BMC Public Health

RESEARCH

Open Access

Comparative analysis of COVID-19 diagnoses and mortality among hospitalized indigenous and non-indigenous populations in Chile: 2020–2021

Sushma Dahal[1*], Iris Delgado[2], Lisa Sattenspiel[3], Svenn-Erik Mamelund[4*] and Gerardo Chowell[1]

Abstract

Background Current literature presents mixed effects of the COVID-19 pandemic on Indigenous communities. We aim to highlight potential disparities and temporal shifts in both the impact of COVID-19 and vaccine uptake among hospitalized Indigenous populations in Chile.

Methods We conducted an observational analysis utilizing 1,598,492 hospitalization records from 2020 to 2021 based on publicly accessible hospital discharge data spanning 65 healthcare facilities of medium and high complexity funded through the Diagnosis-Related Groups (DRG) mechanism in Chile, representing roughly 70% of the country's total hospitalizations. This was supplemented with publicly available municipal data on COVID-19 vaccinations and socio-demographic variables. We performed logistic regression analysis at 0.05 level of significance to assess the bivariate and multivariable association of Indigenous status with COVID-19 diagnosis and COVID-19 deaths among hospitalized populations. We also performed univariate and multiple linear regression to assess the association of COVID-19 vaccination rate and Indigenous status at the municipality level. In addition, we report the distribution of top 10 secondary diagnoses among hospitalized COVID-19 cases and deaths separately for Indigenous and non-Indigenous populations.

Results Indigenous populations displayed lower adjusted odds for both COVID-19 diagnosis (OR: 0.76, 95% CI: 0.74, 0.77) and death (OR: 0.91, 95% CI: 0.85, 0.97) when compared to non-Indigenous groups. Notably, the adjusted odds ratio for COVID-19 diagnosis in Indigenous populations rose from 0.59 (95% CI: 0.57, 0.61) in 2020 to 1.17 (95% CI: 1.13, 1.21) in 2021. Factors such as the significantly higher median age and greater number of comorbidities in the non-Indigenous hospitalized groups could account for their increased odds of COVID-19 diagnosis and mortality. Additionally, our data indicates a significantly negative adjusted association between COVID-19 vaccination rates and the proportion of Indigenous individuals.

*Correspondence:
Sushma Dahal
sdahal2@student.gsu.edu
Svenn-Erik Mamelund
masv@oslomet.no

Full list of author information is available at the end of the article

Conclusion Although Indigenous populations initially showed lower odds of COVID-19 diagnosis and mortality, a marked rise in diagnosis odds among these groups in 2021 underscores the urgency of targeted interventions. The observed negative association between the proportion of Indigenous populations and vaccination rates further underscores the necessity to tackle vaccine access barriers and work towards equitable distribution.

Keywords COVID-19, Chile, Disparity, Indigenous populations, COVID-19 vaccination, Comorbidities

Background

Indigenous populations were disproportionately affected during the 1918 and the 2009 A/H1N1 influenza pandemics [1–7]. In contrast, current reports of the COVID-19 pandemic paint a mixed picture of its impact among Indigenous populations across geographic locations and time [1, 8]. While reports from Canada, Ecuador, and Australia suggest low risks of both infection and death among Indigenous compared to non-Indigenous [1, 8], the data from the USA, Peru (Ucayali region), Brazil, and Mexico point to a higher risk of infection and death [1, 8–10]. A study from Mexico showed a 68% higher mortality rate among Indigenous populations than non-Indigenous populations and an increased mortality rate ratio over the subsequent pandemic waves, indicating a worsening impact of the COVID-19 pandemic over time [10].

The scarcity of studies from different geographic regions examining the impact of the COVID-19 pandemic among Indigenous and non-Indigenous populations stems partly from a lack of detailed epidemiological data [11, 12]. Moreover, historic and ongoing marginalization and systemic policies related to genocide and racism have limited the quality, quantity, access, and use of COVID-19 data relating to Indigenous populations [13]. Therefore, it is critical to conduct careful epidemiological studies evaluating past pandemics' differential impact on Indigenous populations.

Latin America, where the Indigenous population of approximately 58 million people (9.8% of the region's population) is concentrated in Chile, Colombia, Guatemala, Mexico, and Peru [14], has been hit especially hard by the COVID-19 pandemic [15]. Chile, a South American country with about 17.6 million people, has an Indigenous population comprising over 2.1 million people (12.8%), according to the 2017 census [16]. About 80% of the Indigenous population in Chile self-identify as Mapuche. Moreover, Chile's observed case-fatality ratio of 1.2% and cumulative death rate per 100,000 population of 336.22 as of March 2023 ranks it among the top 10 countries globally in terms of pandemic impact [17].

We have used detailed hospital discharge data to investigate differences in the mortality and morbidity impacts of COVID-19 among Indigenous and non-Indigenous populations from Chile. Data on hospitalized COVID-19 cases provide insights into patients with severe manifestations requiring inpatient management [18]. We sought to analyze data from Chile's Diagnosis-Related Groups (DRGs) systems for 2020 and 2021, allowing us to characterize COVID-19 cases and deaths by Indigenous status. We also analyze the top 10 secondary diagnoses among cases and deaths with COVID-19 as a primary diagnosis, separately for Indigenous and non-Indigenous groups. To assess the association between COVID-19 vaccination and Indigenous status, we complement our analysis using COVID-19 vaccination uptake and socio-demographic data, including the proportion of the Indigenous population at the municipality level. Findings from our study can help shed light on disparity drivers in COVID-19 hospitalization and mortality burdens among Indigenous and non-Indigenous populations.

Methods

We used a descriptive cross-sectional design using data from multiple sources as described in the data section.

Data

Individual-level hospital discharge data We sourced de-identified individual-level hospital discharge data for 2020 and 2021 from 65 hospitals across all Chilean regions, available through Fondo Nacional de Salud (FONASA) [19]. These hospitals, funded via the Diagnosis-Related Groups (DRG) payment mechanism, handle all cases of moderate to high complexity and represent roughly 70% of Chile's total hospitalizations. The data includes individuals under Chile's public health insurance system (FONASA), covering 80% of the national population. Among individuals that self-identify with a specific ethnic group, 88% are covered by the public health system while this figure is 77% for individuals that do not self-identify with an ethnic group [20]. For each hospitalization record, we retrieved data on selected variables displayed in Table 1. The names of the conditions for a given ICD code were obtained from eCIEMaps query tool [21].

Data on municipal level COVID-19 vaccination We obtained publicly available data on the total number of second dose COVID-19 vaccines administered at the municipality level by the end of 2021, from the Ministry of Science, Technology, Knowledge and Innovation (Ministerio de Ciencia, Tecnología, Conocimiento e Innovación), Chile [22]. Of the 346 municipalities in Chile, based on map V.2.B published in reference [23], we classified 28 municipalities with more than 49.22% Indigenous

Table 1 Selected variables from the dataset analyzed in the study

Variables	Definition	Type of variable
SEXO	Sex	Categorical
FECHA_NACIMIENTO	Birth date	Continuous
Indigenous status	For the classification of Indigenous status, we used the variable ETNIA in the dataset. There were 11 unique types of entries in this variable: Aymara, Colla, Diaguita, Kawesqar, Lican Antai (Atacameno), Mapuche, Ninguno, Otro, Quechua, Rapa nui (Pascuense), and Yagan (Yamana). Of these entries of self-reported ethnicities, Ninguno (none) was categorized as non-Indigenous, and all others were categorized as Indigenous.	Categorical
COVID-19 diagnosis	The hospitalized cases in which diagnosis was recorded as U07.1 (Laboratory confirmed COVID-19 case) or U07.2 (clinically and epidemiologically confirmed COVID-19 case) among any of the diagnosis variables from diagnostic 1 to diagnostic 35 were classified as a COVID-19 case. Similarly, cases for which U07.1 or U07.2 were recorded in diagnosis 1 were classified as cases with COVID-19 as a primary diagnosis.	Categorical
NACIONALIDAD	Nationality	Categorical
TIPO_INGRESO	Type of hospital entry: urgent, programmed, or obstetric	Categorical
FETCHA_INGRESO	Hospital admission date	Continuous
FECHAALTA	Date of discharge from hospital	Continuous
Death	We used the variable TIPOALTA in the dataset to classify death status. Cases for whom TIPOALTA was equal to FALLECIDO were categorized as deaths, and others were categorized as non-deaths.	Categorical
DIAGNOSTICO	Diagnosis	Categorical
Age (in years)	Computed as the difference between FETCHA_INGRESO and FECHA_NACIMIENTO and categorized into five age groups.	Continuous
Age group	Age categorized into five groups: Less than 18 years, 18–44 years, 45–54 years, 55–64 years, 65 years and above.	Categorical
Length of hospital stay	Computed as the difference between FECHAALTA and FETCHA_INGRESO	Continuous
Comorbidity count	Computed based on the total number of secondary diagnoses for a given case or death	Continuous
Comorbidity category	Comorbidity count categorized into three groups: no comorbidity, one comorbidity and more than one	Categorical

populations as cases. The nearest municipality to each of these 28 municipalities with 7.89–15.13% of Indigenous populations was designated a control 1 municipality and the nearest municipality with 7.88% or less Indigenous population was designated a control 2 municipality. The municipalities that were nearest were visually identified using Chile's municipality-level map. Additional file 1 lists cases, control 1, and control 2 municipalities. We then estimated the second-dose COVID-19 vaccination rate as a percentage of the total population for each case and control municipality using the 2017 population estimate data for the municipalities of Chile [24].

Data on municipal-level socio-demographic variables We used publicly available socio-demographic data from Chile's Population and Housing Census 2017 [16]. We aggregated the person-level data into the municipal level for the following variables: Indigenous population, sex, age group (5 categories), average years of schooling and proportion with paid employment (among those above 17 years old).

Statistical analysis

Temporal distribution of weekly hospitalizations according to indigenous status We present the weekly time series of new hospitalized COVID-19 cases stratified by Indigenous status in 2020 and 2021 in Chile.

Logistic regression for COVID-19 hospitalization and death We used logistic regression analysis at 0.05 level of significance to assess the bivariate and multivariable association of both COVID-19 diagnosis and COVID-19 deaths with selected variables: sex, age, nationality, Indigenous status, type of hospital visit, number of comorbidities and length of hospital stay. Additionally, we present the results of bivariate and multivariable analyses examining the associations between COVID-19 diagnosis and deaths with the selected variables, separately for Indigenous and non-Indigenous patients. We also evaluated the association of Indigenous status with these selected variables separately for COVID-19 cases and deaths. For categorical covariates, we used Chi-Square tests, and for non-normally distributed numerical covariates such as age and length of hospital stay, the Wilcoxon Rank Sum Test was applied.

Top-ranked secondary diagnosis among primary COVID-19 hospitalization and deaths To assess the difference between Indigenous and non-Indigenous groups in the distribution of secondary diagnosis among cases and deaths with COVID-19 as a primary diagnosis, we report 95% confidence intervals (CI) of the estimated proportion for each of the top 10 secondary diagnoses using normal approximation for the binomial CI through an online resource [25].

Vaccination rates in predominantly indigenous municipalities We performed Wilcoxon signed rank tests for the data with 28 pairs of cases and control 1 and cases and control 2 to assess the association between Indigenous status and vaccination rates.

Regression analysis for COVID-19 vaccination rate and indigenous status We performed univariate and multiple linear regression analysis using COVID-19 vaccination rate as percentage of total population as the dependent variable and selected socio-demographic variables at the municipality level to assess the association between Indigenous status and vaccination rates. All the analyses were performed in SAS 9.4.

Results

We analyzed 1,598,492 records in the datasets from 2020 (781,694) and 2021 (816,798), of which 7.43% were COVID-19 positive cases, including 5.79% cases with COVID-19 as a primary diagnosis and 1.28% COVID-19 deaths. Weekly time series of new hospitalized COVID-19 cases and deaths at the national level are shown in Fig. 1.

Table 2 presents the demographic, comorbidity, hospital visit and death outcome related characteristics of the total hospitalized patients, COVID-19 cases, and COVID-19 deaths, separately for Indigenous and non-Indigenous patients. The Indigenous group comprised 10.07% of total hospitalized patients, 7.89% of hospitalized COVID-19 cases and 7.10% of hospitalized COVID-19 deaths (Table 2). Among the hospitalized COVID-19 cases, the median age, median length of hospital stays,

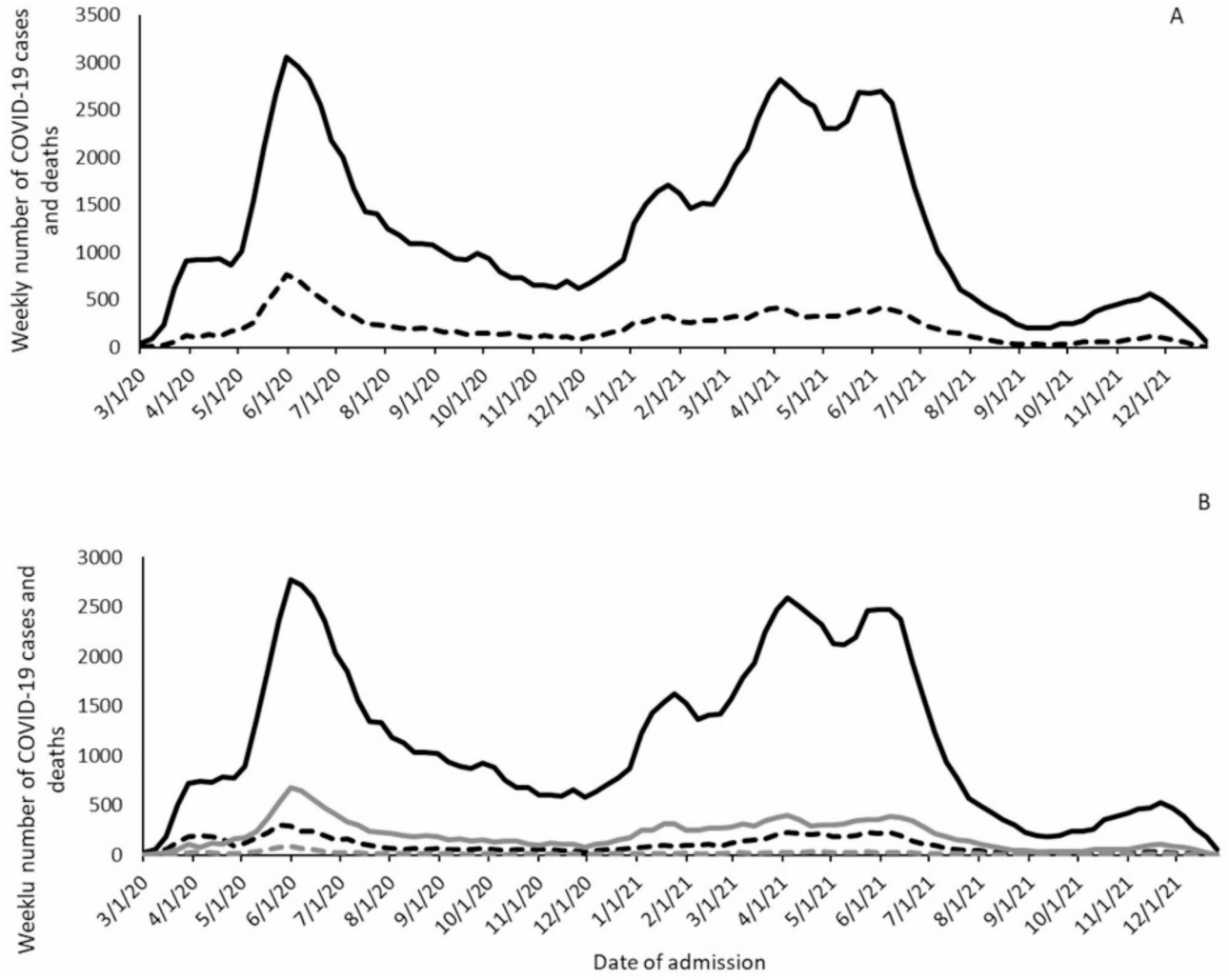

Fig. 1 Weekly number of COVID-19 cases and deaths, Chile, 2020–2021. Panel **A**: Total cases and deaths. The solid line indicates weekly COVID-19 cases and the dashed line indicates weekly COVID-19 deaths, Panel **B**: Total cases and deaths by Indigenous status. The solid and dashed black lines indicate weekly COVID-19 cases among non-Indigenous and Indigenous populations respectively. The grey solid and dashed line indicate weekly COVID-19 deaths among non-Indigenous and Indigenous respectively

Table 2 Characteristics of sample by indigenous status

	Total hospitalization (*n* = 1,598,492)		**COVID-19 diagnosis among hospitalized patients (*n* = 118,788)**		**Death among COVID-19 positive hospitalized patients (*n* = 20,536)**	
	Indigenous (*n* = 160,899) (%)	Non-Indigenous (*n* = 1,437,593) (%)	Indigenous (*n* = 9374) (%)	Non-indigenous (*n* = 109,414) (%)	Indigenous (*n* = 1458) (%)	Non-Indigenous (*n* = 19,078) (%)
Sex						
Male	64,610 (40.16)	596,874 (41.52)	5072 (54.11)	59,182 (54.09)	823 (56.45)	10,962 (57.48)
Female	96,276 (59.84)	840,535 (58.47)	4302 (45.89)	50,207 (45.89)	635 (43.55)	8110 (42.52)
Median age in years (Q1, Q3) **	43.23 (26.68, 65.36)	43.58 (25.77, 65.52)	57.87 (42.08, 70.34)	58.74 (43.57, 71.16)	72.68 (62.41, 80.83)	72.55 (62.55, 80.93)
Age group***†						
< 18 years	20,564 (12.78)	227,013 (15.79)	238 (2.54)	3881 (3.55)	3 (0.21)	37 (0.19)
18–44 years	62,427 (38.80)	509,658 (35.45)	2430 (25.92)	25,257 (23.08)	87 (5.97)	812 (4.26)
45–54 years	16,475 (10.24)	144,108 (10.02)	1470 (15.68)	16,888 (15.43)	96 (6.58)	1429 (7.49)
55–64 years	20,425 (12.69)	187,717 (13.06)	1951 (20.81)	23,232 (21.23)	260 (17.83)	3547 (18.59)
65 and above	41,008 (25.49)	369,097 (25.67)	3285 (35.04)	40,156 (36.70)	1012 (69.41)	13,253 (69.47)
Type of hospital visit						
Urgent	88,908 (55.26)	800,744 (55.70)	8796 (93.83)	102,227 (93.43)	1433 (98.29)	18,853 (98.82)
Programmed (planned)	40,600 (25.23)	379,366 (26.39)	156 (1.66)	2192 (2.00)	25 (1.71)	208 (1.09)
Obstetrics/gynecology	31,381 (19.50)	257,469 (17.91)	422 (4.50)	4994 (4.56)	0 (0)	17 (0.09)
Nationality***†††						
Chilean	149,168 (92.71)	1,358,687 (94.51)	8200 (87.48)	104,631 (95.63)	1361 (93.35)	18,795 (98.52)
Non-Chilean	9053 (5.63)	78,543 (5.46)	1173 (12.51)	4783 (4.37)	97 (6.65)	283 (1.48)
Death***						
Yes	5635 (3.50)	56,205 (3.91)	1458 (15.55)	19,078 (17.44)	-	-
No	155,264 (96.50)	1,381,388 (96.09)	7916 (84.45)	90,336 (84.56)		
Median length of hospital stay (days) (Q1, Q3) *** †††	3 (1, 7)	3 (1, 7)	8 (3, 16)	9 (5, 18)	9 (4, 19)	11 (5, 21)
Median comorbidity count (Q1, Q3) ***††	3 (1, 6)	3 (1, 6)	7 (5, 11)	8 (5, 11)	10 (7, 13)	11 (8, 13)
Comorbidity category***††						
No comorbidity	19,909 (12.37)	181,647 (12.64)	0 (0.00)	75 (0.07)	0 (0)	8 (0.04)
One comorbidity	22,003 (13.68)	191,486 (13.32)	99(1.06)	2069 (1.89)	1 (0.07)	138 (0.72)
More than one comorbidity	118,987 (73.95)	1,064,459 (74.04)	9275 (98.94)	107,270 (98.04)	1457 (99.93)	18,932 (99.23)

***$p < 0.0001$ **$p < 0.001$ *$p < 0.05$ for Indigenous vs. non-Indigenous among COVID-19 positives. †††$p < 0.0001$ ††$p < 0.01$ †$p < 0.05$ for Indigenous vs. non-Indigenous among COVID-19 deaths. Wilcoxon rank sum test was applied for age, length of hospital stay and comorbidity count. For other categorical variables Chi-Square test was applied, Q1: quartile 1, Q3: quartile 3

and the median comorbidity count was significantly higher in the non-Indigenous group compared to the Indigenous group (Table 2).

When comparing the top 10 secondary diagnoses among the two groups, a significantly higher proportion of the Indigenous population with a primary COVID-19 diagnosis had viral pneumonia, unspecified acute respiratory failure, severe respiratory insufficiency, and respiratory distress syndrome compared to the non-Indigenous population. Similarly, a higher proportion of the non-Indigenous populations had cough, unspecified fever, and acute renal failure with acute cortical necrosis as a secondary diagnosis (Table 3). For COVID-19 hospitalized individuals who died with a primary COVID-19 diagnosis, a statistically significant higher proportion of non-Indigenous individuals had nosocomial conditions (Table 4). The proportion of secondary diagnoses for other types of viral pneumonia, essential hypertension, and uncomplicated type II diabetes mellitus did not differ significantly between Indigenous and non-Indigenous groups (Tables 3 and 4).

The overall mortality and morbidity impact of the COVID-19 pandemic was significantly lower among Indigenous populations compared to non-Indigenous with an adjusted OR for COVID-19 diagnosis of 0.76 (95% CI: 0.74, 0.77), and an adjusted OR for COVID-19 death of 0.91 (95% CI: 0.85, 0.97). However, there was a significant increase in adjusted odds of COVID-19 diagnosis among Indigenous populations from 0.59 (95% CI: 0.57, 0.61) in 2020 to 1.17 (95% CI: 1.13, 1.21) in 2021. There was also a slight increase in the odds of COVID-19 death in 2021 compared to 2020, among the Indigenous,

Table 3 Top 10 secondary diagnoses among patients with COVID-19 as a primary diagnosis by indigenous status

Rank	Indigenous		Non-Indigenous	
	Secondary diagnosis (ICD code and name)	Frequency (Percent of total secondary diagnosis recorded ($n=58,653$)) (95% CI)	Secondary diagnosis (ICD code and name)	Frequency (Percent of total secondary diagnosis recorded ($n=712,112$)) (95% CI)
1	J12.8 (Other types of viral pneumonia)	7090 (12.09) (11.82, 12.35)	J12.8 (Other types of viral pneumonia)	80,007 (11.24) (11.16, 11.31)
2	J96.00 (Unspecified acute respiratory failure if with hypoxia or with hypercapnia)/ J96.0 (Severe respiratory insufficiency)/J96.09 (Acute respiratory failure of unspecified cause)	5287 (9.01) (8.78, 9.25)	J96.00 (Unspecified acute respiratory failure if with hypoxia or with hypercapnia)/ J96.09 (Acute respiratory failure of unspecified cause)	51,779 (7.27) (7.21, 7.33)
3	I10 (Essential (primary) Hypertension)	3026 (5.16) (4.98, 5.34)	I10 (Essential (primary) Hypertension)	37,421 (5.25) (5.20, 5.31)
4	R06.0 (Dyspnoea)	2529 (4.31) (4.15, 4.48)	R06.0 (Dyspnoea)	32,281 (4.53) (4.48, 4.58)
5	R05 (Cough)	2010 (3.43) (3.28, 3.57)	R05 (Cough)	26,422 (3.71) (3.67, 3.75)
6	E11.9 (uncomplicated type 2 diabetes mellitus)	1487 (2.54) (2.41, 2.66)	E11.9 (Uncomplicated type 2 diabetes mellitus)	17,909 (2.51) (2.48, 2.55)
7	E66.9 (Obesity, unspecified)	1479 (2.52) (2.38, 2.68)	E66.9 (Obesity, unspecified)	17,482 (2.45) (2.42, 2.49)
8	R50.9 (Fever, unspecified)	1250 (2.13) (2.01, 2.25)	R50.9 (Fever, unspecified)	16,415 (2.31) (2.27, 2.34)
9	J80 (Respiratory distress syndrome)	941 (1.60) (1.50, 1.71)	R51 (Headache)	11,322 (1.59) (1.56, 1.62)
10	M79.19 (Myalgia of unspecified cause)	879 (1.50) (1.40, 1.60)	N17.1 (Acute renal failure with acute cortical necrosis)	11,014 (1.55) (1.52, 1.58)

but it did not reach statistical significance [0.90 (95% CI: 0.82, 0.98) in 2020 to 0.92 (95% CI: 0.84, 1.01) in 2021] (Tables 5 and 6). We hypothesized that this shift in OR could be associated with the differential rate of COVID-19 vaccination among Indigenous and non-Indigenous groups. Therefore, we also evaluated the relationship between COVID-19 vaccination rates and Indigenous status using municipal-level data.

We present the bivariate and multivariable association of selected variables and COVID-19 diagnosis and COVID-19 deaths among Indigenous and non-Indigenous individuals separately in Tables 7 and 8. In the adjusted model for both Indigenous and non-Indigenous individuals, there were significantly higher odds of COVID-19 diagnosis and COVID-19 deaths among males, and a significantly positive association with comorbidity count and age. However, compared to Indigenous males, non-Indigenous males had greater odds of both COVID-19 diagnosis and COVID-19 death compared to their female counterparts. Likewise, with one unit increase in comorbid condition, the odds of COVID-19 death among non-Indigenous group increased by 34% among the non-Indigenous group and by 17% among the Indigenous group. By age, the odds of COVID-19 diagnosis and deaths were comparable between Indigenous and non-Indigenous groups (Tables 7 and 8).

A total of 15,973,895 COVID-19 second dose vaccinations were administered in Chile by the end of 2021. The overall rate of 2nd dose COVID-19 vaccinations in the 28 municipalities with more than 49.22% Indigenous population (case municipalities) was 79.11% compared to the vaccination rate of 86.85% in the rest of the municipalities. The median difference in the vaccination rate of case and control 1 municipalities was −8.24% and was statistically significant (Signed Rank statistics: -158, p-value<0.0001). Similarly, the median difference in the vaccination rate of case and control 2 municipalities was −8.64% and was statistically significant (Signed Rank statistics: -159, p-value<0.0001). There was a statistically significantly negative association between the proportion of the Indigenous population and the vaccination rate such that an increase in the Indigenous population by 1% decreased the vaccination rate by 0.33% (p-value<0.0001). This association remained unchanged (parameter estimate −0.32, p-value<0.0001) after controlling for other socio-demographic variables (proportion of the population aged less than 6 years, proportion of population aged 18–64 years, proportion of males,

Table 4 Top 10 secondary diagnoses among patients with COVID-19 as primary diagnosis who died, by indigenous status

Rank	Indigenous		Non-Indigenous	
	Secondary diagnosis (ICD code and name)	Frequency (percent of total secondary diagnosis recorded ($n=12,765$)) (95% CI)	Secondary diagnosis (ICD code and name)	Frequency (Percent of total secondary diagnosis recorded ($n=170,487$)) (95% CI)
1	J12.8 (Other types of viral pneumonia)	1242 (9.73) (9.22, 10.24)	J12.8 (Other types of viral pneumonia)	15,684 (9.20) (9.06, 9.34)
2	J96.00 (Unspecified acute respiratory failure if with hypoxia or with hypercapnia)/ J96.0 (Severe respiratory insufficiency)/ J96.09 (Acute respiratory failure of unspecified cause)	991 (7.76) (7.30, 8.23)	J96.00 (Unspecified acute respiratory failure if with hypoxia or with hypercapnia)/ J96.09 (Acute respiratory failure of unspecified cause)	11,225 (6.58) (6.47, 6.70)
3	I10 (Essential (primary) Hypertension)	681 (5.33) (4.95, 5.72)	I10 (Essential (primary) Hypertension)	9360 (5.49) (5.38, 5.60)
4	R06.0 (Dyspnoea)	416 (3.26) (2.96, 3.58)	R06.0 (Dyspnoea)	5839 (3.42) (3.34, 3.51)
5	N17.9 (Acute renal failure, unspecified)	337 (2.64) (2.37, 2.93)	N17.9 (Acute renal failure, unspecified)	4360 (2.56) (2.48, 2.63)
6	R05 (Cough)	308 (2.41) (2.15, 2.69)	E11.9 (Uncomplicated type 2 diabetes mellitus)	4208 (2.47) (2.39, 2.54)
7	E11.9 (Uncomplicated type 2 diabetes mellitus)	298 (2.33) (2.07, 2.60)	R05 (Cough)	4138 (2.43) (2.35, 2.50)
8	J80 (Respiratory distress syndrome)	264 (2.07) (1.82, 2.33)	R50.9 (Fever, unspecified)	2468 (1.45) (1.39, 1.50)
9	R50.9 (Fever, unspecified)	174 (1.36) (1.16, 1.56)	Y95 (Nosocomial conditions)	2234 (1.31) (1.26, 1.36)
10	E66.9 (Obesity, unspecified)	170 (1.33) (1.13, 1.53)	E66.9 (Obesity, unspecified)	2228 (1.31) (1.25, 1.36)

average years of schooling, and the proportion of population aged 17 years and above having paid work) (Table 9).

Discussion

Our finding of lower risk of COVID-19 infection and death among the Indigenous population is in line with previous studies from Canada, Ecuador, and Australia [1, 8] and in contrast to findings from the USA, Brazil, and Mexico [1, 8–10]. Our findings indicate that old age and a higher frequency of comorbidities among non-Indigenous populations explain the higher COVID-19 diagnosis and death among non-Indigenous hospitalized populations. Furthermore, our results suggest that COVID-19 vaccination disparities increased the odds of COVID-19 among Indigenous groups from 2020 to 2021. However, temporal changes in social distancing interventions implemented in Chile could also have contributed to this result.

Our findings of lower overall odds of infection and death among hospitalized Indigenous compared to the non-Indigenous could be related to some characteristics of Indigenous populations in Chile compared to other Latin American countries. For example, Chile has one of the lowest proportions of the Indigenous population living in poverty (15.4% Indigenous, 10.2% non-Indigenous) in all Latin America [14]. In contrast, Colombia, Ecuador, Mexico, and Panama all have over 50% of their Indigenous populations living in poverty [14]. The gap in poverty rate between Indigenous and non-Indigenous populations in Chile has also been decreasing over the last 15 years. Specifically, for Indigenous populations, the poverty rate declined from 44% in 2006 to 13.2% in 2020, whereas for non-Indigenous populations, the poverty rate declined from 28% in 2006 to 10.5% in 2020 [26]. Likewise, among the five countries where 80% of the Indigenous population in Latin America reside, Chile has the lowest proportion of the Indigenous population living in municipalities with critical or high vulnerability to COVID-19 infection (20.9% in Chile vs. 77.9% in Guatemala) [14]. Though Indigenous populations in Latin America mostly live in rural areas with poorer access to medical resources, most of the Indigenous populations in Chile live in urban areas [14]. Moreover, age is one of the most important predictors of severe disease and death from COVID-19 [27, 28]. In Chile, the proportion of the population ≥ 60 yrs. is lower among Indigenous groups than non-Indigenous [14].

Table 5 Bivariate and multivariable associations between COVID-19 diagnosis and selected variables among hospitalized cases

Variable	COVID-19 diagnosis Unadjusted OR (95% CI)	COVID-19 diagnosis Adjusted OR[a] (95% CI)	Year 2020 COVID-19 diagnosis Adjusted OR[a] (95% CI)	Year 2021 COVID-19 diagnosis Adjusted OR[a] (95% CI)
Indigenous				
Yes	0.75 (0.73, 0.77) ***	0.76 (0.74, 0.77)***	0.59 (0.57, 0.61)***	1.17 (1.13, 1.21)***
No	Reference	Reference	Reference	Reference
Sex				
Male	1.74 (1.72, 1.76) ***	1.20 (1.19, 1.22) ***	1.24 (1.22, 1.27)***	1.18 (1.16, 1.20) ***
Female	Reference	Reference	Reference	Reference
Age (in years)[b]	1.02 (1.02, 1.02) ***	1.006 (1.006, 1.006)***	1.01 (1.01, 1.01)***	1.001 (1.001, 1.002) ***
Age group (in years)	***	-	-	-
< 18	Reference			
18–44	3.01 (2.91, 3.11)			
45–54	7.63 (7.37, 7.89)			
55–64	8.13 (7.87, 8.41)			
65 and above	7.00 (6.78, 7.23)			
Nationality	***			
Chilean	1.11 (1.08, 1.14)	0.48 (0.47, 0.50)***	0.42 (0.40, 0.44)***	0.55 (0.53, 0.57) ***
Non-Chilean	Reference	Reference	Reference	Reference
Type of hospital visit	***	***	***	***
Urgent	25.35 (24.33, 26.41)	14.45 (13.86, 15.06)	10.76 (10.18, 11.37)	17.95 (16.85, 19.12)
Programmed	Reference	Reference	Reference	Reference
Obstetrics/gynecology	3.40 (3.24, 3.57)	3.25 (3.09, 3.42)	2.72 (2.54, 2.92)	3.76 (3.49, 4.05)
Length of hospital stay in days[b]	1.03 (1.03, 1.03) ***	1.004 (1.004, 1.005) ***	1.004 (1.003, 1.005) ***	1.004 (1.003, 1.004) ***
Comorbidity count[b]	1.25 (1.25, 1.26) ***	1.17 (1.17, 1.17)***	1.13 (1.13, 1.13)***	1.23 (1.22, 1.23) ***
Comorbidity category	***	-	-	-
No comorbidity	0.04 (0.03, 0.05)			
One comorbidity	Reference			
More than one	10.65 (10.20, 11.11)			
Death				
Yes	7.28 (7.15, 7.41)***	2.05 (2.01, 2.09)***	2.26 (2.20, 2.33) ***	1.83 (1.78, 1.88) ***
No	Reference	Reference	Reference	Reference

Age was estimated as the difference between date of admission and birth date [a]Variables in the multivariable logistic regression model: sex, age, nationality, Indigenous status, type of hospital visit, comorbidity count, length of hospital stays, and death [b]median (quartile 1, quartile 3) reported, CI: Confidence Interval
*p-value < 0.05 **p-value < 0.01 ***p-value < 0.0001

Interestingly, the adjusted association of Indigenous status with COVID-19 diagnosis and COVID-19 deaths was higher in 2021 than in 2020. The adjusted odds of COVID-19 diagnosis among Indigenous groups were lower than the non-Indigenous in 2020, but higher among Indigenous in 2021. Likewise, the adjusted odds of COVID-19 deaths among Indigenous groups were lower than the non-Indigenous in 2020, but slightly increased to 0.92 in 2021. This indicates that over time, the Indigenous populations in Chile tended to be negatively impacted by the pandemic even though the initial risk was lower than that of the non-Indigenous groups. A previous study from Mexico also showed that there was an increase in COVID-19 mortality rate ratio of 1.55 in the first wave to 1.65 in the second wave to 1.86 in the third wave, and 2.40 in the fourth wave, reflecting the increased risk of COVID-19 death among Indigenous over time [10]. The increased odds of COVID-19 infection and death over the subsequent years may reflect social disparities in COVID-19 vaccination or other public health measures. Indeed, we found a significantly lower COVID-19 vaccination rate in areas with larger Indigenous populations in Chile.

Besides COVID-19 vaccination disparities, the increase in odds of COVID-19 infections from 2020 to 2021 may result from the differential impact of social distancing interventions. With the relaxation of restrictions on businesses in 2021 in Chile, Indigenous populations who are highly represented in the informal economy [29, 30] might have been infected at higher rates compared to non-Indigenous groups because of the nature of their work. For example, Native Americans in the US have a significant underrepresentation in high-education occupations after controlling for individual differences in demographic characteristics [31], impacting their ability to work remotely [32].

In our study, we found that the odds for COVID-19 diagnosis and death increased in 2021 from the 2020

Table 6 Bivariate and multivariable association between COVID-19 death and selected variables among hospitalized COVID-19 cases

Variable	COVID deaths Unadjusted OR (95% CI)	COVID deaths Adjusted OR (95% CI)[a]	Year 2020 COVID deaths Adjusted OR (95% CI)[a]	Year 2021 COVID deaths Adjusted OR (95% CI)[a]
Indigenous				
Yes	0.87 (0.82, 0.92) ***	0.91 (0.85, 0.97) **	0.90 (0.82, 0.98) *	0.92 (0.84, 1.01)
No	Reference	Reference	Reference	Reference
Sex				
Male	1.17 (1.14, 1.21) ***	1.25 (1.21, 1.29) ***	1.30 (1.23, 1.36) ***	1.23 (1.17, 1.29) ***
Female	Reference	Reference	Reference	Reference
Age (in years)[b]	1.06 (1.06, 1.06) ***	1.06 (1.06, 1.06) ***	1.05 (1.05, 1.06) ***	1.06 (1.06, 1.06) ***
Age group (in years)	***	-	-	-
< 18	Reference			
18–44	3.42 (2.48, 4.70)			
45–54	9.22 (6.73, 12.64)			
55–64	18.13 (13.26, 24.80)			
65 and above	49.78 (36.44, 67.99)			
Nationality				
Chilean	3.19 (2.87, 3.54)***	1.008 (0.900, 1.13)	0.99 (0.83, 1.18)	0.99 (0.85, 1.15)
Non-Chilean	Reference	Reference	Reference	Reference
Type of hospital visit	***	***	***	***
Urgent	2.03 (1.77, 2.32)	1.91 (1.65, 2.21)	1.62 (1.35, 1.93)	2.29 (1.78, 2.95) ***
Programmed	Reference	Reference	Reference	Reference
Obstetrics/gynecology	0.03 (0.02, 0.05)	0.22 (0.13, 0.36)	0.17 (0.09, 0.36)	0.27 (0.13, 0.54)
Length of hospital stay in (days)[b]	1.005 (1.004, 1.005) ***	0.99 (0.99, 0.99) ***	0.99 (0.98, 0.99) ***	0.99 (0.99, 0.99) ***
Comorbidity count[b]	1.15 (1.15, 1.15) ***	1.14 (1.13, 1.14) ***	1.11 (1.11, 1.12) ***	1.21 (1.20, 1.22) ***
Comorbidity category		-	-	-
No comorbidity	1.74 (0.82, 3.70)			
One comorbidity	Reference			
More than one	3.09 (2.60, 3.67)***			

Age was estimated as the difference between date of admission and birth date. [a]Variables in the multivariable logistic regression model: sex, age, Indigenous status, comorbidity count, type of hospital visit, length of hospital stay, and nationality [b]median (quartile 1, quartile 3) reported, CI: Confidence Interval *p-value < 0.05 **p-value < 0.01 ***p-value < 0.0001

level, indicating an increase in worse outcomes such as COVID-19 hospitalizations and deaths due to COVID-19 infection among Indigenous groups. This is supported by our finding of a low overall vaccination rate of second dose COVID-19 vaccination in the municipalities, with a higher proportion of the Indigenous population compared to the rest of the municipalities. Similarly, there was a statistically significantly lower median vaccination rate in municipalities with a higher proportion of the Indigenous population compared to the nearest municipalities with lower proportions of the Indigenous population. This is also supported by the findings from our crude and adjusted regression models.

In the adjusted model, we found significantly higher odds of both COVID-19 diagnosis and COVID-19 deaths among males compared to female for both Indigenous and non-Indigenous groups. However, the OR value was higher for non-Indigenous males than Indigenous males. For example the OR for COVID-19 death among males compared to females was 1.20 in Indigenous group and 1.25 in non-Indigenous group. However, it is not clear whether this difference is explained by biological or societal factors [33].

Our analysis of the top ten secondary diagnoses among hospitalized cases with COVID-19 as a primary diagnosis revealed a statistically significant higher proportion of conditions related to the respiratory system, such as viral pneumonia, and acute respiratory failure among the Indigenous. In contrast, conditions such as fever and acute renal failure were significantly higher among non-Indigenous. Likewise, a significantly higher proportion of non-Indigenous populations who died with COVID-19 as a primary diagnosis had nosocomial conditions and unspecified obesity. Our results align with a previous study that reported an association of Mapuche ancestry with increased mortality due to asthma and decreased mortality from diabetes [34]. Likewise, increased mortality due to conditions of the larynx and bronchus were associated with Aymara ancestry [34]. Notably, in Chile, the largest ethnic group is Mapuche, followed by Aymara [35]. It is reassuring that in our hospitalization data, the highest proportion of Indigenous groups were Mapuche

Table 7 Bivariate and multivariable associations of selected variables with COVID-19 diagnosis and COVID-19 death among hospitalized indigenous patients

	Total hospitalization, Indigenous (*n* = 160,899)				**Total hospitalized COVID-19 positive, Indigenous (*n* = 9374)**			
Variable	COVID-19 diagnosis Unadjusted OR (95% CI)	COVID-19 diagnosis Adjusted OR[a] (95% CI)	Year 2020 COVID-19 diagnosis Adjusted OR[a] (95% CI)	Year 2021 COVID-19 diagnosis Adjusted OR[a] (95% CI)	COVID-19 death Unadjusted OR (95% CI)	COVID-19 death Adjusted OR[a] (95% CI)	Year 2020 COVID-19 death Adjusted OR[a] (95% CI)	Year 2021 COVID-19 death Adjusted OR[a] (95% CI)
Sex								
Male	1.82 (1.75, 1.90) ***	1.19 (1.14, 1.25) ***	1.26 (1.18, 1.34)***	1.12 (1.05, 1.19) **	1.12 (0.99, 1.25)	1.20 (1.06, 1.35)**	1.34 (1.13, 1.60)**	1.07 (0.89, 1.27)
Female	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Age (in years)[b]	1.02 (1.02, 1.02) ***	1.004 (1.003, 1.006)***	1.01(1.01, 1.01)***	0.99 (0.99, 1.00)	1.06 (1.06, 1.07) ***	1.06 (1.05, 1.06)***	1.06 (1.05, 1.07)***	1.05 (1.05, 1.06)***
Age group (in years)	***	-	-	-		-	-	-
< 18	Reference				Reference			
18–44	3.46 (3.02, 3.95)				2.91 (0.91, 9.26)			
45–54	8.36 (7.28, 9.61)				5.47 (1.72, 17.41)**			
55–64	9.02 (7.87, 10.33)				12.04 (3.83, 37.88)***			
65 and above	7.43 (6.51, 8.49)				34.87 (11.14, 109.14)***			
Nationality	***							
Chilean	0.39 (0.37, 0.42)	0.24 (0.22, 0.26)***	0.18 (0.17, 0.21)***	0.34 (0.3, 0.38) ***	2.21 (1.78, 2.74)***	0.71 (0.56, 0.90)**	0.51 (0.36, 0.70)***	0.95 (0.66, 1.35)
Non-Chilean	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Type of hospital visit	***	***	***	***				
Urgent	28.44 (24.26, 33.32)	16.12 (13.73, 18.92)	12.57 (10.34, 15.26)	19.51 (14.68, 25.93)	1.02 (0.66, 1.57)	1.25 (0.77, 2.02)	1.01 (0.58, 1.75)	2.25 (0.78, 6.49)
Programmed	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Obstetrics/gynecology	3.53 (2.94, 4.24)	2.56 (2.12, 3.10)	1.89 (1.48, 2.42)	3.24 (2.36, 4.44)	< 0.001 (< 0.001, > 999.99)	< 0.001 (< 0.001, > 999.99)	< 0.001 (< 0.001, > 999.99)	< 0.001 (< 0.001, > 999.99)
Length of hospital stay in days[b]	1.03 (1.02, 1.03) ***	1.00 (0.99, 1.00)	0.99 (0.99, 0.99) ***	1.001 (0.99, 1.003) ***	1.004 (1.001, 1.007) *	0.99 (0.99, 0.99)***	0.99 (0.98, 0.99)***	0.99 (0.99, 0.99)**
Comorbidity count[b]	1.22 (1.21, 1.22) ***	1.17 (1.16, 1.18)***	1.15 (1.14, 1.16)***	1.23 (1.22, 1.24) ***	1.14 (1.13, 1.16) ***	1.13 (1.11, 1.15)***	1.12 (1.10, 1.14)***	1.17 (1.14, 1.20)***
Comorbidity category		-	-	-		-	-	-
No comorbidity	< 0.001 (< 0.001, > 999.99)				^			
One comorbidity	Reference				Reference			
More than one	18.71 (15.34, 22.81)***				18.25 (2.54, 130.85)**			
Death								
Yes	6.50 (6.10, 6.93)***	1.98 (1.84, 2.12)***	2.09 (1.90, 2.30) ***	1.81 (1.63, 2.02) ***	-	-	-	-
No	Reference	Reference	Reference	Reference				

Age was estimated as the difference between date of admission and birth date [a]Variables in the multivariable logistic regression model for COVID-19 diagnosis: sex, age, nationality, Indigenous status, type of hospital visit, comorbidity count, length of hospital stays, and death; death was the outcome for model for COVID-19 death [b]median (quartile 1, quartile 3) reported, CI: Confidence Interval. *p-value < 0.05. **p-value < 0.01. ***p-value < 0.0001, ^not applicable as there were 0 cases of no comorbidity in both death and no-death group

Table 8 Bivariate and multivariable associations of selected variables with COVID-19 diagnosis and COVID-19 death among hospitalized non-indigenous patients

	Total hospitalization, non-Indigenous (*n* = 1,437,593)				**Total hospitalized COVID-19 positive, non-Indigenous (*n* = 109,414)**			
Variable	COVID-19 diagnosis Unadjusted OR (95% CI)	COVID-19 diagnosis Adjusted OR[a] (95% CI)	Year 2020 COVID-19 diagnosis Adjusted OR[a] (95% CI)	Year 2021 COVID-19 diagnosis Adjusted OR[a] (95% CI)	COVID-19 death Unadjusted OR (95% CI)	COVID-19 death Adjusted OR[a] (95% CI)	Year 2020 COVID-19 death Adjusted OR[a] (95% CI)	Year 2021 COVID-19 death Adjusted OR[a] (95% CI)
Sex								
Male	1.73 (1.71, 1.75) ***	1.21 (1.19, 1.22) ***	1.24 (1.21, 1.27)***	1.19 (1.17, 1.21) **	1.18 (1.14, 1.22)***	1.25 (1.21, 1.30)***	1.29 (1.22, 1.36)***	1.24 (1.19, 1.30)***
Female	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Age (in years)[b]	1.02 (1.02, 1.02) ***	1.006 (1.006, 1.006)***	1.01(1.01, 1.01)***	1.002 (1.001, 1.002)***	1.06 (1.06, 1.07)***	1.06 (1.06, 1.06)***	1.06 (1.05, 1.06)***	1.06 (1.06, 1.06)***
Age group (in years)	***	-	-	-		-	-	-
< 18	Reference				Reference			
18–44	3.00 (2.90, 3.10)				3.44 (2.47, 4.80)			
45–54	7.63 (7.36, 7.91)				9.59 (6.91, 13.31)			
55–64	8.12 (7.84, 8.41)				18.69 (13.49, 25.87)			
65 and above	7.02 (6.79, 7.26)				51.08 (36.94, 70.64)			
Nationality								
Chilean	1.29 (1.25, 1.33)***	0.55 (0.53, 0.57)***	0.48 (0.46, 0.51)***	0.60 (0.58, 0.63)***	3.48 (3.08, 3.93)***	1.12 (0.98, 1.28)	1.23 (1.00, 1.52)*	1.02 (0.87, 1.21)
Non-Chilean	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Type of hospital visit	***	***	***	***	***	***	***	***
Urgent	25.17 (24.12, 26.26)				2.16 (1.87, 2.49)	1.98 (1.70, 2.31)	1.70 (1.41, 2.06)	2.29 (1.76, 2.97)
Programmed	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Obstetrics/gynecology	3.40 (3.24, 3.58)				0.03 (0.02, 0.05)	0.25 (0.15, 0.42)	0.21 (1.002, 1.52)	0.30 (0.15, 0.60)
Length of hospital stay in days[b]	1.03 (1.03, 1.03) ***	1.005 (1.005, 1.005) ***	1.005 (1.004, 1.006) ***	1.004 (1.003, 1.004) ***	1.005 (1.004, 1.005) *	0.99 (0.99, 0.99)***	0.99 (0.98, 0.99)***	0.99 (0.99, 0.99)***
Comorbidity count[b]	1.26 (1.26, 1.26) ***	1.17 (1.17, 1.17)***	1.13 (1.13, 1.13)***	1.23 (1.23, 1.23) ***	1.15 (1.15, 1.15) ***	1.34 (1.32, 1.14)***	1.11 (1.11, 1.12)***	1.22 (1.21, 1.23)***
Comorbidity category		-	-	-	-	-	-	-
No comorbidity	0.04 (0.03, 0.05)***				1.67 (0.79, 3.55)			
One comorbidity	Reference				Reference			
More than one	10.26 (9.82, 10.72)***				3.00 (2.52, 3.56)***			
Death								
Yes	7.34 (7.21, 7.48)***	2.05 (2.01, 2.10)***	2.28 (2.21, 2.35) ***	1.83 (1.78, 1.89) ***	-	-	-	-
No	Reference	Reference	Reference	Reference				

Age was estimated as the difference between date of admission and birth date [a]Variables in the multivariable logistic regression model for COVID-19 diagnosis: sex, age, nationality, Indigenous status, type of hospital visit, comorbidity count, length of hospital stays, and death; death was the outcome for model for COVID-19 death [b]median (quartile 1, quartile 3) reported, CI: Confidence Interval *p-value < 0.05 **p-value < 0.01 ***p-value < 0.0001

and Aymara. Nosocomial infections have been shown to increase the risk of death in severe hospitalized COVID-19 patients [36]. In our study the higher proportion of hospital acquired infections among non-Indigenous populations could also help explain the higher odds of COVID-19 deaths among non-Indigenous compared to Indigenous populations.

In our analysis from hospital discharge data, we did not include important variables such as COVID-19 vaccination or adherence to non-pharmaceutical interventions, which could help us better understand the

Table 9 Univariate and multiple regression models for vaccination rate as a percentage of total population ($n = 346$)

	Parameter estimate*	Standard error*	*P*-value*	*R*-square (%)*	Model with significant variables Parameter estimates (std error) (*p*-value)	Model with all variables Parameter estimates (std error) (*p*-value)
% Indigenous	-0.33	0.06	< 0.0001	8.34	-0.32 (0.06) (< 0.0001)	-0.32 (0.06) (< 0.0001)
% of population aged 0–5 years	-0.98	0.82	0.23	0.41	-	-5.26 (2.26) (0.02)
% of population aged 18–64 years	-0.29	0.22	0.19	0.51	-	-0.77 (0.96) (0.42)
% of population aged 65 years and above	0.63	0.32	0.05	1.11	-	-1.39 (0.91) (0.13)
% of males	-0.31	0.19	0.10	0.78	-	-0.70 (0.42) (0.10)
Average years of schooling (among > 17 years)	-1.18	0.74	0.11	0.73	-	-0.57 (1.18) (0.63)
% having paid work (among > 17 years)	-0.30	0.12	0.014	1.76	-0.27 (0.12) (0.02)	-0.14 (0.21) (0.51)

*Unadjusted univariate models, R-Square for model with significant predictors = 9.82%, R-Square for model with all predictors = 12.14%, std error = Standard error

factors associated with COVID-19 diagnosis and mortality among our study sub-groups. Relying on hospital discharge data, rather than population-level data, might lead us to overlook asymptomatic patients, those with mild symptoms, or individuals who were never tested. This methodological choice limits our results' generalizability, especially for community-level sub-groups, due to varying access to testing and care between them. For Indigenous groups, our findings might underrepresent the actual numbers. Major structural barriers—like geographic isolation, poverty, racism, discrimination, language challenges, and cultural differences [37–39]—hamper their access and utilization of healthcare services. Additionally, there is a dearth of national initiatives or policies addressing the distinct health needs of Indigenous populations. Given that Chile's Indigenous population is generally younger than the non-Indigenous population [14], a larger segment might have been asymptomatic or had mild symptoms, not requiring hospitalization. This could result in a skewed representation with a lower proportion of hospitalized Indigenous COVID-19 cases compared to their non-Indigenous counterparts. A comparison study based on COVID-19 epidemiological data among the general population may provide more reliable estimates of the situation at the population level.

Our results on vaccination rates in the case and control municipalities and the association between the proportion of Indigenous population and vaccination rate may be affected by ecological fallacy as we use municipality-level data, not individual case-level data. On the other hand, our study is the first to investigate the impact of COVID-19 by examining individual-level detailed hospital discharge data available from Chile's Diagnosis-Related Group (DRG) system. We also supported our findings using vaccination data at the municipal level using multiple analytical methods. In addition, to our knowledge, this is the first study to report the distribution of secondary diagnosis among cases and deaths with COVID-19 as primary diagnosis separately for Indigenous and non-Indigenous populations in Chile.

Conclusion

Initially, Indigenous populations displayed lower rates of COVID-19 diagnosis and mortality. However, by 2021, the odds of COVID-19 diagnosis among Indigenous groups had significantly risen. The negative association between the proportion of the Indigenous population and COVID-19 vaccination rates emphasizes the urgency of tackling vaccine access barriers. For emerging economies like Chile, it is crucial to ensure equitable vaccine distribution, especially among vulnerable groups such as Indigenous communities.

Abbreviations

CAS Center for Advanced Study
DRG Diagnosis Related Group
ICD International Classification of Diseases

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-19756-4.

Supplementary Material 1

Acknowledgements

This work was partially supported by the Center for Advanced Study (CAS) in Oslo, Norway under the project "Social Science Meets Biology: Indigenous People and Severe Influenza Outcomes."

Author contributions

ID and GC contributed to data acquisition. SD conducted statistical analysis and prepared the initial draft. SD, ID, LS, SM and GC critically reviewed the successive drafts and contributed to study design development and interpretation of results.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or not-for profit sectors.

Data availability

The data used in this study are publicly accessible in the sources provided in the methods section of the paper.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]School of Public Health, Georgia State University, Atlanta, GA, USA
[2]Center for Epidemiology and Health Policies, Faculty of Medicine, Clinica Alemana Universidad del Desarrollo, Santiago, Chile
[3]University of Missouri, Columbia, MO, USA
[4]Centre for Research on Pandemics & Society (PANSOC), Oslo Metropolitan University, Oslo, Norway

Received: 3 November 2023 / Accepted: 12 August 2024
Published online: 28 August 2024

References

1. Alves DE, Mamelund S-E, Dimka J, Simonsen L, Mølbak M, Ørskov S, et al. Indigenous peoples and pandemics. Scand J Public Health. 2022;50(6):662–7.
2. Castrodale L. Deaths Related to 2009 Pandemic Influenza A (H1N1) Among American Indian/Alaska Natives—12 States, 2009. 2009.
3. Dahal S, Mizumoto K, Bolin B, Viboud C, Chowell G. Natality decline and spatial variation in excess death rates during the 1918–1920 influenza pandemic in Arizona, United States. Am J Epidemiol. 2018;187(12):2577–84.
4. La Ruche G, Tarantola A, Barboza P, Vaillant L, Gueguen J, Gastellu-Etchegorry M. The 2009 pandemic H1N1 influenza and indigenous populations of the Americas and the Pacific. Euro Surveill. 2009;14(42):19366.
5. Mamelund S-E. Geography may explain adult mortality from the 1918–20 influenza pandemic. Epidemics. 2011;3(1):46–60.
6. Nygaard IH, Dahal S, Chowell G, Sattenspiel L, Sommerseth HL, Mamelund S-E. Age-specific mortality and the role of living remotely: the 1918-20 influenza pandemic in Kautokeino and Karasjok, Norway. Int J Circumpolar Health. 2023;82(1):2179452.
7. Wilson N, Barnard LT, Summers JA, Shanks GD, Baker MG. Differential mortality rates by ethnicity in 3 influenza pandemics over a century, New Zealand. Emerg Infect Dis. 2012;18(1):71.
8. Pickering K, Galappaththi EK, Ford JD, Singh C, Zavaleta-Cortijo C, Hyams K et al. Indigenous peoples and the COVID-19 pandemic: a systematic scoping review. Environ Res Lett. 2023.
9. Fellows M, Paye V, Alencar A, Nicácio M, Castro I, Coelho ME et al. Underreporting of COVID-19 cases among indigenous peoples in Brazil: a new expression of old inequalities. Front Psychiatry. 2021:352.
10. Dahal S, Mamelund S-E, Luo R, Sattenspiel L, Self-Brown S, Chowell G. Investigating COVID-19 transmission and mortality differences between indigenous and non-indigenous populations in Mexico. Int J Infect Dis. 2022;122:910–20.
11. Group, RDAC-IDW. in RDA COVID-19 Working Group. Recommendations and Guidelines on Data Sharing. Research Data Alliance.; 2020. Data sharing respecting Indigenous data sovereignty.
12. Mackey K, Ayers CK, Kondo KK, Saha S, Advani SM, Young S, et al. Racial and ethnic disparities in COVID-19–related infections, hospitalizations, and deaths: a systematic review. Ann Intern Med. 2021;174(3):362–73.
13. Carroll SR, Akee R, Chung P, Cormack D, Kukutai T, Lovett R et al. Indigenous peoples' data during COVID-19: from external to internal. Front Sociol. 2021:62.
14. CEPAL. El impacto del COVID-19 en los pueblos indígenas de América Latina-Abya Yala. 2020.
15. LaRotta J, Escobar O, Ávila-Aguero ML, Torres JP, Sini de Almeida R, Morales GC et al. COVID-19 in Latin America: a snapshot in Time and the Road ahead. Infect Dis Ther. 2023:1–22.
16. Instituto Nacional de Estadísticas. Censo de Población y Vivienda. 2017.
17. JHU. Johns Hopkins University & Medicine, Coronavirus resource center. 2023 [https://coronavirus.jhu.edu/data/mortality
18. Gold JA, Wong KK, Szablewski CM, Patel PR, Rossow J, Da Silva J, et al. Characteristics and clinical outcomes of adult patients hospitalized with COVID-19—Georgia, March 2020. MMWR Morb Mortal Wkly Rep. 2020;69(18):545.
19. DRM database [Internet]. 2020. https://www.fonasa.cl/sites/fonasa/datos-abiertos/bases-grd
20. CASEN. Encuesta de caracterización socioeconómica nacional: Ministerio de Desarrollo Social y Familia. 2022 [10/29/2023]. https://observatorio.ministeriodesarrollosocial.gob.cl/encuesta-casen-2022
21. Electronic edition of the ICD-10-ES: Ministry of Health, Spain. 2022 [https://eciemaps.mscbs.gob.es/ecieMaps/browser/metabuscador.html
22. Avance comunal en. Campaña de Vacunación COVID-19 [Chile]: Ministerio de Ciencia, Tecnología, Conocimiento e Innovación de Chile; [https://www.minciencia.gob.cl/covid19/
23. Comisión Económica para América. Latina y el Caribe (CEPAL)/Fondo para el Desarrollo de los Pueblos Indígenas de América Latina y el Caribe (FILAC). Los pueblos indígenas de América Latina - Abya Yala y la Agenda 2030 para el Desarrollo Sostenible: tensiones y desafíos desde una perspectiva territorial. Santiago; 2020.
24. Brinkhoff T. City population [05/21/2023]. https://www.citypopulation.de/
25. Kohn MA, Senyak J, Sample Size Calculators. UCSF CTSI; 20 December 2021 [https://sample-size.net/confidence-interval-proportion/
26. CASEN. Pobreza Por Ingresos 2020 [http://observatorio.ministeriodesarrollosocial.gob.cl/storage/docs/casen/2020/Resultados_Pobreza_por_Ingresos_casen2020_en_pandemia_revisado2022_09.pdf
27. CDC. COVID-19 Risks and Information for Older Adults 2023 [https://www.cdc.gov/aging/covid19/index.html
28. Ho FK, Petermann-Rocha F, Gray SR, Jani BD, Katikireddi SV, Niedzwiedz CL, et al. Is older age associated with COVID-19 mortality in the absence of other risk factors? General population cohort study of 470,034 participants. PLoS ONE. 2020;15(11):e0241824.
29. Nations U. Indigenous people's access to decent work and social protection. 2014.
30. Albertos C, Oueda S. How to Ramp Up the Social and Economic Contributions of Indigenous Peoples. BID|Invest. August 20. 2020.
31. Wise J, Liebler CA, Todd RM. Dissimilarity on the Career Path: The Occupational Structure of the American Indian/Alaska Native Workforce. 2017.
32. Gregg M, Maxim R. Native Americans are getting left behind in the remote work economy. 2022.
33. Islam N, Khunti K, Dambha-Miller H, Kawachi I, Marmot M. COVID-19 mortality: a complex interplay of sex, gender and ethnicity. Eur J Public Health. 2020;30(5):847–8.
34. Lorenzo Bermejo J, Boekstegers F, González Silos R, Marcelain K, Baez Benavides P, Barahona Ponce C, et al. Subtypes of native American ancestry and leading causes of death: Mapuche ancestry-specific associations with gallbladder cancer risk in Chile. PLoS Genet. 2017;13(5):e1006756.
35. IWGIA. Indigenous peoples in Chile [06/24/2023]. https://www.iwgia.org/en/chile.html
36. de Macedo V, Santos GS, Silva RN, Couto CN, Bastos C, Viecelli E, et al. Healthcare-associated infections: a threat to the survival of patients with COVID-19 in intensive care units. J Hosp Infect. 2022;126:109–15.
37. Núñez A, Manzano CA. Identifying local barriers to access to healthcare services in Chile using a communitarian approach. Health Expect. 2022;25(1):254–63.
38. Ferdinand A, Lambert M, Trad L, Pedrana L, Paradies Y, Kelaher M. Indigenous engagement in health: lessons from Brazil, Chile, Australia and New Zealand. Int J Equity Health. 2020;19(1):1–12.
39. United Nations. State of the world's indigenous peoples: Indigenous people's access to health services. 2016.

Publisher's Note