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Exploring Physical and Mental Well-Being of Different Population Groups During the COVID-19 Pandemic as It Relates to Income Inequality

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ABSTRACT

Main: COVID-19 has been reported to impact populations on the international, national, regional, community, and individual level in terms of income inequality (ININ) and socioeconomic status. The primary aim of this narrative literature review was to assess the associations of SARS-CoV-2 infection risk, COVID-19 mortality, and ININ on physical and mental well-being. The WHO classifies health equity as factors of structural determinants (gender, ethnicity, education, occupation, and income) and intermediary determinants (living and working conditions, resource access, behaviors, and psychosocial factors).

Search Methods: The search strategy for the literature of this review was conducted utilizing PubMed with articles published during 2019 to 2022. 24 publications were included in this review with a focus placed on ININ as an aspect of socioeconomic disparity where information was available.

Results: 87.5% of the included articles reported that socioeconomic status or ININ during the COVID-19 pandemic was associated with populations in lower socioeconomic or income brackets. 29.2% of the included literature incorporated intermediary health determinants in addition to structural determinants.

Conclusion: There is a unanimous consensus that international ININ and COVID-19 infection, mortality, and hospitalization are linked. Individuals with lower degrees of education, income brackets, people with disabilities, occupations which require less higher education, and ethnic minorities are all at risk for increased COVID-19 infection. A plethora of information is readily available to advise future policy decisions regarding swift pandemic responses, but additional individual level studies are needed to provide causal links regarding ININ, physical, and mental well-being during the COVID-19 pandemic.

SUMMARY

COVID-19 impacted populations on the international, national, regional, and community level. These impacts were felt in countless sectors of society, resulting in shockwaves that we are just beginning to understand the gravity of. One of these areas that has become clearer includes the global impact on income, income inequality, and physical and mental well-being. It has been well accepted in the international literature that members of society who were considered more disadvantaged than others experienced the COVID-19 pandemic differently. Households in lower income brackets have been more at risk to COVID-19 infection and more severe disease than of those in higher income brackets. A similar statement can be said about those with less higher education, in occupations which pay less, or other single parent households; all experienced the pandemic with a greater risk to SARS-CoV-2 infection and/or death from COVID-19. This has been echoed on an international scale at the time of this writing and during the pandemic. Multiple studies were conducted to aid in understanding this picture, but few studies reported on income and income inequality on the household or individual level. The World Health Organization considers the big key factors for health equity to be social class, income, education, gender, ethnicity, employment type and employment conditions (i.e., workplace safety), housing conditions (i.e., access to clean water), behavioral factors (such as mask use), and psychosocial factors (i.e., social support). Income and income inequality are important to explore due to the impact that income has on an individual's access to vital resources; something that ultimately has the potential to impact their physical and mental well-being. Few studies reported results in which COVID-19 cumulative incidence and mortality increased for individuals in higher income brackets during the beginning waves of the COVID-19 pandemic. This has been thought to be due to members of society in higher income brackets having access to freedom of movement and increased mobility through travel, increased business practices, etc. With few studies reporting on explanatory reasons pertaining to the associations of income inequality, different waves during the pandemic, and COVID-19 risk factors on the individual or household income level, much remains unexplored in terms of fully comprehending income inequality during the COVID-19 pandemic, especially as it relates to physical and mental well-being. Although not as commonly considered in the mainstream media, COVID-19 and income inequality provide an important intersection gap in the international literature, leaving room for further empirical studies.

MAIN

Income inequality (ININ) can be defined as the unequal distribution of capital and wealth in a population. Depending on the reference population of interest, this unequal distribution occurs across individuals, households, municipalities, or across nation states. Additionally, variation of income inequality and income can occur between groups of interest and within the groups themselves, making it crucial to consider these variations in the initial study design. Different metrics can be utilized and compared, depending on the working definition of income at that point in time (often termed 'operationalizing income' in the literature). I will provide an overview of the concepts and definitions that are relevant to income, ININ, and how this was studied during the COVID-19 global pandemic in the international literature. Moreover, what associations existed at the intersection of COVID-19, ININ, mental well-being, and physical well-being?

Concepts and Definitions

The concept of unequal socioeconomic distributions is a component to the disassociated field of socioeconomics attempting to explain the dynamics of social capital (Hellmich 2017). Socioeconomic status is commonly defined as the overall contributing components to the position and access to resources an individual has within society. Individuals or households are separated into tiers of low, medium, and high with three key determining factors for each tier: income, occupational position, and educational attainment (Galobardes 2006). It has been widely reported that socioeconomic status is related to health outcomes, class, and is ultimately connected to mortality and quality of life that ripples through generations (Mackenbach et al. 2008; Ingleby et al. 2022; Sow, Raynault, and De Spiegelaere 2022; Stafford, Keitt, and Irvin 2022; Balaj et al. 2021). These mentioned studies and widespread metanalyses are able to associate socioeconomic status playing a contributing role to childhood mortality (Balaj et al. 2021), mental health (Liu et al. 2022), and access to resources (Phelan, Link, and Tehranifar 2010). Throughout the literature, ININ, socioeconomic status, economic inequality, and financial inequity all seem to be used interchangeably. This review will maintain ININ as being defined as income, capital, wealth, or the collection of financial resources. Socioeconomic inequality will be defined as the collection of factors that differ across populations in relation to socioeconomic status (income, education, and occupational position). A clear description of socioeconomic status allows for the exploration and expansion of the individual factors that contribute to socioeconomic status, namely income.

During the COVID-19 pandemic, research relating directly to SARS-CoV-2 became a primary and needed focus. Research boomed as scientists and academics across the globe came together to further understand the virus that caused mass infections and led to global lockdowns. Although there are still many questions to explore, the focus for some is shifting to the impacts and aftermath of COVID-19. More than two years after the start of the pandemic, we are only beginning to understand the societal impacts that have resulted. At the time of this writing, The World Health Organization has stated that 6.3 million deaths have been reported as a direct result of COVID-19 (Geneva: World Health Organization 2020) and the deaths associated due to the global excess mortality from COVID-19 are estimated at almost 15 million between 2020 and 2021 (Geneva: World Health Organization 2022, 9). With researchers now asking questions pertaining to these impacts, we are just beginning to contend with these after-effects. One area of interest includes untangling the different experiences during the pandemic from people across varying socioeconomic backgrounds. Many studies have reported on the impact of COVID-19 regarding ININ on differing populations (Upshaw et al. 2021; Brown et al. 2021; Wachtler et al. 2020; Khanijahani et al. 2021), but the literature is lacking in measurement consistency across income and ININ. Furthermore, few studies have operationalized income and ININ in a reproducible manner, have been able to report on impacts at the individual level, or have made income comparisons by utilizing data obtained prior to 2020 and data obtained during 2020-2022. To be able to compare international ININ, the primary component, income, must be described and operationalized.

Wealth and Income

Income and capital are unanimously considered as important factors when evaluating socioeconomic status, physical and mental health inequalities, and access to resources. Income and wealth may provide opportunities, increase mobility, and aid in a community's ability to self-sustain itself. Definitions for wealth, capital, and income vary across the literature and must be operationalized according to the definition prior to utilizing them in making inequality assessments. Once defined, relevant comparisons across populations or countries can be made.

To define income and wealth at the fundamental level, I use the definition adopted by the World Inequality Database (WID) (http://WID.world) which includes the net calculation (after tax) of net primary income and net secondary income. Wealth and income on the household level equating to primary income can be separated into four components: compensation of employees, property income, net operating surplus, and net mixed income (Blanchet et al.

2021). Compensation of employees can be regarded as wages, salaries, social contributions from employers, or any income obtained from employment. Property income, when subtracting interest payments and other payments made by unincorporated establishments from the utilization of land or natural resources, includes income obtained from interest and investments on properties, distributed income of corporations, reinvested earnings on foreign direct investments, and income from offshore tax havens. Net operating surplus and net mixed income reporting can vary per country and may provide varying levels of information, at times being reported in an additive manner. WID classifies net operating surplus as actual rental income received by landlords and/or imputed rental income of owner-occupied residences. WID classifies net mixed income as compensation from wages and profits resulting from ownership of unincorporated establishments (enterprises) (Blanchet et al. 2021). Wealth and income on the household level equating to secondary income (after subtracting social contributions such as social health insurance contributions) includes social benefits or governmental subsidies resulting from social security in the form of cash, social pension benefits, and other social assistance benefits that result in cash value (Blanchet et al. 2021). Following income distinctions, differing ININ measures must be considered; not every comparison measure is equal.

Income Inequality Measures

ININ relates to the distribution of income and wealth within a particular society or a particular population group of interest (Trapeznikova 2019). ININ can be measured in a myriad of ways, with each technique having its strengths and weaknesses. The most common methods observed in the literature include the Gini coefficient, income deciles, relative income quartiles, availability of disposable income, and income quintiles or other quantiles (also termed the P80/P20 method). Income redistribution can also be measured based on redistribution of the overall capital in a population. ININ measures are difficult to compare if income is not operationalized in the literature in a reproducible manner, making it difficult to make distinctions across studies.

ININ is most frequently measured utilizing the Gini indices or the Gini coefficient (see Figure 1). The Gini coefficient uses the concept of the Lorenz curve to define the distribution of wealth in the population. A society where wealth is distributed equally would result in equal quantiles fractionating the total income for the society (the red 45-degree line of equality in Figure 1). The Lorenz curve (the dark curved line in Figure 1) uses this principal of equality to calculate

the Gini coefficient (G) by calculating the size of the area between the 45-degree line and the Lorenz curve and dividing it by the total area under the 45-degree line G = A / (A + B) (De Maio 2007). Once the Gini coefficient is calculated, it can be utilized as a summary statistic of a population's income distribution with values ranging from 0 to 1 and higher values indicating larger income inequalities.

The generalized entropy (GE) index and the Atkinson index each are methods which include sensitivity measures within the calculations by applying weights to specific areas of the income distribution (such as at the top or bottom of an unequal distribution) (De Maio 2007). Another common method to measure inequality includes the use of quantile ratios for comparing populations. The quantile ratios (often P80/P20) is calculated by taking the upper 10% or 20% of income at the household level and dividing it by the household income from the lower 10% or 20% (De Maio 2007). Quantile ratios are commonly observed in the literature as quartiles, quintiles, or deciles. Quantile ratios are easily calculated to make swift comparisons across groups (assuming equal comparisons across income sources). The studies included within this review compared ININ using either the Gini coefficient, income deciles, or quantile ratio comparisons on income including regional or national income, before tax (gross) income, and after tax (net) income.

Defining Populations

As mentioned above, populations in the literature have large amounts of variation amongst each other in terms of income and ININ. Some studies are conducted on the individual, community, zip code, county, regional, district or country level. Most of the literature has compared countries on an international level or compared regions within a single country. Adults are mainly the focus of interest due to them being the primary income earners of a household (although one correlation study utilized survey data from individual families enrolled in a youth study to perform pattern learning analyses from recorded participant surveys (Yip et al. 2022).) Some studies have included members of a household by assigning scores and ranks depending on the social status of the family member and the overall contribution that family member has on the total household income. A single individual will have a differing financial burden when facing unemployment compared to a single parent household. Economists have made it a priority to consider these household dynamics when conducting individual level studies. Few studies have operationalized income and ININ measures such as to be able to make comparisons on the individual or household level. Regional compared to

individual level studies can be beneficial when attempting to evaluate the effects from implementing new policy measures or when equating differing pandemic responses across nations. After having the relevant concepts and definitions laid out, I will provide the theoretical framework that is used to consider ININ as it relates to well-being.

Theoretical Framework and Hypotheses

This review aims to explore the reported health impacts from ININ that various populations encountered during the COVID-19 global pandemic as well as possible mechanisms to explain these impacts by reviewing primary literature, narrative reviews, and systematic reviews. To do this, multiple interdisciplinary fields need to be bridged by uniting different schools of thought in socioeconomics, sociology, and public health epidemiology. With these goals in mind, an overview will be provided for the relevant definitions of income and income measures, socioeconomic theories, and the relation to COVID-19 epidemiology will be provided. This review's primary aim is to review what the international literature has reported on the existence of the ININ during COVID-19, the associations between ININ and well-being, and what is not known about ININ in COVID-19 public health contexts. I hypothesize that ININ was associated with well-being during the COVID-19 pandemic following the well-accepted consensus that ININ is associated with individual health outcomes in public health contexts (Bor, Cohen, and Galea 2017). To be able to solidify the rational answering these questions, the framework used by the World Health Organization is considered as a reference for global health equity.

Solar and Irwin Framework and Pandemic Policy

The Solar and Irwin Framework from the World Health Organization (World Health Organization 2010) has been designed as a global reference to understand the relevant theories, the importance of health equity in public health, and the intersection of policy that exists within these contexts. Using this framework, we have a reference point for what to strive for when we are trying to increase well-being across humanity. Below, some of the theories and key points of this framework are outlined to explain the significance of considering ININ in public health contexts.

When examining social determinants of health inequalities, the main focal points include the structure of society, the societal stratifications and dividing factors, and the related differential consequences that result from these factors. Each of these focal points impact the preceding

components, ultimately instituting feedback loops for the entire system. Although many factors may influence socioeconomic status and societal stratification, the biggest influencers include income, education, gender, ethnicity, occupation, and social class (World Health Organization 2010). Figure 2 shows the amalgamation of policy, culture, and socioeconomic factors that ultimately contribute to well-being. From a top-down approach, policy is instituted to either resolve an issue that presented in society or streamline an existing process. Following policy development and enactment, the related population begins to experience the effects from the implemented policy. This implementation impacts each subgroup in the population to a varying degree. To provide an example from (Cohen and Botz 2022), consider the impact from mandated seatbelt laws in the United States in relation to traffic fatalities. It has been well established that seatbelts successfully lower automobile fatalities, but it was important for policy to be implemented to aid the population in this safety measure. Cohen and Liran explained the importance of this safety policy enactment by showing that local areas with seatbelt laws lowered overall traffic fatalities. This concept is transferred over to multiple avenues of social and public policy including housing policy, public health policy, education policy, and social protection policy. Enacted policy on the population level plays a role in the overall health and well-being on the individual level. It is important to keep in mind that the concepts and policies from the Solar and Irwin Framework (and any framework that alters policy) are not instituted in a vacuum, so the resulting influence makes an impact at the population level. The Solar and Irwin Framework explains the possible mechanisms to how this happens.

Public health policy measures during COVID-19 were implemented at varying degrees across countries, regions, and towns, ultimately impacting that regional target population. Some policy measures were successful in reducing the spread of infection and the overall mortality rate, while others were seen to do just the opposite (Hale et al. 2022). This diversity in public health policy was replicated in all sectors relating to the pandemic response. Some countries successfully offered financial support to citizens in need with hopes of mitigating an increase in ININ during the COVID-19 pandemic, while others were not able to offer such support. Similar scenarios occurred following the availability of COVID-19 vaccines, crafting global vaccine inequity; higher income countries had the financial capacity to implement a vast and strategic vaccination campaign. This illuminated existence of varying health equity on an international, country, and community level. Reflecting on the unevenness experienced during the COVID-19 pandemic, the Solar and Irwin Framework provides a thorough overview of the

important factors to consider in terms of social capital, health systems, and material circumstances.

Following the contribution from governance on these socioeconomic factors (Figure 2), the intermediary determinants pillar of the Solar and Irwin Framework involves individual level contexts such as physical circumstances (safe and sanitary housing, nutrition access), behaviors and biological factors, and psychosocial factors. It has been well recognized, for example, that employment environments can have acute and/or long-term impacts on an individual's health. Essential workers were expected to work in demanding, at times unsanitary, working conditions during the pandemic to sustain themselves and their families. Some of the economic sectors which highlighted these health disparities included livestock plants. With few other options, these members in society are at higher risk for contracting and spreading COVID-19 amongst themselves and their surrounding communities (Taylor et al. 2021). As portrayed from positive and negative feedback loops, these pillars are complex adaptive systems which vary across nations with an ultimate impact on individuals, community health, and well-being.

In addition to governance and policy, the framework also emphasizes the role of the distribution of power in a population. Power has the potential to mold how a community operates. These power dynamics ripple throughout the society and influence the success or failure of public health. When members of a community have an equal distribution of power, agree, and feel supported, a foundation of trust is established. When analyzing perceived happiness in a society, a common perception that occurs for an individual can be explained as the tunnel effect (Davis 2019; Hirschman and Rothschild 1973). This concept describes individual satisfaction in society following the awareness of success from members in parallel socioeconomic positions to themselves if they are under the impression that someone else's success also equates to success for themselves. The satisfaction obtained from the perceived success of close individuals can also work in the opposite manner, causing distress if societal counterparts experience disadvantageous socioeconomic occurrences. This concept is utilized to explain the amicability of members in the society succeeding unilateral economic gains that are miniscule. With the relevant theoretical and conceptual topics laid out and compared, I will report on what the international literature has reported on the associations of income inequalities and COVID-19.

SEARCH STRATEGY AND METHODS

The search strategy for the background literature of this review was conducted utilizing PubMed with articles published during the dates 2019-2022. These dates were utilized to ensure that articles regarding COVID-19 were captured. The search terms utilized to conduct this search included: COVID-19, SARS-CoV-2, ININ, socioeconomics, socioeconomic inequality, social inequality, financial inequity, and household income.

RESULTS

Table 1 shows an overview of the studies (n = 24) included within this narrative review with listed information including author and year, the population domain included in the publication, the ININ measure, the specific definition of income that the study operationalized on, and the relevant outcomes or key takeaways. Bias and study design methods are also listed in Table 1 including data collection methods, timelines, measurements, variables, and the reported structural and intermediary determinants of interest in terms of socioeconomic status, well-being, and ININ. A focus was placed on ININ as an aspect of socioeconomic disparity where information is available.

Health Determinants and COVID-19

The majority of studies [87.5%] included within this narrative review reported that lower socioeconomic status was either highly correlated with COVID-19 infection risk, COVID-19 mortality, or was associated with increased COVID-19 hospitalization and severity. Table 2 provides an overview of the proportional measures including the population location (international, country, or regional), studies including an individual level analysis, and studies including a longitudinal study design. Some studies [29.2%] included intermediary determinants in addition to structural determinants when utilizing the Solar and Irwin Framework as a reference. The intermediary determinants encompassed living conditions, working conditions, residency crowding, access to running water, behaviors such as mask use, and the existence of social support for individuals. Only one international study was considered longitudinal by design (Sepulveda and Brooker 2021) and operationalized on national median income per capita. The listed publications reported income operationalized as net household or individual income, monthly income, median per capita income, disposable income per capita, regional income, GDP per capita, or household income estimated from rent contributions. A single study operationalized income as a net income per person equivalence factor by utilizing census data, zip code income measures, and household sizes (Xia et al. 2022).

A key driver of this research on ININ involves the relationship to mental and physical health. It has already been reported that socioeconomic status impacts health, but COVID-19 was able to highlight this in a new way. While the pandemic affected us all on varying levels, one of the illuminating aspects that resulted from the pandemic consisted of the ways in which different countries and even different populations were able to cope with the pandemic. This revealed to us the strengths and weaknesses of the social structures that exist in our communities. Few studies reported on mental and physical well-being during the COVID-19 pandemic as it relates to ININ or socioeconomic status.

The Solar and Irwin Framework's included psychosocial factors and behaviors as intermediary determinants of health (inequality) were found to be relevant during the COVID-19 pandemic in terms of infection status, the spread of COVID-19, or COVID-19 treatment. Although most studies reported on structural determinants, studies that did report on intermediary determinants also reported on structural determinants (Delaporte, Escobar, and Peña 2021; Huyser, Yang, and Yellow Horse 2021; S. B. Kim and Jeong 2022; Sepulveda and Brooker 2021; Tan et al. 2021; Upshaw et al. 2021; Yip et al. 2022). A zip code level regional study on the population in New Mexico, U.S.A. found that COVID-19 cases were associated with disadvantaged populations at a higher level in areas consisting of indigenous populations compared to other populations in the region (see Figure 3) (Huyser, Yang, and Yellow Horse 2021). Huyser et al. 2021 assessed associations by considering housing characteristics such as living conditions, all available income including government subsidies, education, unemployment rate, poverty rate, and confirmed COVID-19 cases. Huyser et al. 2021 also reported on associations involving living conditions such as the availability of clean water and adequate access to vital resources when comparing COVID-19 incidence in geospatial contexts. Very few studies to date have explored indigenous communities, ININ, and COVID-19. When assessing these characteristics, the authors determined that concentrated disadvantages were spatially associated with COVID-19 cases. In Figure 3, the red portion overlaid on the state reflects areas which had a very high association of disadvantage and COVID-19 cases. This is interesting due to the area covering some of the indigenous or native American nation areas in New Mexico, as well as being an area that does not include the most populous city, Albuquerque. The yellow also reflects a high association of disadvantage and COVID-19 cases, includes indigenous or native American nation areas, but also includes highly populated areas. The areas in the southeast of the state were found to have negative associations. This study highlights the

importance of geographical and ethnic considerations when exploring structural and intermediary determinants of health in pandemic contexts.

A similar analysis from (Abedi et al. 2021) reported on the associations between ethnicity and COVID-19 infection and mortality at the county level in the United States with included variables such as mobility, ethnicity, poverty level, median income, education, and disability. Abedi's group uniquely had a focus on disability disparities across counties when assessing COVID-19 infection and mortality rates, concluding that higher levels of mortality were associated with smaller populations, higher poverty, and higher disability rates (with an insignificant coefficient resulting from the poverty and disability interaction). It was hypothesized that larger cities have the available resources to institute a substantial pandemic response compared to smaller cities. Figures 4 and 5 depict the association of COVID-19 infection rates and COVID-19 mortality rates with the total county population, median income, and non-Hispanic ethnicity in California and Pennsylvania, U.S.A. There is a clear visual association between ethnicity and increased mortality in California, U.S.A. and a clear visual association between median income and mortality in Pennsylvania, U.S.A.

A highly powered individual level study from Sweden (n = 7,775,064) was conducted to assess COVID-19 hazard ratios with socioeconomic and other demographic risk factors. This study is unique due to the interconnected and detailed nature of Sweden's healthcare data, demographic characteristics, and socioeconomic health determinants. It was reported that less individual income, being male, having lower education, and being a single parent had a higher mortality risk from COVID-19 while including all other causes of death. Being a migrant from lower/middle income countries predicts a higher risk of COVID-19 mortality but not for other death causes. Figure 6 provides hazard ratios from dying of COVID-19 in Sweden between March 2020 and May 2020. Visually, those who are male, never married, only have primary school as an education level, are in the lowest income bracket, or are from a low/middle income country have a higher hazard ratio from dying due to COVID-19 compared to their reference.

DISCUSSION

Although the ININ and COVID-19 literature on the individual (household) level is sparse, several studies have reported on regional or international analyses. Almost every analysis (individual, regional, or international) found an association with COVID-19 incidence or mortality with ININ. These measures ranged from comparisons utilizing regression analyses,

principal component analysis, systematic reviews, survival analysis, correlation studies, stochastic kernels, or microsimulations. All publications included within this review who reported at the individual or household income level found health disparities and lower socioeconomic status to be significant variables when considering COVID-19 outcomes except for (S. B. Kim and Jeong 2022; Grabka 2021). Grabka 2021 stated that the conclusion of decreased ININ was most likely due to a drop in income from self-employed individuals (Grabka 2021). Kim and Jeong 2022 reported an increased COVID-19 infection risk for those in higher socioeconomic brackets compared to others, paralleling two studies in the meta-analysis findings from (Wachtler et al. 2020) during the first wave of COVID-19. It was hypothesized that an increased COVID-19 infection or mortality risk for those in higher socioeconomic status brackets were observed within individuals in the early stage of the pandemic due to increased means of mobility or travel. These risk factors changed during the second wave of the pandemic once lockdown measures and mobility restrictions were put into place (Wachtler et al. 2020).

Regional ININ reports included outcomes analyzing COVID-19 severity, cases, mortality, tests, regional incidence, and hospitalization. Income and ININ were primarily measured with income per capita and the Gini coefficient, respectively. A new index was created from (Chen, Gozgor, and Koo 2021) termed as the World Pandemic Discussion Index (WPDI) with the aim of filling in the missing components of the ININ and COVID-19 literature by measuring words surrounding uncertainty. The WPDI is modeled off of the world uncertainty index which aims to measure consumer, economic, or financial uncertainty in the presence of certain world events (Ahir, Bloom, and Furceri 2022) by quantifying words relating to uncertainty in published governmental reports, policy, etc. in international contexts. Pairing uncertainty related words with data from outcome variables like country level GDP growth rates, election data, wars, climate change, etc. can be associated with levels of poised risk surrounding the indicated outcome (Ahir, Bloom, and Furceri 2022). Using this discussion index, uncertainty can be measured via text mining. It was reported that a positive association existed when observing ININ and the WPDI in 34 Organization for Economic Co-operation and Development (OECD) countries and a negative association with 104 non-OECD countries (Chen, Gozgor, and Koo 2021). Associations of pandemic related uncertainty at the country level in OECD and non-OECD countries with ININ is an interesting find, further solidifying similar associations found from other ININ studies.

Limitations that exist within this narrative review include the fact that selection bias is possible due to a single individual conducting most of the literature search. Furthermore, with the wide range of population domains, comparisons and replications across studies are difficult to compare. Unfortunately, a lot of information is lost with the broad level studies at the regional or country level. Lastly, termed as the ecological fallacy, it is important to consider that it is not logically sound to generalize at the individual level when utilizing group or population level data.

As mentioned before, future studies should focus on assessing income at the individual level when exploring ININ. ININ and COVID-19 is complex with few streamlined approaches to explore social determinants in health. Underexplored concepts for future studies include the impact of unemployment in relation to health insurance from COVID-19 patients (Khanijahani et al. 2021), the impact of COVID-19 and policy measures on social well-being, individual level studies with income operationalized at the household level that explore ININ with COVID-19 in geospatial contexts, and additional studies in Latin American countries. Most of the present studies have been conducted in the United States or Europe, leaving gaps in the international literature in terms of global ININ. As recommended from Friedman et al. 2021, analyses should be conducted exploring the impact and quality from subsidies and welfare systems that were utilized during the pandemic (Friedman et al. 2021). Furthermore, efforts should be made to standardize and improve our social welfare systems by evaluating them with ININ and health equity in mind.

CONCLUSION

When contrasting the literature from the varying waves of the pandemic, there is a unanimous consensus that ININ and COVID-19 infection, mortality, and hospitalization are linked and interconnected. Individuals with lower degrees of education, in lower income brackets, people with disabilities, occupations which require less higher education, social class, and ethnic minorities are all at risk for increased COVID-19 infection. Although current studies remain ecological, few (if any) causal studies have been conducted. To date, there is enough evidence to improve future policy either relating to COVID-19 or future pandemic response measures. ININ is an economic and social issue that society has the capability to resolve. With the Solar and Irwin Framework in mind, health equity, well-being, and equality across social structures should be a top priority moving forward. International publications have reported on ININ and

the associations to COVID-19, but further studies reporting on the causal roles are needed to further expand upon the current global picture of ININ and COVID-19.

Table 1: COVID-19 and income inequality (ININ) association studies on the regional or individual level. A focus is placed on ININ as an aspect of socioeconomic disparity where information is available.

Author	Population; n	Income Inequality (ININ) Measure	Income Measure	Key Takeaway	Study Design Methods
Abedi et al. 2021 (Abedi et al. 2021)	n = 102,178,117, 369 counties: U.S.A.	NA	County level median income	Counties are at higher risk of COVID-19 when considering an increase for all the following: diversity, population, education, income, and lower proportion with disabilities. Counties with a greater proportion with disability and poverty have a higher death rate.	County level with 44 measurement variables for patient socioeconomic and determinant information obtained in April 2020.
Bruce et al. 2022 (Bruce et al. 2022)[1]	National survey, n = 13,590 random households: U.S.A.	NA	Household gross annual income: less than 25k, 25k-49,999, 75k-149,999, >= 150k	Analysis on financial vulnerability during COVID-19 based on national survey. Hispanic respondents, those with less than B.Sc. and with more than 1 health risk factor were more financially vulnerable. Individuals who were financially at risk were 6 times more likely to experience lower household income during COVID-19.	Multivariate linear regression with 6 socioeconomic variables. Bias due to underrepresented black community and overrepresented Asian community. 40 question survey administered in May 2020.

Author (Cont.)	Population; n (Cont.)	Income Inequality (ININ) Measure (Cont.)	Income Measure (Cont.)	Key Takeaway (Cont.)	Study Design Methods (Cont.)
Chen et al. 2021 (Chen, Gozgor, and Koo 2021)	34 OECD countries, 104 non-OECD countries.	Gini coefficient	Net income	There was a positive association with ININ and the World Pandemic Discussion Index (measuring pandemic uncertainty in Int. reports from text mining) in 34 OECD countries and negative association with 104 non-OECD countries.	General least squares estimation. World Pandemic Discussion Index to link ININ measured in 141 countries from 1996 to 2020.
Christi et al. 2022 (Christl et al. 2022)	Austria	Gini coefficient, Quintile ratio (P80/P20), Redistribution index, and Decile ratio.	Household disposable income	Women experienced greater loss – market income. Low-income households were affected more during COVID-19; subsidiary benefits helped level this.	Micro-simulation with data from March to December 2020. Includes government subsidiary income.
Çitak et al. 2022 (Çıtak and Pekçolaklar 2022)	197 countries	Gini coefficient; Quintile ratio P80/P20; Human Development Index (HDI)	GDP per capita	ININ was positively associated with COVID-19 tests.	Correlation analysis, multivariate linear regression. Data from 2020 or most recent published data.
Dauderstädt 2022 (Dauderstädt 2022)	Between and within the EU	Quantile ratio P80/P20	Disposable income and GDP per capita	GDP was lower for most countries in 2020 compared to 2019. Savings habits increased during 2020. Global inequality decreased until 2020, then reversed. It is projected that ININ will increase within countries for lower income countries.	Compares 2019 country GDP data to 2020, obtains quantile ratio income data from countries with published data.

Author (Cont.)	Population; n (Cont.)	Income Inequality (ININ) Measure (Cont.)	Income Measure (Cont.)	Key Takeaway (Cont.)	Study Design Methods (Cont.)
Delaporte et al. 2021 (Delaporte, Escobar, and Peña 2021)[1,2,5]	20 Latin American and Caribbean Countries	Gini coefficient	Individual annual labor income	ININ and poverty increased in most countries studied, highest in El Salvador for Gini coefficient. Estimated labor income loss based on teleworkability index (measure used to assess the ability to work from home or not for different fields).	Household surveys on determinants collected from 2013 – 2019 used to explain possible impacts from policy, social distancing measures, and ability to work from home. Some countries only included urban dwelling data. Government subsidy income not included.
Drefahl et al. 2020 (Drefahl et al. 2020)[2]	Adults >= 20, n = 7,775,064: Sweden	NA	Individual net income tertiles	Less individual income, male, lower education, and single predict higher mortality risk from COVID-19 and all other death causes. Being a migrant from a low/middle-income country predicts higher risk of COVID-19 mortality but not for other death causes.	Individual-level survival analysis. Mortality data obtained from March 2020 and May 2020 with socioeconomic and determinant data.
Esseau-Thomas et al. 2022 (Esseau-Thomas, Galarraga, and Khalifa 2022)	191 countries, Int.	Gini coefficient	NA	COVID-19 deaths per 100,000 is positively associated with the Gini coefficient. It is stated that their model properly determines that pandemics have an increase in ININ.	Fixed effects estimation and three-stage least squares regression analysis. Data from 2000-2020.

Author (Cont.)	Population; n (Cont.)	Income Inequality (ININ) Measure (Cont.)	Income Measure (Cont.)	Key Takeaway (Cont.)	Study Design Methods (Cont.)
García 2021 (García 2021)[3]	17 regions: Spain	Gini measured but not compared (mean = 0.39, SD = 0.25).	Log GDP per capita	Socioeconomic determinants are statistically significantly associated with mortality and cumulative incidence of COVID-19 when comparing regions. 1% GDP per capita increase is associated with 3.21 % increase in mortality.	Linear regression with determinant data obtained from 2019. COVID-19 mortality rate as of 23 May 2020. COVID-19 cumulative incidence calculated during May 2020. 14 regional variables and socioeconomic determinant information obtained.
Grabka 2021 (Grabka 2021)[2,3]	n = 2500; households; Germany;	Income deciles, Gini coefficient	Household equivalent income	Looked at net household income in 10th, 50th, 90th (increased from 2010 to 2019 except for 90th percentile which declined). Using 90th and 10th percetile ratio; ININ decreased at start of 2021.	Households with weights for head, other adults, children, etc. Relation to self-employed persons. Cross-sectional. Compared income from 2019 to 2021. Other years included report on ININ from 2000 to 2019.
Huyser et al., 2021 (Huyser, Yang, and Yellow Horse 2021)[1,5]	n = 372 zip codes, mean = 5664 per zip code; New mexico, USA	Gini Coefficient	Log median income	Covid-19 cases vary spatially and are concentrated in areas of lower socio-economic status. GINI Coefficient had strong positive correlation with COVID-19 cases.	Poission regression/PCA, American Community Survey from 2014-2018, COVID-19 data as of 24 May 2020. Disadvantage measured across (in proportions): female Hoh, household obtaining subsidies as income, population over 25 without high school diploma, unemployment rate, and poverty rate.
Kim et al. 2021 (H. H.-S. Kim and Katelyn Kim 2021)[1,2]	n = 13,661 adults >= age 55: Between and within 67 countries.	Gini coefficient	Quintiles of gross monthly household income	Self-reported health was higher in top quintile income brackets within a country during COVID-19 when controlling for country random effects.	Country random effects and cross-sectional analysis. Sampling bias (age). Int. online survey late March 2020 to early April 2020 during 1st wave (Fetzer et al. 2020). Household income, self-rated health survey, and mortality.

Author (Cont.)	Population; n (Cont.)	Income Inequality (ININ) Measure (Cont.)	Income Measure (Cont.)	Key Takeaway (Cont.)	Study Design Methods (Cont.)
Kim and Jeong 2022 (S. B. Kim and Jeong 2022)[2,3,5]	n = 220,970 adults > 19: South Korea	Regional income was coded as above average or below average (using mean per capita).	Household income from income quintile data.	Higher risk of COVID-19 infection for: age < 40, higher income levels, higher education levels, single, social support of > 3 people, and high regional income.	2020 Korea Community Health Survey from 16 Aug 2020 – 31 Oct 2020. Sampling bias due to excluding nursing homes. Measured income from April 2020 and self-reported COVID-19 infections reported on survey.
Quispe et al. 2022 (Quispe Mamani et al. 2022)[1,2]	13 provinces and 110 districts of all self-employed workers (n = 213 Hoh): Puno, Peru	Gini coefficient; Self-employed: 2019 Gini = 0.61, 2020 Gini = 0.71; National: Gini = 0.415 on 2020 vs Gini = 0.431 in 2020	Natural log of monthly income	Comparison of Gini for self-employed to the national average found educational level to be significant.	Ordinary least squares regression model, National Household Survey conducted in 2019 – 2020. Measured income, education of self-employed, years of education received, age, sex.
Sepulveda et al. 2021 (Sepulveda and Brooker 2021)[4,5]	22 OECD countries	Gini coefficient on disposable income	National median per capita income	ININ on the country level is positively associated with COVID-19 deaths across age groups.	Poisson multivariate regression and 9-month longitudinal study with end on 15 Jan 2021. Measured COVID-19 mortality from John Hopkins. Income and ININ data obtained from most recent OECD 2021. Measured ability to work from home, residency type (long-term care) and prop of >= age 80, and age stratified.
Shen et al. 2021 (Shen et al. 2021)	295 cities: China	Relative disposable income quartiles divided by the mean of all cities for comparisons.	Disposable income per capita	ININ on the regional level has intensified during COVID-19 compared to the city level when analyzing income distributions.	Non-parametric – stochastic kernels. Quarterly income per capita from Oct 2019 to June 2020 separated into three categories (Pre-COVID, COVID, Post-COVID). Measured income in rural and urban regions changing with time.

Author (Cont.)	Population; n (Cont.)	Income Inequality (ININ) Measure (Cont.)	Income Measure (Cont.)	Key Takeaway (Cont.)	Study Design Methods (Cont.)
Tan et al., 2021 (Tan et al. 2021)[1,5]	3220 counties: U.S.A.	Gini coefficients per county	NA	Positive correlation between county Gini coefficients and county COVID-19 cases deaths; strongest association during Summer 2020	American Community Survey county income data of 2014-2018. COVID-19 cases and COVID-19 mortality from March 2020 to Feb 2021. Time as fixed effect to see time interaction with cases, deaths, and Gini coefficients: non-cumulative cases and deaths obtained each 2 months. Determinants include age, ethnicity, crowding, urban vs rural, physicians available, and mask use. Limitations include not utilizing time series data.
Upshaw et al. 2021 (Upshaw et al. 2021)[5]	42 studies; Int.	NA	NA	Well reported that individuals are disproportionality affected from ethnicity, income, housing, and employment in terms of COVID-19.	Systematic review of early pandemic from Dec 2019 to April 2020; topics mainly surrounding income, housing, mental health, age, and occupation
Wachtler et al., 2020 (Wachtler et al. 2020)	46 studies: Int. with majority US, UK, and some Europe (1 Germany)	Regional income inequality	Regional income, individual income	Socioeconomic inequalities exist across populations relating to COVID-19; less privileged populations hit harder; more severe disease in less privileged populations.	1st meta-analysis with articles up to 15 June 2020; Publication bias, selection bias; few individual studies.

Author (Cont.)	Population; n (Cont.)	Income Inequality (ININ) Measure (Cont.)	Income Measure (Cont.)	Key Takeaway (Cont.)	Study Design Methods (Cont.)
Wildman 2021 (Wildman 2021)	OECD countries, cases per million (mean = 2474, SD = 2077), deaths per million (mean = 175, SD = 214).	Gini coefficient (mean = .327, SD = .0523).	GDP per capita	ININ and COVID-19 deaths; significant positive association with ININ and COVID-19 deaths per million. 1% increase in Gini coefficient is associated with 4% increase in COVID-19 cases per million and 5% increase in COVID-19 deaths per million. Higher ININ was associated with increased cases and deaths from COVID-19.	Cross sectional study with COVID-19 cases and deaths up to 18 May 2020. Gini coefficients obtained from World Bank Data from 2016-2018 and income from 2018. Linear regression. Determinants include age, population proportion > 65, health status, average life expectancy at birth, Limitations due to aggregate level data.
*** Xia et al. 2022 (Xia et al. 2022)**	4 regions: British Colombia, Manitoba, Ontario, Quebec, Canada	Gini coefficient	Net income per person equivalent (estimated from census zip code income measures and household sizes)	Concentrated COVID-19 cases in areas of lower income in spatial contexts.	Cross sectional study with COVID-19 data from 23 Jan 2020 to 28 Feb 2021. 2016 Canadian Census used to calculate Gini coefficient and Gini covariance (co-Gini), and income. Determinants include occupation, education, housing, and self-identified minority status.
Yip et al. 2022 (Yip et al. 2022)[5]	n = 9267 youth and parent combinations: U.S.A.	NA	Household income	Found associations and predictors for COVID-19 inequity, specifically that household income and family structure are correlated with COVID-19 inequity. Families from lower socioeconomic backgrounds were found to be impacted more.	Multivariate pattern learning strategy; Income data obtained from 2016 to 2018. COVID-19 data obtained during May 2020 to Aug 2020. correlation study.

Author (Cont.)	Population; n (Cont.)	Income Inequality (ININ) Measure (Cont.)	Income Measure (Cont.)	Key Takeaway (Cont.)	Study Design Methods (Cont.)
Zhang et al. 2022 (Zhang et al. 2022)	Microsimulation: China	Gini coefficient	Household income based on rent	Highest loss of employment and income in female, urban dwellers, and low education. Higher decrease of income per capita for rural dwellers.	Microsimulation. Income data obtained from the 2013 Chinese Household Income Project, determinants were obtained from 2010 Census including urban vs. rural, gender, and education. Factors obtained from other studies indicating percentage impact on sectors are used to simulate COVID-19 scenarios (i.e., impact on production, investment, consumption, government, foreign, and inventory).

Relevant Abbreviations: SD = Standard Deviation, OECD = Organization for Economic Co-operation and Development, k = thousand, Hoh = head of household, ININ = Income Inequality, Int = International

1. Indicates the study used a similar questionnaire to the German Socio-Economic Panel (SOEP) during the study design.
2. Indicates the study design utilized an individual level analysis.
3. Indicates that the study had contradictory conclusions to the majority of studies included within this narrative review.
4. Indicates the study was longitudinal by design.
5. Indicates a study reported on intermediary determinants when using the Solar and Irwin Framework as a reference.

Table 2: Proportional measures across studies included within this narrative review on 24 total publications (each row measure sums to 24).

Measure	**Proportion [%]**	**1-Proportion [%]**
COVID-19 Impacted Lower Socioeconomic Classes	21 [87.5%]	3 [12.5%]
International Study Design	11 [45.8%]	13 [54.2%]
Individual Level Analysis	6 [25.0%]	18 [75.0%]
Included Self-Reported Questionnaires	6 [25.0%]	18 [75.0%]
Country Level	10 [41.7%]	14 [58.3%]
Country Regional Level	4 [16.7%]	20 [83.3%]
Longitudinal Design	1 [4.1%]	23 [95.9%]
Intermediary Determinants Included	7 [29.2%]	17 [70.8%]

Figure 1: A representation of the Gini Coefficient.

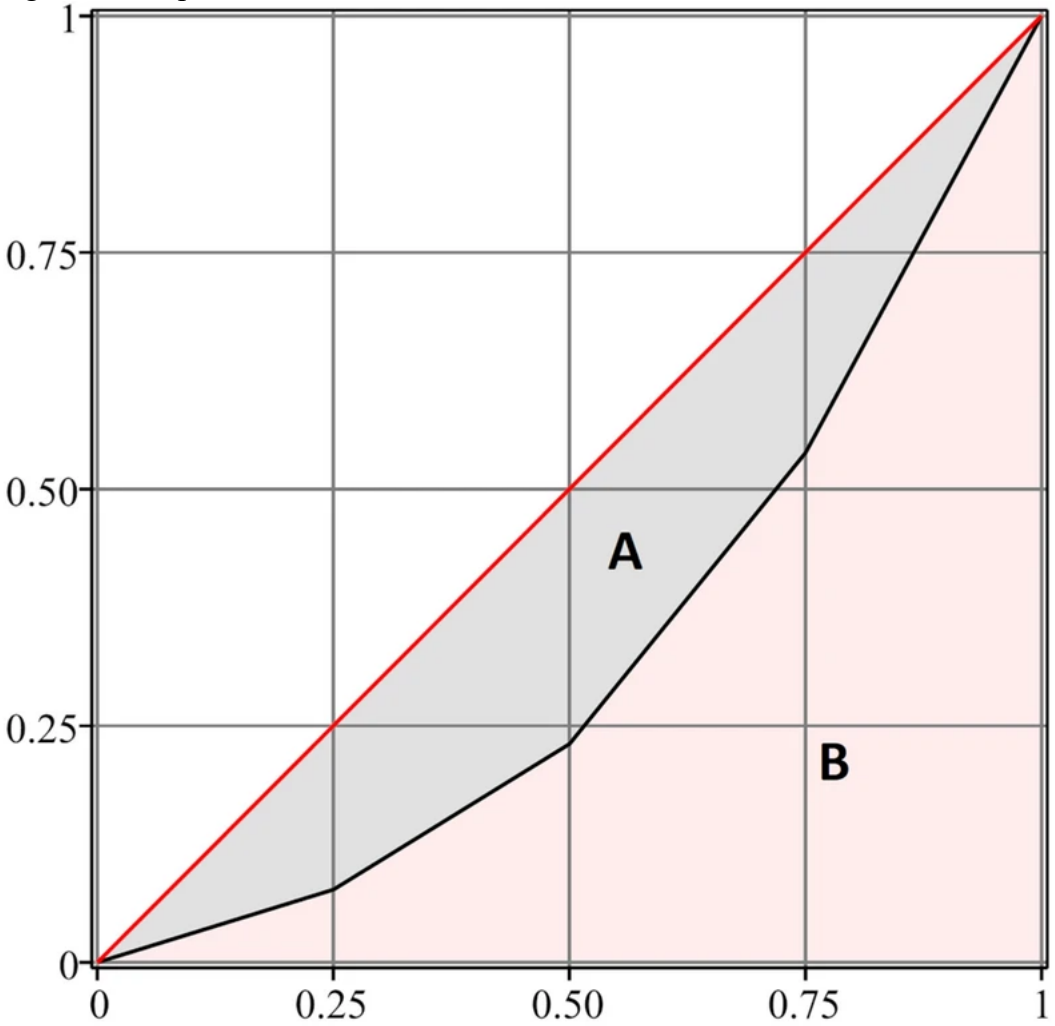

Figure 1: Diagram depicting the Gini Coefficient commonly used to measure ININ. The Gini index can be calculated as G=A/(A+B). Image reprinted from (Lechthaler, Pauly, and Mücklich 2020) with alterations to the axes and equation placement under the CC BY 4.0 License (https://creativecommons.org/licenses/by/4.0/).

Figure 2: The Dynamics of ININ

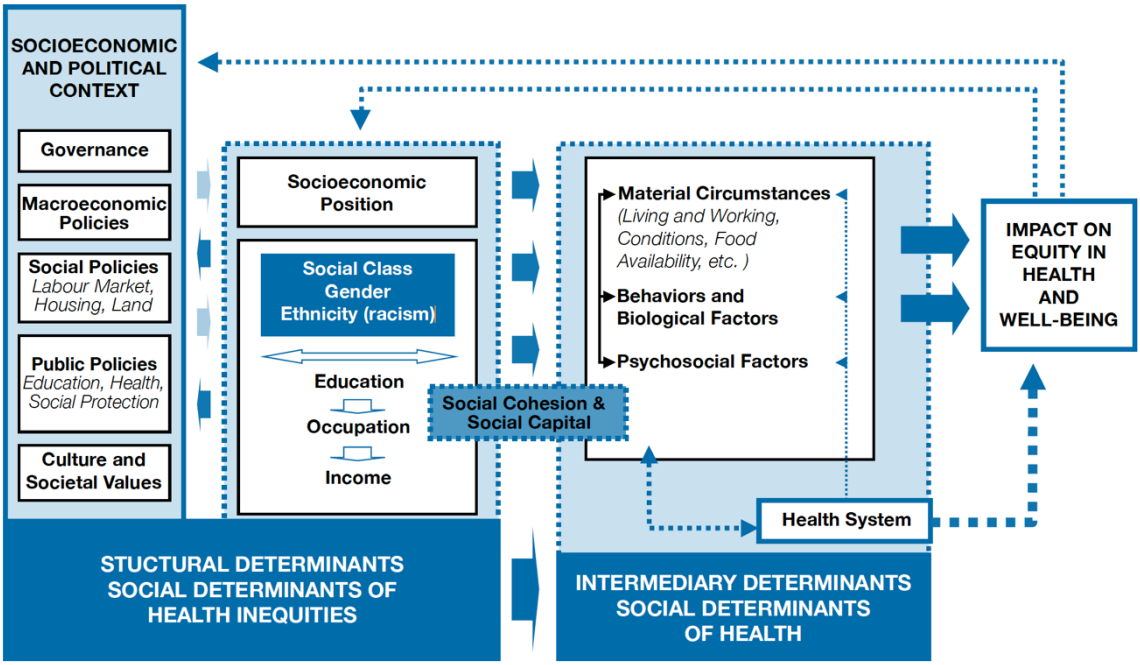

Figure 2: Diagram depicting the dynamics socioeconomic status including ININ on health outcomes. Image reprinted from (World Health Organization 2010) with no alterations under the CC BY-NC-SA 3.0 IGO License (https://creativecommons.org/licenses/by-nc-sa/3.0/igo/).

Figure 3: COVID-19 Map New Mexico

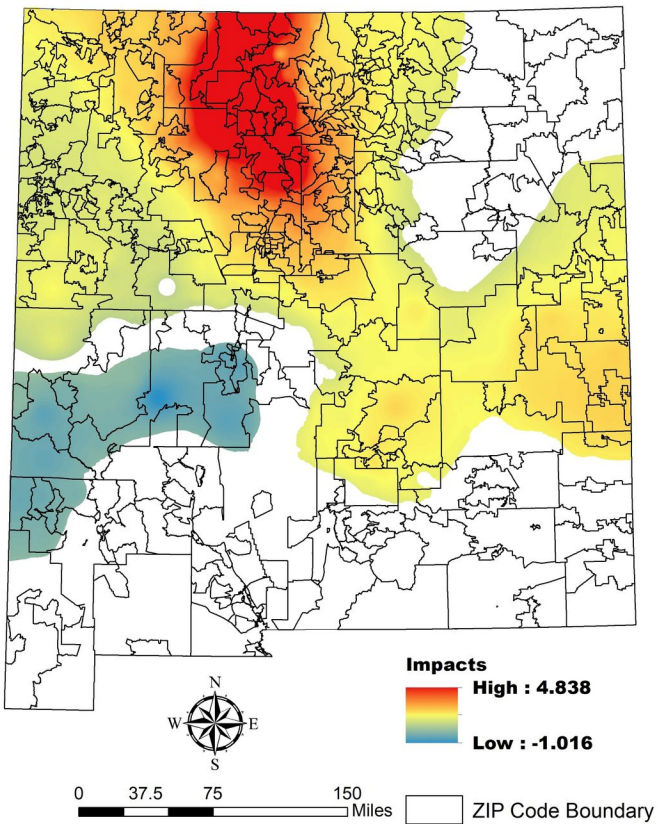

Figure 3: A Map of New Mexico, U.S.A. displaying the disproportion of COVID-19 cases across the region when comparing ININ based on zip code boundaries. The area in red reflects indigenous nation states such as the Pueblo lands. Reprinted from (Huyser, Yang, and Yellow Horse 2021) with no modification under the CCC License (License Number 5305350244378).

Figure 4: COVID-19 Infections and Mortality in California

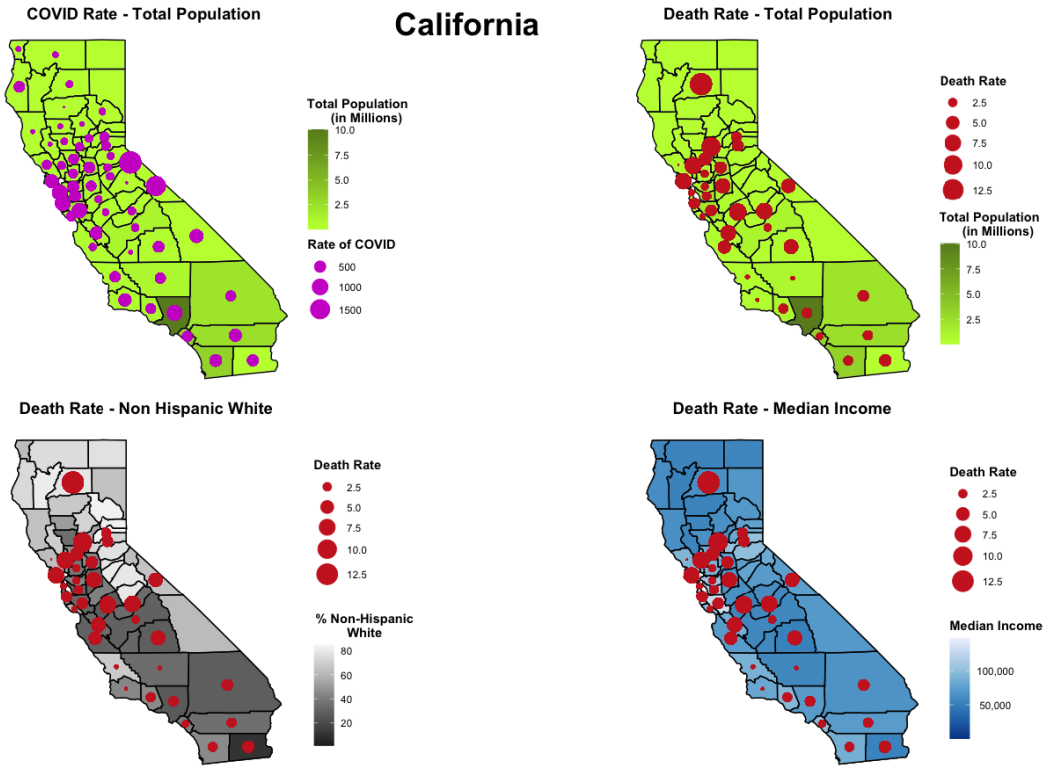

Figure 4: COVID-19 infection and death rate when comparing total population, non-Hispanic white ethnicity, and median income in California, U.S.A. Reprinted from (Abedi et al. 2021) with no modification under the CCC License (License Number 5322710320482).

Figure 5: COVID-19 Infections and Mortality in Pennsylvania

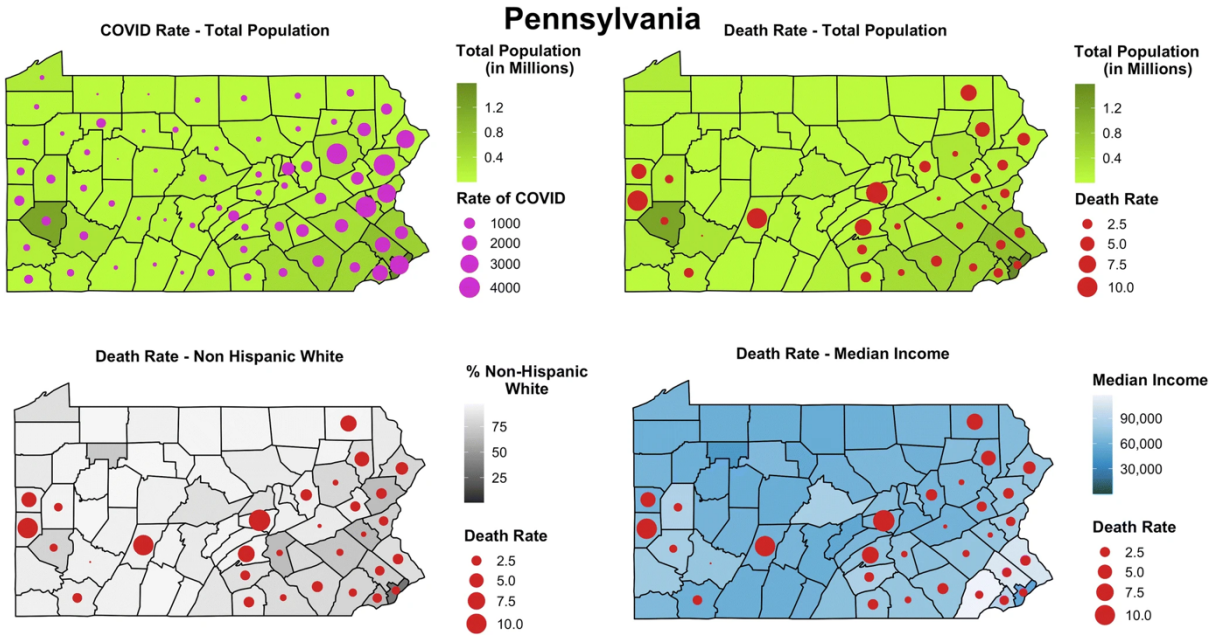

Figure 5: COVID-19 infection and death rate when comparing total population, non-Hispanic white ethnicity, and median income in Pennsylvania, U.S.A. Reprinted from (Abedi et al. 2021) with no modification under the CCC License (License Number 5320820358308).

Figure 6: COVID-19 in Sweden

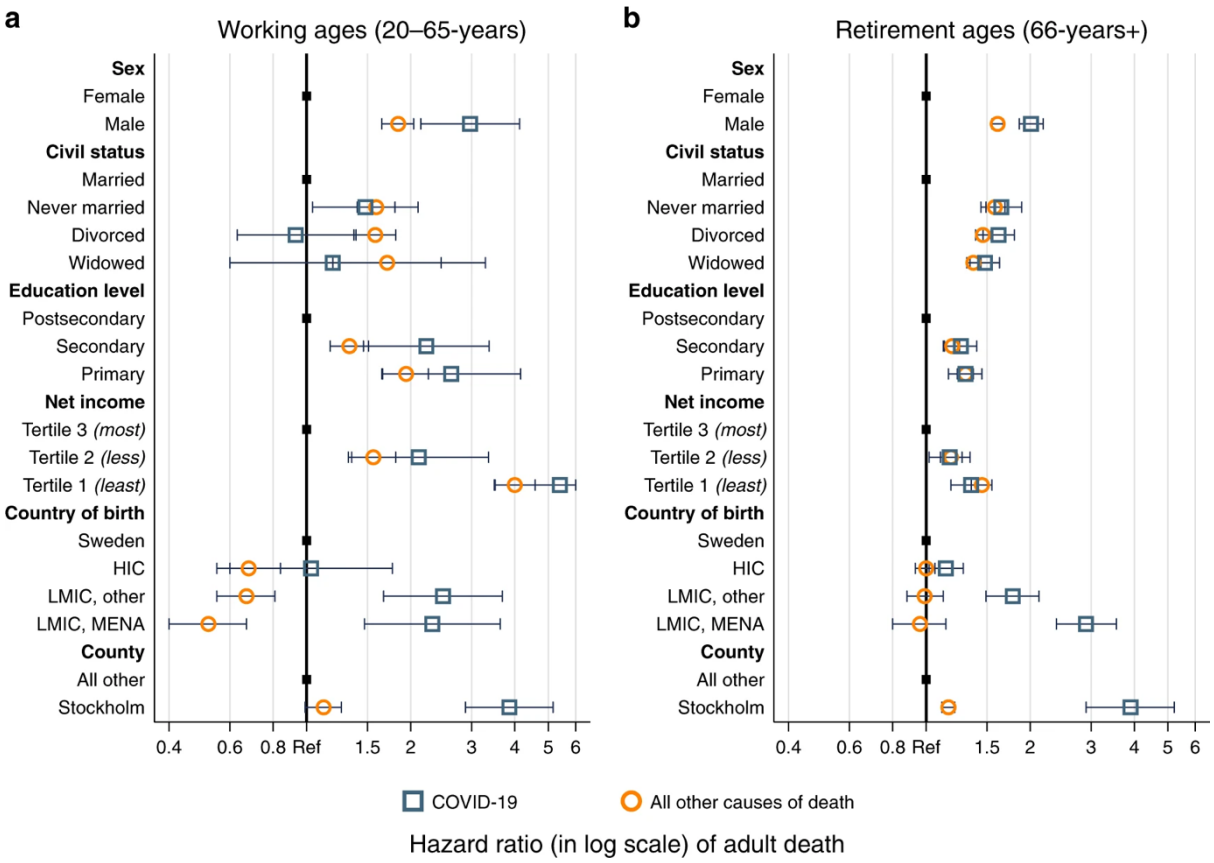

Figure 6: Hazard ratios from dying due to COVID-19 from individuals in Sweden (n = 5,813, 359 in 6a and n = 1,979,710 in 6b). Reprinted from (Drefahl et al. 2020) with no alterations under the CC BY 4.0 License (https://creativecommons.org/licenses/by/4.0/).

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