAE							
≤ 0.87	166 (26.9)	154 (25.0)	152 (24.6)	145 (23.5)	1	1	1
0.88-2.4	136 (22.1)	149 (24.2)	167 (27.1)	164 (26.6)	1.4 (1.0-1.8)*	1.3 (0.9-1.8)†	1.1 (0.8-1,6)†
2.41-7.2	135 (21.9)	162 (26.3)	159 (25.8)	161 (26.1)	1.3 (0.9-1.8)†	1.2 (0.9-1.7)†	1.2 (0.9-1.7)†
> 7.2	180 (29.2)	153 (24.8)	140 (22.7)	144 (23.3)	0.9 (0.6-1.2)†	0.8 (0.6-1.1)†	0.9 (0.6-1.2)†

** P<0.001; * p≤0.05 † NS.

ANALF = percentage of illiterate population aged 15 and over; SBASC = percentage of population aged 15 and over without basic education; OVSDE = percentage of occupants in private dwellings without drainage or toilet; OVSEE = percentage of occupants in private dwellings without electricity; OVSAE = percentage of occupants in private dwellings without piped water.

Source: Registered deaths for 2019 and 2020 from the Mexican Ministry of Health (2022), Demographic information was obtained from the population projections of the National Population Council (2018), Marginalization Indicators developed by the National Population Council (2020).

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Table 3

Relationship between the loss in years of life expectancy and indicators of social marginalization in Mexico's municipalities, 2020

Variables	≤1.6 n (%)	1.6-4.7 n (%)	4.7-7.8 n (%)	>7.8 n (%)	>7.8 vs ≤1.6 OR (95%CI)	4.7-7.8 vs ≤1.6 OR (95%CI)	1.6-4.7 vs ≤1.6 OR (95%CI)
OVPT							
≤ 1.6	107 (17.3)	155 (25.1)	177 (28.7)	178 (28.8)	1	1	1
1.61-4.7	120 (19.4)	147 (23.8)	182 (29.4)	169 (27.3)	0.8 (0.6-1,1)†	0.9 (0.6-1.2)†	0.8 (0.5-1.1)†
4.71-11.0	146 (23.7)	163 (26.4)	154 (25.0)	154 (25.0)	0.6 (0.4-0.8)*	0.6 (0.4-0.8)*	0.7 (0.5-1.0)†
> 11.0	244 (39.7)	153 (24.9)	105 (17.1)	113 (18.4)	0.2 (0.2-0.4)**	0.2 (0.1-0.3)**	0.4 (0.3-0.5)**
VHAC							
≤18.7	128 (20.7)	139 (22.5)	189 (30.6)	161 (26.1)	1	1	1
18.8-25.0	131 (21.2)	158 (25.5)	145 (23.4)	185 (29.9)	1.1 (0.8-1.5)†	0.7 (0.5-1.0)†	1.1 (0.7-1.5)†
25.1-32.8	156 (25.4)	157 (25.5)	151 (24.6)	151 (24.6)	0.7 (0.5-1.0)†	0.6 (0.4-0.8)*	0.9 (0.6-1.2)†
>32.8	202 (32.8)	164 (26.6)	133 (21.6)	117 (21.6)	0.4 (0.3-0.6)**	0.4 (0.3-0.6)**	0.7 (0.5-1.0)†
POB_TOT							
≤ 4476	278 (45.1)	118 (19.1)	122 (19.8)	99 (16.0)	1	1	1
4477-13552	183 (29.7)	169 (27.4)	127 (20.6)	137 (22.2)	2.1 (1.5-2.8)**	1.6 (1.2-2.1)*	2.1 (1.6-2.9)**
13553-35286	114 (18.5)	181 (29.3)	164 (26.6)	158 (25.6)	3.8 (2.7-5.4)**	3.2 (2.3-4.5)**	3.7 (2.7-5.1)**
>35286	42 (6.8)	150 (24.3)	205 (33.2)	220 (35.7)	14.7 (9.8-21.9)**	11.1 (7.4-16.4)**	8.4 (5.6-12.6)**
PO2SM							
≤ 74.6	86 (13.9)	139 (22.5)	184 (29.8)	208 (33.7)	1	1	1
74.7-84.6	109 (17.6)	168 (27.2)	193 (31.2)	148 (23.9)	0.5 (0.3-0.7)**	0.8 (0.5-1.1)†	0.9 (0.6-1.3)†
84.7-91.6	170 (27.6)	170 (27.6)	134 (21.8)	142 (23.1)	0.3 (0.2-0.4)**	0.3 (0.2-0.5)**	0.6 (0.4-0.8)*
> 91.6	252 (40.9)	141 (22.9)	107 (17.4)	116 (18.8)	0.1 (0.1-2.0)**	0.1 (0.1-0.2)**	0.3 (0.2-0.4)**

** P<0.001; * p≤0.05 † NS.

OVPT = percentage of occupants of private homes with dirt floors; VHAC = percentage of private homes with overcrowding; POB_TOT = total population by municipality; PO2SM = Percentage of employed population with income below 2 minimum wages.

Source: Registered deaths for 2019 and 2020 from the Mexican Ministry of Health (2022), Demographic information was obtained from the population projections of the National Population Council (2018), Marginalization Indicators developed by the National Population Council (2020).

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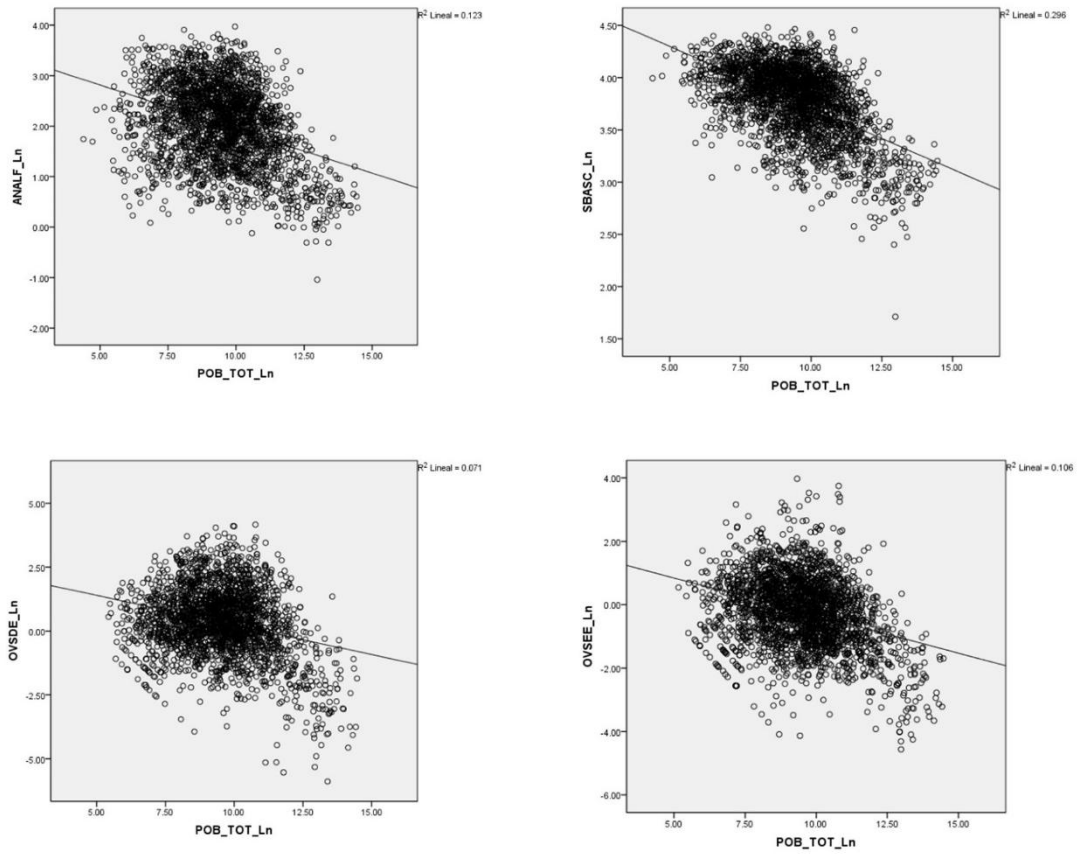
Figure 1

Scatter plot for the variable population size of the municipalities and the results of the marginalization indicators for 2020 in Mexico.



Source: Indicators developed by the National Population Council (2020): POB_TOT = total population of the municipalities; ANALF = percentage of illiterate population 15 years of age or older; SBASC = percentage of population 15 years of age or older without basic education; OVSDE = percentage of occupants in private dwellings without drainage or toilet; OVSEE = percentage of occupants in private dwellings without electricity.

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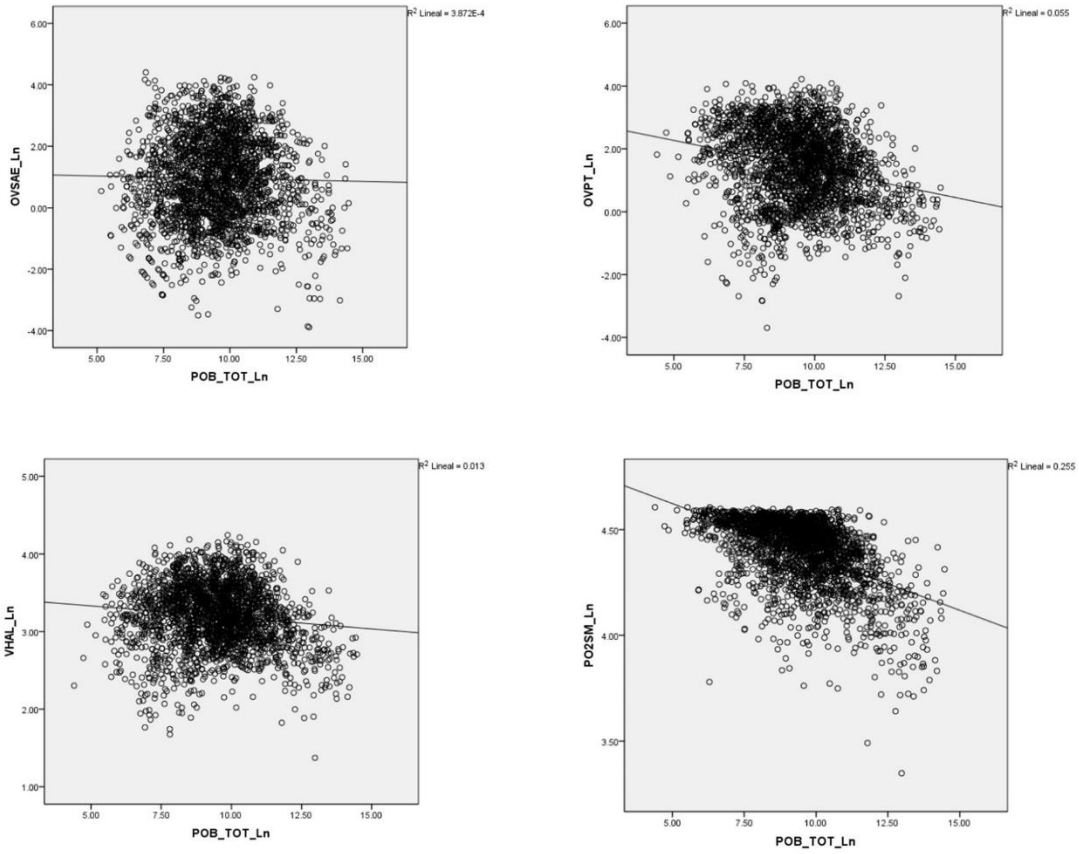
Figure 1.1 (Continued)

Scatter plot for the variable population size of the municipalities and the results of the marginalization indicators for 2020 in Mexico



Source: Indicators developed by the National Population Council (2020): POB_TOT = total population of the municipalities; OVSAE = percentage of occupants in private dwellings without piped water; OVPT = percentage of occupants in private dwellings with dirt floors; VHAL = percentage of private dwellings with overcrowding; PO2SM = Percentage of employed population with income below 2 minimum wages.

A MCA was performed on a total of 2 469 municipalities. Of these, 2 467 presented complete information, reaching convergence in the 21st iteration with a total explained variance of 1.90. The factorial model obtained from the MCA had a total inertia of 0.760, indicating that the first two dimensions explained 76% of the joint variance of the included variables. Most of the information (46.6%) was concentrated in the first dimension, which had a Cronbach's alpha of 0.713, an eigenvalue of 2.328 and inertia of 0.466; the second dimension had 29.5% of the of the variance (α=0.401), an eigenvalue of 1.473 and inertia of 0.295. The relevant correlations between the variables were as follows: 0.657 for SBASC and PO2SM; 0.457 for POB_TOT and PO2SM; 0.460 for POB_TOT and SBASC; 0.325 for perdidaev and POB_TOT; and 0.285 for perdidaev and SBASC.

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Table 4

Contribution of variables to the multiple correspondence analysis (dimension 1).

Variables	Discriminant measure (dimension 1)	Eigenvalue	Contribution to the model (MCA, %)
SBASC	0.722	2.328	31.0
PO2SM	0.706	2.328	30.3
POB_TOT	0.495	2.328	21.2
OBSAE	0.130	2.328	5.6
Perdidaev (dependent)	0.250	2.328	10.7

Source: Registered deaths for 2019 and 2020 from the Mexican Ministry of Health (2022), Demographic information was obtained from the population projections of the National Population Council (2018), Marginalization Indicators developed by the National Population Council (2020).

Table 4 shows the contribution of each variable to the MCA via the dimension 1 discriminant measures. As can be seen, the variables that contributed most to the model were SBASC, PO2SM and POB_TOT, in order of importance. The MCA map (figure 2) illustrates how the categories of the analyzed variables are distributed across two dimensions. Dimension 1 is the main axis of differentiation between the variable categories and shows that municipalities with a lower loss of LE years (perdidaev≤1.6%), a higher proportion of the population earning less than two minimum wages (PO2SM>91.6%), a higher proportion of the population over 15 years old without basic education (SBASC>55.6%), and a smaller municipal population size (POB_TOT≤ 4 476) are grouped at the positive end. Dimension 2 explains a smaller proportion of the variability, primarily distinguishing municipalities with a larger population size (POB_TOT>35 286), a lower proportion of the population earning less than two minimum wages (PO2SM≤74.6), and a lower proportion of the population over 15 years of age without a basic education (SBASC≤35.7).

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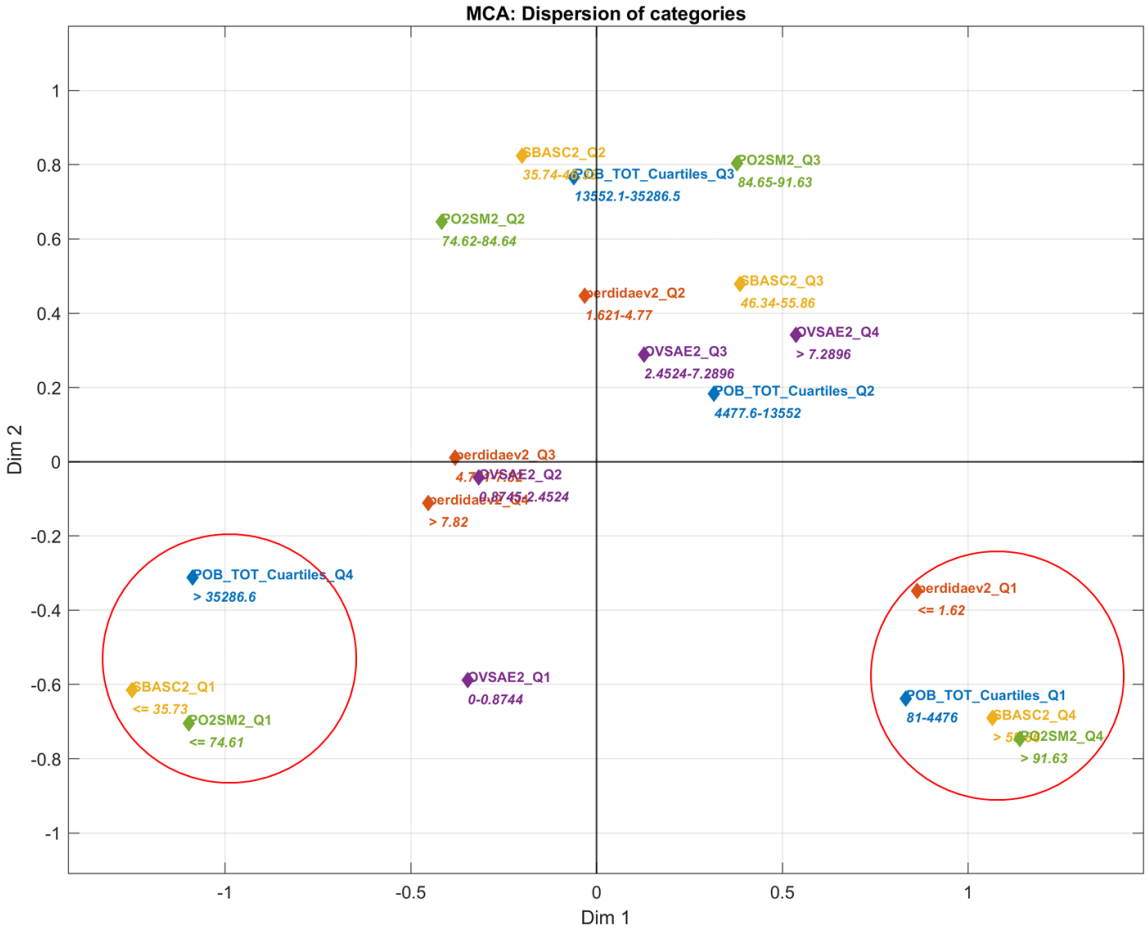
Figure 2

Correspondence analysis map of life years lost and marginalization indicators



Source: Registered deaths for 2019 and 2020 from the Mexican Ministry of Health (2022), Marginalization Indicators developed by the National Population Council (2020).

5. Discussion

Marginalization indicators have been used in this paper to assess the impact on the loss of years of life expectancy by 2020. Since the indicators are expressed in percentages, the significance of the correlations indicates that the higher the percentage of the indicator, the lower the loss in years of life expectancy. However, these correlations are not reflected in the bivariate analysis when odds ratios were calculated. The educational indicators (ANALF and SBASC) showed decreasing magnitudes of association when the category with the lowest proportion of the indicators and the category with the lowest loss of years of LE were taken as references. This indicates that populations with the highest percentages of illiteracy and those without basic education were at greatest risk of loss in years of LE. Although no studies have been conducted in Mexico that relate indicators of

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marginalization to life expectancy in Mexican municipalities, these results are consistent with the findings on Covid-19 mortality in a study that analyzed the proportion of the population under 5 years of age or older who were illiterate, stratified by quintiles (Contreras-Manzano et al, 2022).

The indicators of marginalization of housing characteristics showed that the higher the percentage of occupants of private dwellings without drainage or toilet (OBSDE), without electricity (OVSEE), without piped water (OVPT), and with dirt floors (VHAC), the higher the effect of loss of years of life expectancy. Although housing indicators have not been analyzed in relation to loss of LE years, a study about predictors of mortality from the Covid-19 virus in Mexico at the municipal level, did not show clear associations with the proportion of houses lacking drainage or water services, or with houses having dirt floors (Contreras-Manzano et al, 2022).

The indicator related to the percentage of the working population with an income up to 2 minimum wages (PO2SM), showed that the higher the percentage of the indicator, the higher the effect in years of life expectancy, presenting an ORs lower than 1 with a downward trend. Although no studies have been published that separately analyze marginalization indicators to evaluate the minimum wage indicator, Chávez-Almazan *et al* (2022) used the Human Development Index (HDI), which includes the income variable, and found positive correlations between morbidity and mortality due to Covid-19 and the HDI, meaning that the lower the index value, the lower the morbidity and mortality due to Covid-19 and vice versa. Conversely, our results show that the greater the proportion of the population earning less than two minimum wages, the greater the impact in lost LE years.

The population size of municipalities had a positive relationship with the loss of years of life expectancy, with positive and significant ORs. This indicates that the loss of years of life expectancy increases as the population size increases. This trend has also been reported along Mexican municipalities with populations greater than 50,000 inhabitants, with 3.24 and 2.56 times higher risks for Covid-19 morbidity and mortality, respectively, compared with populations smaller than 49,999 inhabitants, although in the case of Covid-19 lethality, the effect was protective for populations greater than 50,000 inhabitants (Chávez-Almazán et al, 2022). In India, these trends have also been demonstrated using the Covid-19 disability-adjusted life-years lost index, the magnitude of which was greater in urban than in rural areas (Singh et al, 2020). In addition, the importance of population size lies in its inverse relationship with all indicators of marginalization, except the SBASC variable. This means that the smaller the population, the higher the marginalization rate.

Taken together, these results suggest that the impact of the Covid-19 epidemic on life expectancy in Mexico was greater in populations with a higher demographic concentration in Mexican municipalities, and at the same time, the highest percentage of marginalization was found in populations with smaller population size at the municipal level. On the one hand, population size was associated with greater interaction among people in larger urban centers, which increases the likelihood of Covid-19 transmission as expressed in health indicators such as morbidity, mortality (Bilal, 2020; Chávez-Almazán et al, 2022; Bhadra *et al*, 2021) and life expectancy (Uribe-Salas *et al*,

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2023); on the other hand, the distribution of percentages of marginalization indicators tends to increase as population size decreases, as shown by the results of the correlation analysis between population size and the distribution of marginalization indicators. This second part of the phenomenon has not been reported in studies that have correlated indicators of marginalization and poverty with health outcomes by Covid-19 infection in Mexico (Chávez-Almazán *et al*, 2022; Contreras-Manzano *et al*, 2022; Millán-Guerrero *et al*, 2021; Lozano Asencio y Ramírez-García, 2023; Bancet y Sosa-Sanchez, 2022; Mendoza-González, 2020; Muñíz-Montero *et al*, 2022).

The variables that had the greatest impact on the MCA were those related to education (SBASC), income (PO2SM), and population size (POB_TOT). Furthermore, the highest correlations were found between SBASC and PO2SM, POB_TOT and PO2SM, and POB_TOT and SBASC, in that order. Overall, the factorial plane exhibits a high degree of consistency: the variables relating to education, income, population size and LE are arranged according to the same structural pattern. Thus, MCA reveals clear territorial polarization of well-being and longevity in Mexican municipalities, with educational attainment, income and population size remaining key determinants of LE. To the best of our knowledge, no studies have been published in Mexico or in the international literature in which an MCA incorporating indicators of marginalization and loss of LE years at the municipal level.

6. Conclusions

As outlined in the study´s objectives, the results clearly demonstrate that municipal-level indicators of marginalization had a significant impact on LE during the Covid-19 pandemic in Mexico. The effect of the indicators of marginalization on the loss in years of LE was direct, that is, the higher the percentage of marginalization in the indicators of education, housing and income, the higher the effect on life expectancy, except for the OVSAE indicator. In contrast, the population size of the municipalities had a positive relationship with the loss of years of life expectancy. It was also found that the smaller the population size, the greater the marginalization. The MCA revealed a clear gradient of welfare and marginalization across Mexican municipalities, with education, income and population size emerged as key determinants of LE.

7. Limitations

Although LE was calculated using the lifetable function belonging to the demography package, available in the R programming language in 2,469 municipalities (Uribe-Salas *et al*, 2023), no weighting by population size was performed. It is advisable to apply the methodological proposal by Silva *et al*, (2023), which uses a linear disaggregation model to measure LE using sociodemographic variable at the municipal level in Mexico. This model allows for the verification of consistency between special levels and the creation of dynamic maps that reveal regional inequalities.

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