What have we learned about socioeconomic inequalities in the spread of COVID-19? A systematic review

Francisco Benita [a],[*], Leonardo Rebollar-Ruelas [b], Edgar David Gaytán-Alfaro [b]

[a] *Engineering Systems and Design, Singapore University of Technology and Design, 8 Somapah Road, Singapore 487372, Singapore*
[b] *Department of Economics, Colegio de la Frontera Norte, Tijuana, Mexico*

ABSTRACT

This article aims to provide a better understanding of the associations between groups of socioeconomic variables and confirmed cases of COVID-19. The focus is on cross-continental differences of reported positive, negative, unclear, or no associations. A systematic review of the literature is conducted on the Web of Science and SCOPUS databases. Our search identifies 314 eligible studies published on or before 31 December 2021. We detect nine groups of frequently used socioeconomic variables and results are presented by region of the world (Africa, Asia, Europe, Middle East, North American and South America). The review expands to describe the most used statistical and modelling techniques as well as inclusion of additional dimensions such as demographic, healthcare weather and mobility. Meanwhile findings agree on the generalized positive impact of population density, per capita GDP and urban areas on transmission of infections, contradictory results have been found concerning to educational level and income.

1. Introduction

As the coronavirus disease 2019 (COVID-19) situation develops and moves through different stages, recent studies provide compelling evidence that the outbreak is exacerbating inequalities of health, wealth, and income worldwide (Benítez et al., 2020; Raharja, Tamara, & Kok, 2021; Strully, Yang, & Liu, 2021). History also tells us that social inequalities not only affect the distribution of infection diseases but also the course of the disease in those affected. For instance, some of the most important lessons from the *Spanish flu* (1918 to 1919) and the *H1N1 influenza* (2009) events are about how they disproportionately affected marginalized groups. Reports (Bengtsson, Dribe, & Eriksson, 2018; Rutter, Mytton, Mak, & Donaldson, 2012) clearly demonstrate that socioeconomically less-privileged populations incurred in greater risk of contracting and dying from the disease as compared to their counterparts. Similarly by the end of 2000, the HIV/AIDS epidemic started to affect exclusively the most marginalized sectors of society, including people suffering from structural violence, poverty, or racism (Parker, 2002). One of the most common arguments medical sociologists and other health scientists make is that social inequalities reliably beget health inequalities (Link & Phelan, 1995). With the aim of designing prevention strategies in today's global context, policy makers and civil

society leaders have all drawn attention to the need for knowledge about the role of socioeconomic status on the risk distribution patters.

Although the Covid-19 pandemic has been around with us for a relatively short period of time, a massive amount of research efforts has been poured into many aspects of this highly infectious disease. To start with, several studies from various countries such as United States (Andersen, Harden, Sugg, Runkle, & Lundquist, 2021; Maroko, Nash, & Pavilonis, 2020), Italy (Buja et al., 2020), Turkey (Coşkun, Yıldırım, & Gündüz, 2021) or India (Arif & Sengupta, 2021) have reported strong evidence for increasing population density as a threat to pandemic-free time intervals in dense urban environments. Conversely, when examining interrelationships between positive cases and other socioeconomic variables, such as proxies for poverty, the findings remain largely inconclusive (Akanbi et al., 2021; Andersen et al., 2021; Varkey et al., 2021). Household size is another important factor behind the relationship between crowded living conditions and the possible increasing risk of virus transmission. Past substantial evidence (Doshi et al., 2015) demonstrates that household overcrowding promotes influenza incidence, and early COVID-19-realted research (Buja et al., 2020; Desmet & Wacziarg, 2021) did point in the same direction.

The epidemic growth curve of COVID-19 has provided a genuine opportunity for urban scientist, planners, and designers to learn more

---

about the different aspects of the socioeconomic context in relation to health inequity. The quick responses by the global research help generate a large corpus of academic literature related to how social inequalities are linked to COVID-19 transmission. The primary aim of this paper is to conduct an in-depth examination of COVID-19 research to explore the body of emerging knowledge, with a focus on social inequalities and disease transmission in different regions of the world.

1.1. Existing literature reviews

Review-based studies on individual socioeconomic inequalities exist. Wachtler et al. (2020) conducted a systematic review of early findings from 46 (peer-reviewed and non-peer-reviewed) studies published over January to June 2020 on the unequal distribution of infections and severe cases across society. Their findings indicated that, during the first wave of COVID-19, socioeconomically deprived population groups faced increased risk of contracting the virus. Ayyoob & Khavarian-Garmsir (2020) presented an overview of 147 articles using Scopus database. The study, covering the period from inception to June 2020, discovered thematic categories, including geographic focus, sectoral focus, socioeconomic and environmental factors, impacts, and key lessons. In other studies, meta-analyses have been performed for published articles with emphasis on racial disparities in COVID-19 incidence, disease severity and mortality (Raharja, Tamara, & Kok, 2021; Magesh et al., 2021). Similarly, the systematic reviews of Briz-Redón & Serrano-Aroca (2020) or Mecenas et al. (2020) have documented how the spread of COVID-19 may be influenced by climatic variables such as temperature and humidity.

Those reviews have made a significant contribution to mapping economic, environment and health inequality and COVID-19 infection. However, previous research has little emphasis on geographical differences in the trajectory of the pandemic. To fill the gap, the present review applies a systematic methodology to map results of the association between socioeconomic inequalities and COVID-19 transmission in terms of geographical distribution, analyzed socioeconomic factors, methodologies, key findings, and policy recommendations.

1.2. Purpose of the study

Given the critical need for identifying the disparities associated with greater occurrences of the infectious disease among different populations, this paper aims to provide a summary of evidence-based research about the effect of socioeconomic factors on the diffusion of COVID-19. The study adopts a systematic literature review methodology. Moreover, findings are desegregated by geographical region as follows: Africa, Asia, Europe, Middle East, North American and South America. Nine groups of frequently used socioeconomic variables are identified, namely, population density, poverty measure, per capita gross domestic product (GDP), income, income inequality, education level, unemployment, urban areas, and household size.

2. Methods

2.1. Search strategy

The international databases of Web of Science and SCOPUS were searched for *peer-reviewed* journal articles published till December 31, 2021. Both databases are generally accepted as the most comprehensive sources for various purposes (Zhu & Liu, 2020). While the Web of Science is a smaller and more selective database, SCOPUS has a wider coverage of journals. Two reasons drove our choice to utilize both databases. Firstly, databases such as PubMed focuses mainly on life sciences and biomedical disciplines whereas SCOPUS and Web of Science are multidisciplinary. Secondly, Google Scholar, bioRxiv, arXiv, or medRxiv allow online posting of manuscripts prior to peer review and give the opportunity to disseminate knowledge rapidly. Nonetheless,

publishing of scientific study without peer-review may decrease methodological quality and reliability. Contrary to preprint services or open access repositories offering *grey literature*, Web of Science and SCOPUS index documents that have passed rigorous peer-review processes.

The inclusion criteria comprise items with the following terms in titles, abstracts, or keywords: Coronavirus* (including its variations) AND (society* OR region* OR association OR transmission OR health disparities*). Searches were not limited to any country or region and were restricted only to "full text articles" in English-language. Furthermore, searches were not refined by research areas. The complete search strategy is presented in the Online Supplementary Material 1.

2.2. Eligibility criteria

To be included in this review, articles must examine the role of socioeconomic indicators on numbers of COVID-19 positive cases, active cases, incidence rates or any other variable measuring infections but not deaths. Studies with an exclusive focus on ethnicity were excluded. The reason behind this is simply to ensure internationally comparable evidence. Literature on the examination of only demographic variables such as age or gender was excluded. The interested reader is referred to Gebhard et al. (2020) and Haitao et al. (2020) for comprehensive literature reviews of demographic-related differences on COVID-19 outcomes. We discarded all publications describing biomedical research, and articles that did not consider individual or regional-level socioeconomic variables.

2.3. Data extraction and synthesiser

2.3.1. Identification of studies

Searches were conducted during two periods. The first one from February 2021 to March 2021 with published articles in 2020, only. This first search led to 15,875 (SCOPUS) and 8,665 (Web of Science) identified journal articles which were downloaded into Excel and duplicates removed. All titles and abstracts were screened for inclusion by all three authors (FB, LR, EG) independently. The full text of articles identified as either relevant or possibly relevant from the title and abstract were obtained and assessed to determine whether they met the inclusion criteria. Discrepancies between authors were resolved via discussion. After full-text eligibility assessment on 165 records, 88 were included as the remaining 77 had focus on mortality as explanatory variable rather than infections.

A second search was conducted in early January 2022 with a duration of two months in order to update our database. To this end, a full search on both SCOPUS and Web of Science was conducted for journal articles published till December 31, 2021. Duplicate articles were removed and authors FB, LR and EG proceeded to conduct the screening of titles and abstracts independently. Again, discrepancies between the authors were resolved via discussion. Two hundred and seventy full-text articles were obtained and reviewed. Forty-four papers were excluded on assessment of the full-text versions based on the inclusion and exclusion criteria.

2.3.2. Data extraction
The process of extracting key socioeconomic group of factors was as follows:

- In the first stage, this is, with the database of published articles in 2020, a data extraction form was developed and tested by author FB. Data were then extracted by two authors (LR and EG) by taking note of every single socioeconomic variable used to explain the disease transmission.
- Individual variables were grouped into conceptually meaningful categories. Meanwhile "% of bachelors or graduate" or "% of 25 years old+ adults with less than high school" were both labeled as

"Education level", "% of rural population" or "metropolitan area" were labeled as "Urban areas", for example.

- The assessment of manuscripts and extraction was performed in parallel by the three authors and discrepancies between the reviewer's findings were discussed and resolved.
- After identification of major groups of socioeconomic factors, we assessed literature published in 2021 and extracted relevant factors according to pre-identified socioeconomic group of variables.
- By following the approach of Briz-Redón & Serrano-Aroca (2020), associations between groups of socioeconomic factors and COVID-19 cases were classified as: "Positive", "Negative", "No association", "Unclear" and "Not analyzed". The difference between no association and unclear is that the latter refers to the case where statistical significance is lost after being controlled for other factors, whereas in the former studies concluded no association. Here, it is important to notice that effects of all socioeconomic variables were treated so that they reflect the same tendency. This is, while some authors present results for employment levels some others report unemployment figures.
- The final association between socioeconomic indicators and infections was recorded through several iterations and discussions of reviewers.

The above information of included articles was encoded into Excel Spreadsheets. Manuscripts considering sex/gender or race/ethnicity variables, but no other relevant socioeconomic factors, were discarded. We also excluded articles that resulted into "Not analyzed" for all groups of socioeconomic factors. Subsequently, basic information such as authors, publication venue, month of publication, country of study, unit of analysis (e.g., countries, states, regions, counties, etc.) or temporal time span was extracted. Apart from that, several key research attributes such as methodological approach, response variable or additional considered dimensions (i.e., "Demographic", "Healthcare", "Weather" and "Mobility") attempted to explain the disparities observed in COVID-19

outcomes were also retrieved. The systematic review and meta-analysis have been performed in line with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines.

3. Findings and discussion

3.1. Literature selection

For the period up to 31 December 2021, the search of keywords resulted in 31,922 (SCOPUS) and 18,455 (Web of Science) journal articles. Duplicated records were removed, which left us with 36,502 unique records. After completing the data extraction and synthesiser methodology described in the previous section, altogether, we identified 314 articles (see Fig. 1). Among those studies, 88 (28%) were published in 2020 which were used for the identification of relevant groups of socioeconomic factors. We detected nine groups of most frequently used variables: population density, poverty measure, per capita gross domestic product (GDP), income, income inequality, education level, unemployment, urban areas and household size. Results with the Systematic review are provided in the Online Supplementary Material 2.

3.2. Publication venues, regions of study and time span

Fig. 2 shows publication venues with at least three published papers. Studies were published in 159 different journals from different fields of study. There were 107 journals (67.3%) with only 1 article, follower by 46 journals (28.9%) with 2 published articles. There are 4 journals with at least 10 publications, classified in the Environmental Science, Multidisciplinary and Social Sciences categories. As expected, major portion of the research has been published in public health venues. However, environmental community has contributed significantly to identifying connections between socioeconomic inequalities and the environment. Journals like *International Journal of Environmental Research and Public Health, Science of the Total Environment* or *Sustainable*
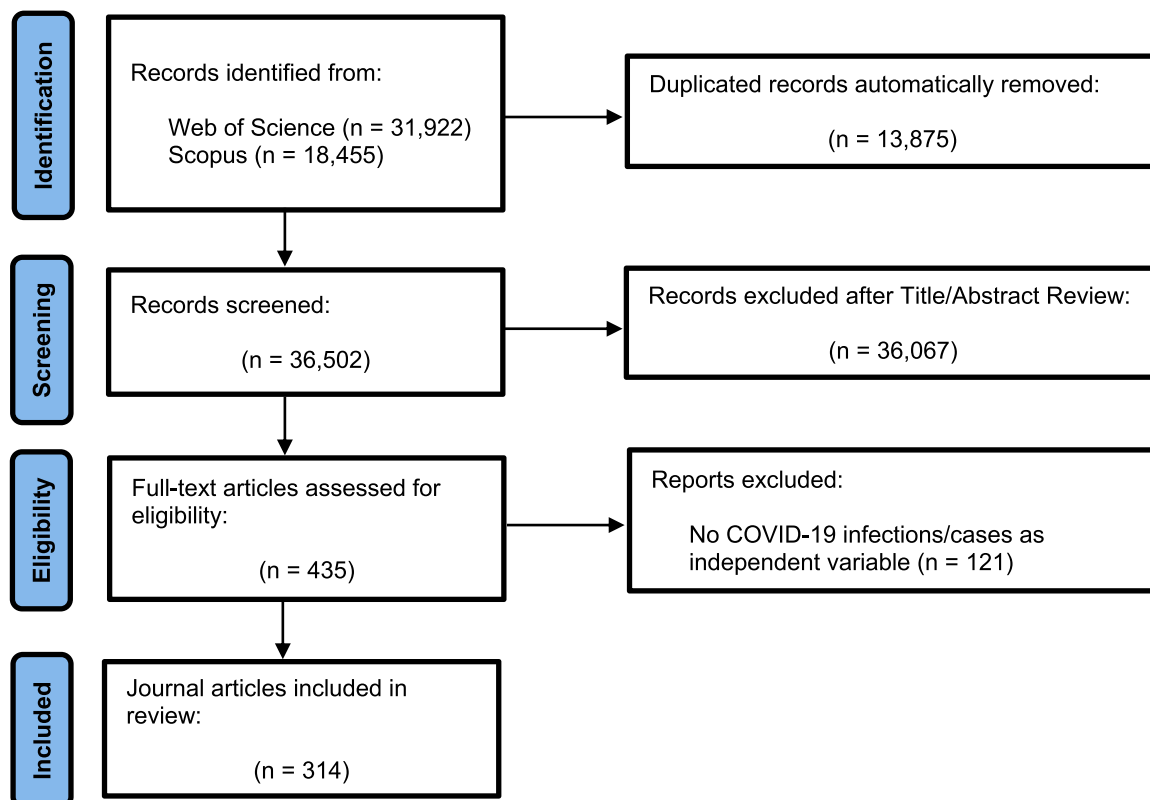

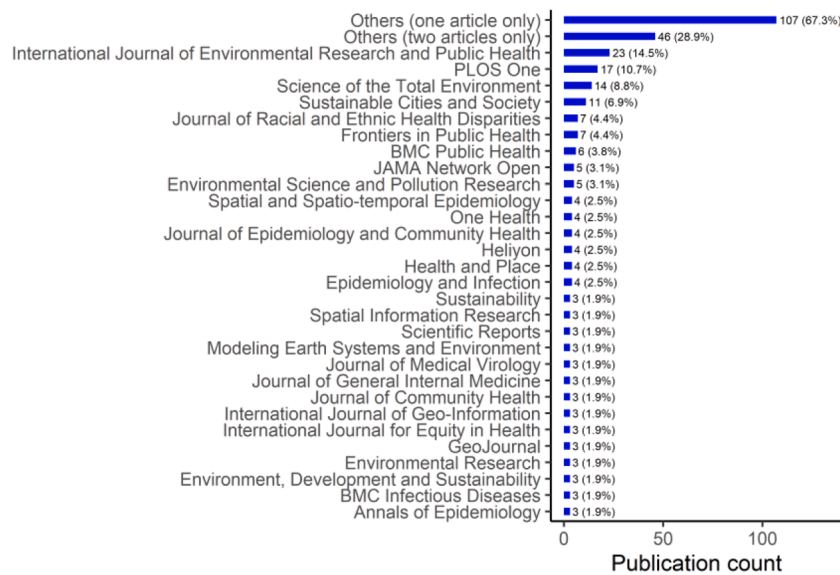**Fig. 1.** PRISMA flowchart: data search and screening process.

Fig. 2. Publication venues with at least three published journal articles.

Cities and Society have not only been intensively published scientific work assessing the (possible) correlations between climatological factors and cases of COVID-19, but also literature with emphasis on social inequalities. We noticed that journals with focus on urban-, regional studies, and city planning were less active in publishing content related to health disparities and the pandemic.

Our attention is on the specific regions as depicted in Fig. 3. As of 31 December 2021, Europe has been the most affected area with more than 84 million confirmed cases, followed by the North America, with more than 62 million. Nevertheless, the proportion of research explicitly focused on the latter region is relatively higher by comprising about one third of the existing published research (106 out of 314 articles), see the left panel of Fig. 3. On the one hand, Oceania continues experiencing low numbers of infections (559,339 cases) that were hard to visualize in Fig. 3 (right panel), therefore excluded from the area plot. On the other hand, interestingly, none of the articles in the sample have explicit emphasis on regions from that continent. We found, however, results related to Australia or New Zealand that were present in articles with a focus on the "World" as a region of study (Anser et al., 2021; Mayer, Schintler, & Bledsoe, 2020).

Fig. 4 shows the top studied countries/regions. The amount of work reporting results for the United States ($n = 97$, 30.8%) is by far the most comprehensive. Furthermore, much of the available literature documenting the relationship between socioeconomic inequalities and

infected cases has an exclusive focus on New York. Particularly, after the pioneering work from Millett et al. (2020), showing the first formal analysis of racial and ethnic disparities related to COVID-19 in the United States, subsequent studies attempted to understand the socio-economic, demographic and health determinants affecting the outbreaks in that country. Studies with focus on several territories around the world are the second most frequently found in the literature ($n = 39$, 12.4%) whereas China ranks third on the list of most studied countries/regions ($n = 30$, 9.5%). An important observation is that the most studied countries/regions do not fully correspond to major industrialized nations. For instance, only United States, United Kingdom and Italy from the Group of Seven, G7, figure in the top fifteen most studied countries. Alternately, we found a number of published works about BRIIC countries (Brazil, Russia, India, Indonesia, and China) and other emerging markets such as Turkey, Mexico or Malaysia. COVID-19 hit in a world where inequality was already pervasive and early evidence indicated that low-income countries, with limited health system capacities, were likely to suffer infection rates similar or to greater than those suffered by high-income countries (Walker et al., 2020).

The studied time spans by region of the world are presented as boxplots in the right panel of Fig. 4. There is large variation in the periods of analysis, ranging from 3 days (Benitez, Courtemanche, & Yelowitz, 2020) to almost two years (Gonzalez-Val & Sanz-Gracia, 2021). From visual inspection, the period of analysis covered by studies
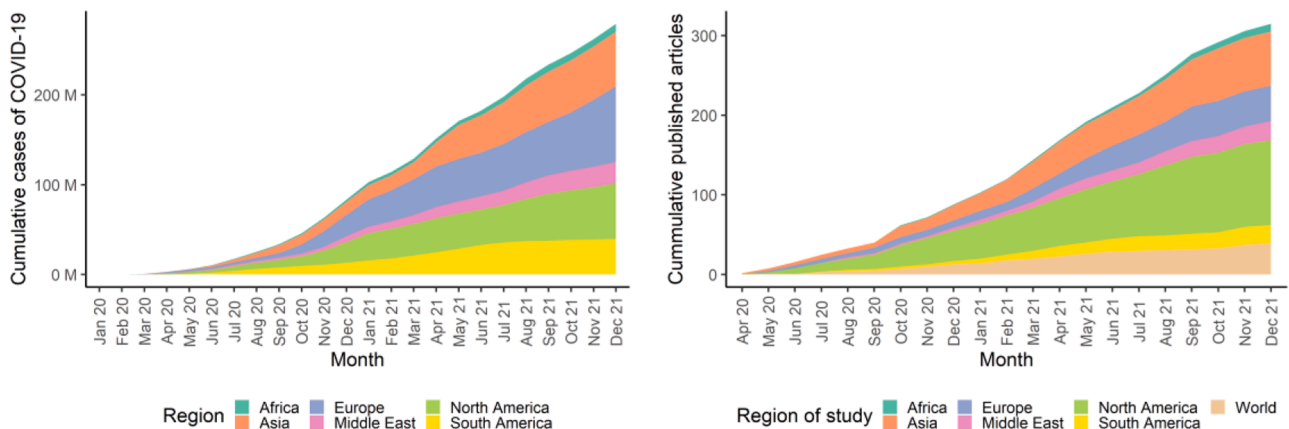

Fig. 3. Cumulative confirmed COVID-19 cases (*left*) and cumulative articles published (*right*) by region of study.
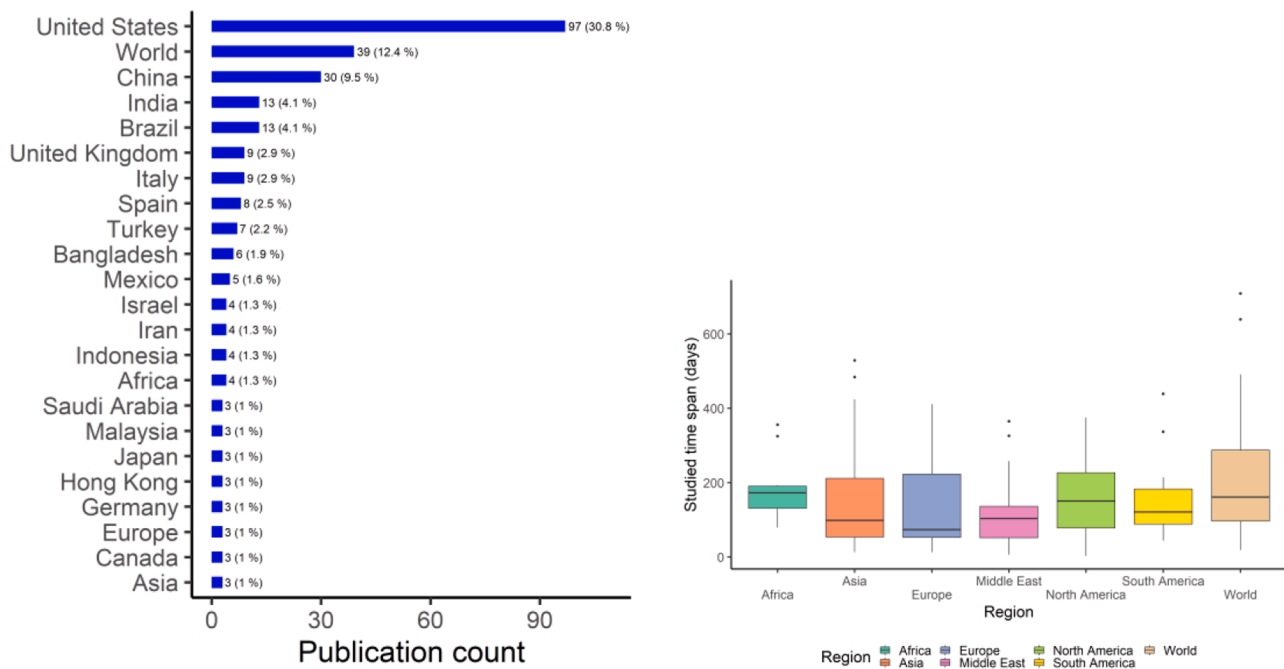
Fig. 4. *Left*: Studied countries/regions. *Right*: Time span for the datasets considered in the literature.

in, say, Europe, is shorter than those in North America and South America. These differences in time length could perhaps be associated with reported differentiated effects of the socioeconomic variables as further explained in the next section. Furthermore, studied independent variables were also different, ranging from confirmed COVID-19 cases to incidence rate, to diffusion ratio and to morbidity (see Online Supplementary Material 2).

3.3. Socioeconomic variables

Population density. Currently, the most widely used variable describing the link between socioeconomic conditions and positive cases. It is often measured by people per sq. km of land area. The evidence from Fig. 5 points that 209 (66.6%) articles included this variable as useful predictor for infections. Among them, 141 have found residents living in areas with high population density are at higher risk to come into close contact with others and consequently any contagious disease
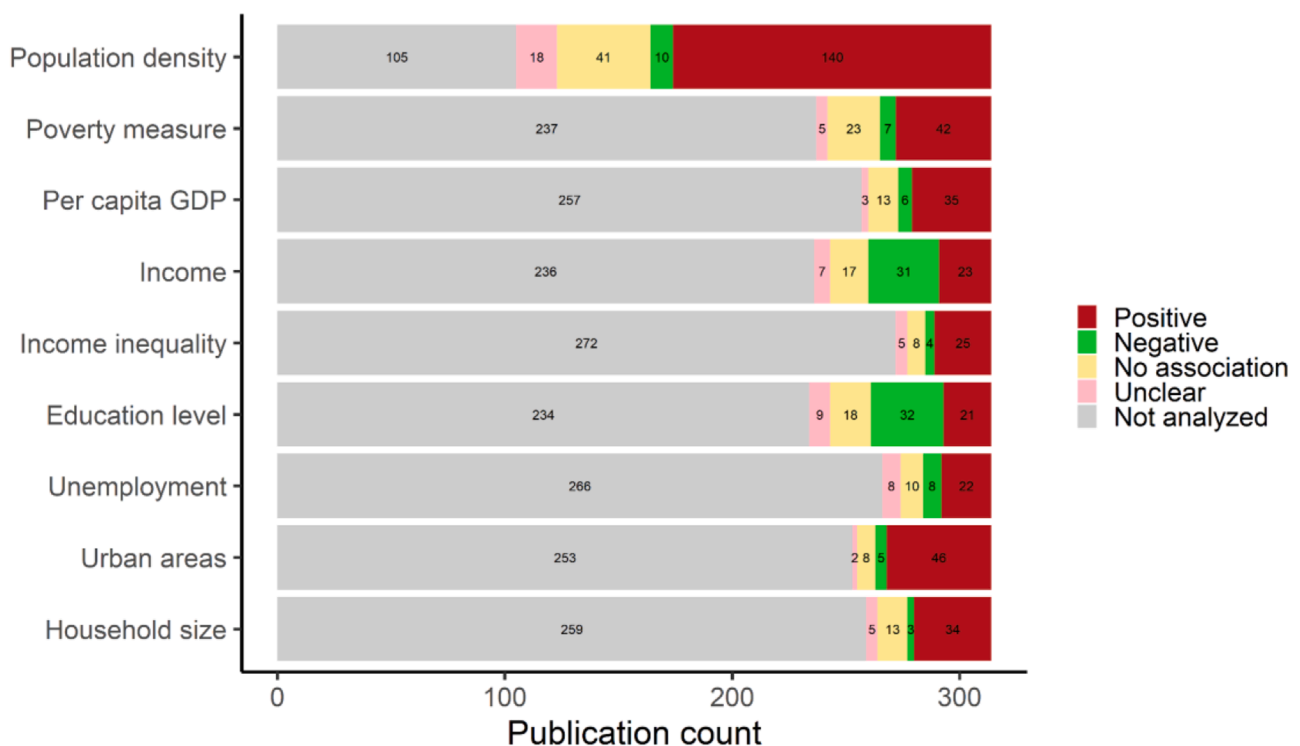

Fig. 5. Association between major groups of socioeconomic variables and COVID-19 positive cases.

is expected to spread rapidly (Andersen et al., 2021; Nguimkeu & Tadadjeu, 2021; Parvin et al., 2021; Wang et al., 2021).

Poverty measure. Usually captured by either the percentage of people below the poverty line or a similar development index. This variable is of particular interest as it seems that there is no obvious link between poverty rate and COVID-19-confirmed cases. At the moment, findings are mixed and inconclusive. Some authors (Federgruen & Naha, 2021; Wang et al., 2021) support the idea that each percentage point of residents under the poverty line contributes to increase confirmed cases. Some others (Andersen et al., 2021; Maroko, Nash, & Pavilonis, 2020) find no direct association. The argument is that other proxies for poverty such as racial, ethnic, or income inequalities correlate higher to cases. These alternative explanatory variables relate to high numbers of individuals with pre-existing medical conditions that put them at a higher risk of contracting the disease.

Per capita GDP. A simple tool to measure the economic progress of a country/region is given the per capita GDP. Among the 57 studies dealing with this variable, 35 (61.4%) revealed that the higher the gross domestic product per capita, the higher the rate of infection (Varkey, Joy, Sarmah, & Panda, 2021; Baser, 2021; Libório, Ekel, de Abreu, & Laudares, 2021). Caution is needed in interpreting findings. From Fig. 4 (right panel) we observe early studies covered a relatively short time span, and hence an alternative way to understand the result is in terms of mobility. This is, population of countries/regions with high per capita GDP is characterized by high integration in international travel networks, therefore, they may be more exposed to importation of the virus.

Income. The literature has highlighted the mechanisms by which proxies for income level (such as per-capita income, median household income, percentage of low-income residents, etc.) can influence infection dynamics. Current existing findings seem to provide inconsistent evidence. On the one side of the spectrum, 31out of the 78 (39.7%) journal articles including income-related variables show that more affluent countries/regions have less infections (Viezzer & Biondi, 2021; Kjøllesdal et al., 2022; Mena et al., 2021). Potential explanations for the expanding evidence of COVID-19 disparities generally include the higher prevalence of comorbidities among racial/ethnic minorities or that low-income minority workers do not have the luxury of working from home during physical distancing periods. On the other side of the spectrum, 23 (29.5%) studies argue that the relationship is in the opposite direction (Maiti et al., 2021; Kan et al., 2021; Leung, Sharma, Adithipyangkul, & Hosie, 2020).

Income inequality. This variable differs from income measures for a number of reasons. It captures the distribution of income across residents; thus, it tells us how the income is distributed throughout a country/region. About one-tenth ($n = 42$, 13.4%) of the reviewed literature made use of this metric. Gini index of household income is often employed to investigate whether regions with rising income inequalities experience larger number of cases. The evidence seems to favour the idea that areas with greater spread of income inequality tend to experience a more rapid COVID-19 surge (Benita & Gasca-Sanchez, 2021; Wang et al., 2021; Jannot et al., 2021).

Education level. One of the most challenging type of variables to be clustered within a single category is the education level. % of illiteracy (Niedzwiedz et al., 2020), high school graduate rate (Ojinnaka, Adepoju, Burgess, & Woodard, 2021), % without high school degree (Maroko, Nash, & Pavilonis, 2020), % of college-educated population (Hamid et al., 2020), and so forth, they all try to assess the knowledge-behavior gap. Similar to findings from income-related variables, evidence is not conclusive as from Fig. 5 we do not observe any pattern in its influence on COVID-19 incidence rates. A possible explanation of the mixed empirical results is the fact that income and education level are known to be strongly positively correlated. Studies demonstrating that prevalence of COVID-19 cases in people with lower education level argue that higher levels of information and education can be associated with more positive attitudes towards COVID-19 preventive practices.

Unemployment. Apart from income inequality, literature including

proxies for unemployment as predictors for infections is scarce. Labor force unemployment rate can contribute to the global expansion of COVID-19 and other contagious diseases. Unemployment rate highly correlates to higher percentage of minority ethnicities, greater percentage of people with lower income, lower education and high poverty. Consequently, it is probable that unemployment persistency is disproportionally exposing to contagion as individuals who have been involuntarily terminated from their jobs experience barriers to healthcare access or social distancing. According to our findings, there is no accepted consensus regarding the above-mentioned association. Even though 22 out of the 48 (45.8%) articles found a positive relationship between unemployment and infections (Kjøllesdal et al., 2022; Strully, Yang, & Liu, 2021; Ortiz-Prado et al., 2021), yet the other half of studies show either negative, unclear or no association.

Urban areas. The virus first spread with outbreaks in such urban spaces, hence, many studies ($n = 61$, 19.4%) have tried to evaluate potential rural-urban differences. Scientists (Andersen et al., 2021; Chang, Moonesinghe, & Truman, 2022; Hamidi, Sabouri, & Ewing, 2020) have been virtually unanimous in illustrating that metropolitan areas, urban centers and connected cities play a major in the spread of the pandemic.

Household size. Average household size (Maroko, Nash, & Pavilonis, 2020; Martin et al., 2020; Sugg et al., 2021; Strully, Yang, & Liu, 2021), % of more than 1 occupant per room (Hu et al., 2020) or number of family members per square meter (Buja et al., 2020) are socioeconomic variables characterizing situations in which more people per household could contribute to higher risk of COVID-19 infection. A total of 56 (17.8%) studies assessing the effect of household size and overcrowding on infections were found. Among them, 34 (61.8%) reported higher impact of the ongoing pandemic on traditionally vulnerable communities associated with more people per household. These studies have found that the virus transmits more easily indoors when people are close to one another.

3.4. Different associations around the world

In this section we present a cross-continental comparison of results as shown by Fig. 6.

World. 39 out of 314 (12.4%) studies compared datasets at the country-level. Not surprisingly, population density (included in 29 out of 39) and per capita GDP (24 out of 39) stand as the most suitable indicators for signalling the spread of the virus. Interestingly, there is currently no consensus around the effect of population density on the spread of the infection. While about one half of the studies point towards the positive link (Gonzalez-Val & Sanz-Gracia, 2021; Kianfar, Mesgari, Mollalo, & Kaveh, 2022; Li et al., 2021), the other half of them had shown no association (Kumru, Yiğit, & Hayran, 2021; Teh et al., 2021). Only a handful of studies have examined the role of measures of income level (Leung, Sharma, Adithipyangkul, & Hosie, 2020; Li et al., 2021), amount of education (Li et al., 2021; Bański, Mazur, & Kamińska, 2021), unemployment (Jain & Singh, 2020) or household size (El Mouhayyar, Jaber, Bergmann, Tighiouart, & Jaber, 2021) on infection rate. Perhaps this is because of two reasons. First, the difficulty of producing comparable indicators for many countries. Second, at the country-level per capita GDP could account for income measurements whereas population density could perhaps relate to household size (Allel, Tapia-Muñoz, & Morris, 2020; Jain & Singh, 2020; Lulbadda, Kobbekaduwa, & Guruge, 2021; Siddik, 2020). Lastly, the work of Li et al. (2021) stands out for its comprehensive assessment of critical factors associates with positive cases in 154 countries. Among all 314 journal articles, the work of Li and colleges was identified as the one simultaneously evaluating correlations of COVID-19 cases with the largest number socioeconomic variables (except for household size and unemployment).

Africa. Few studies ($n = 9$, 2.9%) were found addressing this continent. The focus is either on individual regions within a country, such as Angola (Sebastião et al., 2021); Nigeria (Bayode et al., 2022);

Fig. 6. Cross-continental socioeconomic differences around the globe.

Zambia (Phiri et al., 2021); and Ethiopia (Birhanu, Ayana, Bayu, Mohammed, & Dessie, 2021), or cross-country assessments. Population density, per capita GDP and urbanization levels are found to be among the most commonly used groups of indicators. In general, there seems to be agreement that infection rates considerably differ between urban and rural areas. Another interesting result is that education level did not affect reported transmissions and infections (Bayode et al., 2022; Birhanu, Ayana, Bayu, Mohammed, & Dessie, 2021).

Asia. Asian studies are about one-fifth (*n* = 68, 21.6%). Most of the literature comparing rural-to-urban migrants, urbanization rate and other proxies for urban areas with reported cases recognize urbanization poses considerable challenges for the prevention of emerging infectious diseases in China (Geng et al., 2021), Hong Kong (Kwok et al., 2021) or India (Gupta, Biswas, & Kabiraj, 2021). Nevertheless, there is still a gap of evidence on possible connections between income inequality and the COVID-19 outbreak across Asian regions. The only two studies so far to have examined the these connections have shown either positive or no association observed in the case of Japan (Yoshikawa & Kawachi, 2021) and Bangladesh (Rahman, Zafri, Ashik, Waliullah, & Khan, 2021), respectively. Similarly, proxies for unemployment have been seldom included. Furthermore, findings are mixed among those that have explored such possible correlations (Yoshikawa & Kawachi, 2021; Yuan et al., 2021).

Europe. 44 out of 314 (14%) studies aimed to assess how socioeconomic inequalities impacted the spread of the outbreaks along the continent. Most of the existing articles include not only population density but also differences by education level and household size. Numerous studies support positive associations between densely

populated environments (Kulu & Dorey, 2021; Gaudart et al., 2021; Morrissey, Spooner, Salter, & Shaddick, 2021), household size (Buja et al., 2020; Morrissey, Spooner, Salter, & Shaddick, 2021; Florida & Mellander, 2021) and virus spread. Yet evidence on differences of education level and COVID-19 infections is inconclusive.

Middle East. The early literature from this region of the world was reported in studies from Turkey (Coşkun, Yıldırım, & Gündüz, 2021) and Israel (Birenbaum-Carmeli & Chassida, 2021) in August 2020. Yet, it was not until 2021, when the number of publications large increased as illustrated by the right panel of Fig. 3. Furthermore, time spans analyzed by this stream of research are considerably different, see the right panel of Fig. 4. Turkey, Israel and Iran are the top 3 most frequented studies countries. Poverty (Selcuk, Gormus, & Guven, 2021), income (Khavarian-Garmsir, Sharifi, & Moradpour, 2021), urban and household size (Abdulateef et al., 2021) are among the least studied socioeconomic inequalities that could play a role on disease transmission.

North America. Among the articles with focus on this region (*n* = 106, 33.7%), 97 document outbreaks in the United States, five in Mexico three in Canada and one more in the Caribbean (Moonsammy, Oyedotun, Renn-Moonsammy, & Oyedotun, 2021). Hence, findings summarized in Fig. 6 constitute biased views towards the United States. Major lessons learnt from the research documenting the United States' pandemic can be enlisted as follows. First, it is the sole country worldwide for which all groups of socioeconomic indicators have been investigated. Second, there is clear positive relationship between poverty (Ahmad et al., 2020; Benitez, Courtemanche, & Yelowitz, 2020), household size (Desmet & Wacziarg, 2021; Maroko, Nash, & Pavilonis, 2020) and number of infections. Third, although mixed, the

empirical evidence often suggests negative associations between income (Cordes & Castro, 2020), education level (Cordes & Castro, 2020; Maroko, Nash, & Pavilonis, 2020) and the risk of contracting the virus.

South America. It is believed that the outbreak in this region of the world is far larger than the official numbers show due to the relatively low numbers of tests conducted in the first stages of the pandemic (Benítez et al., 2020). It also has the highest number of COVID-19 deaths of any region in the globe. Even though South America has only 5% of world's population, the region accounts for about quarter of all COVID-19 deaths. Brazil has consistently been the most studied country over time. Meanwhile, research with focus on countries such as Argentina, Colombia, Peru or Venezuela are limited to one article per country only. The empirical literature documenting this region of the world is scarce confined to testing between various forms of population density and income-related variables. The regional data show consistency of positive linear relationship between attributable population density (Oyedotun & Moonsammy, 2021; Mena et al., 2021), poverty (Viezzer & Biondi, 2021), and confirmed cases. The pandemic has re-leveled the weakness of the economic, social and environmental aspects and has highlighted the need for comprehensive policies in order to remove structural barriers, and address inequalities in access to health services and social development.

Oceania. Although none of the reviewed articles had explicit emphasis on these regions of the globe, we found 22 manuscripts incorporating data of Oceania (Australia included) in cross-country studies. Results from Fig. 3 (left panel) are indicative of the small number of COVID-19 cases in the continent. This could be explained due to the combination of implemented strict border controls, effectiveness of nation's lockdown and early deployment of testing and tracing systems. Published studies focusing on Oceanian countries/regions are mainly epidemiology reports, fitting of Susceptible-Infected-Recovered models (Chang et al., 2020) or public perceptions towards COVID-19 vaccines (Borriello et al., 2021) but with little to no focus on the role of socioeconomic factors in the spread of the virus.

3.5 Statistical methods and other factors

Although one of the plausible explanations that could justify the many contradictory findings across variables (Fig. 5) and regions is the different time span over which these studies have been carried out (Fig. 4, right panel), we suggest two additional explanations, namely, statistical methods, and non-socioeconomic parameters.

The literature draws on a wide range of methods. Fig. 7 (left panel) depicts the main statistical tools used to understand the effect of socioeconomic factors on the spread of the virus. The linear regression model, estimated using ordinary least squares (OLS), has been largely applied to fit independent variables to COVID-19 cases. Multiple regression models allow for the consideration of several variables that are possibly implicated in the spread of the disease but impose restrictive requirements and assumptions in terms of large sample sizes and the normality of the data. The second most frequently used tool is correlation analysis from estimates of the Pearson r, Kendall τ, and Spearman ρ (Cordes & Castro, 2020; Martin et al., 2020; Xiong et al., 2020). Although Kendall τ and Spearman ρ offer some advantages by relaxing the normal distribution assumption, they do not account for the possible presence of temporal trends, which can strongly affect the correlation value and yield artefactual associations. More sophisticated methods such as spatial (Andersen et al., 2021; Maroko, Nash, & Pavilonis, 2020; Parvin et al., 2021) or generalized linear models for count data, including Logistic (Kwok et al., 2021; Birhanu, Ayana, Bayu, Mohammed, & Dessie, 2021), Poisson (Sugg et al., 2021; Morrissey, Spooner, Salter, & Shaddick, 2021) and Negative Binomial (Benita & Gasca-Sanchez, 2021; Strully, Yang, & Liu, 2021), have been also applied. Machine learning models and classification algorithms figure from amongst the most popular approaches for predicting COVID-19 occurrence using socioeconomic inputs (Phiri et al., 2021; Li et al., 2021). In addition to the choice of model, articles also differ in their choice of response variables, ranging from cumulative number of COVID-19 cases, active cases, number of new daily cases, incidence rations to COVID-19 hospital admissions. Hence, a meta-analysis comparing the magnitude of the effects is a challenging task, see Online Supplementary Material 2.

Estimated coefficients could vary in statistical significance or sign after controlling for a much broader set of non-socioeconomic factors. We used the Venn diagram in Fig. 7 (right panel) to visualize counts of reviewed literature in the union of socioeconomic factors (in yellow color) and Health (green), Weather (blue), Mobility (blue), and Demographic (red). For example, only 10 articles considered all the above-mentioned dimensions. Socioeconomic, demographic (such as age or
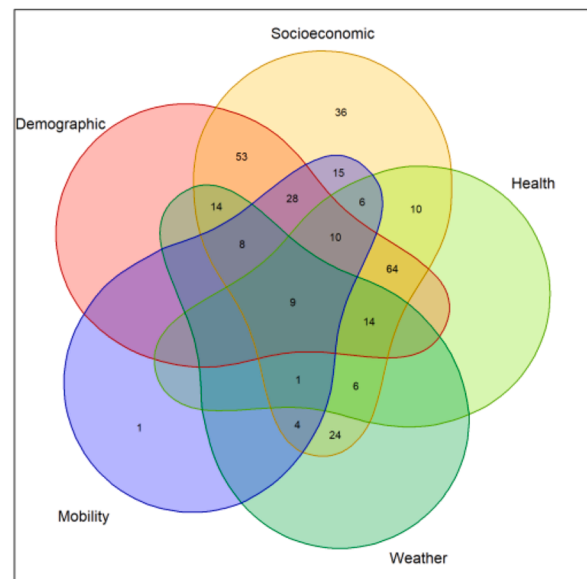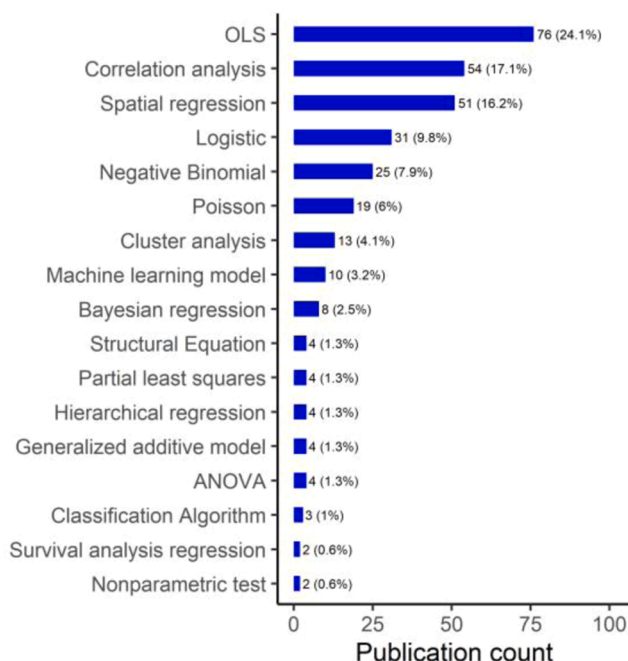

Fig. 7. *Left*: Main statistical and modelling techniques. *Right*: Number of articles considering non-socioeconomic dimensions.

gender-related variables), and health (nursing staff rate, hospital beds per 1,000 people, prevalence of comorbidities, etc.) factors are most of the time jointly examined. Proxies for human mobility, on the other hand, have been less documented.

4. Policy implications and future research directions

4.1. Policy recommendations

In terms of policy implications, reviewed articles document many lessons learned and relevant strategies for sustainable cities and communities. A stream of studies stresses the importance of conveying accurate and rapid information on COVID-19 risk factors and transmissibility. Arif & Sengupta (2021) encorage addressign the three crucial areas of response according to the "T3" strategy: testing, tracing and treatment. Gupta et al. (2021) conclude that effors for disease monitoring and control need to be multi-disciplinary, evidence-based, and from holistic standpoints. According to the authors, critical consideration should be given to both demographic and environmental variables when predicting the impact of COVID-19. In the same vein, Siddik (2020), Hu et al. (2020), Andersen et al. (2021) or Rios & Gianmoena (2021) suggest leveraging on data-driven approaches with individual socioeconomic health records data. This would enable the effective distribution of limited vaccine supplies by providing policymakers with insight into which populations to prioritize and provide with sufficient economic stimulus packages.

A different group of studies (Selcuk, Gormus, & Guven, 2021; Parvin, Ali, Hashmi, & Ahmad, 2021), from a mobility perspective, suggest that ensuring social distancing, avoiding social meet, staying at home, avoiding public transport, self-quarantine and isolation are amongst the most important factors to prevent the spread in hotspot zones. Allel, Tapia-Muñoz, & Morris (2020) and Kan et al. (2021) advocate for earlier interventions by the government enforcing strict social distancing measures to control the short-term spread of the virus. In this regard, a more sustainable policy for containing social interactions could be to apply lockdowns in proportion to the transport accessibility of hotspot zones, in the sense that the higher the accessibility, the tighter should be the mobility restriction policies adopted.

A considerable number of studies indicate the need for interventions in racial/ethnic populations at the highest risk of being hospitalized with COVID-19 (Niedzwiedz et al., 2020; Yuan et al., 2021; Chang, Moonesinghe, & Truman, 2022). For instance, Akanbi et al. (2021) and Ojinnaka et al. (2021) draw attention to the urgent need to institute long-term policies to improve health of African Americans, Hispanics and other ethnic minorities in the United States. Policymakers should therefore be sensitive to the specificities of different locations when designing responses contain the outbreaks. Although it is possible that local characteristics do not exhibit persistent effects, they often display systematic time paths which turn out to be informative for policymakers interested in spatially allocating resources over the life-cycle of the pandemic (Hamidi, Sabouri, & Ewing, 2020; Desmet & Wacziarg, 2021).

The effects of the pandemic might further challenge established principles and practices on urban infrastructure planning and management. Some authors (Khavarian-Garmsir, Sharifi, & Moradpour, 2021) advice planners and policymakers to continue promoting compact urban forms and advocate transdisciplinary approach to urban planning practices (Bayode et al., 2022). While reviewed studies suggest local governments to establish planning and design policies to minimize disease transmission in the short-term and better urban planning in the long-term (Kwok et al., 2021), scaling-up of vaccination, active surveillance on emerging variants, and fast quarantine/lockdown responses by health authorities will be needed during the post-COVID years (Rios & Gianmoena, 2021).

4.2. Research agenda and outlook

Our systematic review establishes a direction for future research and intervention development. For instance, the blank areas of the heatmaps depicted in Fig. 6 indicate a lack of work investigating relationships between specific socioeconomic variables and COVID-19 cases. Ideally, at least one cell of each row in every heatmap in the figure should be colored. This, to indicate that all groups of socioeconomic indicators have been examined in every region of the world. It is possible that many other studies published in non-English language have already identified existing links between variables of interest and cases, but further exploration and investigation for different countries is an area for research. Fig. 7 (right panel) points to similar opportunities. Of note, only few reviewed articles demonstrated awareness of going beyond and accounted for interactions between socioeconomic, non-socioeconomic variables (demographic, healthcare predispositions, weather and mobility) and cases. Therefore, need for conducting multidimensional studies for robust associations between independent and dependent variables is found to be another area of study. Lastly, once a longer time series of data has been established, multidisciplinary teams should revisit and update previous findings with the purpose of identifying possible significant changes to associations due to new waves of steep infection growth.

5. Concluding remarks

5.1. Strengths and limitations of our review

This review has numerous strengths. It is the first systematic review of evidence on the association between socioeconomic inequalities and COVID-19 cases using peer reviewed journals only. Findings have allowed for the categorization of nine groups of socioeconomic indicators which could have an impact on virus transmission. Results are synthesized by regions of the world and provide a summary of the main methodological tools suitable for such analysis. Moreover, we put special emphasis on communicating reported findings effectively through different data visualizations.

However, several limitations of this review should also be noted. First, it excludes documents indexed in more comprehensive databases such as PubMed, Global Health, medRxiv or Google Scholar. Therefore, findings do not cover grey literature. Even though publishing in academic journals is critical to health researchers' success, many structural barriers prevent researchers in low- and middle-income countries from publishing their work. Therefore, such researchers are underrepresented in academic literature resulted from our search strategy and eligibility criteria. With changes in publishing trends during the COVID-19 era, there is a growing popularity of publishing preprints (Homolak, Kodvanj, & Virag, 2020). Meanwhile non-peer-reviewed articles and grey literature such as regulatory data, unpublished trial data or government publications are still an important source of information, assessing their quality is not a straightforward task as their reliability should not be taken for granted. Second and very much related to the first point, we observed a publication bias towards studies carried out with data from the United States and China. Only these two countries accounted for about 40% of all reviewed studies. Although we attempted to refine findings by cross-continental trends (Fig. 6), results' generalizability must be interpreted with caution.

5.2. Conclusions

Based on systematic literature review, our findings provide new evidence on the relevance of different channels that are associated with socioeconomic inequalities in COVID-19 infections. Our observations demonstrated that researchers paid more attention to population density, measures of poverty, income, and education level. Other factors such as income inequality or unemployment have been less studied thus

far, perhaps due to its inherent difficulty in constructing these indicators. Income inequality has shown to be strongly positively associated with transmission. Thus, further research should consider income inequalities among socially vulnerable groups to better to promote equitable COVID-19-related healthcare. Our findings point to a large body of literature (about one third of the studies) with focus on the United States followed by cross-country studies (about 12%) and China (10%). In contrast, none of the studies was found to examine the case of countries in Oceania. This current study contributes significantly to the body of knowledge in social gradients in COVID-19 infection. The findings (Fig. 6) reveal gaps in Africa and Middle East which could guide researchers and policymakers regarding the understanding of both the specific patterns of COVID-19 inequalities and the possibilities for public policies and planning interventions. Lastly, it is recommended that future studies should critically evaluate the role of socioeconomic factors on the different waves of the epidemic, as for instance, infections could largely be driven by inequalities in the absence of widespread vaccination.

Funding

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Our submission contains main datasource to replicate results.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.scs.2022.104158.

References

Abdulateef, D., Rahman, H., Salih, J., Osman, S., Mahmood, T., Omer, S., & Ahmed, R. (2021). COVID-19 severity in relation to sociodemographics and vitamin D use. *Open Medicine, 16*(1), 591–609.

Ahmad, K., Erqou, S., Shah, N., Nazir, U., Morrison, A., Choudhary, G., & Wu, W. (2020). Association of poor housing conditions with COVID-19 incidence and mortality across US counties. *PLoS ONE, 15*, Article e0241327, 11 November.

Akanbi, M., Rivera, A., Akanbi, F., & Shoyinka, A. (2021). An ecologic study of disparities in COVID-19 incidence and case fatality in Oakland County, MI, USA, during a state-mandated shutdown. *Journal of Racial and Ethnic Health Disparities, 8*(6), 1467–1474.

Allel, K., Tapia-Muñoz, T., & Morris, W. (2020). Country-level factors associated with the early spread of COVID-19 cases at 5, 10 and 15 days since the onset. *Global Public Health, 15*(11), 1589–1602.

Andersen, L., Harden, S., Sugg, M., Runkle, J., & Lundquist, T. (2021). Analyzing the spatial determinants of local Covid-19 transmission in the United States. *Science of the Total Environment, 754*, Article 142396.

Anser, M., Usman, B., Hyder, S., Nassani, A., Askar, S., Zaman, K., & Abro, M. (2021). Does improvement in the environmental sustainability rating help to reduce the COVID-19 cases? Controlling financial development, price level and carbon damages. *Environmental Science and Pollution Research, 28*(36), 49820–49832.

Arif, M., & Sengupta, S. (2021). Nexus between population density and novel coronavirus (COVID-19) pandemic in the south Indian states: A geo-statistical approach. *Environment, Development and Sustainability, 23*(7), 10246–10274.

Ayyoob, S., & Khavarian-Garmsir, A. (2020). The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management. *cience of the Total Environment, 749*, Article 142391.

Bański, J., Mazur, M., & Kamińska, W. (2021). Socioeconomic conditioning of the development of the covid-19 pandemic and its global spatial differentiation. *International Journal of Environmental Research and Public Health, 18*(9), 4802.

Baser, O. (2021). Population density index and its use for distribution of Covid-19: A case study using Turkish data. *Health Policy, 125*(2), 148–154.

Bayode, T., Popoola, A., Akogun, O., Siegmund, A., Magidimisha-Chipungu, H., & Ipingbemi, O. (2022). Spatial variability of COVID-19 and its risk factors in Nigeria: A spatial regression method. *Applied Geography, 138*, Article 102621.

Bengtsson, T., Dribe, M., & Eriksson, B. (2018). Social class and excess mortality in Sweden during the 1918 influenza pandemic. *American Journal of Epidemiology, 187*(12), 2568–2576.

Benita, F., & Gasca-Sanchez, F. (2021). The main factors influencing COVID-19 spread and deaths in Mexico: A comparison between phases I and II. *Applied Geography, 134*, Article 102523.

Benitez, J., Courtemanche, C., & Yelowitz, A. (2020). Racial and Ethnic Disparities in COVID-19: Evidence from Six Large Cities. *Journal of Economics, Race, and Policy, 3*(4), 243–261.

Benítez, M., Velasco, C., Sequeira, A., Henríquez, J., Menezes, F., & Paolucci, F. (2020). Responses to COVID-19 in five Latin American countries. *Health Policy and Technology, 9*(4), 525–559.

Birenbaum-Carmeli, D., & Chassida, J. (2021). Health and socio-demographic implications of the Covid-19 second pandemic wave in Israel, compared with the first wave. *International Journal for Equity in Health, 20*(1), 1–12.

Birhanu, A., Ayana, G. M., Bayu, M., Mohammed, A., & Dessie, Y. (2021). Features associated with SARS-COV-2 positivity among people presenting with acute respiratory tract infections to public Hospitals in Harari region, Ethiopia. *SAGE Open Medicine, 9*, Article 20503121211062793.

Borriello, A., Master, D., Pellegrini, A., & Rose, J. M. (2021). Preferences for a COVID-19 vaccine in Australia. *Vaccine, 39*(3), 473–479.

Briz-Redón, Á., & Serrano-Aroca, Á. (2020). The effect of climate on the spread of the COVID-19 pandemic: A review of findings, and statistical and modelling techniques. *Progress in Physical Geography, 44*(5), 591–604.

Buja, A., Paganini, M., Cocchio, S., Scioni, M., Rebba, V., & Baldo, V. (2020). Demographic and socio-economic factors, and healthcare resource indicators associated with the rapid spread of COVID-19 in Northern Italy: An ecological study. *PLoS ONE, 15*, Article e0244535, 12 December.

Chang, M., Moonesinghe, R., & Truman, B. (2022). COVID-19 Hospitalization by Race and Ethnicity: Association with Chronic Conditions Among Medicare Beneficiaries, January 1–September 30, 2020. *Journal of Racial and Ethnic Health Disparities, 9*, 325–334.

Chang, S. L., Harding, N., Zachreson, C., Cliff, O. M., & Prokopenko, M. (2020). Modelling transmission and control of the COVID-19 pandemic in Australia. *Nature Communications, 11*(1), 1–13.

Cordes, J., & Castro, M. (2020). Spatial analysis of COVID-19 clusters and contextual factors in New York City. *Spatial and Spatio-temporal Epidemiology, 34*, Article 100355.

Coşkun, H., Yıldırım, N., & Gündüz, S. (2021). The spread of COVID-19 virus through population density and wind in Turkey cities. *Science of the Total Environment, 751*, Article 141663.

Desmet, K., & Wacziarg, R. (2021). Understanding spatial variation in COVID-19 across the United States. *Journal of Urban Economics*, Article 103332.

Doshi, S., Silk, B., Dutt, D., Ahmed, M., Cohen, A., Taylor, T., & Ram, P. (2015). Household-level risk factors for influenza among young children in Dhaka, Bangladesh: A case-control study. *Tropical Medicine and International Health, 20*(6), 719–729.

El Mouhayyar, C., Jaber, L., Bergmann, M., Tighiouart, H., & Jaber, B. (2021). Country-level determinants of COVID-19 case rates and death rates: An ecological study. *Transboundary and Emerging Diseases*, 14360.

Federgruen, A., & Naha, S. (2021). Crowding Effects Dominate Demographic Attributes in COVID-19 Cases. *International Journal of Infectious Diseases, 102*, 509–516.

Florida, R., & Mellander, C. (2021). The geography of COVID-19 in Sweden. *Annals of Regional Science*, 1–26.

Gaudart, J., Landier, J., Huiart, L., Legendre, E., Lehot, L., Bendiane, M., & Rebaudet, S. (2021). Factors associated with the spatial heterogeneity of the first wave of COVID-19 in France: A nationwide geo-epidemiological study. *The Lancet Public Health, 6*(4), e222–e231.

Gebhard, C., Regitz-Zagrosek, V., Neuhauser, H., Morgan, R., & Klein, S. (2020). Impact of sex and gender on COVID-19 outcomes in Europe. *Biology of Sex Differences, 11*(1), 1–13.

Geng, M., Wang, L., Ren, X., Yu, J., Chang, Z., Zheng, C., & Feng, Z. (2021). Risk factors for developing severe COVID-19 in China: An analysis of disease surveillance data. *Infectious Diseases of Poverty, 10*(1), 1–10.

Gonzalez-Val, R., & Sanz-Gracia, F. (2021). Urbanization and COVID-19 incidence: A cross-country investigation. *Papers in Regional Science*, 12647.

Gupta, D., Biswas, D., & Kabiraj, P. (2021). COVID-19 outbreak and Urban dynamics: Regional variations in India. *GeoJournal*, 1–19.

Haitao, T., Vermunt, J., Abeykoon, J., Ghamrawi, R., Gunaratne, M., Jayachandran, M., & Garovic, V. (2020). *95. COVID-19 and sex differences: Mechanisms and biomarkers* (pp. 2189–2203). Mayo Clinic Proceedings.

Hamidi, S., Sabouri, S., & Ewing, R. (2020). Does Density Aggravate the COVID-19 Pandemic? *Journal of the American Planning Association, 86*(4), 495–509.

Homolak, J., Kodvanj, I., & Virag, D. (2020). Preliminary analysis of COVID-19 academic information patterns: a call for open science in the times of closed borders. *Scientometrics, 124*(3), 2687–2701.

Hu, T., Yue, H., Wang, C., She, B., Ye, X., Liu, R., & Bao, S. (2020). Racial segregation, testing site access, and covid-19 incidence rate in Massachusetts, USA. *International Journal of Environmental Research and Public Health, 17*(24), 9528.

Jain, V., & Singh, L. (2020). Global Spread and Socio-Economic Determinants of Covid-19 Pandemic. *Seoul Journal of Economics, 33*(4), 561–600.

Jannot, A., Countouris, H., Van Straaten, A., Burgun, A., Katsahian, S., & Rance, B. (2021). Low-income neighbourhood was a key determinant of severe COVID-19 incidence during the first wave of the epidemic in Paris. *Journal of Epidemiology and Community Health, 75*(12), 1143–1146.

Kan, Z., Kwan, M., Wong, M., Huang, J., & Liu, D. (2021). Identifying the space-time patterns of COVID-19 risk and their associations with different built environment features in Hong Kong. *Science of the Total Environment, 772*, Article 145379.

Khavarian-Garmsir, A., Sharifi, A., & Moradpour, N. (2021). Are high-density districts more vulnerable to the COVID-19 pandemic? *Sustainable Cities and Society, 70*, Article 102911.

Kianfar, N., Mesgari, M., Mollalo, A., & Kaveh, M. (2022). Spatio-temporal modeling of COVID-19 prevalence and mortality using artificial neural network algorithms. *Spatial and Spatio-temporal Epidemiology, 40*, Article 100471.

Kjøllesdal, M., Skyrud, K., Gele, A., Arnesen, T., Kløvstad, H., Diaz, E., & Indseth, T. (2022). The correlation between socioeconomic factors and COVID-19 among immigrants in Norway: A register-based study. *Scandinavian Journal of Public Health, 50*(1), Article 14034948211015860.

Kulu, H., & Dorey, P. (2021). *Infection rates from Covid-19 in Great Britain by geographical units: A model-based estimation from mortality data, 67*. Health and Place, Article 102460.

Kumru, S., Yiğit, P., & Hayran, O. (2021). Demography, inequalities and Global Health Security Index as correlates of COVID-19 morbidity and mortality. *International Journal of Health Planning and Management*.

Kwok, C., Wong, M., Chan, K., Kwan, M., Nichol, J., Liu, C., & Kan, Z. (2021). Spatial analysis of the impact of urban geometry and socio-demographic characteristics on COVID-19, a study in Hong Kong. *Science of the Total Environment, 764*, Article 144455.

Leung, T., Sharma, P., Adithipyangkul, P., & Hosie, P. (2020). Gender equity and public health outcomes: The COVID-19 experience. *Journal of Business Research, 116*, 193–198.

Li, M., Zhang, Z., Cao, W., Liu, Y., Du, B., Chen, C., & Wang, X. (2021). Identifying novel factors associated with COVID-19 transmission and fatality using the machine learning approach. *Science of the Total Environment, 764*, Article 142810.

Libório, M., Ekel, P., de Abreu, J., & Laudares, S. (2021). Factors that most expose countries to COVID-19: A composite indicators-based approach. *GeoJournal*.

Link, B., & Phelan, J. (1995). Social conditions as fundamental causes of disease. *Journal of Health and Social Behavior, Spec*, 80–94.

Lulbadda, K., Kobbekaduwa, D., & Guruge, M. (2021). The impact of temperature, population size and median age on COVID-19 (SARS-CoV-2) outbreak. *Clinical Epidemiology and Global Health, 9*, 231–236.

Magesh, S., John, D., Li, W., Li, Y., Mattingly-App, A., Jain, S., & Ongkeko, W. (2021). Disparities in COVID-19 outcomes by race, ethnicity, and socioeconomic status: A systematic-review and meta-analysis. *JAMA Network Open, 4*(11), Article e2134147. e2134147-.

Maiti, A., Zhang, Q., Sannigrahi, S., Pramanik, S., Chakraborti, S., Cerda, A., & Pilla, F. (2021). Exploring spatiotemporal effects of the driving factors on COVID-19 incidences in the contiguous United States. *Sustainable Cities and Society, 68*, Article 102784.

Maroko, A., Nash, D., & Pavilonis, B. (2020). COVID-19 and Inequity: A comparative spatial analysis of New York City and Chicago hot spots. *Journal of Urban Health, 97*(4), 461–470.

Martin, C., Jenkins, D., Minhas, J., Gray, L., Tang, J., Williams, C., & Pareek, M. (2020). Socio-demographic heterogeneity in the prevalence of COVID-19 during lockdown is associated with ethnicity and household size: Results from an observational cohort study. *EClinicalMedicine, 25*, Article 100466.

Mayer, J., Schintler, L., & Bledsoe, S. (2020). Culture, Freedom, and the Spread of Covid-19: Do Some Societies and Political Systems Have National Anti-Bodies? *World Medical and Health Policy, 12*(4), 498–511.

Mecenas, P., da Rosa Moreira Bastos, R., Rosário Vallinoto, A., & Normando, D (2020). Effects of temperature and humidity on the spread of COVID-19: A systematic review. *PLoS one, 15*(9), Article e0238339.

Mena, G., Martinez, P., Mahmud, A., Marquet, P., Buckee, C., & Santillana, M. (2021). Socioeconomic status determines COVID-19 incidence and related mortality in Santiago, Chile. *Science, 372*(6545), eabg5298.

Millett, G., Jones, A., Benkeser, D., Stefan, B., Mercer, L., Beyrer, C., & Sullivan, P. S. (2020). Assessing differential impacts of COVID-19 on black communities. *Annals of Epidemiology, 47*, 37–44.

Moonsammy, S., Oyedotun, T., Renn-Moonsammy, D., & Oyedotun, T. (2021). COVID-19 modelling in the Caribbean: Spatial and statistical assessments. *Spatial and Spatio-temporal Epidemiology, 37*, Article 100416.

Morrissey, K., Spooner, F., Salter, J., & Shaddick, G. (2021). Area level deprivation and monthly COVID-19 cases: The impact of government policy in England. *Social Science and Medicine, 289*, Article 114413.

Nguimkeu, P., & Tadadjeu, S. (2021). Why is the number of COVID-19 cases lower than expected in Sub-Saharan Africa? A cross-sectional analysis of the role of demographic and geographic factors. *World Development, 138*, Article 105251.

Niedzwiedz, C., O'Donnell, C., Jani, B., Demou, E., Ho, F., Celis-Morales, C., & Katikireddi, S. (2020). Ethnic and socioeconomic differences in SARS-CoV-2 infection: Prospective cohort study using UK Biobank. *BMC Medicine, 18*(1), 1–14.

Ojinnaka, C., Adepoju, O., Burgess, A., & Woodard, L. (2021). Factors associated with COVID-related mortality: The case of Texas. *Journal of Racial and Ethnic Health Disparities, 8*(6), 1505–1510.

Ortiz-Prado, E., Simbaña-Rivera, K., Barreno, L., Diaz, A., Barreto, A., Moyano, C., & Lowe, R. (2021). Epidemiological, socio-demographic and clinical features of the early phase of the COVID-19 epidemic in Ecuador. *PLoS Neglected Tropical Diseases, 15*(1), Article e0008958.

Oyedotun, T., & Moonsammy, S. (2021). Spatiotemporal Variation of COVID-19 and Its Spread in South America: A Rapid Assessment. *Annals of the American Association of Geographers, 111*(6), 1868–1879.

Parker, R. (2002). The global HIV/AIDS pandemic, structural inequalities, and the politics of health. *American Journal of Public Health, 92*(3), 343–347.

Parvin, F., Ali, S., Hashmi, S., & Ahmad, A. (2021). Spatial prediction and mapping of the COVID-19 hotspot in India using geostatistical technique. *Spatial Information Research, 29*(4), 479–494.

Phiri, D., Salekin, S., Nyirenda, V., Simwanda, M., Ranagalage, M., & Murayama, Y. (2021). Spread of COVID-19 in Zambia: An assessment of environmental and socioeconomic factors using a classification tree approach. *Scientific African, 12*, e00827.

Raharja, A., Tamara, A., & Kok, L. (2021). Association between ethnicity and severe COVID-19 disease: A systematic review and meta-analysis. *Journal of Racial and Ethnic Health Disparities, 8*(6), 1563–1572.

Rahman, M., Zafri, N., Ashik, F., Waliullah, M., & Khan, A. (2021). Identification of risk factors contributing to COVID-19 incidence rates in Bangladesh: A GIS-based spatial modeling approach. *Heliyon, 7*(2), e06260.

Rios, V., & Gianmoena, L. (2021). On the link between temperature and regional COVID-19 severity: Evidence from Italy. *Regional Science Policy and Practice, 13*(S1), 109–137.

Rutter, P., Mytton, O., Mak, M., & Donaldson, L. (2012). Socio-economic disparities in mortality due to pandemic influenza in England. *International Journal of Public Health, 57*(4), 745–750.

Sebastião, C., Neto, Z., Martinez, P., Jandondo, D., Antonio, J., Galangue, M., & Morais, J. (2021). Sociodemographic characteristics and risk factors related to SARS-CoV-2 infection in Luanda, Angola. *PLoS ONE, 16*, Article e0249249, 3 March.

Selcuk, M., Gormus, S., & Guven, M. (2021). Impact of Weather Parameters and Population Density on the COVID-19 Transmission: Evidence from 81 Provinces of Turkey. *Earth Systems and Environment, 5*, 87–100.

Siddik, M. (2020). Economic stimulus for COVID-19 pandemic and its determinants: Evidence from cross-country analysis. *Heliyon, 6*(12), e05634.

Strully, K., Yang, T., & Liu, H. (2021). Regional variation in COVID-19 disparities: Connections with immigrant and Latinx communities in U.S. counties. *Annals of Epidemiology, 53*, 62.e2.

Sugg, M., Spaulding, T., Lane, S., Runkle, J., Harden, S., Hege, A., & Iyer, L. (2021). Mapping community-level determinants of COVID-19 transmission in nursing homes: A multi-scale approach. *Science of the Total Environment, 752*, Article 141946.

Teh, J., Bradley, D., Chook, J., Lai, K., Ang, W., Teo, K., & Peh, S. (2021). Multivariate visualization of the global COVID-19 pandemic: A comparison of 161 countries. *PLoS ONE, 16*, Article e0252273, 5 May.

Varkey, R., Joy, J., Sarmah, G., & Panda, P. (2021). Socioeconomic determinants of COVID-19 in Asian countries: An empirical analysis. *Journal of Public Affairs, 21*(4), e2532.

Viezzer, J., & Biondi, D. (2021). The influence of urban, socio-economic, and eco-environmental aspects on COVID-19 cases, deaths and mortality: A multi-city case in the Atlantic Forest, Brazil. *Sustainable Cities and Society, 69*, Article 102859.

Wachtler, B., Michalski, N., Nowossadeck, E., Diercke, M., Wahrendorf, M., Santos-Hövener, C., & Hoebel, J. (2020). Socioeconomic inequalities and COVID-19–A review of the current international literature. *Journal of Health Monitoring, 5*(S7), 1–17.

Walker, P., Whittaker, C., Watson, O., Baguelin, M., Winskill, P., Hamlet, A., & Ghani, A. (2020). The impact of COVID-19 and strategies for mitigation and suppression in low- and middle-income countries. *Science, 369*(6502), 413–422.

Wang, L., Zhang, S., Yang, Z., Zhao, Z., Moudon, A., Feng, H., & Cao, B. (2021). What county-level factors influence COVID-19 incidence in the United States? Findings from the first wave of the pandemic. *Cities, 118*, Article 103396.

Xiong, Y., Wang, Y., Chen, F., & Zhu, M. (2020). Spatial statistics and influencing factors of the COVID-19 epidemic at both prefecture and county levels in Hubei Province, China. *International Journal of Environmental Research and Public Health, 17*(11), 3903.

Yoshikawa, Y., & Kawachi, I. (2021). Association of Socioeconomic Characteristics with Disparities in COVID-19 Outcomes in Japan. *JAMA Network Open, 4*(7), Article e2117060. ♠.

Yuan, Y., Zhao, Y., Zhang, Q., Zhang, L., Cheung, T., Jackson, T., & Xiang, Y. (2021). COVID-19-related stigma and its sociodemographic correlates: A comparative study. *Globalization and Health, 17*(1), 1–9.

Zhu, J., & Liu, W. (2020). A tale of two databases: The use of Web of Science and Scopus in academic papers. *Scientometrics, 123*(1), 321–335.