Programa de Estudios de Honor
Universidad de Puerto Rico
Recinto de Río Piedras

Honors Program
University of Puerto Rico
Rio Piedras Campus

TESIS O PROYECTO DE CREACIÓN

APROBADO COMO REQUISITO PARCIAL DEL
PROGRAMA DE ESTUDIOS DE HONOR

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10 de mayo de 2022
Fecha

Impact of Social Vulnerability on COVID-19 Health Indicators in Puerto Rico

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May 2022

Abstract

The COVID-19 pandemic has impacted many communities globally, especially socially vulnerable communities. This study emphasizes how the characteristics of the environment and the host facilitated the risk of disease and mortality from COVID-19 in 2020. In this study, age-adjusted YPLL rates due to COVID-19 were higher in Hispanics in the United States than in residents of Puerto Rico. The age-adjusted incidence, mortality, and case-fatality rates in Puerto Rico by region were not significantly associated with the Puerto Rico Social Vulnerability Index and the Puerto Rico Socioeconomic Vulnerability Index. The low number of data points could account for the high p-values obtained. The implications of this study suggest that the PRSVI and PRSEVI may not be adequate to assess the vulnerability of Health Regions of Puerto Rico when facing a pandemic.

Introduction

According to the Centers for Disease Control and Prevention, (1986) mortality indexes are calculated to know the impact of diseases that are public health problems. This helps to gear public policy towards allocating resources for the mitigation of adverse outcomes from specific diseases. Years of Potential Life Lost (YPLL) measures the burden of social and economic loss in a certain population (Gardner & Sanborn, 1990). The YPLL attributed to COVID-19 has shown significant disparities between races and ethnicities in the United States (Xu et al., 2021a). Health disparities are “differences in the incidence, prevalence, and mortality of a disease and the related adverse health conditions that exist among specific population groups” (National Center for HIV, Viral Hepatitis, STD, and TB Prevention, 2020). The increase in incidence and mortality from several chronic diseases, such as heart disease and diabetes, is associated with socioeconomic factors in Puerto Rico; therefore, it is expected that these factors may also be associated with the impact of COVID-19 on the island (Departamento de Salud, 2014). The measure of the overall social vulnerability index is a percentile rank, and it includes socioeconomic status, housing/transportation status, household composition and disability status, and minority status (Tormos-Aponte, García-López, & Painter, 2021). The socioeconomic vulnerability measure is also a percentile rank, and it includes data on poverty level, percent unemployment, education level and mean per capita income rank (Tormos-Aponte, García-López, & Painter, 2021). The research questions were:

1. Is social vulnerability associated with the age-adjusted case-fatality, mortality, and incidence rates of COVID-19 in different regions of Puerto Rico?
2. Is socioeconomic vulnerability associated with the age-adjusted case-fatality, mortality, and incidence rates of COVID-19 in different regions of Puerto Rico?
3. How does the age-adjusted YPLL due to COVID-19 in Puerto Rico compare to that of Hispanics in the United States?

Specific Aims

Aim 1. Evaluate associations between the COVID-19 age-adjusted case-fatality, incidence, and mortality rates, and the overall social vulnerability in all regions of Puerto Rico.

Aim 2. Evaluate associations between the COVID-19 age-adjusted case-fatality, incidence, and mortality rates, and the socioeconomic vulnerability in all regions of Puerto Rico.

Aim 3. Evaluate the difference between the age-adjusted YPLL rates due to COVID-19 in Hispanics from the United States and the age-adjusted YPLL rates due to COVID-19 in Puerto Rico.

Literature Review

The COVID-19 Pandemic

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the virus that causes COVID-19. This virus rapidly spread from Wuhan, China to the rest of the world. In a study of the clinical characteristics of COVID-19 in China with data up to January 31, 2020, it was found that "fever was present in 43.8% of the patients on admission but developed in 88.7% during hospitalization […] the second most common symptom was cough (67.8%)" (Guan et al., 2020). The World Health Organization declared COVID-19 a pandemic on March 11, 2020 (Ghebreyesus, 2020). At the start of the pandemic, policy measures centered on the fact that older people were the ones dying due to COVID-19. However, the spread of the Delta variant caused increasing deaths due to COVID-19 in younger people; in the case of Japan and the United States, while the Delta variant was spreading, the vaccination efforts were prioritized for the older population (Kamp & Overberg, 2021; Mainichi Japan, 2021).

Impact of COVID-19 on Health Indicators

Years of potential life lost. Years of Potential Life Lost (YPLL) are years of potential life lost due to premature death, calculated by subtracting the age at death from a predefined endpoint (Gardner & Sanborn, 1990). This indicator has been used to highlight particular causes of death in relation to their effect on a population (Gardner & Sanborn, 1990). The prevention of premature mortality is a goal to prevent social and economic loss (Gardner & Sanborn, 1990). There have been various ways of calculating YPLL since its introduction by Mary Dempsey in 1947 (Centers for Disease Control and Prevention [CDC], 1986). YPLL can be calculated directly from death counts or estimated from grouped data. For example, calculating YPLL from grouped data for the age-group of 0-4 starts by identifying the midpoint of the age interval (summing one plus the youngest and the oldest age; and, dividing by two) which is 2.5 years (CDC, 2006, p. 3.35). After calculating the midpoint, it is subtracted from the endpoint (80 minus 2.5) and it results in 77.5 years of potential life lost (CDC, 2006, p. 3.35). To compare YPLL between different populations, it is important to consider the age distribution. Therefore, calculating age adjusted YPLL rates would be more appropriate (CDC, 1986, p. 5S). In a study comparing age adjusted male-to-female YPLL rate ratios, it was found that there is a trend of males dying due to COVID-19 at higher rates and earlier ages than females in the U. S. (Xu et al., 2021b). In the United States, the YPLL of deaths due to COVID-19 was 2.5 million in early October 2020 (Elledge, 2020). In the first year of the COVID-19 pandemic, there were 48 million years of life lost in 124 countries, which represented 0.018% of all expected years of life in those countries (Andersen & Gonzáles, 2021). In 1987, males represented 58.6% of all deaths in Puerto Rico; however, the YPLL from the thirteen leading causes of death was disproportionately high in comparison to females (Ramírez de Arellano, 1992).

Incidence. Incidence is defined as, "a measure of the frequency with which new cases of illness, injury, or other health condition occurs among a population during a specified period." (CDC, 2006, p. G-10). To calculate the incidence rate, the number of new cases that happen during a specific time interval is divided by the average population in that time interval (CDC, 2006). The incidence can be multiplied by a power of 10 to be expressed, for example, per 1,000, 10,000, or 100,000. (Gordis, 2004, p. 33). Various studies have concluded that COVID-19 incidence was higher in counties with a higher social vulnerability in the United States (Dasgupta et al., 2020; Biggs, Maloney, Rung, Peters & Robinson, 2021; Karmakar, Lantz & Tipirneni, 2020). However, a study by Neelon, Mutiso, Mueller, Pearce & Benjamin-Neelon (2021) examined death rates and incidence of COVID-19 from March 15, 2020 to December 31, 2020 and found that the incidence and death rates were higher in counties with low vulnerability at the start and end of the study. From late March to late September, incidence and death rates were higher in counties with high vulnerability (Neelon et al., 2021). The authors indicated that the initial change could reflect local and state policy decisions, an example of this was that there were early re-openings in states like Georgia that had many vulnerable counties (Neelon et al., 2021). By late September, the counties with low vulnerability overturned the counties with high vulnerability and this could have been related to more re-openings and heightened surveillance (Neelon et al., 2021). The authors concluded that the impact of the COVID-19 pandemic is subject to spatial and temporal variability.

Mortality. The mortality rate is a measurement of the frequency and risk of death in a certain population, during a specified period (CDC, 2006). The mortality measure that could help indicate the impact of COVID-19 on death is the cause-specific death rate. According to the CDC, the cause-specific death rate is calculated dividing the "number of deaths assigned to a specific cause during a given time interval" by the "mid-interval population" and multiplying by 100,000 (2006, p. 3.20). Since this study will compare the mortality rate in different populations, it is important to adjust the mortality rate for age by selecting a standard population (Gordis, 2004, p. 60). With changes in vaccination rates, discovery of effective therapeutic drugs, and new COVID-19 variants, mortality rates from COVID-19 may vary more in 2021.

Lethality. Lethality is measured with the case-fatality rate (CFR), which is "[…] the proportion of persons with the disease who die from it" (CDC, 2006, p. 3.8). According to Gordis, (2004, p. 51) "the case-fatality rate is a measure of the severity of the disease." It is important to account for the limitations of the case-fatality rate in the context of COVID-19. According to the Puerto Rico Department of Health (PRDoH), COVID-19 must be reported in the death certificate of all of those deceased in which the illness caused or is assumed that caused or contributed towards the death (Departamento de Salud, 2020). The testing rates vary among countries, and this may affect the magnitude of cases that are reported. A systematic review of 28 eligible studies concluded that the pooled proportion of asymptomatic COVID-19 cases was 25% (95%CI: 16–38) (Alene et al., 2021). Asymptomatic or mildly asymptomatic cases of COVID-19 will influence the CFR measure if cases go unreported. A study of global trends in case-fatality rates of COVID-19 revealed that the reported CFR was decreasing since May 2020, not because of more testing, but because of "an increased rate of infection in younger people or by the improvement of health care management, shielding from infection, and/or repurposing of several drugs that had shown a beneficial effect on reducing fatality because of COVID-19" (Hasan et al., 2021). Out of the global reported CFRs in that study, the peak reported CFR was 7.23% and the most recent one was December 29-31, 2020; 2.2% (Hasan et al., 2021). "Our World in Data" has been providing data visualizations of daily case fatality rates in different countries; on October 10, 2021, the COVID-19 CFR of the United States was 1.61%, in Italy and Brazil it was 2.79%, in India it was 1.33%, in China it was 4.80%, and in New Zealand it was 0.60% (Ritchie et al., 2020). The global CFR of COVID-19 was 2.04% as of October 10, 2021 (Ritchie et al., 2020). In four studies with data collected between late December, 2020 and late March, 2020 the case-fatality rate for patients hospitalized due to COVID-19 was 1.4%, 4.3%, 14.1% and 28.3% (Guan et al., 2020; Wang et al., 2020a; Chen, 2020; Zhou et al., 2020). These discrepancies could be due to differences in patient characteristics, especially a higher prevalence of comorbidities in some cohorts in comparison to others (Guan et al., 2020; Wang et al., 2020a; Chen, 2020; Zhou et al., 2020). In studies that collected data from critically ill patients that were in the ICU; the case-fatality rate was, (cited in their respective order) 26%, 38.7%, 50% and 61.5% (Grasselli et al., 2020; Wang et al., 2020b; Bhatraju et al., 2020; Yang et al., 2020).

Social Vulnerability and COVID-19

According to Mendez (2021), COVID-19 greatly reflects the geographical and political contexts under the intersectional ties of gender, race-ethnicity, and socioeconomic level. As an example: "[…] within Israel, the country that was the fastest to establish an immunization program, Palestinians have no access to vaccination" (Mendez, 2021; Martin & Arawi, 2021). A study on YPLL due to COVID-19 in the U.S. concluded that non-Hispanic Blacks and Hispanics had a disproportionately high YPLL; meanwhile, non-Hispanic Whites had a disproportionately low YPLL (Xu et al., 2021a). This study indicated that YPLL shows disparities to be more pronounced in comparison to death counts because of the greater quantity of disparities at younger ages (Xu et al., 2021a). The study concluded that the magnitude of the association of race/ethnicity and social determinants of health varies by state (Xu et al., 2021a). Mendez (2021) cites the Economic Commission for Latin America and the Caribbean; "[...] it is estimated that the total number of people living in poverty increased from 185.5 million in 2019 to 230.9 million in 2020, representing 37.3% of the population" (Filguera, Galindo, Giambruno, Blofield, 2020). Mendez (2021) expresses that the impact of the COVID-19 pandemic is not only economic; it also further deepens inequalities. In a study that used the 2018 CDC social vulnerability index (SVI) dataset, it was found that higher vulnerability related to housing type, transportation, English proficiency, and ethnic minority status was associated with a higher risk of being a COVID-19 hotspot (Dasgupta et al., 2020). This study will use a modified 2018 CDC social vulnerability index (SVI) because it will better reflect social vulnerability in Puerto Rico. This modified index will exclude the ranks of two variables originally included in CDC's SVI:

the percent Hispanic rank and the English language proficiency rank from the Minority Status & Language vulnerability (Tormos-Aponte, García-López, & Painter, 2021).

It's important to contextualize the COVID-19 pandemic within the population of Puerto Rico, a population that is facing "fiscal austerity, increasing income and wealth inequality, the debt crisis, significant emigration, and a dysfunctional health care system." (García, Rivera, Garcia, Burgos, Aranda, 2020). The population is becoming older; therefore, there will be a bigger need of care within the five leading causes of death: cancer, diseases of the heart, diabetes, Alzheimer's disease, cardiovascular disease, and also prevalent conditions like asthma and hypertension (Perreira, Lallemand, Napoles, Zuckerman, 2017). The Puerto Rico Chronic Disease Action Plan indicates that there are socioeconomic factors that result in disparities in health indicators for heart disease, diabetes, malignant neoplasms, arthritis, and asthma (Departamento de Salud, 2014). According to Garriga-López (2020) "About 20% of the population in Puerto Rico is over 60 years of age, most live in poverty. At least 16% of the population is diabetic". This population is at high risk of death from COVID-19 due to the higher prevalence of conditions that are comorbidities of COVID-19 (Perreira et al., 2017; Garriga-López, 2020; Ssentongo et al., 2020; Deng et al., 2020).

Theoretical framework

Ecologic Model

The theoretical framework for this study is the ecologic model of disease, also known as the epidemiologic triad of agent, host, and environment. According to the CDC (2006, p. 1.52), the agent is usually an "infectious microorganism or pathogen", the host is "the human who can get the disease", and the environment can be the "extrinsic factors that affect the agent and the opportunity for exposure". One of the earliest uses of this triad concept could be attributed to

Wade Hampton Frost in 1928 (Frost, 1976). The purpose of the epidemiologic triad is to help visualize the three groups of factors that can affect the spread of disease. Preventing or controlling the disease requires looking at these three groups of factors and their connections (CDC, 2006).

The Natural History of Disease

The natural history of disease is the development of a disease in an individual over time, without treatment or intervention. According to Gordis, (2004, p. 95) the natural history of disease in a patient can be thought of as the following timeline, which is divided into a preclinical and clinical phase: biologic onset of disease, pathologic evidence of disease (if searched), signs and symptoms of disease, medical care sought, diagnosis, and treatment. After this, the outcome could be a cure of the disease, management or control of the disease in the patient, or death (Gordis, 2004, p. 95). According to Gordis (2004, p. 96) and the CDC, (2006) the appearance of symptoms of the disease marks the beginning of the clinical phase. Gordis (2004, p. 95) uses the term natural history of disease and prognosis interchangeably because natural history of disease can be quantified to understand the severity of the disease and the expected outcomes of a disease without treatment, to serve as comparison for the outcomes with treatment. According to Gordis, (2004, p. 96) “the first way to express prognosis is the case-fatality rate”. Gordis, (2004, p. 114) mentions that the goal of clinical practice and public health is to change the outcomes of the natural history of disease to improve health. To modify the outcomes that are seen in the natural history of COVID-19, preventive or therapeutic measures have been taken like the development of vaccines, physical distancing, mask wearing, lockdowns, etc. The FDA approved remdesivir as a treatment against COVID-19 and it has authorized various monoclonal antibody treatments under an Emergency Use Authorization

(Know Your Treatment Options for COVID-19, 2021). Evaluating health indicators of COVID-19 in Puerto Rico will help to inform and further investigate its natural history.

Hypotheses

Hypothesis 1. Regions of Puerto Rico with a higher overall social vulnerability will have higher case-fatality, incidence, and mortality rates.

Hypothesis 2. Regions of Puerto Rico with a higher socioeconomic vulnerability will have higher case-fatality, incidence, and mortality rates.

Hypothesis 3: The age adjusted YPLL will be higher in Hispanics from the United States in comparison with Puerto Rico.

Justification

YPLL is not reported by the PRDoH and there are few publications about YPLL in Puerto Rico (Ramírez de Arellano, 1992; Ortiz-Zuazaga, Arce-Corretjer, Solá-Sloan, & Conde, 2015). The effects of the COVID-19 pandemic on premature mortality among the Puerto Rican population are poorly understood. This study will associate various COVID-19 health indicators with socioeconomic vulnerability due to the relationship that has been established between health indicators of chronic diseases and socioeconomic factors in Puerto Rico (Departamento de Salud, 2014). A relationship has been established between racial and ethnic origin, and YPLL due to COVID-19 (Xu et al., 2021a). Since minority status is a component of social vulnerability, the YPLL due to COVID-19 of Hispanics in the U.S. will be calculated and compared with Puerto Rico. This research may be useful for setting public health priorities related to social health disparities.

Methodology

Data and Variables

This was an ecologic study in which social vulnerability was the exposure variable. According to the CDC, social vulnerability is a collection of social conditions that communities exhibit that may weaken their ability to prevent human suffering and financial loss in a disaster (Agency for Toxic Substances and Disease Registry, CDC, 2021). A dataset of the 2018 CDC social vulnerability index (SVI) was obtained from a previous study that modified the social vulnerability measures to better reflect the context of Puerto Rico; creating the PRSVI (Tormos-Aponte, García-López, & Painter, 2021). The measure of the overall social vulnerability index is a percentile rank, and it is calculated by summing all the ranks for variables included in the socioeconomic, housing/transportation, and household composition and disability statuses; and subtracting income and percent white (Tormos-Aponte, García-López, & Painter, 2021). The first difference between the 2018 CDC SVI and this modified PRSVI is that it does not include English language proficiency since a low rank of this variable does not necessarily increase their vulnerability in the island because the Spanish language is dominant (Tormos-Aponte, García-López, & Painter, 2021). The second difference between the 2018 CDC SVI and this modified SVI is that the Hispanic/Latino variable is excluded from the minority status variable (Tormos-Aponte, García-López, & Painter, 2021). The measure of socioeconomic status is calculated by adding the poverty level, percent unemployment, and education ranks, subtracting mean per capita income, and dividing by the total number of data points (Tormos-Aponte, García-López, & Painter, 2021). The household composition and disability status index is calculated by obtaining percentile ranks of the percent elderly, young, disabled, and single-parent households; summing them, and obtaining percentile ranks of those sums (Tormos-Aponte, García-López, &

Painter, 2021). The housing or transportation status is calculated by obtaining percentile ranks of multi-unit housing, crowding, and vehicle accessibility variables; summing them, and obtaining percentile ranks of those sums. (Tormos-Aponte, García-López, & Painter, 2021). All the variables that are part of the formula for social vulnerability were obtained from the American Community Survey data (Tormos-Aponte, García-López, & Painter, 2021). Since the social vulnerability dataset contained data by census tract, the mean of the SVI was calculated by municipality. Then, the indexes by municipality were multiplied by the weight of the population of the municipality in its respective region. The population-weighted indexes by municipality were summed according to their respective regions, resulting in population-weighted averages per region. The regions corresponded to those defined by the PRDoH: Metropolitana (hereafter Metro), Bayamón, Arecibo, Mayagüez, Ponce, Caguas, and Fajardo (Departamento de Salud, 2021c).

Data of COVID-19 deaths and cases were obtained from the PRDoH website (Departamento de Salud, 2022). Deaths and cases only corresponded to the year 2020 because data from 2021 and 2022 was subjected to ongoing data cleaning by the PRDoH, this caused the data to change frequently during the period of data collection. It is not known if the data from the PRDoH contains the region of death or the region of residence of the death of a patient due to COVID-19. From March to July 2020, 83.6% of COVID-19 deaths in Puerto Rico occurred in a hospital and 10.7% occurred in an outpatient setting (emergency department); therefore, many patients could have been treated in areas with higher availability of hospitals and ICU beds (Azofeifa et al., 2021). The term “case” could be defined in different ways, the case definition for this study was that of the PRDoH. The PRDoH defines a confirmed COVID-19 case as one that shows positive on a RT-PCR-based diagnostic test, and it is required that the clinical laboratory is CLIA certified (Departamento de Salud, 2021a; Mellado-López, 2021). The CDC defines a confirmed COVID-19 case as one positive on a RT-PCR-based diagnostic test performed by a "Clinical Laboratory Improvement Amendments (CLIA) certified provider" or detection of SARS-CoV-2 by genomic sequencing (Coronavirus Disease 2019 (COVID-19) 2021 Case Definition, 2021). The age-structure of the population of Puerto Rico by municipality was obtained from estimates for July 1, 2020 (U.S. Census Bureau, 2021). The standard population for age-adjustment in the United States and in Puerto Rico was obtained from the 2000 U.S. population (Klein & Schoenborn, 2001). The standard age distribution of COVID-19 cases for year 2020 was obtained from the CDC (2020a). Deaths due to COVID-19 in the United States by age-group and Hispanic origin were obtained from CDC WONDER (2021). CDC WONDER (2021) was filtered for Hispanic or Latino origin, the year 2020, cause of death from confirmed COVID-19 diagnosis (ICD-10 code U07.1), and five-year age groups. To calculate an age adjusted YPLL rate, the following formula was used:

(1)

$$\sum_{i=0}^{80}((80-i)\ (w_i)(100{,}000))$$

Where "i" is the midpoint in a certain age group, and "w_i" is the number of individuals in age i divided by the standard population (Dranger & Remington, 2004). The following formula was used to compute an age adjusted mortality rate:

(2)

$$\textstyle\sum_i w_i \frac{n_i}{\bar{x}_i}(100{,}000)$$

Where "n_i" is the number of COVID-19 deaths at age i, "$\bar{x}_i$" is the average population in that time interval in age i, and "w_i" is the number of individuals in age i divided by the standard population (CDC, 2006). The following formula was used to calculate the age adjusted incidence rate:

(3)

$$\sum_i w_i \frac{n_i}{\bar{x}_i}(100{,}000)$$

Where "n_i" is the number of new COVID-19 cases that happen during a specific time interval in age i, "w_i" is the number of individuals in age i divided by the standard population, and "$\bar{x}_i$" is the average population in that time interval in age i (CDC, 2006). To calculate the age adjusted case-fatality rate, the following formula was used:

(4)

$$\sum_i sc_i \frac{n_i}{c}(100{,}000)$$

Where "n_i" is the number of COVID-19 deaths due to COVID-19 in age i, "c" is the number of COVID-19 cases in age i, and "sc_i" is the number of individuals with COVID-19 in age i divided by the standard number of individuals infected with COVID-19 (CDC, 2006).

Statistical Analyses

Age-adjusted rates, crude rates, and age-specific rates were obtained using the epiR package for R software (Stevenson & Sergeant, 2021). For deaths, the date corresponded to the death date and for cases, the date corresponded to the sample date. To calculate the YPLL, data from deaths in Puerto Rico and deaths in Hispanics in the United States by age group was obtained. Since deaths were reported in specific age groups, a column for the ending age of the age group was created, and a column for the starting age was created. Then, a function which calculated the midpoint between the starting and the ending age was used. 80 was subtracted by this midpoint and the total YPLL was calculated for Puerto Rico and Hispanics in the United States. To adjust the rates, the following table was obtained: a column of the observations (number of deaths, cases or YPLL), the population estimates, and the standard populations for each age group and region. To adjust all the indicators for age, the observations were converted into a matrix, with a column for each age group and a row for each region (in the case of YPLL, it had one row for Puerto Rico and one row for Hispanics in the United States) and stored into a variable. The same was done to obtain separate matrices for the population estimates and the standard populations. Inserting each matrix in “epi.directadj” from the epiR package would provide the age-adjusted estimates, as well as lower and upper estimates from a 95% confidence interval. For the case-fatality rate, the cases were inserted in “epi.directadj,” to replace the population estimates. The source code is available for additional details (Torres, 2022).

Overall social vulnerability (PRSVI) and socioeconomic vulnerability (PRSEVI) by census tract in Puerto Rico was obtained. The mean vulnerability by municipality was calculated. Then, population weights by region were created and multiplied by the mean vulnerability for each municipality. The weighted average vulnerability by municipality was summed to obtain a population-weighted vulnerability index by region. The Spearman rank correlation coefficient was applied to test the correlation between social vulnerability and case-fatality, mortality, and incidence of COVID-19 in Puerto Rico. The level of significance was $p < 0.05$. All analyses were carried out using the statistical software R, with the following packages: openxlsx, gtsummary, ggplot2, kableExtra, lubridate, dplyr, ggpubr, and epiR (v4.1.0; R Core Team, 2021; Schauberger & Walker, 2021; Wickham, 2016; Kassambara, 2020; Wickham, François, Henry & Müller, 2021; Grolemund & Wickham, 2011; Sjoberg et al., 2021; Zhu, 2021; Stevenson & Sergeant, 2021).

Results

As of April 1, 2022, the PRDoH reported 273 probable deaths and 1,409 confirmed deaths from COVID-19 in 2020 (Table 2). There were 4,771 probable cases and 76,080 confirmed COVID-19 cases for Puerto Rico in 2020 (Table 1). The dates for deaths and cases in Puerto Rico ranged from March 1, 2020, to December 31, 2020. As of April 1, 2022, CDC WONDER had reported 65,237 deaths of Hispanics in the 50 states and the District of Columbia for all of 2020 (Table 3). For both Puerto Rico and Hispanics in the United States, deaths due to COVID-19 were higher in those in older age groups (Tables 2 and 3). In Puerto Rico, COVID-19 cases were higher in those in younger age groups (Table 2). For Puerto Rico, no deaths due to COVID-19 were reported between the ages of 0 and 9, in 2020 (Table 2). The Metro and Bayamón regions had higher deaths and cases due to COVID-19, while the Fajardo region had the lowest deaths and cases due to COVID-19 (Tables 1 and 2). The Metro and Bayamón regions had the highest age-adjusted incidence and mortality rates (Tables 6 and 8). The Bayamón and Fajardo regions had the highest age-adjusted case-fatality rates (Table 10). The Fajardo region had the highest age-specific mortality and case-fatality rates in the age group 0 to 39 (Tables 5 and 9). The Metro region had the highest age-specific incidence in the age group 0 to 39 (Table 7). The Ponce region had the lowest age-adjusted mortality, incidence, and case-fatality rates (Tables 6, 8, 10).

The region with the highest PRSVI was Arecibo and the lowest PRSVI was the Metro region (Table 4). The region with the highest PRSEVI was Mayagüez and the lowest PRSEVI was the Metro region (Table 4). The mortality and PRSVI correlation was slightly negative and the p-value was high (Figure 1). The mortality and PRSEVI correlation was moderately negative and the p-value was high (Figure 2). The incidence and PRSVI correlation was mildly negative and the p-value was high (Figure 3). The incidence and PRSEVI correlation was negative and moderate to strong, and the p-value was high (Figure 4). The case-fatality ratio and PRSVI correlation was mildly negative and the p-value was high (Figure 7). The case-fatality ratio and PRSEVI correlation was moderately negative and the p-value was high (Figure 8). For the correlations of COVID-19 health indicators, the high p-values reflected the small amount of data points.

Puerto Rico had 478.9 crude years of potential life lost (YPLL) per 100,000 and Hispanics in the United States had 1417.1 crude YPLL per 100,000 in 2020 (Table 12). The crude YPLL per 100,000 was 66.2% less in the population of Puerto Rico than in the population of Hispanics in the United States. Puerto Rico had 390.7 (384.0, 397.5) age-adjusted YPLL per 100,000 population and Hispanics in the United States had 1630.4 (1626.8, 1633.9) age-adjusted YPLL per 100,000 population (Table 12). The age-adjusted YPLL rate of Puerto Rico was 76.0% less than that of Hispanics in the United States.

Table 1

General characteristics. Cases of COVID-19. Puerto Rico, 2020.

	N = 80,851	Percentage (%)
Sex		
Female	43,600	53.9
Male	37,251	46.1
Region[1]		
Arecibo	9,704	12.0
Bayamón	18,021	22.3
Caguas	12,793	15.8
Fajardo	2,504	3.1
Mayagüez	7,647	9.5
Metro	23,665	29.3
Ponce	6,316	7.8
Missing	201	0.2
Class		
Confirmed	76,080	94.1
Probable	4,771	5.9
Age-group		
0 to 39	39,293	48.6
40 to 49	13,363	16.5
50 to 59	12,228	15.1
60 to 69	7,840	9.7
70 to 79	4,916	6.1
80 +	3,011	3.7
Missing	200	0.25

[1]Names of municipalities in Puerto Rico within each region. Mayagüez: Aguada, Aguadilla, Isabela, Moca, and San Sebastián; Arecibo: Arecibo, Barceloneta, Camuy, Ciales, Florida, Hatillo, Lares, Manatí, Morovis, Quebradillas, Utuado, and Vega Baja; Bayamón: Barranquitas, Bayamón, Cataño, Comerío, Corozal, Dorado, Naranjito, Orocovis, Toa Alta, Toa Baja, and Vega Alta; Caguas: Aguas Buenas, Aibonito, Caguas, Cayey, Cidra, Gurabo, Humacao, Juncos, Las Piedras, Maunabo, Naguabo, San Lorenzo, and Yabucoa; Fajardo: Ceiba, Culebra, Fajardo, Luquillo, Río Grande, and Vieques; Mayagüez: Añasco, Cabo Rojo, Hormigueros, Lajas, Las Marías, Maricao, Mayagüez, Rincón, Sabana Grande, and San Germán; Metro: Canóvanas, Carolina, Guaynabo, Loíza, San Juan, and Trujillo Alto; Ponce: Adjuntas, Arroyo, Coamo, Guánica, Guayama, Guayanilla, Jayuya, Juana Díaz, Patillas, Peñuelas, Ponce, Salinas, Santa Isabel, Villalba, and Yauco.

Table 2

General characteristics. Deaths from COVID-19. Puerto Rico, 2020.

	N = 1,682	Percentage (%)
Sex		
Female	698	41.5
Male	984	58.5
Region		
Arecibo	200	11.9
Bayamón	407	24.2
Caguas	227	13.5
Fajardo	54	3.2
Mayagüez	160	9.5
Metro	514	30.6
Ponce	110	6.5
Missing	10	0.6
Class		
Confirmed	1,409	83.8
Probable	273	16.2
Age-group		
0 to 39	38	2.3
40 to 49	77	4.6
50 to 59	203	12.1
60 to 69	301	17.9
70 to 79	470	27.9
80 +	593	35.3

Table 3

General characteristics. Deaths from COVID-19. Hispanics in the United States, 2020 (Puerto Rico not included).

	N = 65,237	Percentage (%)
Age-group		
0 to 39	2,257	3.5
40 to 49	4,724	7.2
50 to 59	9,871	15.1
60 to 69	15,155	23.2
70 to 79	15,733	24.1
80 +	17,497	26.8

Table 4

Social and Socioeconomic Vulnerability Indices for Puerto Rico, 2018 (weighted by population).

Region	Overall Social Vulnerability	Socioeconomic Vulnerability
Arecibo	0.7014	0.6100
Bayamón	0.5997	0.4610
Caguas	0.6042	0.4261
Fajardo	0.5719	0.5162
Mayagüez	0.6882	0.6248
Metro	0.5110	0.3315
Ponce	0.5732	0.5514

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Table 5

*Age-Specific Mortality Rates due to COVID-19 by Region (per 100,000 population). Puerto Rico, 2020.**

Age-group	Arecibo	Bayamón	Caguas	Fajardo	Mayagüez	Metro	Ponce	Total
0 to 39	1.7	2.0	1.7	3.9	0.5	3.4	1.4	2.0
40 to 49	16.2	21.0	10.0	20.5	10.8	30.1	3.4	16.4
50 to 59	35.3	55.6	45.9	57.0	13.3	62.8	13.0	40.9
60 to 69	71.6	96.9	45.1	58.3	33.6	94.4	29.5	63.6
70 to 79	141.2	194.4	114.1	88.9	81.9	167.9	47.2	125.5
80 +	236.0	461.1	226.0	111.7	157.1	308.2	94.7	252.9

* There were 8 missing regions that were not part of the data for confirmed deaths.

Table 6

*Crude and Age-adjusted Mortality Rates by Region (per 100,000 population). Puerto Rico, 2020.**

Region	Deaths	Population	Crude Mortality Rate	Adjusted Mortality Rate (95% CI)
Arecibo	175	391046	44.8	28.8 (24.6, 33.8)
Bayamón	356	531924	66.9	44.4 (39.8, 49.6)
Caguas	196	526559	37.2	25.1 (21.7, 29.1)
Fajardo	41	114866	35.7	24.9 (17.6, 35.0)
Mayagüez	122	454407	26.8	15.9 (13.1, 19.4)
Metro	434	672518	64.5	40.6 (36.6, 44.9)
Ponce	77	468023	16.5	10.9 (8.5, 13.8)
Total	1401	3159343	44.3	28.6 (27.1, 30.3)

Note. CI = confidence interval

* There were 8 missing regions that were not part of the data for confirmed deaths.

Figure 1

Age-adjusted Mortality Rates vs Overall Social Vulnerability Index. Puerto Rico, 2020.

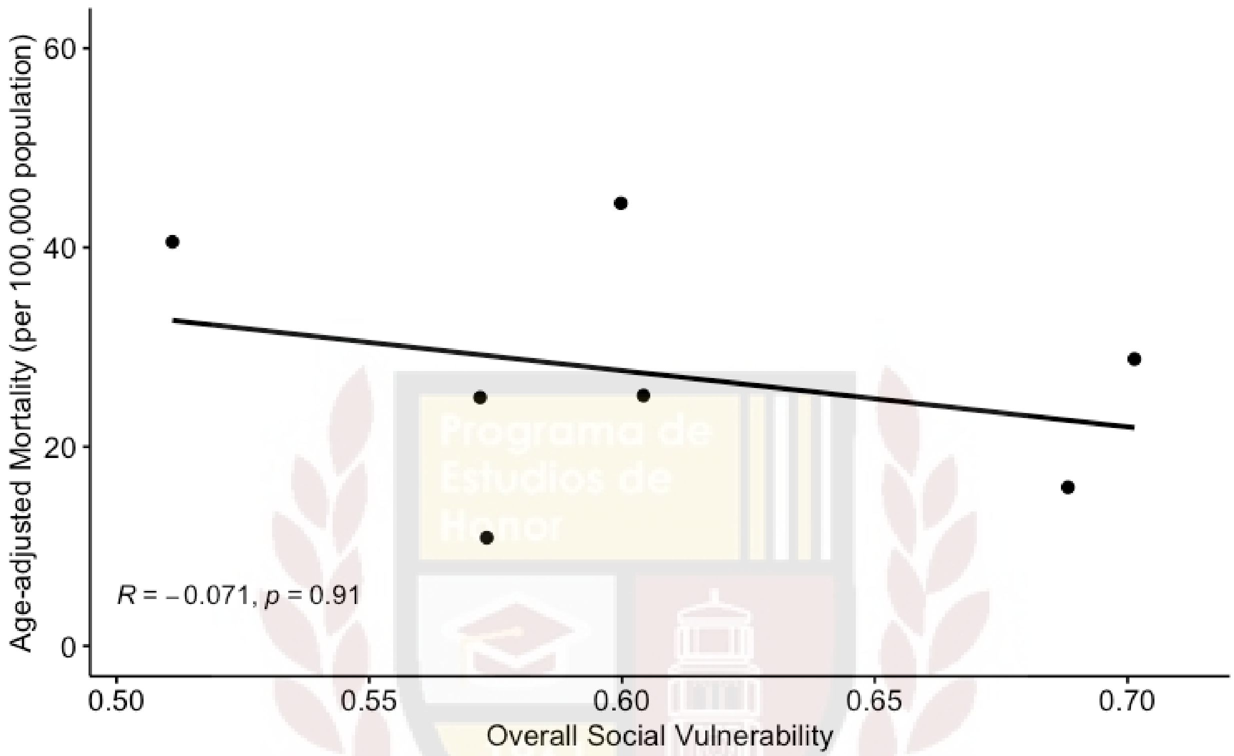

Figure 2

Age-adjusted Mortality Rates vs Socioeconomic Vulnerability Index. Puerto Rico, 2020.

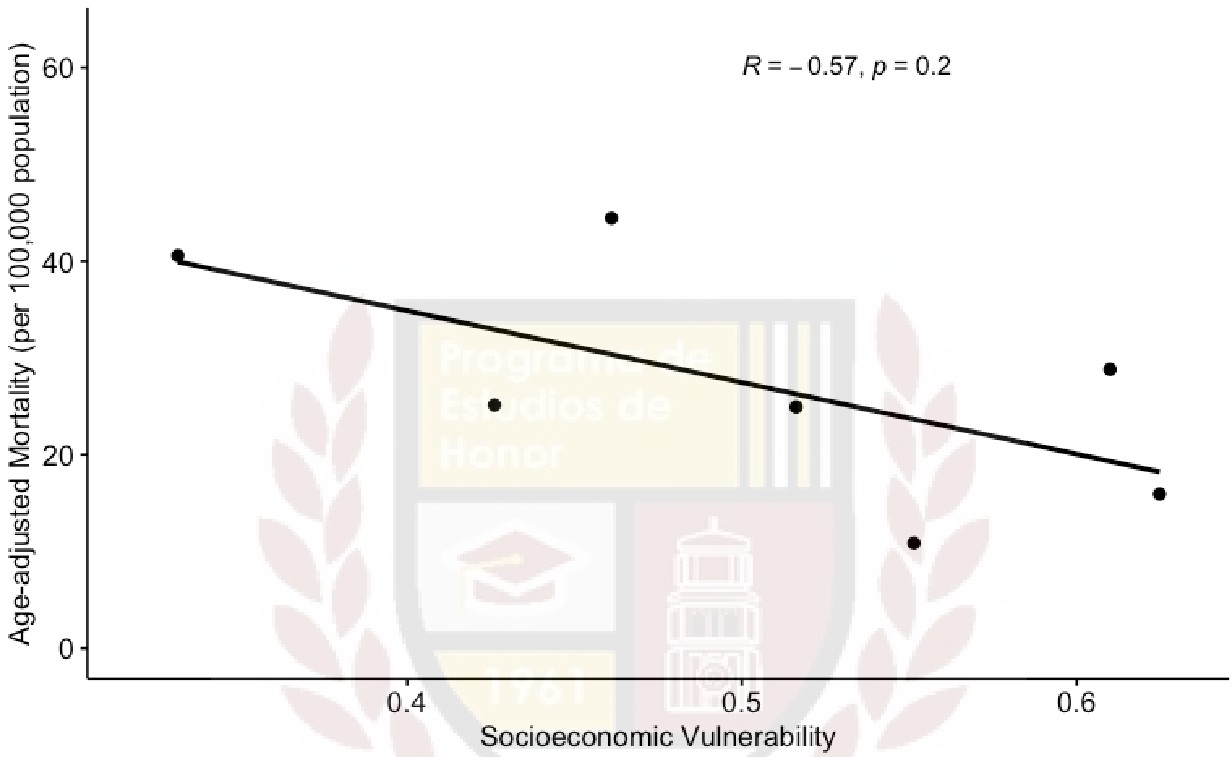

Table 7

*Age-Specific Incidence Rates due to COVID-19 by Region (per 100,000 population). Puerto Rico, 2020.**

Age-group	Arecibo	Bayamón	Caguas	Fajardo	Mayagüez	Metro	Ponce	Total
0 to 39	2634.6	3363.7	2536.2	1903.2	1586.9	3638.2	1343.1	2587.6
40 to 49	3040.0	4127.2	2861.7	2500.0	2107.9	4520.3	1765.1	3162.1
50 to 59	2519.1	3683.4	2363.8	2148.7	1717.2	3955.4	1399.3	2707.3
60 to 69	1729.5	2545.0	1705.9	1413.5	1189.0	2683.2	887.5	1840.2
70 to 79	1545.8	2018.9	1314.8	1034.4	1005.1	2016.0	790.3	1465.4
80 +	1242.3	1976.1	1338.6	642.4	840.0	1868.2	710.4	1375.8

* There were 198 missing regions and 186 missing age-groups that were not part of the data for confirmed cases.

Table 8

*Crude and Age-adjusted Incidence Rates by Region (per 100,000 population). Puerto Rico, 2020.**

Region	Cases	Population	Crude Incidence Rate	Adjusted Incidence Rate (95% CI)
Arecibo	9241	391046	2363.1	2507.6 (2455.0, 2561.2)
Bayamón	17027	531924	3201.0	3331.7 (3280.4, 3383.6)
Caguas	11952	526559	2269.8	2394.8 (2350.8, 2439.4)
Fajardo	2047	114866	1782.1	1893.5 (1809.6, 1980.4)
Mayagüez	6833	454407	1503.7	1593.4 (1554.3, 1633.3)
Metro	22727	672518	3379.4	3585.1 (3536.8, 3633.9)
Ponce	5871	468023	1254.4	1327.4 (1292.7, 1362.9)
Total	75698	3159343	2396.0	2528.4 (2509.8, 2547.1)

Note. CI = confidence interval

* There were 198 missing regions and 186 missing age-groups that were not part of the data for confirmed cases.

Figure 3

Age-adjusted Incidence Rates vs Overall Social Vulnerability Index. Puerto Rico, 2020.

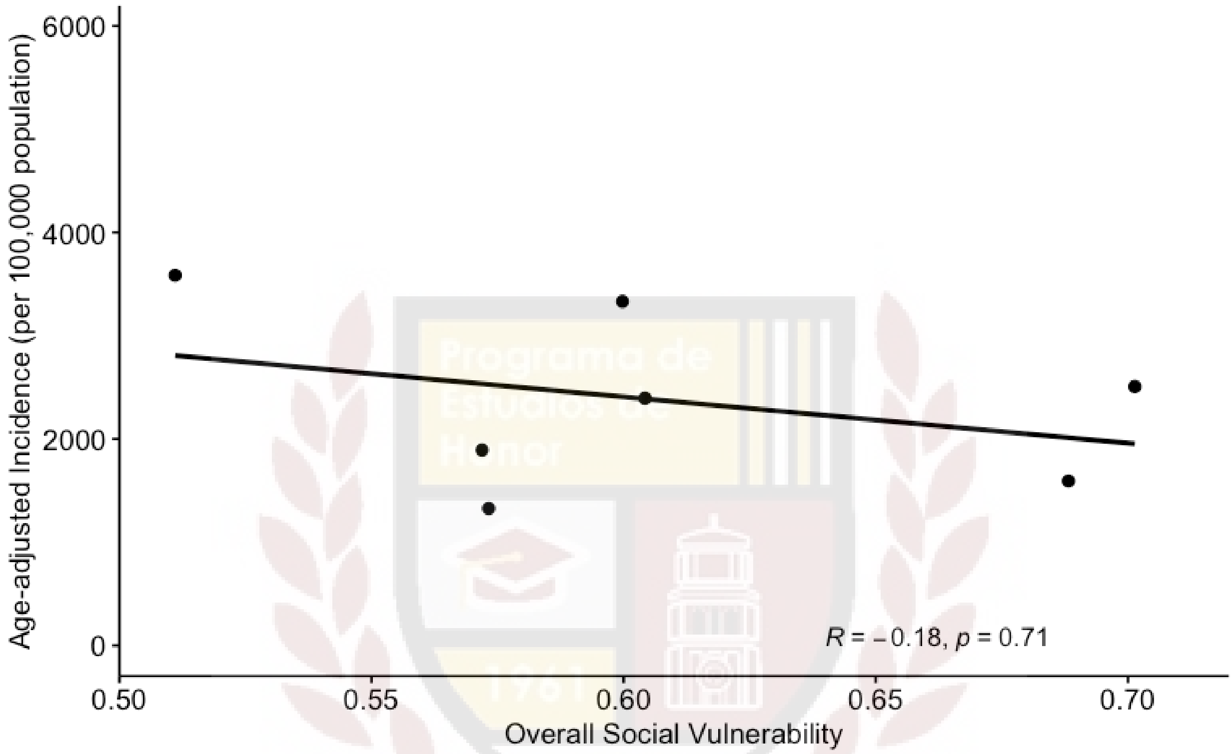

Figure 4

Age-adjusted Incidence Rates vs Socioeconomic Vulnerability Index. Puerto Rico, 2020.

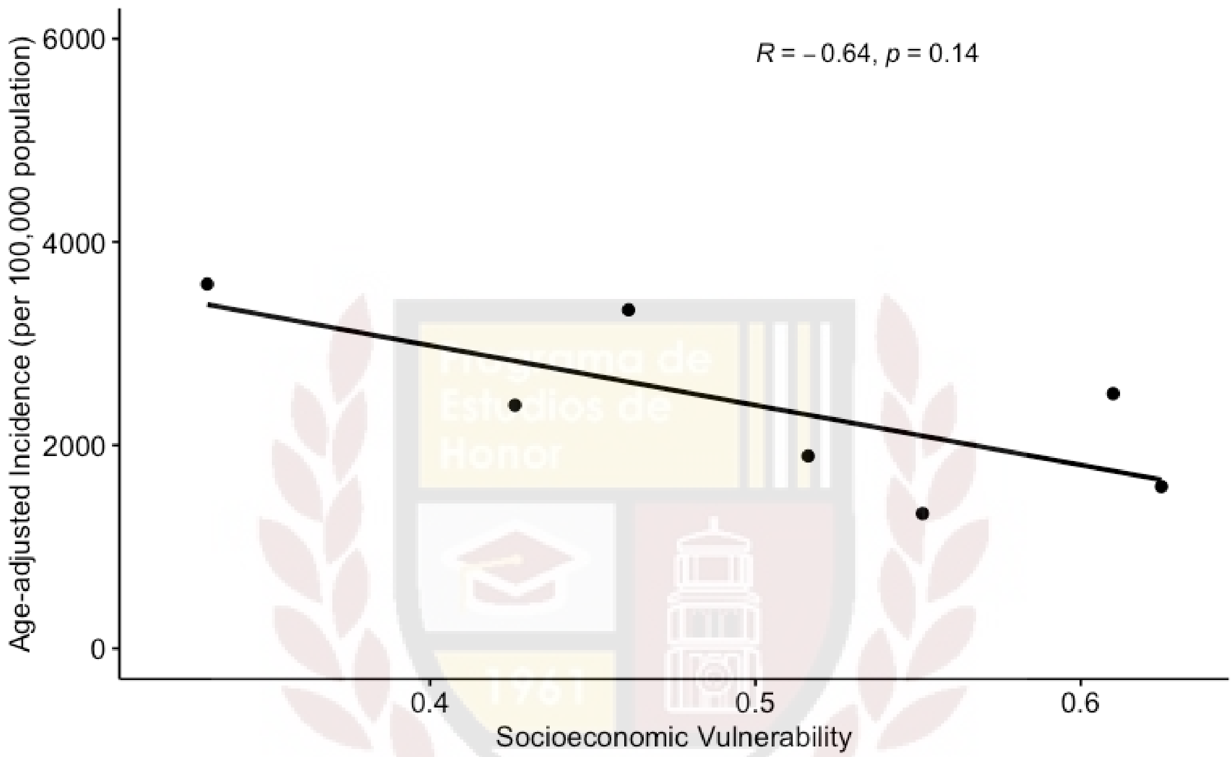

Table 9

*Age-Specific Case-fatality Rates due to COVID-19 by Region (per 100,000 population). Puerto Rico, 2020.**

Age-group	Arecibo	Bayamón	Caguas	Fajardo	Mayagüez	Metro	Ponce	Total
0 to 39	64.8	59.5	65.9	205.1	31.6	92.2	103.7	75.7
40 to 49	534.0	509.6	349.3	821.9	511.5	666.1	194.0	517.1
50 to 59	1403.2	1509.4	1943.5	2654.9	772.2	1587.3	932.4	1509.6
60 to 69	4142.7	3808.9	2645.5	4123.7	2828.9	3518.0	3321.0	3458.1
70 to 79	9135.4	9631.1	8675.8	8593.8	8151.1	8327.2	5978.3	8560.9
80 +	18996.4	23333.3	16883.1	17391.3	18699.2	16499.4	13333.3	18382.1

* There were 198 missing regions and 186 missing age-groups that were not part of the data for confirmed cases and 8 missing regions that were not part of the data for confirmed deaths.

Table 10

Crude and Age-adjusted Case-fatality Rates by Region (per 100,000 population). Puerto Rico, 2020.

Region	Deaths	Cases	Crude Case-fatality Rate	Adjusted Case-fatality Rate (95% CI)
Arecibo	175	9241	1893.7	2084.9 (1781.9, 2428.0)
Bayamón	356	17027	2090.8	2272.6 (2041.6, 2523.2)
Caguas	196	11952	1639.9	1864.6 (1611.1, 2148.4)
Fajardo	41	2047	2002.9	2279.6 (1604.3, 3187.2)
Mayagüez	122	6833	1785.5	1767.0 (1463.3, 2117.9)
Metro	434	22727	1909.6	1927.8 (1750.4, 2118.6)
Ponce	77	5871	1311.5	1474.8 (1159.7, 1854.0)
Total	1401	75698	1850.8	1972.9 (1870.3, 2079.9)

Note. CI = confidence interval

* There were 198 missing regions and 186 missing age-groups that were not part of the data for confirmed cases and 8 missing regions that were not part of the data for confirmed deaths.

Figure 7

Age-adjusted Case-fatality Rates vs Overall Social Vulnerability Index. Puerto Rico, 2020.

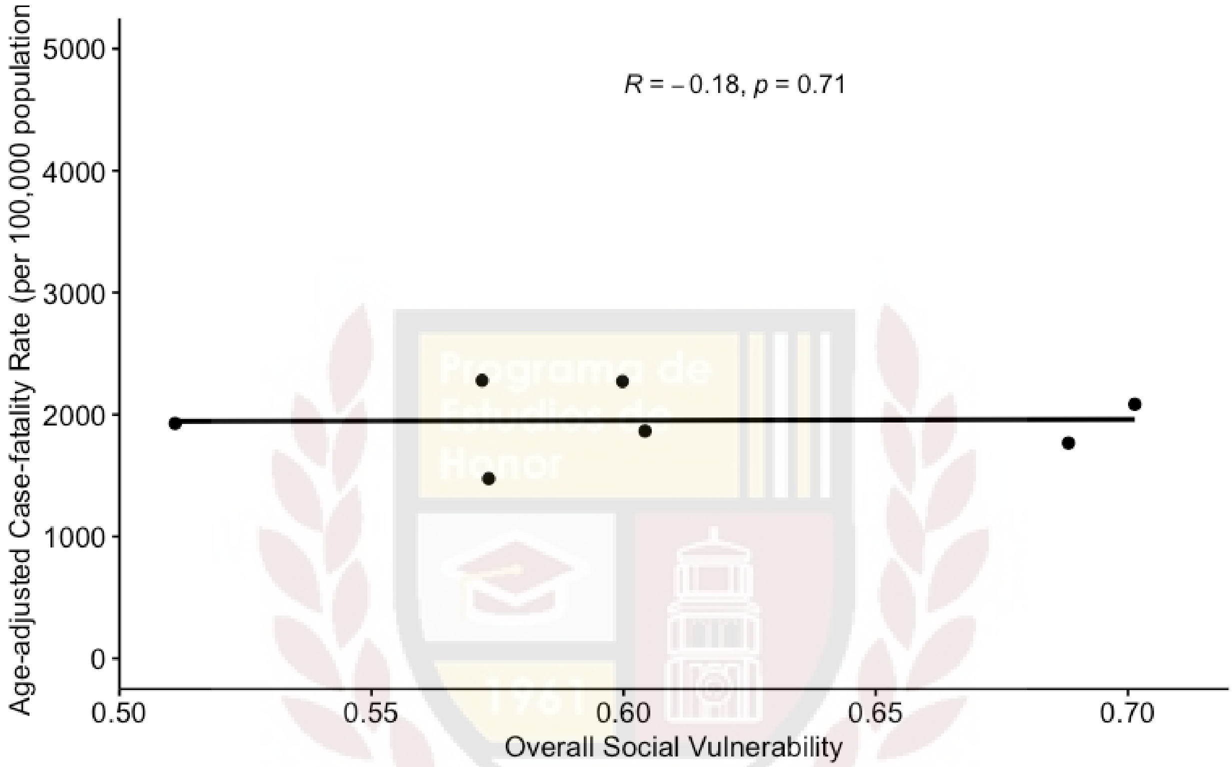

Figure 8

Age-adjusted Case-fatality Rates vs Socioeconomic Vulnerability Index. Puerto Rico, 2020.

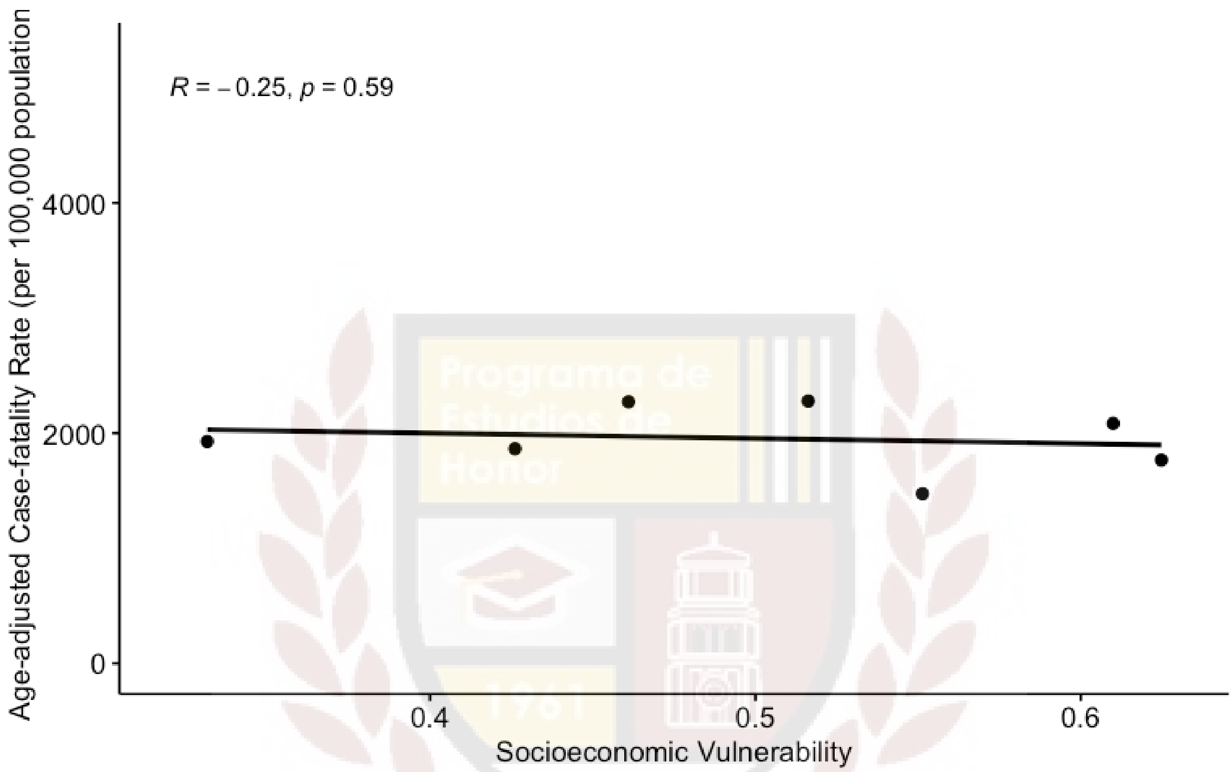

Table 11

Age-Specific YPLL Rates due to COVID-19 (per 100,000 population). Puerto Rico and Hispanics in the United States, 2020.

Age-group	Puerto Rico	United States (Hispanics only)
0 to 39	117.6	341.1
40 to 49	572.3	2043.3
50 to 59	1033.5	3907.9
60 to 69	965.8	5607.0

Age-group	Puerto Rico	United States (Hispanics only)
70 to 79	632.0	3793.5

Table 12

Age-adjusted YPLL Rates (per 100,000 population). Puerto Rico and Hispanics in the United States, 2020.

	YPLL	Population	Crude YPLL Rate	Adjusted YPLL Rate (95% CI)
Puerto Rico	14215	2967963	478.9	390.7 (384.0, 397.5)
Hispanics in the U.S.	853525	60229798	1417.1	1630.4 (1626.8, 1633.9)

Note. CI = confidence interval

Discussion

Estimating deaths and cases due to COVID-19 in the first stages of the COVID-19 pandemic may be difficult due to how data was managed and reported. During March 2020, the PRDoH went through different health secretaries, "all these administrative changes were a barrier to unify that information system that runs in the Department of Health, for both internal and external audiences" (Semanaz, 2020). "During the early stages, data and information exchange between testing facilities, the PRDOH, and the municipal authorities was deficient and unreliable" (Lamba-Nieves, 2021). In Puerto Rico, early lockdowns were put in place due to an already compromised health infrastructure; however, the government did not prepare for the eventual lifting of restrictions (Lamba-Nieves, 2021). "As a result, essential tools to contain the coronavirus were lacking, such as effective public education campaigns, widespread testing, reliable statistics, and a robust contact tracing strategy" (Lamba-Nieves, 2021). During the first half of year 2020, there was a severe lag in testing and tracing of COVID-19 cases (Semanaz, 2020). However, some local governments acknowledged the vulnerability and susceptibility of the residents and ensured adequate monitoring in the form of contact tracing; many of these were in the Ponce region (Lamba-Nieves, 2021). Considering the natural history of COVID-19, one in three COVID-19 cases will be asymptomatic (World Health Organization, 2022). Many presymptomatic or asymptomatic patients may infect others, but do not seek diagnosis do to being unaware of infection (Slifka & Gao, 2020; Moghadas et al., 2020; Subramanian & Pascual, 2021). In Puerto Rico, local programs of contact tracing permitted the identification of cases that could have potentially gone unreported due to lack of symptoms (Lamba-Nieves, 2021). Nonetheless, the poor initial surveillance at the beginning of 2020 could result in an underestimate of the incidence rate and an overestimate of the case-fatality rate. The case-fatality rate could also be overestimated if a person with COVID-19 in 2020 died in early 2021 due to the same infection from COVID-19 (Ritchie et al., 2020). Another cause for overestimation of the case-fatality rate may be if a person with COVID-19 was asymptomatic and did not have a reason to get tested. The age-adjusted case-fatality rate for Puerto Rico was 1972.9 per 100,000 persons or 1.97%, which was lower than the global cumulative CFR of 2.2% as of December 31, 2020 (Hasan et al., 2021).

In 2021, an investigation by the Centro de Periodismo Investigativo (CPI), indicated that populations with less income per cápita in Puerto Rico had less access to COVID-19 vaccinations after the first phase of vaccinations ended; this gives evidence to how the PRDoH did not establish an efficient plan to reduce health inequity (Sosa & Wiscovitch, 2021). Among the barriers to access to vaccinations, the lack of transportation was the most significant, especially in communities with older adults; and this could be applied to the access to testing facilities as well; which requires a referral from a doctor, posing another barrier (Sosa & Wiscovitch, 2021). In the Fajardo region, there are many communities with older adults without access to transportation and with less resources (Sosa & Wiscovitch, 2021). The use of internet to make appointments to get vaccinated hindered the vaccination of older adults that were in municipalities in the southeastern part of Puerto Rico, like Humacao (Sosa & Wiscovitch, 2021). Limited access to internet has been correlated with COVID-19 mortality in the United States (Lin, Paykin, Halpern, Martinez-Cardoso & Kolak, 2022). Based on data from the BioPortal of the PRDoH, the RT/PCR cumulative testing rates per 100,000 habitants during 2020 (March 12 to December 31) from highest to lowest were: Metro, 55,295; Bayamón, 43,365; Arecibo, 38,692; Caguas, 32,579; Ponce, 29,022; Mayagüez, 28,417; Fajardo, 24,983 (*Monitoreo de COVID-19 en Puerto Rico*, 2022). The lower testing rates for the Fajardo region could be an explanation of its high age-adjusted case-fatality rate relative to other regions. In addition, the Fajardo region had a low number of cases and deaths, this results in greater changes in the case-fatality rate if the number of cases or deaths change slightly.

Individual municipalities showed vulnerability indexes that were not expected due to these having higher poverty rates and higher percentages of older adults (Inteligencia Económica, 2020; Sosa & Wiscovitch, 2021). The PRSVI's differ greatly from an investigation funded by the Government of Puerto Rico, taken on by the firm Inteligencia Económica (2020). According to Inteligencia Económica (2020), "the five most vulnerable municipalities are Guánica, Arroyo, Loíza, Jayuya and Comerío. Guánica finds itself at the top of this list due to its high poverty rate and disabled population." In this study, the overall social vulnerability for Guánica, Arroyo, Loíza, Jayuya, and Comerío were 0.27, 0.79, 0.51, 0.77, and 0.68, respectively. The PRSVI for Guánica is 0.27 and the PRSEVI is 0.74. The cause of the lowering of the PRSVI could be the Household Composition and Disability index, this index was the only one negatively associated with the predicted number of days to electrical service after Hurricane

Maria in the study that created the PRSVI (Tormos-Aponte, García-López, & Painter, 2021). Using the PRSVI, the five most vulnerable municipalities were: Las Piedras (0.93), Juncos (0.93), Naguabo (0.92), Patillas (0.90), and Quebradillas (0.90). Inteligencia Económica (2020) found that the least vulnerable municipalities were Guaynabo, Dorado, Hatillo, Toa Alta and Gurabo. "These municipalities all show low poverty rates, high levels of per capita income, high levels of access to vehicles and low unemployment rates (Inteligencia Económica, 2020)." The PRSVI for Guaynabo, Dorado, Hatillo, Toa Alta and Gurabo were 0.46, 0.76, 0.82, 0.70, and 0.84, respectively. Using the PRSVI, the five least vulnerable municipalities were: Culebra (0.05), Peñuelas (0.10), Guánica (0.27), Maricao (0.36), and Caguas (0.39).

It is important to give context to what the social vulnerability index does not assess. For example, the overall social vulnerability of Culebra is 0.05 and its socioeconomic vulnerability is 0.39; however, the island municipality does not have a primary care center that is close, and with no invasive mechanical ventilation located in the island, emergencies require paramedical intervention while on helicopter or even plane, until a hospital on the mainland (Puerto Rico) is reached. This situation is not only faced in Culebra, but also in other rural municipalities like Adjuntas, Coamo, Jayuya, Las Marías, Maricao, Salinas, and Santa Isabel do not have a critical access hospital (García et al., 2020). For further research, it is necessary to involve an analysis of how the various components of health care access can influence COVID-19 health indicators in Puerto Rico. Culebra is part of the region of Fajardo, which had the highest age-adjusted COVID-19 case-fatality rate for Puerto Rico in 2020: 2.28% (CI: 1.60%-3.19%).

In the study for which the Puerto Rico Social Vulnerability Index (PRSVI) was created, there was "a statistically significant relationship between the PRSVI and the log mortality rate ratio (deaths due to hurricane María), controlling for the median days to power restoration crew deployment, social capital, urban area, density of government buildings, ruling party support, hurricane damage, and hospital proximity (Tormos-Aponte, García-López & Painter, 2021)". In addition, Social Vulnerability Index as calculated by the CDC was associated with increased COVID-19 incidence and death rates in the United States in 2020; however, the correlation was initially negative, then positive, and then negative again (Neelon et al., 2021).

The negative correlation of COVID-19 health indicators with the social vulnerability index is inconsistent with some studies that had been done in the United States in 2020 (Khazanchi et al., 2020; Dasgupta et al., 2020; Biggs et al., 2021). A possible explanation to the negative correlation is that counties with low vulnerability had re-openings or heightened surveillance due to increased testing rates during the moment that the negative correlation was found (Neelon et al., 2021). For this study, the Metro region had low vulnerability relative to other regions, but it had more available testing facilities, hospitals, ICU beds, airport traffic, and population density in comparison to other regions, affecting the mortality, incidence, and case-fatality rates. Some studies have found that higher population density in an area is associated to higher COVID-19 cases and deaths (Kadi & Khelfaoui, 2020; Roy & Ghosh, 2020; Yin et al., 2021). In Puerto Rico, municipalities with higher population densities are in the Metro, Bayamón, and Caguas regions (U.S. Census Bureau, 2020a). According to the Department of Health and Human Services, Office of the Assistant Secretary for Planning and Evaluation; (2017) for 2014, the amount of beds per resident was (in order of highest to lowest): Metro (4.2 beds per 1,000 residents), Fajardo (4.2 beds per 1,000 residents), Ponce (2.3 beds per 1,000 residents), Arecibo (2.1 beds per 1,000 residents), Caguas (2.1 beds per 1,000 residents), Mayagüez (1.8 beds per 1,000 residents), and Bayamón (1.3 beds per 1,000 residents).

Physicians in the island are poorly distributed, with many in the metro area (Perreira, Lallemand, Napoles, Zuckerman, 2017).

The age adjusted YPLL rate for Puerto Rico was much lower than that of Hispanics in the United States. The YPLL rates for Hispanics in the U.S. could be biased to the extent of the existence of misreporting Hispanic origin on death certificates due to these depending on an informant or observation, and the ethnicity information of the denominator of the YPLL rates is self-identified (CDC WONDER, 2021). Hispanics make up roughly 18.5% of the U.S. population (U.S. Census Bureau, 2020b). Social vulnerability for Hispanics in the United States can look different relative to social vulnerability for residents of Puerto Rico. Latinos in the U.S. may be susceptible to provider bias and have less access to culturally appropriate health care services (Hall et al., 2015; Velasco-Mondragon, Jimenez, Palladino-Davis, Davis & Escamilla-Cejudo, 2016). According to the CDC (2015), “About one in three Hispanics have limited English proficiency”, this is a factor of social vulnerability and a barrier to accessing adequate care. This does not necessarily apply to residents that are treated in Puerto Rico. When Hispanics in the United States are monolingual Spanish speakers, they are more likely to be occupationally exposed to COVID-19 (Rodriguez-Diaz, 2020). Many Latino migrants worked in meatpacking plants that remained open during 2020 and had experienced increases in COVID-19 deaths (Waltenburg, 2020; Rodriguez-Diaz, 2020). Many Hispanics in the United States work in frontline jobs and live in multigenerational households; therefore, they are exposed to COVID-19 more frequently (Centers for Disease Control and Prevention, 2020b; Cohn & Passel, 2018).

According to the literature, factors most associated with mortality from COVID-19 are cardiovascular disease, chronic kidney disease, respiratory disease, hypertension, congestive heart failure, diabetes, and cancer (Ssentongo, Ssentongo, Heilbrunn, Ba & Chinchili, 2020;

Deng, Yin, Chen & Zeng, 2020). A 2013 study by Tierney et al., found that municipalities in Puerto Rico had a range of 9.9% to 18.0% of diabetes prevalence in 2009, and a lower variability when compared to diabetes prevalence for all U.S. counties in 2008 (range of 3.0% to 18.2%). Further research on COVID-19 comorbidities by region in Puerto Rico is needed to assess the role of diabetes on COVID-19 incidence, mortality, and case-fatality rates in Puerto Rico. For 2020, the Behavioral Risk Factor Surveillance System for Puerto Rico showed that 8.4% of respondents had reported having myocardial infarction or coronary heart disease, 16.5% of respondents had been told they had asthma at a point in time, 15.8% of respondents had been told by a doctor they had diabetes at a point in time and 3.3% had been pre-diabetic (Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Division of Population Health, 2020). A study conducted from 2008 to 2011 found that the prevalence of diabetes in a sample of Hispanics in the United States from diverse backgrounds was 16.9% (16.11-17.69) (Schneiderman et al., 2014). For 2018, 11.5% of Hispanics had been told they ever had asthma (US Department of Health and Human Services, Office of Minority Health, 2021). Hispanic people are the largest population segment without health insurance coverage in the United States and their leading causes of death include heart disease, cancer, unintentional injuries (accidents), stroke, and diabetes (US Department of Health and Human Services, Office of Minority Health, 2021). A factor that could influence the difference in the YPLL rates between Puerto Rico and Hispanics in the U.S. is the initial date of lockdown. In Puerto Rico, the first COVID-19 death was documented on March 17, 2020, and by mid-March went into lockdown; meanwhile, in the United States the first COVID-19 death was documented on February 29, 2020, and lockdowns were put in place at different times in different states, mostly between mid-March and April (Lamba-Nieves, 2021; History.com

Editors, 2021; *First Day of Stay at Home Order in the United States*, 2022). In addition, Hispanics in the U.S. might be distributed in higher frequency in areas with higher population densities in comparison to Puerto Rico, which affects the transmission of COVID-19 (Brown & Hugo, 2013; Frey, 2019). Another factor is that in Puerto Rico there were no large protests in 2020; in the United States there were unmasked protests against COVID-19 restrictions and large protests for the "Black Lives Matter" movement, which affected COVID-19 transmission.

Conclusions

Contrary to the hypothesis, the age-adjusted incidence, mortality, and case-fatality rates in the Health Regions of Puerto Rico were not significantly correlated with the Puerto Rico Social Vulnerability Index and the Puerto Rico Socioeconomic Vulnerability Index. The low number of data points could account for the high p-values obtained. The magnitudes of the social vulnerability indices that employed the method of the CDC might not be representative of the social vulnerability of Puerto Rico when it comes to facing a pandemic. More geographic granularity and the consideration of several variables in addition to social vulnerability are needed to further understand how social factors influence COVID-19 health indicators in Puerto Rico. COVID-19 testing rates were lower in the Fajardo, Mayagüez, and Ponce regions (*Monitoreo de COVID-19 en Puerto Rico*, 2022). In addition to testing rates, COVID-19 comorbidities, and various aspects of health care access like hospital proximity should be assessed to further improve research on the vulnerability of Puerto Rico in the face of a pandemic. Early in 2020, the lockdown in Puerto Rico helped prevent the rapid spread of COVID-19; however, the surveillance system was not implemented efficiently to minimize the risk of resurgence of COVID-19 (Lamba-Nieves, 2021). Better strategies to mitigate inequity in COVID-19 vaccinations and surveillance should be implemented. As we hypothesized, the residents of Puerto Rico lost 76.0% less age-adjusted YPLL rate due to COVID-19 in comparison to Hispanics in the United States for year 2020. Hispanics in the United States were in states that may have had more flexible COVID-19 measures than Puerto Rico in 2020 and they found themselves at greater risk of exposure to COVID-19 through work (Centers for Disease Control and Prevention, 2020b; Waltenburg, 2020; Rodriguez-Diaz, 2020; Lamba-Nieves, 2021; *First Day of Stay at Home Order in the United States*, 2022).

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