JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Coronavirus Pandemic

COVID-19 cases, hospitalizations, outpatients, and deaths in Mexico by ethnicity and state-level income

Elba Ronquillo De Jesús[1], Víctor Suárez[2], Patricia López-Perea[1], Monserrat Suárez Quezada[3], Erich von Borries-Medrano[4]

[1] Universidad Politécnica de Francisco I. Madero, Dirección de Ingeniería Agroindustrial, Tepatepec, Hidalgo, Mexico
[2] CONACyT - Universidad Autónoma Metropolitana-Iztapalapa, Departamento de Química, Mexico City, Mexico
[3] Instituto Politécnico Nacional, Unidad Profesional Interdisciplinaria de Ingeniería y Ciencias Sociales y Administrativas, Departamento de Química, Mexico City, Mexico
[4] Instituto Politécnico Nacional, Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada – Unidad Legaria, Mexico City, Mexico

Abstract

Introduction: Mexico is one of the countries that is most affected by mortality due to COVID-19. Once infected, the indigenous population living in the lower-income states had worse outcomes. Our objectives were to analyze outcomes by ethnic group, and determine the association between state-level income and the incidence, hospitalizations, outpatients, and death rates per 100,000 population.

Methodology: We analyzed 1,037,567 confirmed COVID-positive cases from February 29 to November 13, 2020 recorded in the Mexican COVID-19 cases database. Sociodemographic characteristics, comorbidities, and outcomes were analyzed. Data was allocated according to the state where the patients were treated. Statistical association between age-adjusted incidence and death rates with state-level GDP per capita (as a measure of income), were ascertained using Spearman correlations. Kruskal-Wallis tests examine the association of cumulative incidence, hospitalizations, outpatients, and death rates, with income quartiles. When significant, a follow-up analysis (Mann-Whitney) was conducted.

Results: Respective cumulative incidence rates and death rates were: 900.3 (non-indigenous) and 94.4 (indigenous), and 87.1 (non-indigenous) and 13.9 (indigenous). Spearman correlation coefficients of income with age-standardized incidence and death rates were 0.657 and 0.607 ($p < 0.001$ for both). Kruskal-Wallis H-Values indicate significant median differences by income in total population rates: cumulative incidence 13.47 ($p < 0.01$), hospitalizations 11.67 ($p < 0.01$), outpatients 12.86 ($p < 0.01$), and deaths 8.92 ($p < 0.05$).

Conclusions: Cumulative incidence, hospitalizations, outpatients, and mortality rates presented a reversed socioeconomic status health gradient in Mexico. Less adverse outcomes were observed in the lowest-income states compared to higher-income states.

Key words: COVID-19; Mexico; ethnicity; income disparities; health; vulnerability.

J Infect Dev Ctries 2022; 16(6):969-980. doi:10.3855/jidc.15618

(Received 05 July 2021 – Accepted 20 February 2022)

Introduction

On February 29, 2020, two months after the first case of coronavirus disease 2019 (COVID-19) in the world was reported in Wuhan, China [1], the first two imported cases of COVID-19 were confirmed in Mexico; both had a travel history to Italy [2,3]. On March 24, 2020, the Ministry of Health introduced social distancing measures whereby all shopping malls, department stores, restaurants, bars, cafes, cinema halls, and fitness centers were temporarily closed, in an effort to reduce the rate of transmission of the virus and avoid overburdening of the healthcare system [4]. On March 30, 2020, with the number of new daily cases at around two hundred, the General Health Council declared a COVID-19 health emergency [5], and the following day the Ministry of Health established extraordinary measures to address it, reiterating the social distancing measures, and suspending all non-essential economic activities temporarily [6], although no sanctions were established for infringement. It was recommended that the population leave their homes only when absolutely necessary (particularly older adults, people with underlying medical conditions, and pregnant women), and maintain a distance of at least 5 feet from other people when outside their homes [6]; however, the use of face masks was not endorsed by the Mexican health authorities. By the end of April, with the weekly average of new daily cases nearing two thousand [7],

school classes of every level had switched to online mode [8]. Yet no international flights were suspended, and interstate travel within Mexico was never restricted.

Since the preventive measures had general applicability, the economy was greatly affected. This prompted the Mexican government to allow non-essential economic activities to be resumed in early June, even though the weekly average of new daily cases was approaching five thousand. By mid-July, the weekly average of new daily cases reached seven thousand, and then slowly descended to around 4,500 in late September [7].

The weekly average of new daily cases was again nearing seven thousand by mid-November 2020, with 823.4 cumulative cases per 100,000 population –much lesser than the most affected countries: Belgium (4,583.3 cases), the United States of America (3,214.9 cases), Spain (3,119.7 cases), France (2,938.9 cases), Argentina (2,868.4 cases), Peru (2,828.6 cases), and Brazil (2,733.7 cases). Yet in terms of cumulative deaths per 100,000 population, Mexico, with 80.2 deaths, belongs in the group of the most affected countries: Belgium (123.4 deaths), Peru (106.5 deaths), Spain (87.2 deaths), Argentina and Brazil (77.5 deaths each), and The United Kingdom (76.3 deaths) [7,9]. Mexico is thus one of the most affected countries in terms of mortality due to COVID-19.

Since the beginning of the outbreak, several authors suggested the presence of a socioeconomic status (SES) health gradient in the COVID-19 pandemic [10-12]. The SES health gradient has been confirmed for COVID-19 in high-income countries such as Canada [13], Spain [14] and the United States of America [15,16]. Hence, it would be expected that the indigenous population in Mexico –one of the poorest population groups representing approximately 10% of the total population [17], concentrated in some of the poorest regions in the country (according to state-level Gross Domestic Product (GDP) per capita, whose diverse evolution since the start of the present century has resulted in a widening gap between prosperous states, i.e. the nation's capital and the industrialized North of the country, with the traditionally poor South [18]) would have worse COVID-19 outcomes due to their more limited access to health services than the non-indigenous population [19].

The objectives of this study were to analyze the different COVID-19 outcomes by ethnic group (indigenous and non-indigenous), and to determine the relationship between COVID-19 incidence rates, hospitalizations, outpatient numbers, as well as death rates, and the GDP per capita (as a measure of income) of the 32 states in Mexico. If the SES health gradient applies to the COVID-19 pandemic in Mexico, worse outcomes would be observed in states with lower GDP per capita than in states with higher GDP per capita.

Methodology

Data sources

The data utilized in this study was extracted from the Mexican Ministry of Health COVID-19 cases open-access database [7], containing data accumulated from the start of the pandemic in Mexico on February 29, 2020 to the cut-off point on November 13, 2020. The data originated from the Epidemiological Surveillance System of Viral Respiratory Diseases (SISVER) implemented on April 5, 2020 [20], whereby the healthcare system in Mexico conducts epidemiological surveillance by laboratory (sentinel surveillance) under a sampling rate of 10% for outpatient cases of viral respiratory disease, and 100% for severe hospitalized cases. Up to the cut-off point, the database contained information on 2,630,258 patients from health care units in the 32 Mexican states, of which 1,037,567 were COVID-19 positive cases, confirmed by Reverse Transcription Polymerase Chain Reaction (RT-PCR). We focus our analysis on such confirmed positive cases; no cases were excluded.

The variables from the database used in this study were: sociodemographic characteristics (age, sex, "indigenous" –chosen over "speaks indigenous tongue" to include patients of all ages when determining ethnicity, and location of medical unit), type of patient (hospitalized or outpatient), reported comorbidities (diabetes, chronic obstructive pulmonary disease, asthma, immunodeficiency, hypertension, cardiovascular disease, obesity, chronic kidney disease, tobacco use, and "other comorbidities"), and outcomes (ICU admission, invasive ventilation, recovery, or death). The variable "severe cases" was used to refer to the occurrence of the outcomes ICU admission, invasive ventilation, or death. The variable "died at home" refers to ambulatory patients whose outcome was death. Data was allocated geographically according to the location, by state, of the hospitals where the patients were treated.

Gross Domestic Product (GDP) per capita by state, expressed in current United States Dollars, was calculated using 2019 state-level GDP data extracted from the National Institute of Statistics and Geography (INEGI) website [21], 2019 state population estimates extracted from the National Population Council (CONAPO) website [22], and the 2019 Mexican Peso – United States dollar exchange rate extracted from the

Banco de México (Mexico's central bank) website [23]. The 32 Mexican states were classified by quartiles of GDP per capita in current United States dollars, and this information was incorporated into the database for analysis.

Cumulative incidence, hospitalizations, outpatients, and deaths per 100,000 population were calculated using data from the 2020 Population Census [24] for non-indigenous population, and data from the National Institute of Indigenous People (2017) [17] for indigenous population. To standardize the state-level incidence rates and death rates by age, we used the direct method with the 2018 National Survey on Population Dynamics [25] as reference.

Statistical analysis

Numerical variables contained in the database are presented as patient counts and means; categorical variables are presented as patient counts and percentages.

Correlation graphics were used to ascertain the statistical association between age-adjusted incidence rates and age-adjusted death rates with GDP per capita by state. Ryan-Joiner tests were performed to examine the distribution of the variables involved, which showed that neither state-level GDP per capita (RJ = 0.882, $p < 0.01$) nor age-adjusted incidence rates (RJ = 0.952, $p < 0.05$) were normally distributed. The Ryan-Joiner test did not show evidence of non-normality (RJ = 0.987, $p > 0.05$) for age-adjusted death rates. Thus, Spearman correlations (95% CI) were calculated. A p-value < 0.05 criterion was used for determining a significant correlation between variables.

The data were further analyzed using the Kruskal-Wallis test to examine associations of COVID-19-related variables (crude rates of cumulative incidence, hospitalized patients, outpatients, and deaths per 100,000 population), with state-level GDP per capita categories (quartiles). Where the Kruskal Wallis test results were significant, a follow-up analysis using the Mann-Whitney statistic (W value) was conducted. All statistical analyses were performed using Minitab software version 19.1.

No ethical review was required for this study, since the open-access database used contains anonymized information.

Results

Infected population characteristics and outcomes

With a population of 126.0 million [24] (114.0 million non-indigenous and 12.0 million indigenous), the overall cumulative COVID-19 incidence rate in Mexico was 823.4 cases per 100,000 inhabitants between February 29, 2020 and November 13, 2020. Cumulative cases per 100,000 population were 900.3 for non-indigenous people and 94.4 for indigenous people.

The age group 30 to 59 presented 60.5% of the cumulative cases in the non-indigenous population, and 55.5% of cumulative cases in the indigenous population (Table 1).

In both population groups, more than 80% of case fatalities were concentrated in age groups 50 and above. The case fatality rate (CFR), or the proportion of patients who died among confirmed COVID-19 cases, was lower for the non-indigenous population (9.7%) than for the indigenous population (14.7%), as was the percentage of patients who died at home (respectively: 10.9% and 12.0% overall; 13.3% and 29.6% for the 30 to 39 year age group).

The overall cumulative deaths per 100,000 population were substantially higher for the non-indigenous population (87.1) than for the indigenous population (13.9). Deaths rose significantly in the older age groups in both populations, reaching 572.8 and 104.4 respectively in the 80 years or older group.

Table 1. Confirmed COVID-19 cases, confirmed deaths, and death rates in Mexico from February 29, 2020 to November 13, 2020, by age group and ethnic group [7,17,24].

Age Group	Confirmed COVID-19 cases n (%) (n = 1,037,567)		Confirmed deaths N (%) (n = 101,005)		Died at home (Outpatient deaths) n (% of deaths)		Deaths per 100,000 population	
	Non-indigenous	Indigenous	Non-indigenous	Indigenous	Non-indigenous	Indigenous	Non-indigenous	Indigenous
0-9	11,483 (1.1)	156 (1.4)	228 (0.2)	9 (0.5)	12 (5.3)	0 (0.0)	1.2	0.4
10-19	32,398 (3.2)	305 (2.7)	169 (0.2)	2 (0.1)	15 (8.9)	0 (0.0)	0.9	0.1
20-29	167,297(16.3)	1,392 (12.3)	1,161 (1.2)	20 (1.2)	150 (12.9)	1 (5.0)	6.2	1.2
30-39	226,708 (22.1)	2,092 (18.4)	4,065 (4.1)	54 (3.2)	541 (13.3)	16 (29.6)	24.2	3.3
40-49	216,648 (21.1)	2,139 (18.8)	11,408 (11.5)	152 (9.1)	1,359 (11.9)	16 (10.5)	76.1	10.4
50-59	177,821 (17.3)	2,067 (18.2)	21,622 (21.8)	345 (20.7)	2,505 (11.6)	41 (11.9)	187.3	29.0
60-69	110,435 (10.8)	1,677 (14.8)	27,602 (27.8)	474 (28.4)	2,861 (10.4)	59 (12.4)	359.3	60.5
70-79	57,805 (5.6)	1,026 (9.0)	21,644 (21.8)	385 (23.1)	2,142 (9.9)	44 (11.4)	530.9	99.9
≥ 80	25,620 (2.5)	498 (4.4)	11,437 (11.5)	228 (13.7)	1,199 (10.5)	23 (10.1)	572.8	104.4
Total	**1,026,215 (100)**	**11,352 (100)**	**99,336 (100)**	**1,669 (100)**	**10,784 (10.9)**	**200 (12.0)**	**87.1**	**13.9**
CFR*			**9.7%**	**14.7%**				

*CFR: Case Fatality Rate.

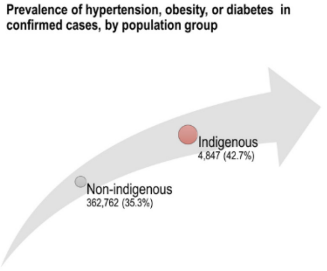
The mean age of the confirmed cases in the non-indigenous population was 44.3 years, whereas confirmed cases in the indigenous population were older, with a mean age of 48.2 years. There was an approximately even split between males and females in confirmed cases of the non-indigenous population, but in the case of the indigenous population there was a higher proportion of males (55.8%) (Table 2). Of the total confirmed cases for each population, the proportion of patients that reported having at least one comorbidity was 43.0% for the non-indigenous population, and 49.8% for the indigenous population. In both population groups, patients with at least one comorbidity were older (50+ years) than the average age of confirmed cases.

Severe cases, grouped here in a composite endpoint [26,27] consisting of admittance to an intensive care unit (ICU), or invasive ventilation, or death, represented 11.0% of confirmed cases among the non-indigenous population, and 16.6% of confirmed cases in the indigenous population. Confirmed deaths represented 9.7% of confirmed cases in the non-indigenous population, and 14.7% of confirmed cases in the indigenous population. In both instances, the male population comprised 60% or higher of the total COVID-19 cases. The mean age of the severe cases and the confirmed deaths were, respectively, 61.6 and 62.7 years for the non-indigenous population, and 62.5 and 64.0 years for the indigenous population. Comorbidities, which have been suspected to be at least partly responsible for COVID-19-related deaths since the start of the pandemic [28], were present in 73% of the deceased, both in non-indigenous and indigenous populations. The proportion of deceased females presenting comorbidities was 78.4% for the non-indigenous population, and 82.9% for the indigenous population, compared to the corresponding 69.9% and 67.8% for deceased males.

The prevalence of any of the three main comorbidities (hypertension, obesity, or diabetes) was higher in the indigenous group than in the non-indigenous group (42.7% vs. 35.3%). The prevalence of tobacco use was lower in the indigenous group than in the non-indigenous group (5.9% vs. 7.3%). The prevalence of the rest of the comorbidities was similar for both population groups, except for chronic obstructive pulmonary disease (COPD), which in the indigenous group was more than double that of the non-indigenous group (2.9% vs. 1.3%) (Figure 1).

Of the 46,558 patients that were admitted to an ICU or received invasive ventilation, 32,737 (70.3%) died and 13,821 (29.7%) recovered (Table 3). However, not all of the severe cases were admitted to an ICU or received invasive ventilation: 68,268 of 114,826 severe cases (59.5%) resulted in death in this situation; 57,284 (49.9%) of these patients had been hospitalized, but 10,984 (9.6%) died at home (outpatient deaths). Regarding indigenous patients, 63.4% of severe cases culminated in death without being admitted to an ICU

Figure 1. Prevalence of comorbidities in confirmed cases, by ethnic group [7].



Prevalence of comorbidities in confirmed cases, by population group

Comorbidity	Non-indigenous N (%)	Indigenous N (%)
Hypertension	194,081 (18.9)	2,414 (21.3)
Obesity	176,061 (17.2)	2,215 (19.5)
Diabetes	152,384 (14.8)	2,202 (19.4)
Tobacco use	76,108 (7.4)	667 (5.9)
Asthma	25,883 (2.5)	300 (2.6)
Cardiovascular	19,213 (1.9)	246 (2.2)
Chronic kidney disease	18,528 (1.8)	231 (2.0)
COPD	13,808 (1.3)	324 (2.9)
Immunodeficiency	10,523 (1.0)	130 (1.1)
Other	23,449 (2.3)	285 (2.5)

Table 2. Demographic and clinical characteristics of the infected population by ethnic group [7].

Sex	Confirmed cases		Any comorbidity		Outcome					
	N	Distribution by gender (%)	N (% of confirmed cases)	Distribution by gender (%)	Severe cases N (% of confirmed cases)	Distribution by gender (%)	Confirmed deaths N (% of confirmed cases)	Distribution by gender (%)	Deceased w/ comorbidities N (% of confirmed deaths)	Distribution by gender (%)
Non-indigenous population										
Female	502,967	49.0	210,476 (41.8)	47.7	41,247 (8.2)	36.5	36,032 (7.2)	36.3	28,237 (78.4)	38.9
Male	523,248	51.0	230,820 (44.1)	52.3	71,692 (13.7)	63.5	63,304 (12.1)	63.7	44,275 (69.9)	61.1
Total	**1,026,215**	**100.0**	**441,296 (43.0)**	**100.0**	**112,939 (11.0)**	**100.0**	**99,336 (9.7)**	**100.0**	**72,512 (73.0)**	**100.0**
Mean age (years ± SD)	**44.3 ± 16.8**	-	**50.7 ± 16.3**	-	**61.6 ± 15.0**	-	**62.7 ± 14.2**	-	**63.4 ± 13.8**	-
Indigenous population										
Female	5,013	44.2	2,548 (50.8)	45.1	675 (13.5)	35.8	589 (11.7)	35.3	488 (82.9)	40.0
Male	6,339	55.8	3,100 (48.9)	54.9	1,212 (19.1)	64.2	1,080 (17.0)	64.7	732 (67.8)	60.0
Total	**11,352**	**100.0**	**5,648 (49.8)**	**100.0**	**1,887 (16.6)**	**100.0**	**1,669 (14.7)**	**100.0**	**1,220 (73.1)**	**100.0**
Mean age (years ± SD)	**48.2 ± 18.1**	-	**53.9 ± 16.5**	-	**62.5 ± 15.6**	-	**64.0 ± 14.4**	-	**64.3 ± 13.4**	-

or having received invasive ventilation (52.8% had been hospitalized, but 10.6% died at home).

The presence of comorbidities was more common in severe cases than in non-severe cases (72.1% vs. 39.5%). In severe cases resulting in death, 73% of the patients had at least one comorbidity; in severe cases where the patient recovered, this proportion dropped to 65.3%.

Two or more comorbidities were observed in 40.1% of hospitalized patients admitted to an ICU or that received invasive ventilation, as compared to hospitalized patients not admitted to an ICU and that did not receive invasive ventilation (35.6%), and ambulatory patients (12.3%).

Table 3. Confirmed COVID-19 cases in Mexico, grouped by type of patient, and outcome [7].

Age Group	Cases N	One co-morbidity N (% of cases)	2+ co-morbidities N (% of cases)	Deaths N	One co-morbidity N (% of deaths)	2+ co-morbidities N (% of deaths)	Recovered N	One co-morbidity N (% of recovered)	2+ co-morbidities N (% of recovered)
Hospitalized patients, admitted to intensive care unit (ICU) or received invasive ventilation									
0-9	559	127 (22.7)	37 (6.6)	142	38 (26.8)	13 (9.2)	417	89 (21.3)	24 (5.8)
10-19	255	85 (33.3)	38 (14.9)	82	26 (31.7)	22 2 (6.8)	173	59 (34.1)	16 (9.2)
20-29	1,022	331 (32.4)	224 (21.9)	413	130 (31.5)	121 (29.3)	609	201 (33.0)	103 (16.9)
30-39	3,035	1,086 (35.8)	654 (21.5)	1,527	555 (36.3)	407 (26.7)	1,508	531 (35.2)	247 (16.4)
40-49	6,761	2,292 (33.9)	2,182 (32.3)	4,160	1,418 (34.1)	1,463 (35.2)	2,601	874 (33.6)	719 (27.6)
50-59	11,029	3,355 (30.4)	4,344 (39.4)	7,673	2,308 (30.1)	3,121 (40.7)	3,356	1,047 (31.2)	1,223 (36.4)
60-69	12,214	3,608 (29.5)	5,595 (45.8)	9,311	2,697 (29.0)	4,332 (46.5)	2,903	911 (31.4)	1,263 (43.5)
70-79	8,216	2,397 (29.2)	4,009 (48.8)	6,619	1,908 (28.8)	3,265 (49.3)	1,597	489 (30.6)	744 (46.6)
≥ 80	3,467	1,048 (30.2)	1,600 (46.1)	2,810	851 (30.3)	1,306 (46.5)	657	197 (30.0)	294 (44.7)
Total	**46,558**	**14,329 (30.8)**	**18,683 (40.1)**	**32,737**	**9,931 (30.3)**	**14,050 (42.9)**	**13,821**	**4,398 (31.8)**	**4,633 (33.5)**
Non-indigenous	45,867	14,113 (30.8)	18,418 (40.2)	32,264	9,783 (30.3)	13,853 (42.9)	13,603	4,330 (31.8)	4,565 (33.6)
Indigenous	691	216 (31.3)	265 (38.4)	473	148 (31.3)	197 (41.6)	218	68 (31.2)	68 (31.2)
Hospitalized patients, not admitted to ICU and did not receive invasive ventilation									
0-9	1,597	300 (18.8)	105 (6.6)	83	24 (28.9)	13 (15.7)	1,514	276 (18.2)	92 (6.1)
10-19	1,347	359 (26.7)	133 (9.9)	74	31 (41.9)	9 (12.2)	1,273	328 (25.8)	124 (9.7)
20-29	7,511	1,933 (25.7)	1,026 (13.7)	617	198 (32.1)	213 (34.5)	6,894	1,735 (25.2)	813 (11.8)
30-39	17,611	5,012 (28.5)	3,100 (17.6)	2,035	660 (32.4)	675 (33.2)	15,576	4,352 (27.9)	2,425 (15.6)
40-49	31,041	9,439 (30.4)	8,178 (26.3)	6,025	1,856 (30.8)	2,212 (36.7)	25,016	7,583 (30.3)	5,966 (23.8)
50-59	42,042	12,760 (30.4)	15,121 (36.0)	11,748	3,401 (28.9)	5,075 (43.2)	30,294	9,359 (30.9)	10,046 (33.2)
60-69	40,453	11,278 (27.9)	18,155 (44.9)	15,845	4,233 (26.7)	7,635 (48.2)	24,608	7,045 (28.6)	10,520 (42.8)
70-79	27,392	7,682 (28.0)	13,124 (47.9)	13,224	3,676 (27.8)	6,440 (48.7)	14,168	4,006 (28.3)	6,684 (47.2)
≥ 80	13,807	4,170 (30.2)	6,153 (44.6)	7,633	2,351 (30.8)	3,425 (44.9)	6,174	1,819 (29.5)	2,728 (44.2)
Total	**182,801**	**52,933 (29.0)**	**65,095 (35.6)**	**57,284**	**16,430 (28.7)**	**25,697 (44.9)**	**125,517**	**36,503 (29.1)**	**39,398 (31.4)**
Non-indigenous	179,759	51,990 (28.9)	64,106 (35.7)	56,288	16,149 (28.7)	25,238 (44.8)	123,471	35,841 (29.0)	38,868 (31.5)
Indigenous	3,042	943 (31.0)	989 (32.5)	996	281 (28.2)	459 (46.1)	2,046	662 (32.4)	530 (25.9)
Outpatients									
0-9	9,483	689 (7.3)	111 (1.2)	12	5 (41.7)	1 (8.3)	9,471	684 (7.2)	110 (1.2)
10-19	31,101	3,608 (11.6)	445 (1.4)	15	5 (33.3)	3 (20.0)	31,086	3,603 (11.6)	442 (1.4)
20-29	160,156	31,066 (19.4)	6,454 (4.0)	151	43 (28.5)	43 (28.5)	160,005	31,023 (19.4)	6,411 (4.0)
30-39	208,154	48,103 (23.1)	14,595 (7.0)	557	175 (31.4)	155 (27.8)	207,597	47,928 (23.1)	14,440 (7.0)
40-49	180,985	47,852 (26.4)	22,955 (12.7)	1,375	426 (31.0)	443 (32.2)	179,610	47,426 (26.4)	20,512 (12.5)
50-59	126,817	37,122 (29.3)	25,963 (20.5)	2,546	742 (29.1)	999 (39.2)	124,271	36,380 (29.3)	24,964 (20.1)
60-69	59,445	18,377 (30.9)	17,368 (29.2)	2,920	836 (28.6)	1,302 (44.6)	56,525	17,541 (31.0)	16,066 (28.4)
70-79	23,223	7,142 (30.8)	8,236 (35.5)	2,186	601 (27.5)	985 (45.1)	21,037	6,541 (31.1)	7,251 (34.5)
≥ 80	8,844	2,748 (31.1)	3,070 (34.7)	1,222	354 (29.0)	506 (41.4)	7,622	2,394 (31.4)	2,564 (33.6)
Total	**808,208**	**196,707 (24.3)**	**99,197 (12.3)**	**10,984**	**3,187 (29.0)**	**4,437 (40.4)**	**797,224**	**193,520 (24.3)**	**94,760 (11.9)**
Non-indigenous	800,589	194,550 (24.3)	98,119 (12.3)	10,784	3,118 (28.9)	4,371 (40.5)	789,805	191,432 (24.2)	93,748 (11.9)
Indigenous	7,619	2,157 (28.3)	1,078 (14.1)	200	69 (34.5)	66 (33.0)	7,419	2,088 (28.1)	1,012 (13.6)
Severe cases									
Total	**114,826**	**33,946 (29.6)**	**48,817 (42.5)**	**101,005**	**29,548 (29.3)**	**44,184 (43.7)**	**13,821**	**4,398 (31.8)**	**4633 (33.5)**
Non-indigenous	112,939	33,380 (29.6)	48,027 (42.5)	99,336	29,050 (29.2)	43,462 (43.8)	13,603	4,330 (31.8)	4,565 (33.6)
Indigenous	1,887	566 (30.0)	790 (41.9)	1,669	498 (29.8)	722 (43.3)	218	68 (31.2)	68 (31.2)
Non-severe cases									
Total	**922,741**	**230,023 (24.9)**	**134,158 (14.5)**	**-**	**-**	**-**	**922,741**	**230,023 (24.9)**	**134,158 (14.5)**
Non-indigenous	913,276	227,273 (24.9)	132,616 (14.5)	-	-	-	913,276	227,273 (24.9)	132,616 (14.5)
Indigenous	9,465	2,750 (29.1)	1,542 (16.3)	-	-	-	9,465	2,750 (29.1)	1,542 (16.3)

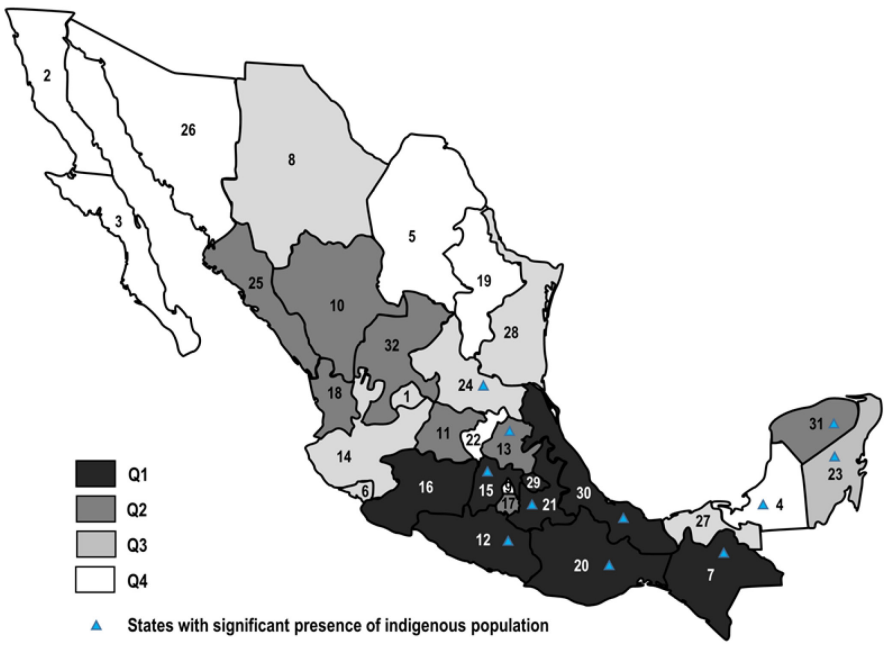
Differences by state-level income in COVID-19 cumulative incidence, hospitalized patients, outpatients, and deaths per 100,000 population

Mexico spans a vast territory of nearly 2 million square kilometers [29], divided into 32 states. Each state presents a unique combination of socioeconomic and demographic characteristics, as well as different incidence and mortality rates. State-level Gross Domestic Product (GDP) per capita, as a measure of income, ranged from 2,395 US dollars in the state of Chiapas to 27,324 US dollars in the state of Campeche. Classified by quartiles (Q) of GDP per capita, six of the eight states in the lowest income quartile (Q1) are part of the group of eleven states with the most significant presence of indigenous population, i.e., the poorest states in the country frequently have a considerable proportion of indigenous population (Figure 2).

Upon visual inspection, an upward trend in both cumulative incidence and death rates was observed, corresponding to increasing GDP per capita by state. The lowest age-standardized incidence and age-standardized death rates were observed in the remote state of Chiapas bordering Guatemala, which has the lowest GDP per capita; these rates were, respectively, 14.4 times and 5.6 times lower than those observed in Mexico City, the nation's capital, which has the second-highest GDP per capita in the country (18,048 US dollars), the highest population density, and houses the most important airport hub in the country. Oaxaca and Guerrero, the next-lowest states in terms of GDP per capita (3,178 and 3,427 US dollars, respectively), with relative proximity to the nation's capital and with important tourist destinations located in specific areas, exhibited incidence rates 3.8 and 3.2 times lower than Mexico City, while the corresponding death rates were 3.4 and 2.2 times lower.

Five of the eight states in the highest income quartile, Q4 (Baja California Sur, Sonora, Coahuila, and Nuevo León in the northern part of the country, as well as Mexico City), had incidence rates above 1,000 and death rates of 100 or above (except Nuevo Leon, with 79). The state of Campeche, with the highest GDP per capita in the country due to crude oil production concentrated in two specific areas, had a death rate of 108 deaths per 100,000 population, but its incidence rate was one of the lowest in this quartile (753). It must be noted, however, that the state is scarcely populated and has a high presence of indigenous population (> 20%) dedicated to agriculture, living in remote regions.

Figure 2. Map showing: the 32 states of Mexico, classified by quartiles (Q) of Gross Domestic Product (GDP) per capita in current US Dollars (Q1 < 6,376.05; Q2 ≥ 6,376.05 and < 9,038.97; Q3 ≥ 9,038.97 and < 11,622.10; Q4 ≥ 11,622.10), the 11 states with the most significant presence of indigenous population, and a list showing the age-adjusted incidence rate and the age-adjusted death rate in each state [7,17,21-25].



State	Age-adjusted Incidence Rate (x 100,000)	Age-adjusted Death Rate (x 100,000)
1 Aguascalientes	880	83
2 Baja California	659	123
3 Baja California Sur	1,665	100
4 Campeche	753	108
5 Coahuila	1,242	104
6 Colima	946	107
7 Chiapas	154	26
8 Chihuahua	764	91
9 Ciudad de México	2,213	146
10 Durango	1,045	59
11 Guanajuato	936	67
12 Guerrero	689	68
13 Hidalgo	550	82
14 Jalisco	460	56
15 México	425	70
16 Michoacán	591	47
17 Morelos	346	59
18 Nayarit	569	77
19 Nuevo León	1,058	79
20 Oaxaca	578	43
21 Puebla	627	84
22 Querétaro	780	66
23 Quintana Roo	802	151
24 San Luis Potosí	1,170	82
25 Sinaloa	773	124
26 Sonora	1,398	117
27 Tabasco	1,538	143
28 Tamaulipas	949	84
29 Tlaxcala	611	99
30 Veracruz	458	61
31 Yucatán	964	87
32 Zacatecas	900	72

Using state-level results, a Spearman correlation analysis was performed to determine the relationship between GDP per capita and the cumulative incidence rate, as well as the death rate in each state. There was a strong, positive correlation between income and both the age-standardized incidence rate and the age standardized death rate, i.e., the higher the state-level income, the higher the COVID-19 incidence and death rates; the respective Spearman correlation coefficient values were 0.657 and 0.607 ($p < 0.001$ in both cases) (Figures 3A and 3B).

Moreover, Kruskal-Wallis test results indicate differences, by income quartile, in the medians of the following Total Population COVID-19 rates per 100,000 population: cumulative incidence (H = 13.47, $p < 0.01$), hospitalized patients (H = 11.67, $p < 0.01$), outpatients (H = 12.86, $p < 0.01$), and deaths (H = 8.92, $p < 0.05$) (Table 4). Regarding specific population groups, only the cumulative incidence rate and outpatients rate proved significantly different between income quartiles: for the non-indigenous population, the corresponding H-values were 11.58 ($p < 0.01$) and 9.24 ($p < 0.05$); for the indigenous population, the H-values were, respectively, 11.66 ($p < 0.01$) and 10.73 ($p < 0.05$).

Mann-Whitney tests were carried out to follow up on such differences (Table 5). The total population rates per 100,000 population were significantly lower for income quartile Q1 (< 6,376.05 USD) compared to quartile Q3 (≥ 9,038.97 and < 11,622.10 USD), and for

Figure 3. Correlation of state-level Gross Domestic Product (GDP) per capita, in current US dollars, with COVID-19 incidence and death rates (95% CI) [7,17,20-25]. (A) GDP per capita correlated with age-standardized incidence rate (B) GDP per capita correlated with age-standardized death rate.

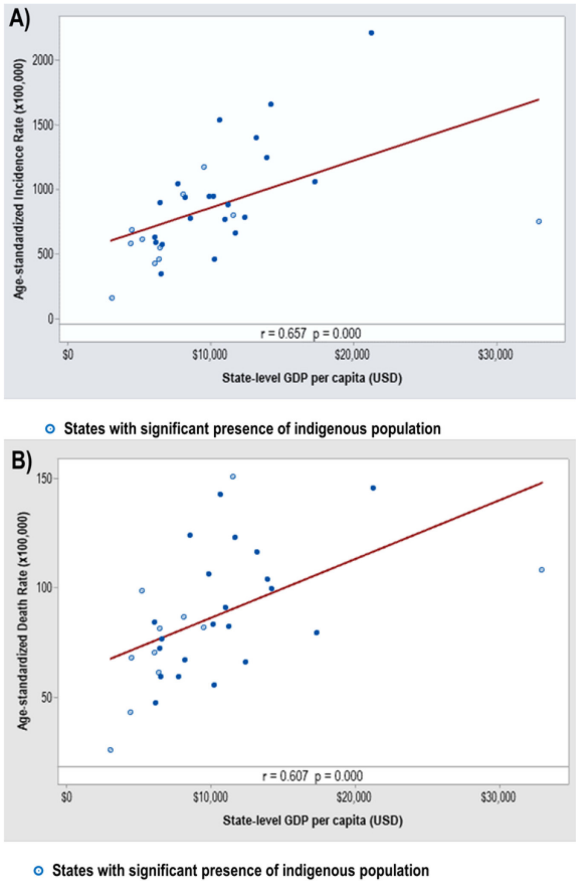


Table 4. Kruskal-Wallis test results of Association of state-level income category with COVID-19 cumulative incidence, hospitalized patients, outpatients, and deaths per 100,000 population in Mexico from February 29, 2020 to November 13, 2020 [7,21-24].

Variable / Income category*	Total population			Non-indigenous			Indigenous		
	Median	H	*p*	Median	H	*p*	Median	H	*p*
Cumulative incidence per 100,000 population									
Q1 < 6,376.05 USD**	563.66	13.47	**0.004**	603.34	11.58	**0.009**	54.733	11.66	**0.009**
Q2 ≥ 6,376.05 and < 9,038.97 USD	821.84			830.98			142.130		
Q3 ≥ 9,038.97 and < 11,622.10 USD	906.04			980.75			182.735		
Q4 ≥ 11,622.10 USD	1152.62			1164.82			138.008		
Hospitalized patients per 100,000 population									
Q1 < 6,376.05 USD	145.613	11.67	**0.009**	163.435	7.11	0.068	25.4228	5.82	0.121
Q2 ≥ 6,376.05 and < 9,038.97 USD	173.291			179.439			51.5484		
Q3 ≥ 9,038.97 and < 11,622.10 USD	197.039			200.140			49.8471		
Q4 ≥ 11,622.10 USD	205.294			209.257			44.8220		
Outpatients per 100,000 population									
Q1 < 6,376.05 USD	428.013	12.86	**0.005**	468.584	9.24	**0.026**	24.995	10.73	**0.013**
Q2 ≥ 6,376.05 and < 9,038.97 USD	608.881			615.450			103.103		
Q3 ≥ 9,038.97 and < 11,622.10 USD	683.261			721.892			108.184		
Q4 ≥ 11,622.10 USD	953.263			963.350			103.429		
Deaths per 100,000 population									
Q1 < 6,376.05 USD	66.5135	8.92	**0.030**	74.383	4.76	0.190	10.8997	6.17	0.103
Q2 ≥ 6,376.05 and < 9,038.97 USD	74.1873			76.482			20.1055		
Q3 ≥ 9,038.97 and < 11,622.10 USD	84.1571			90.427			21.1443		
Q4 ≥ 11,622.10 USD	97.4364			102.767			22.0480		

* Gross Domestic Product per capita is used as a measure of income; ** USD represents United States Dollars.

quartile Q1 (< 6,376.05 USD) compared to quartile Q4 (≥ 11,622.10 USD): respectively, Mann-Whitney W values were 42 ($p < 0.01$) and 36 ($p < 0.01$) for cumulative incidence; 46 ($p < 0.05$) and 39 ($p < 0.01$) for hospitalized patients; 41 ($p < 0.01$) and 39 ($p < 0.01$) for outpatients; 46 ($p < 0.05$) and 34 ($p < 0.05$) for deaths. For the non-indigenous population, cumulative incidence per 100,000 population and outpatients per 100,000 population were significantly lower for quartile Q1 compared to quartile Q3, and for quartile Q1 compared to quartile Q4: respectively, Mann-Whitney W values were 44 ($p < 0.05$) and 40 ($p < 0.01$) for cumulative incidence; 47 ($p < 0.05$) and 42 ($p < 0.01$) for outpatients.

In the case of the indigenous population, cumulative incidence and outpatients per 100,000 population were

Table 5. Analysis of Mann-Whitney W based on Kruskal-Wallis test results of association of state-level income category with COVID-19 cumulative incidence, hospitalized patients, outpatients, and deaths per 100,000 population in Mexico from February 29, 2020 to November 13, 2020 [7,21-24].

Variable / Income category*	Total population			Non-indigenous			Indigenous		
	Median	W	*p*	Median	W	*p*	Median	W	*p*
Cumulative incidence per 100,000 population									
Q1 < 6,376.05 USD**	563.657	52.00	0.104	603.338	52.00	0.104	54.733	42.00	**0.007**
Q2 ≥ 6,376.05 and < 9,038.97 USD	821.835			830.979			142.130		
Q1 < 6,376.05 USD	563.657	42.00	**0.007**	603.338	44.00	**0.014**	54.733	41.00	**0.005**
Q3 ≥ 9,038.97 and < 11,622.10 USD	906.039			980.746			182.735		
Q1 < 6,376.05 USD	563.66	36.00	**0.001**	603.34	40.00	**0.004**	54.733	44.00	**0.014**
Q4 ≥ 11,622.10 USD	1152.62			1164.82			138.008		
Q2 ≥ 6,376.05 and < 9,038.97 USD	821.835	61.00	0.495	830.979	60.00	0.431	142.130	65.00	0.793
Q3 ≥ 9,038.97 and < 11,622.10 USD	906.039			980.746			182.735		
Q2 ≥ 6,376.05 and < 9,038.97 USD	821.84	51.00	0.083	830.98	51.00	0.083	142.130	74.00	0.564
Q4 ≥ 11,622.10 USD	1152.62			1164.82			138.008		
Q3 ≥ 9,038.97 and < 11,622.10 USD	906.04	59.00	0.372	980.75	59.00	0.372	182.735	74.00	0.564
Q4 ≥ 11,622.10 USD	1152.62			1164.82			138.008		
Hospitalized patients per 100,000 population									
Q1 < 6,376.05 USD	145.613	51.00	0.083						
Q2 ≥ 6,376.05 and < 9,038.97 USD	173.291								
Q1 < 6,376.05 USD	145.613	46.00	**0.024**						
Q3 ≥ 9,038.97 and < 11,622.10 USD	197.039								
Q1 < 6,376.05 USD	145.613	39.00	**0.003**						
Q4 ≥ 11,622.10 USD	205.294								
Q2 ≥ 6,376.05 and < 9,038.97 USD	173.291	59.00	0.372						
Q3 ≥ 9,038.97 and < 11,622.10 USD	197.039								
Q2 ≥ 6,376.05 and < 9,038.97 USD	173.291	51.00	0.083						
Q4 ≥ 11,622.10 USD	205.294								
Q3 ≥ 9,038.97 and < 11,622.10 USD	197.039	59.00	0.372						
Q4 ≥ 11,622.10 USD	205.294								
Outpatients per 100,000 population									
Q1 < 6,376.05 USD	428.013	53.00	0.128	468.584	56.00	0.227	24.995	44.00	**0.014**
Q2 ≥ 6,376.05 and < 9,038.97 USD	608.881			615.450			103.103		
Q1 < 6,376.05 USD	428.013	41.00	**0.005**	468.584	47.00	**0.031**	24.995	42.00	**0.007**
Q3 ≥ 9,038.97 and < 11,622.10 USD	683.261			721.892			108.184		
Q1 < 6,376.05 USD	428.013	39.00	**0.003**	468.584	42.00	**0.007**	24.995	44.00	**0.014**
Q4 ≥ 11,622.10 USD	953.263			963.350			103.429		
Q2 ≥ 6,376.05 and < 9,038.97 USD	608.881	59.00	0.372	615.450	60.00	0.431	103.103	63.00	0.637
Q3 ≥ 9,038.97 and < 11,622.10 USD	683.261			721.892			108.184		
Q2 ≥ 6,376.05 and < 9,038.97 USD	608.881	50.00	0.066	615.450	53.00	0.128	103.103	71.00	0.793
Q4 ≥ 11,622.10 USD	953.263			963.350			103.429		
Q3 ≥ 9,038.97 and < 11,622.10 USD	683.261	59.00	0.372	721.892	59.00	0.372	108.184	74.00	0.564
Q4 ≥ 11,622.10 USD	953.263			963.350			103.429		
Deaths per 100,000 population									
Q1 < 6,376.05 USD	66.5135	56.00	0.227						
Q2 ≥ 6,376.05 and < 9,038.97 USD	74.1873								
Q1 < 6,376.05 USD	66.5135	46.00	**0.024**						
Q3 ≥ 9,038.97 and < 11,622.10 USD	84.1571								
Q1 < 6,376.05 USD	66.5135	44.00	**0.014**						
Q4 ≥ 11,622.10 USD	97.4364								
Q2 ≥ 6,376.05 and < 9,038.97 USD	74.1873	57.00	0.270						
Q3 ≥ 9,038.97 and < 11,622.10 USD	84.1571								
Q2 ≥ 6,376.05 and < 9,038.97 USD	74.1873	53.00	0.128						
Q4 ≥ 11,622.10 USD	97.4364								
Q3 ≥ 9,038.97 and < 11,622.10 USD	84.1571	63.00	0.637						
Q4 ≥ 11,622.10 USD	97.4364								

* Gross Domestic Product per capita is used as a measure of income; ** USD represents United States Dollars.

significantly lower for income quartile Q1 (< 6,376.05 USD) compared to quartile Q2 (≥ 6,376.05 and < 9,038.97 USD), for quartile Q1 (< 6,376.05 USD) compared to quartile Q3 (≥ 9,038.97 and < 11,622.10 USD), and for quartile Q1 (< 6,376.05 USD) compared to quartile Q4 (≥ 11,622.10 USD): respectively, Mann-Whitney W values were 42 ($p < 0.01$), 41 ($p < 0.01$), and 44 ($p < 0.05$) for cumulative incidence; the corresponding values for outpatients were 44 ($p < 0.05$), 42 ($p < 0.01$), and 44 ($p < 0.05$).

Discussion

Once infected, the indigenous population, being older and more likely to have comorbidities, had worse outcomes than the non-indigenous population, as indicated by the corresponding proportion of severe illness cases (16.6% vs. 11.0%) and proportion of outpatient deaths (12.0% vs. 10.9%), yet the cumulative incidence and death rates per 100,000 population were considerably lower for the indigenous population compared to the non-indigenous population (94.4 vs. 900.3, and 13.9 vs. 87.1, respectively). Spearman correlation analysis indicates that the higher the state-level income, the higher the COVID-19 age-standardized cumulative incidence and death rates by state for the population as a whole. Kruskal-Wallis test results and Mann-Whitney follow-up tests indicate that crude rates of cumulative incidence, hospitalized patients, outpatients, and deaths differ significantly by state-level income quartiles. However, when analyzed by ethnic group, only cumulative incidence and outpatients rates were significantly different between quartiles (originating from the different rates that result once we separate indigenous and non-indigenous populations): significantly lower for income quartile Q1 compared to quartiles Q2, Q3, and Q4 for the indigenous population, and significantly lower for income quartile Q1 compared to quartiles Q3 and Q4 in the case of the non-indigenous population. Such results evidence that the socioeconomic status health gradient for the COVID-19 pandemic is reversed for the case of Mexico.

To our knowledge, this is the first study to examine the differences by state-level income in COVID-19 cumulative incidence, deaths, hospitalizations, and outpatient rates in Mexico, in addition to presenting results by ethnic group. Ortiz-Hernández and Pérez-Sastré analyze the risk of severe COVID-19 outcomes in Mexico by ethnicity and municipality-level margination indices dating from 2015 and conclude that the risk is highest among low socioeconomic status indigenous population living in the country's southern states [30]. Argoty-Pantoja *et al.* compare fatality rates between the indigenous and non-indigenous populations in Mexico, concluding that fatality is higher in the former population group, particularly among outpatients [31]. Ibarra-Nava *et al*. study the fatality rate of the indigenous population in Mexico, concluding that indigenous people have a higher risk of death from COVID-19 [32]. Our study confirms such findings regarding fatality by means of a case fatality rate, which is higher for the indigenous population compared to the non-indigenous population (14.7% vs. 9.7%); this variable is not analyzed further because the true number of infected persons is underestimated in the case of Mexico due to limited testing (the cumulative number of COVID-19 laboratory tests performed by November 13, 2020 was 18.29 people tested per 1,000 population, as compared to 526.90 tests performed per 1,000 population in the United States of America [33]), resulting in an inflated rate. Furthermore, our results regarding a higher proportion of outpatient deaths for the indigenous population (12.0%) compared with the non-indigenous population (10.9%) are in line with the Argoty-Pantoja *et al's*. conclusion that indigenous outpatients are at a higher risk of death than non-indigenous outpatients. It is likely that in both population groups, such outpatients were misdiagnosed regarding the severity of their COVID-19 infection, given the narrow suspected COVID-19 case operational definition that was utilized. At the outset of the pandemic in Mexico, a suspected COVID-19 case was one where in the previous 7 days, the patient presented at least two of the following: cough, fever, headache, and one or more of either dyspnea, arthralgia, myalgia, odynophagia, rhinorrhea, conjunctivitis, or chest pain. This definition was updated on August 24, 2020, and COVID-19 was suspected when in the previous 10 days, the patient presented one or more of the following: cough, fever, dyspnea, headache, and one or more of either arthralgia, myalgia, odynophagia, chills, rhinorrhea, conjunctivitis, chest pain, anosmia, or dysgeusia [34]. Additionally, the higher proportion of indigenous patients in this situation might indicate a language barrier, where the symptoms of the indigenous patient are not clearly understood by the attending health professional, since 12.3% of the indigenous population that speaks an indigenous language are monolingual [17].

We found that beyond the potentially higher risk of more severe outcomes in the indigenous population in Mexico due to older age, proportionally more comorbidities, and higher health vulnerability (approximately 80% of indigenous language-speaking

indigenous population live in poverty or extreme poverty conditions, and more than 80% of older adults lack social security [19]), the fact that they live mainly in states with lower GDP per capita helped them attain better COVID-19 outcomes than the non-indigenous population.

Our study has several strengths. The large sample size (over one million confirmed cases) confers reliability to our results, particularly descriptive statistics. The study considers the 2020 Population Census, published by the National Institute of Statistics and Geography in January 2021, allowing for more precise rates per 100,000 population. Another key strength is that by November 2020, the Mexican Ministry of Health had incorporated the "indigenous" variable to the COVID-19 cases database to determine ethnicity (previously, the database only included a "speaks indigenous tongue" variable), allowing us to include patients of all ages, and thus utilize population data from the National Institute of Indigenous People, which we consider to be the most reliable source at present.

The limitation of our study is that the COVID-19 cases database suffers from underreporting due to the sentinel surveillance system, which only tests a proportion of patients and leaves out mild or asymptomatic cases. Another limitation is the use of data aggregated at the state level due to the level of aggregation of GDP information; thus, possible variations at the municipality level are not captured. Also, further studies are necessary at the municipality level to analyze the effect of population density on the spread of COVID-19.

While higher health literacy in high-income states contributes to the SES health gradient by facilitating the population's adherence to outbreak containment measures [14], the fact that we are observing a reversed SES health gradient in Mexico suggests that other factors are outweighing its effect. One such factor could be that testing for COVID-19 could be even more limited in low-income states, resulting in a deceptively low incidence rate [35]. However, the sheer differences in age-adjusted incidence and death rates by state-level income, as observed in Figure 2, indicate the presence of other factors as well. In this regard, Hamidi *et al*. found that in the United States, connectivity is a more important contributor to the spread of the COVID-19 pandemic than population density [36]. In Mexico, the states with the lowest GDP per capita, such as Chiapas, Guerrero, and Oaxaca, tend to have important tourist destinations located in specific areas. The majority of the population, including a high presence of indigenous population, live in deprived, low-density rural areas with only local economic activities. In states with higher GDP per capita –many of them located in the northern part of Mexico and with low population density, economic activities tend to be more tightly linked together, with more business-related interaction and travel. It could be assumed that the more frequent economic and social interaction among the population in higher-GDP per capita states contributes to the higher incidence rates and death rates of COVID-19. Up to the November 13 cut-off point, connectivity, and the more frequent testing in higher GDP per capita states, apparently outweighed the effect of higher health literacy.

Conclusions

COVID-19 cumulative incidence, hospitalizations, outpatients, and mortality rates presented a reversed socioeconomic status health gradient in Mexico according to GDP per capita by state, characterized by less adverse outcomes in the lowest-income states compared to states with higher income. A health strategy should be designed to assure positive health outcomes are maintained in regions with low cumulative incidence rates even after becoming more integrated with the rest of the economy, particularly low-income areas with a significant presence of indigenous population.

Acknowledgements

We thank Baudelio Ramirez Loya (Independent Consultant) for assistance in the statistical analysis and for translating this research paper from Spanish to English.

Authors' contributions

Conceptualization: Elba Ronquillo De Jesús; Data curation: Monserrat Suárez Quezada, Erich von Borries-Medrano; Formal analysis: Elba Ronquillo De Jesús, Víctor Suárez, Patricia López-Perea; Research: Elba Ronquillo De Jesús, Monserrat Suárez Quezada, Erich von Borries-Medrano; Methodology: Elba Ronquillo De Jesús, Víctor Suárez, Patricia López-Perea; Project administration: Elba Ronquillo De Jesús ; Supervision: Víctor Suárez, Patricia López-Perea; Writing – original draft: Elba Ronquillo De Jesús; Writing – review and editing: Elba Ronquillo De Jesús, Víctor Suárez, Patricia López-Perea, Monserrat Suárez Quezada, Erich von Borries-Medrano.

References

1. WHO-China Joint Mission (2020) Report of the WHO-China Joint Mission on coronavirus disease 2019 (COVID-19). Available: https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf. Accessed 21 December 2020.

2. World Health Organization (WHO) (2020) Coronavirus disease (COVID-19) Situation Report – 40. https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200229-sitrep-40-covid-19.pdf?sfvrsn=849d0665_2. Accessed 21 December 2020.
3. Suarez V, Suarez Quezada M, Oros Ruiz S, Ronquillo De Jesús E (2020) Epidemiology of COVID-19 in Mexico: from the 27th of February to the 30th of April 2020. Rev Clínica Esp 220: 463-471.
4. Diario Oficial de la Federación (2020) RESOLUTION establishing the preventive measures to be implemented for the mitigation and control of the health risks posed by the SARS-CoV2 virus disease (COVID-19). Available: https://www.dof.gob.mx/nota_detalle.php?codigo=5590339&fecha=24/03/2020. Accessed 27 December 2020. [Article in Spanish].
5. Diario Oficial de la Federación (2020) RESOLUTION declaring the epidemic of disease caused by the SARS-CoV2 virus (COVID-19) as a sanitary emergency due to force majeure. Available: https://www.dof.gob.mx/nota_detalle.php?codigo=5590745&fecha=30/03/2020. Accessed 27 December 2020. [Article in Spanish].
6. Diario Oficial de la Federación (2020) RESOLUTION establishing extraordinary actions to address the health emergency generated by the SARS-CoV2 virus. Available: https://www.dof.gob.mx/nota_detalle.php?codigo=5590914&fecha=31/03/2020. Accessed 27 December 2020. [Article in Spanish].
7. Mexican Ministry of Health, Directorate General of Epidemiology. COVID-19 Mexico (2020) COVID-19 Mexico. Available: https://coronavirus.gob.mx/datos/#DOView. Accessed 1 December 2020.
8. Diario Oficial de la Federación (2020) RESOLUTION number 06/03/20 extending the suspension period from March 27 to April 30 of the current year and modifying number 02/03/20 suspending classes in preschool, primary, secondary, teacher education and other schools for the training of basic education teachers of the National Education System, as well as those of the upper secondary and higher education levels under the Ministry of Public Education. Available: https://www.dof.gob.mx/nota_detalle.php?codigo=5590981&fecha=01/04/2020. Accessed 21 December 2020. [Article in Spanish].
9. World Health Organization (WHO) (2020) Coronavirus disease (COVID-19) situation report – 193. Available: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200731-covid-19-sitrep-193.pdf?sfvrsn=d9c2eaef_2. Accessed 21 December 2020.
10. Chung RY-N, Dong D, Li MM (2020) Socioeconomic gradient in health and the covid-19 outbreak. BMJ: m1329.
11. Bambra C, Riordan R, Ford J, Matthews F (2020) The COVID-19 pandemic and health inequalities. J Epidemiol Community Health 74: 964.
12. The Lancet (2020) Redefining vulnerability in the era of COVID-19. Lancet 395: 1089.
13. Chung H, Fung K, Ferreira-Legere L, Chen B, Ishiguro L, Kalappa G, Gozdyra P, Campbell T, Paterson JM, Bronskill SE, Kwong JC, Guttmann A, Azimaee M, Vermeulen MJ, Schull MJ (2020) COVID-19 laboratory testing in Ontario: patterns of testing and characteristics of individuals tested, as of April 30, 2020. Toronto: ICES 107p.
14. Baena-Díez JM, Barroso M, Cordeiro-Coelho SI, Díaz JL, Grau M (2020) Impact of COVID-19 outbreak by income: hitting hardest the most deprived. J Public Health 42: 698–703.
15. Clouston SAP, Natale G, Link BG (2021) Socioeconomic inequalities in the spread of coronavirus-19 in the United States: an examination of the emergence of social inequalities. Soc Sci Med 268: 113554.
16. Holmes L, Enwere M, Williams J, Ogundele B, Chavan P, Piccoli T, Chinaka C, Comeaux C, Pelaez L, Okundaye O, Stalnaker L, Kalle F, Deepika K, Philipcien G, Poleon M, Ogungbade G, Elmi H, John V, Dabney KW (2020) Black–white risk differentials in COVID-19 (SARS-COV2) transmission, mortality and case fatality in the United States: translational epidemiologic perspective and challenges. Int J Environ Res Public Health 17: 4322.
17. Instituto Nacional de los Pueblos Indígenas (2017) Socioeconomic indicators of indigenous peoples in Mexico, 2015 (sections 1-4). Available: https://www.gob.mx/inpi/articulos/indicadores-socioeconomicos-de-los-pueblos-indigenas-de-mexico-2015-116128. Accessed 19 January 2021. [Article in Spanish].
18. Cañas J, Gutierrez E (2015) Mexico's four economies reflect regional differences, challenges. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2670353. Accessed 27 January 2022.
19. Juárez-Ramírez C, Márquez-Serrano M, Salgado de Snyder N, Pelcastre-Villafuerte BE, Ruelas-González MG, Reyes-Morales H (2014) Health inequality among vulnerable groups in Mexico: the elderly, indigenous people and migrants. Rev Panam Salud Pública 35: 284–290. [Article in Spanish].
20. Comité Nacional para la Vigilancia Epidemiológica (CONAVE) (2020) Epidemiological Notice CONAVE/09/2020/COVID-19. COVID-19 disease caused by SARS-CoV-2. Available: https://www.gob.mx/cms/uploads/attachment/file/545445/AE_Enfermedad_COVID-19_SARS-CoV-2_2020.04.06.pdf. Accessed 27 December 2020. [Article in Spanish].
21. Instituto Nacional de Estadística y Geografía (INEGI) System of National Accounts of Mexico. Gross Domestic Product by state. Base year 2013. Series from 2003 to 2019. 2019 preliminary. https://www.inegi.org.mx/app/tabulados/default.aspx?pr=17&vr=6&in=2&tp=20&wr=1&cno=2. Accessed 12 January 2021. [Article in Spanish].
22. CONAPO (2018) Population projections for Mexico and its states 2016-2050: population at mid-year. Available: https://www.datos.gob.mx/busca/dataset/proyecciones-de-la-poblacion-de-mexico-y-de-las-entidades-federativas-2016-2050. Accessed 19 January 2021. [Article in Spanish].
23. Banco de México. Exchange rate to settle obligations denominated in U.S. dollars, payable in the Republic of Mexico. Available: https://www.banxico.org.mx/tipcamb/main.do?page=tip&idioma=sp. Accessed 12 January 2021. [Article in Spanish].
24. Instituto Nacional de Estadística y Geografía (INEGI) (2021) Population and Housing Census 2020: total population by state and municipality, according to age. Available: https://www.inegi.org.mx/sistemas/olap/consulta/general_ver4/MDXQueryDatos.asp?proy=. Accessed 31 January 2021. [Article in Spanish].

25. Instituto Nacional de Estadística y Geografía (INEGI) (2019) National Survey of Demographic Dynamics (ENADID) 2018: timely tabulations. Available: https://www.inegi.org.mx/programas/enadid/2018/#Tabulados. Accessed 7 January 2021. [Article in Spanish].
26. McCoy CE (2018) Understanding the use of composite endpoints in clinical trials. West J Emerg Med 19: 631–634.
27. Guan W, Liang W, Zhao Y, Liang H, Chen Z, Li Y, Liu X, Chen R, Tang C, Wang T, Ou C, Li L, Chen P, Sang L, Wang W, Li J, Li C, Ou L, Cheng B, Xiong S, Ni Z, Xiang J, Hu Y, Liu L, Shan H, Lei C, Peng Y, Wei L, Liu Y, Hu Y, Peng P, Wang J, Liu J, Chen Z, Li G, Zheng Z, Qiu S, Luo J, Ye C, Zhu S, Cheng L, Ye F, Li S, Zheng J, Zhang N, Zhong N, He J (2020) Comorbidity and its impact on 1590 patients with COVID-19 in China: a nationwide analysis. Eur Respir J 55: 2000547.
28. Porcheddu R, Serra C, Kelvin D, Kelvin N, Rubino S (2020) Similarity in case fatality rates (CFR) of COVID-19/SARS-COV-2 in Italy and China. J Infect Dev Ctries 14: 125-128. doi: 10.3855/jidc.12600.
29. SEMARNAT (2020) Oceans and seas of Mexico. Available: https://www.gob.mx/semarnat/articulos/oceanos-y-mares-de-mexico. Accessed 27 June 2021. [Article in Spanish].
30. Ortiz-Hernández L, Pérez-Sastré MA (2020) Social inequities in the progression of COVID-19 in Mexican population. Rev Panam Salud Publica. 44: 1. [Article in Spanish].
31. Argoty-Pantoja AD, Robles-Rivera K, Rivera-Paredez B, Salmerón J (2021) COVID-19 fatality in Mexico's indigenous populations. Public Health 193: 69-75.
32. Ibarra-Nava I, Flores-Rodriguez KG, Ruiz-Herrera V, Ochoa-Bayona HC, Salinas-Zertuche A, Padilla-Orozco M, Salazar-Montalvo RG (2021) Ethnic disparities in COVID-19 mortality in Mexico: a cross-sectional study based on national data. PLoS One 16: e0239168.
33. Our World in Data (2020) Total COVID-19 tests per 1,000 people. Official sources collated by Our World in Data. Available: https://ourworldindata.org/grapher/full-list-cumulative-total-tests-per-thousand?time=2020-02-24..latest&country=MEX~USA. Accessed 28 June 2021.
34. Martinez-Fierro ML, Diaz-Lozano M, Alvarez-Zuñiga C, Ramirez-Hernandez LA, Araujo-Espino R, Trejo-Ortiz PM, Mollinedo-Montaño FE, Ortiz-Castro Y, Vazquez-Reyes S, VeADlasco-Elizondo P, Garcia-Esquivel L, Araujo-Conejo A, Garza-Veloz I (2021) Population-based COVID-19 screening in Mexico: assessment of symptoms and their weighting in predicting SARS-CoV-2 infection. Medicina (Mex) 57: 363.
35. Kobia F, Gitaka J (2020) COVID-19: Are Africa's diagnostic challenges blunting response effectiveness? AAS Open Res 3: 4.
36. Hamidi S, Sabouri S, Ewing R (2020) Does density aggravate the COVID-19 pandemic? Early findings and lessons for planners. J Am Plann Assoc 86: 495–509.

Corresponding authors

Elba Ronquillo de Jesús, PhD
Researcher
Universidad Politécnica de Francisco I. Madero, Dirección de Ingeniería Agroindustrial, Domicilio Conocido SN, Tepatepec, Hidalgo, 42660, Mexico
Tel: +52-738-724-1174
Email: eronquillo@upfim.edu.mx

Erich von Borries-Medrano, PhD
Researcher
Instituto Politécnico Nacional, Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada – Unidad Legaria, Calzada Legaria 694, Colonia Irrigación, 11500, Mexico City, Mexico
Tel: +52-55-5729-6000 ext 67778
Fax: +52-55-5395-4147
Email: evonborries@ipn.mx

Conflict of interests: No conflict of interests is declared.