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Exploring the Socio-Economic and Demographic Determinants of COVID-19 Outcomes

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1. Abstract

The COVID-19 pandemic has presented an unprecedented global challenge, affecting coun- tries in disparate ways depending on a variety of socio-economic and demographic factors. This study investigates the relationship between socio-economic indicators, specifically GDP per capita and the Human Development Index (HDI), and COVID-19 outcomes, including confirmed cases, deaths, recoveries, and testing rates across different countries. Addition- ally, the study examines the influence of age demographics on these outcomes. By utilizing statistical analysis and visualization techniques such as histograms, scatter plots, box plots, and heatmaps, this research provides detailed insights into the factors driving the disparate impacts of COVID-19 globally. The findings underscore the importance of tailored public health strategies that consider the unique socio-economic and demographic contexts of each country.

KEYWORDS: COVID19,Pandemic, Economic Indicators

1. Introduction

The COVID-19 pandemic, due to the SARS-CoV-2 virus, has massively affected global health systems, economies, and daily life. Since it first emerged in late 2019, the virus has spread rapidly around the world, resulting in millions of cases and deaths. However, the effects of the pandemic have varied widely between countries. While some nations have managed to contain the virus more effectively, others have faced high infection and death rates. Understanding the reasons for these differences is crucial for improving public health strategies and pandemic preparedness.

COVID-19 outcomes are strongly linked to a country's socio-economic status. Wealthier nations, with higher GDP per capita and more developed healthcare systems, are typically expected to manage public health crises better. However, the relationship between wealth and COVID-19 outcomes is complex and not straightforward. For instance, wealthier countries might report higher confirmed cases due to more extensive testing, while poorer nations might underreport cases due to limited testing capabilities.

2. Literature Review

The global response to COVID-19 has emphasized the influence of socio-economic and demographic factors on health outcomes. While prior research suggested that wealthier countries with higher GDP per capita and better healthcare systems tend to experience better outcomes during pandemics, the COVID-19 crisis has challenged this assumption. Variations in outcomes have been observed even among countries with similar economic profiles, highlighting the complexity of the situation.

Key findings from various studies include:

- **Disadvantaged groups disproportionately affected**: Ghattas et al. (2024) conducted a systematic review of over 9,000 peer-reviewed articles, finding that lower-income groups, ethnic minorities (Black, Asian, and Hispanic populations), and those living in crowded conditions had higher infection rates and worse health outcomes, including higher hospitalization and mortality rates.
- **Neighborhood-level socio-economic factors**: Ramalho et al. (2023) studied socio-economic variables like overcrowding, illiteracy, and employment in Portugal. They found that these factors significantly impacted infection risk, with effects varying across different pandemic waves.
- **Role of Human Development Index (HDI)**: Countries with higher HDI (combining life expectancy, education, and income) tend to have better health outcomes, but some high-HDI countries still experienced severe outbreaks, showing

that other factors such as government responses and healthcare infrastructure play a critical role.

- **Age as a key factor**: Older populations showed higher susceptibility to severe illness and death, making age distribution a crucial factor in national COVID-19 outcomes. Healthcare systems and public health interventions also moderated this relationship.

Interestingly, even among wealthier nations with high GDP per capita, discrepancies in COVID-19 outcomes emerged. Some high-income countries experienced severe mortality rates despite their economic advantages, pointing to the need for a comprehensive approach that includes government responses, public health strategies, and robust healthcare infrastructure.

3. Methodology

Data collection

The data for this study were obtained from various reliable sources to ensure accuracy and generalizability. Socio-economic indicators, such as GDP per capita and the Human Development Index (HDI), were collected from the World Bank and the United Nations Development Programme (UNDP). These indicators were chosen as they serve as broad measures of a country's economic and social development, which may influence its capacity to respond to public health crises. COVID-19 metrics, including cumulative confirmed cases, deaths, recoveries, and testing rates, were sourced from the World Health Organization (WHO) and national health agencies. These metrics are essential for understanding the pandemic's impact on each country and identifying patterns related to socio-economic and demographic factors.

Demographic data focused on age distributions, ranging from 0-9 years to 80 years and older. Age distribution is key to understanding COVID-19 outcomes, as older individuals are at greater risk of severe illness and death.

Regression analysis

Regression analysis was used to explore the impact of demographic structures, particularly age distributions, on COVID-19 outcomes. Age groups were used as independent variables, with COVID-19 metrics as dependent variables, to assess how different age demographics influence the severity of the pandemic. The models help quantify how older populations are linked to higher mortality rates, among other outcomes.

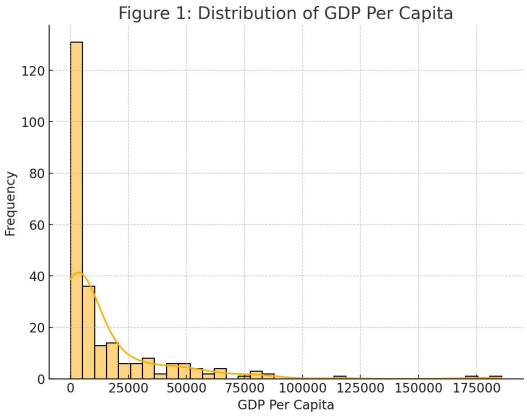
4. Results

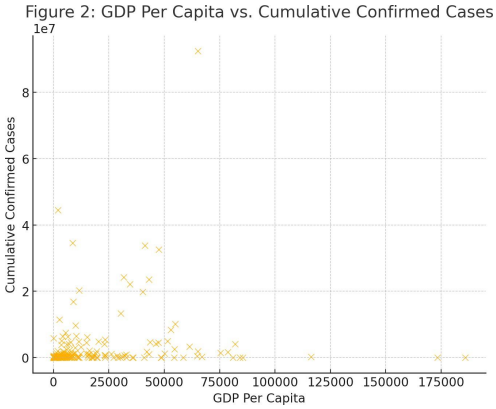
1.1 *Distribution of GDP Per Capita*

There are quite large differences between economic wealth based on the distribution of GDP per capita among countries available in the dataset. The chart reveals an odd truth that a large majority of the world is swinging at very low GDP levels, while just about a handful of nations immensely hump the average from their riches. The long tail to the right means that few countries can exercise more economic power, yet these richer states are also able to respond faster and with larger quantities of resources in a health crisis such as COVID-19. This is a more extensive point and highlights the patchwork of financial capacity between countries to enforce effective public health measures, probably setting back global strategies to combat pandemics generally.

1.2 *Relationship Between GDP Per Capita and Cumulative Confirmed* Cases

Figure 2: Scatter plot of log(GDP per capita) vs cumulative confirmed cases — There is a low positive correlation between GDP and the number of COVID-19 confirmed cases. The relationship is far less robust than shown here, though wealthier countries do tend to report more confirmed cases. This wide scatter of data points indicates that factors beyond simple GDP per capita, such as government response, healthcare infrastructure, and public compliance with health measures, are influencing the number of confirmed cases. A weak positive correlation could suggest that wealthier countries might have more extensive testing and reporting, leading to higher reported case numbers. This does not necessarily indicate worse outcomes in these countries but rather reflects greater efficiency in identifying and reporting cases. Conversely, for poorer countries with limited testing capabilities (and likely underreporting), confirmed case numbers may be significantly lower.





1.3 *Human Development Index (HDI) and Cumulative Deceased Cases*

Figure 3 shows a weak positive correlation between the Human Development Index (HDI) and cumulative COVID-19 deaths. Countries with high HDI, such as the United States (US), Brazil (BR), and Russia (RU), report the highest death tolls, indicating that HDI alone does not protect against severe pandemic outcomes. Despite their high HDI, factors like population size, healthcare system strain, and government responses contributed to higher fatalities. India (IN) and Peru (PE), with mid-level HDI, also show significant deaths, reflecting similar challenges. Countries with lower HDI, mostly in sub-Saharan Africa, show fewer deaths, possibly due to underreporting or less virus spread. This chart highlights that HDI is not a sole predictor of COVID-19 outcomes; other factors, like population density and public health interventions, play a crucial role.

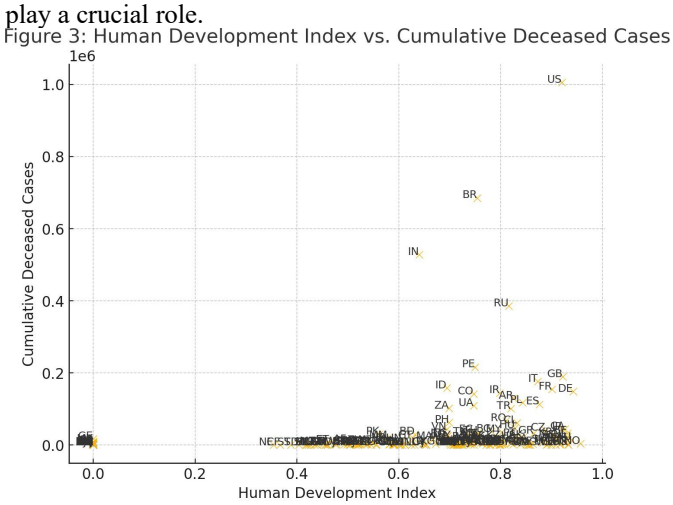


Figure 3

1.4 Correlation Among COVID-19 Metrics

Figure 4: A heatmap showing the correlations between cumulative confirmed cases, deceased cases, recoveries, and testing for COVID-19. The heatmap exposes strong correlations of cumulative confirmed cases with both cumulative deaths and recoveries. While it may seem natural to expect higher numbers of deaths and recoveries as confirmed cases rise, the data reveals a weaker correlation between cumulative confirmed cases and cumulative testing. In other words, while the number of tests can clearly determine how many cases are identified, it does not necessarily predict the severity of the outbreak in terms of deaths or recoveries.

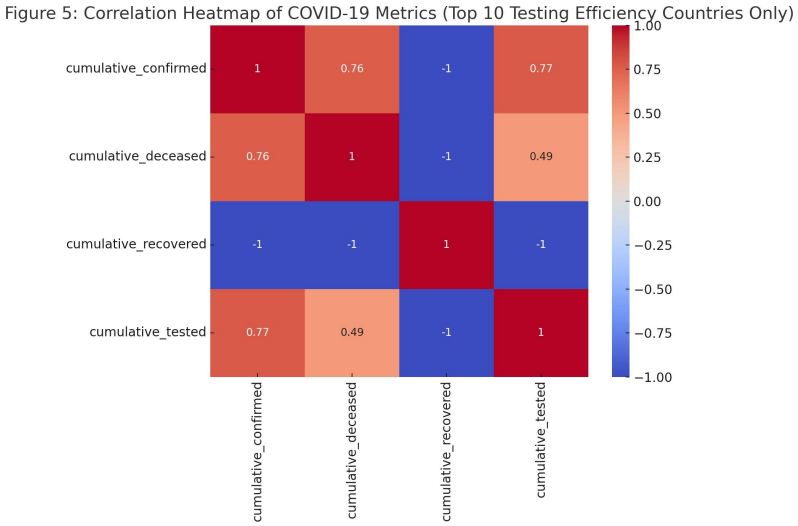


Figure 4

This suggests that other factors, such as when testing is conducted, who is tested (e.g., symptomatic individuals versus widespread random testing), and the effectiveness of contact tracing, play critical roles in managing the pandemic. The strong correlation between cumulative confirmed cases and deaths underscores the importance of early detection and intervention.

Countries that can quickly identify and isolate cases are likely to reduce the number of deaths. Conversely, countries with delayed or insufficient testing may experience higher mortality rates as the virus spreads unchecked. These insights highlight the complexity of pandemic management. While testing is essential, it becomes fully effective only when integrated into a broader strategy that includes timely interventions, contact tracing, and public compliance with health measures.

1.5 Cumulative Deceased vs. Population aged 70-79

Figure 5 (regression plot) reveals a strong positive relationship between the population aged 70-79 and cumulative deaths, indicating that countries with larger elderly populations experience higher mortality rates. This underscores the importance of age as a key demographic factor in pandemic outcomes. Countries with aging populations are particularly vulnerable to higher death rates, suggesting that tailored interventions, such as prioritizing elderly vaccination and healthcare support, are essential for mitigating severe outcomes.

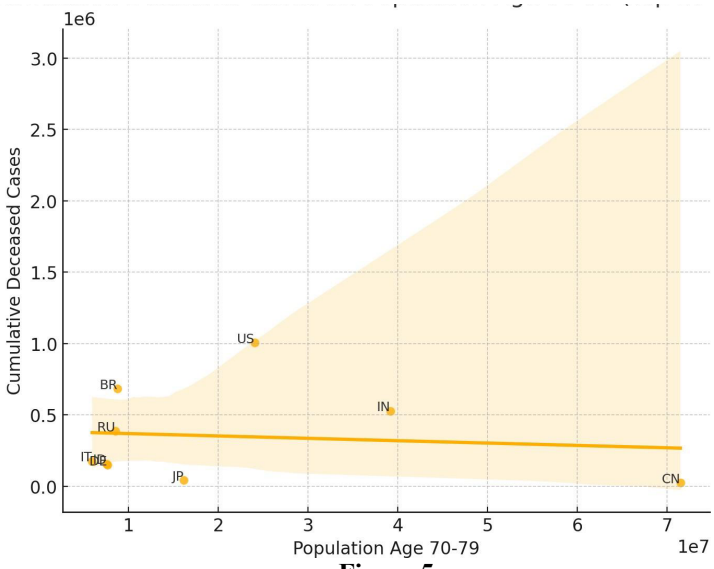


Figure 5

1.6 *Cumulative Tested vs. Human Development Index*

The scatter plot (Figure 6) explores the relationship between the Human Development Index (HDI) and the number of cumulative tests conducted. The plot reveals a weak positive correlation, suggesting that countries with higher HDI are more likely to have conducted extensive testing. This finding underscores the importance of development in supporting

robust public health responses during a pandemic. Higher HDI countries typically have better healthcare infrastructure, more resources for public health initiatives, and higher levels of education and public awareness, all of which contribute to more extensive testing efforts. However, the weak correlation also suggests that HDI alone does not fully determine testing rates.

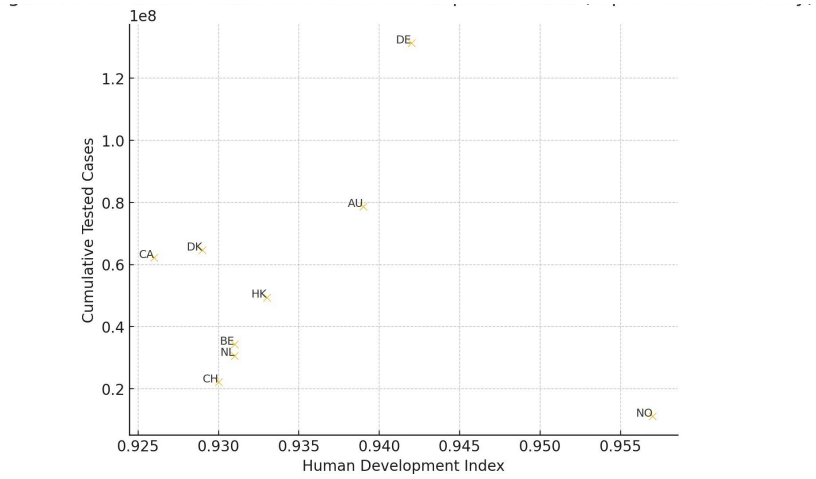


Figure 6

Some lower HDI countries have managed to implement effective testing strategies, perhaps due to international aid, government prioritization, or innovative approaches to testing. This relationship is crucial for understanding the role of development in pandemic preparedness and response. While development is a significant factor, it is not the only one. Policymakers in lower HDI countries can learn from successful examples in similar contexts to enhance their testing and public health strategies. Countries like Germany (DE) and Australia(AU) display both high HDI and substantial testing efforts, whereas Norway (NO), despite its top-ranking HDI, shows fewer tests comparatively. This illustrates the complexity of factors influencing testing beyond development level alone.

1.7 Physicians per 1000 vs. Cumulative Confirmed Cases

Figure 7 shows COVID-19 cumulative confirmed cases among regions and the number of physicians per 1,000 people. Regions with the highest case rates, such as Europe and North America, also have more doctors. This is partly due to stronger healthcare infrastructure, allowing for more effective case identification and treatment. However, other factors like urbanization and global mobility in these regions likely contributed to the rapid spread of the virus, making them more susceptible to larger outbreaks. Conversely, regions like Oceania and Africa report fewer confirmed cases, not only due to limited healthcare capacity but also because of geographic isolation and early interventions, such as lockdowns and travel restrictions. For example, Oceania's early containment strategies played a crucial role despite having lower physician density.

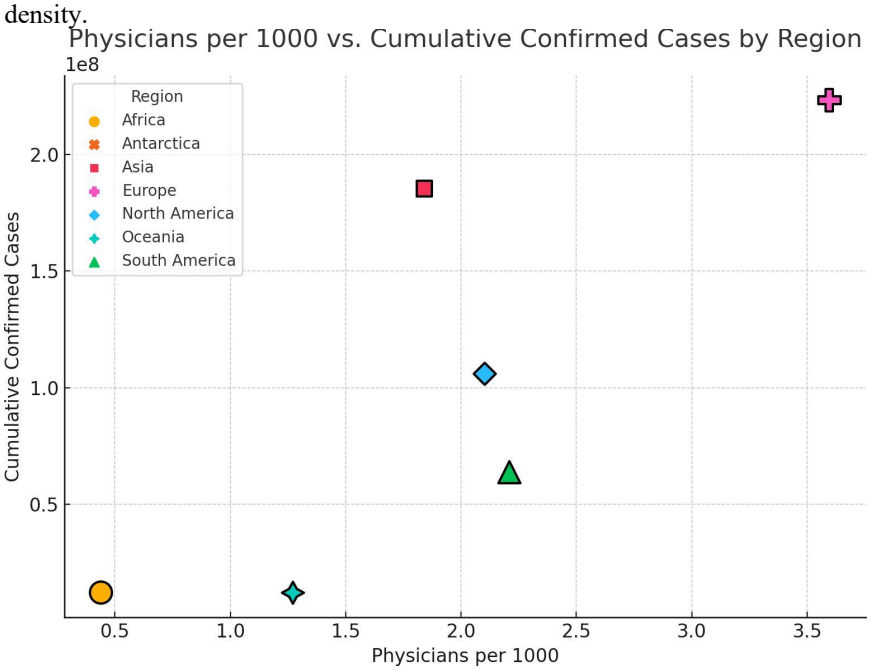
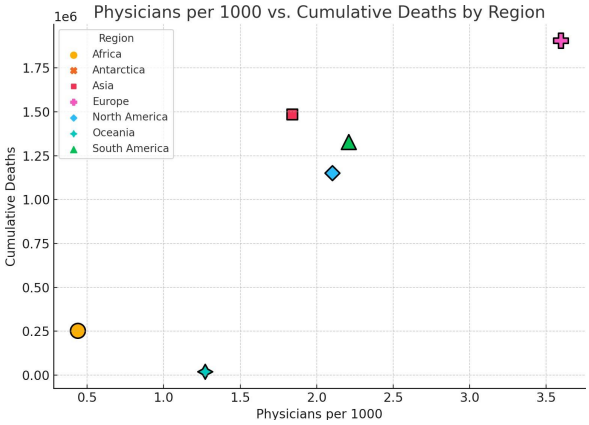


Figure 7

1.8 Physicians per 1000 vs. Cumulative Deaths

In **Figure 8**, Regions like Europe and North America, which have a higher number of physicians per 1,000 people, show higher cumulative deaths. This trend can be attributed to better healthcare infrastructure and efficient reporting systems. However, the correlation between physicians and deaths is not straightforward; higher deaths are likely due to the greater number of cases rather than a lack of healthcare resources. On the other hand, Africa and Oceania report lower deaths, possibly due to both fewer cases and underreporting, as well as effective control measures in regions like Oceania.

Figure 9 examines the relationship between cumulative recovered cases and physicians per 1,000 people at the regional level. According to the scatter plot, regions with a high number of physicians, such as Europe and North America, tend to have higher recovery rates, suggesting a positive correlation. This is likely due to easier healthcare access, efficient treatment protocols, and better-established medical infrastructure, which improves patient survival chances. On the other hand, regions like Africa, with fewer doctors, show lower recovery numbers due to both reduced case reporting and limited healthcare capacity. Overall, the pattern highlights how well-prepared healthcare systems are crucial for managing recoveries during the pandemic.



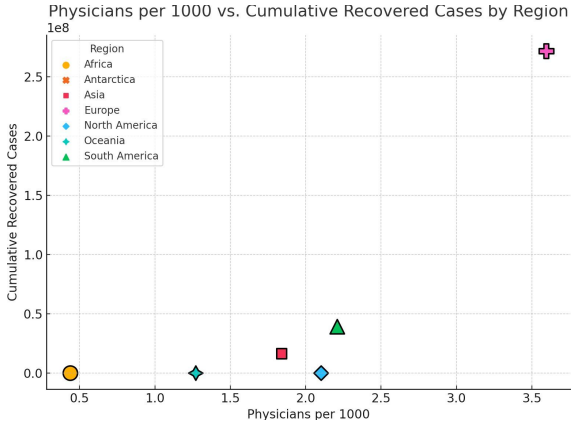


Figure 8 **Figure 9**

1.9 Nurses per 1000 vs. Cumulative Confirmed Cases

Figure 10 shows a positive relationship between nurse density and cumulative confirmed cases. Countries with a higher ratio of nurses, such as Europe, report more confirmed cases, reflecting their capacity to provide healthcare services and respond to patient needs. This underscores the role that nursing staff plays in managing pandemic caseloads and delivering primary care services during health crises.

In contrast, regions like Africa, with fewer nurses per 1,000 people (around 2), report significantly fewer confirmed cases. This lower number could be partly due to underreporting, as regions with fewer healthcare workers may lack the resources for widespread testing and case identification. Limited healthcare capacity in these regions can result in an incomplete picture of the pandemic's impact, as fewer healthcare professionals may not be able to manage or record all cases effectively.

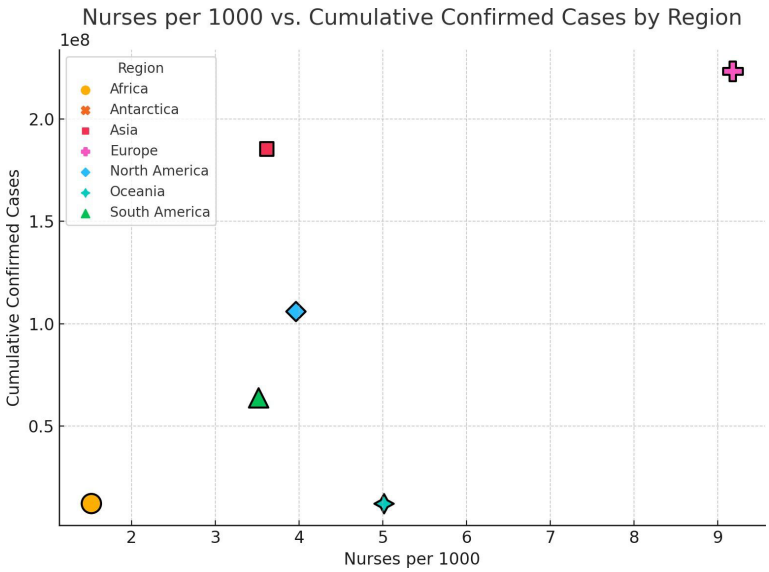


Figure 10

1.10 Nurses per 1000 vs. Cumulative Deaths

Figure 11 - This graph indicates a correlation between higher nurse density and reported death counts, but this relationship is influenced by factors such as population size, age demographics, and urbanization. Regions like Europe and North America, with more developed healthcare systems, report and treat more cases, but also experience larger outbreaks due to higher population density and mobility. In contrast, regions with lower nurse density, such as Africa, report fewer deaths, though this may reflect underreporting and limited healthcare access rather than fewer actual fatalities. Public health interventions and geographical factors also play a role, as seen in Oceania, where strong early measures helped keep death rates low despite moderate nurse density.

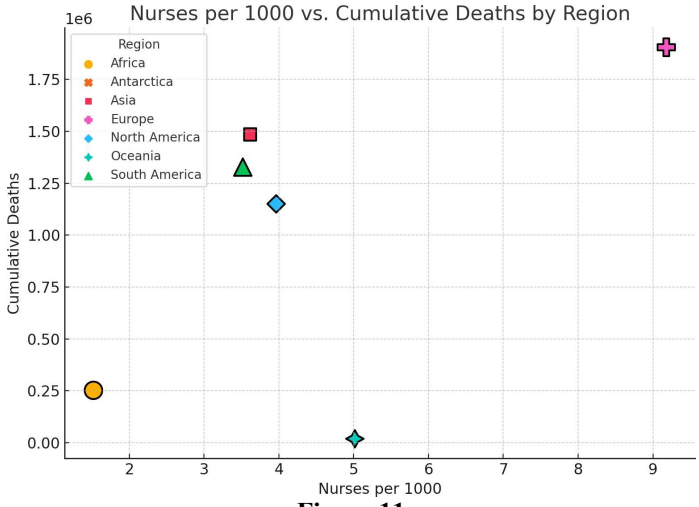


Figure 11

1.11 Nurses per 1000 vs. Cumulative Recovered Cases

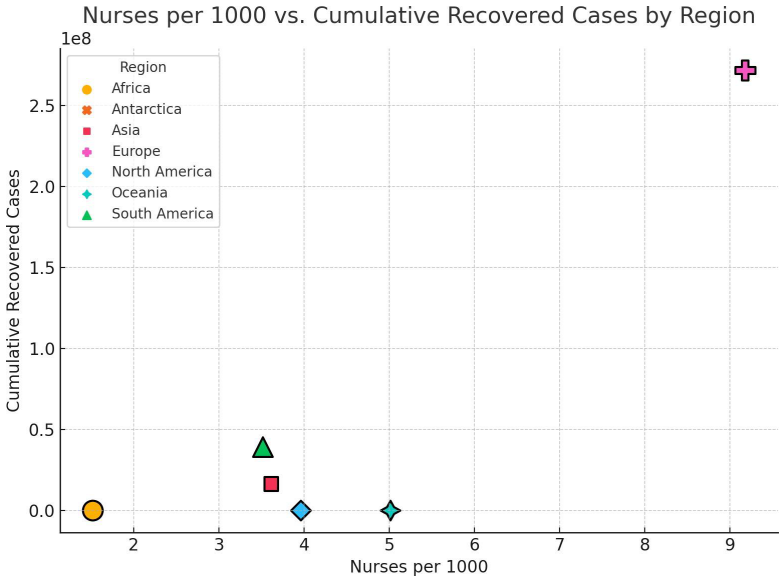


Figure 12

Figure 12 reveals a positive relationship between the number of nurses per 1,000 people and cumulative recovered cases. Regions with more nurses tend to have higher recovery rates, likely because enhanced care and support from more nurses lead to better patient outcomes. Additionally, regions with higher numbers of nurses are often better equipped to handle large patient loads, contributing to better overall outcomes. The correlation between nurse density and recovery rates suggests that healthcare infrastructure, including staffing levels, plays a critical role in determining patient outcomes during a pandemic. At the same time, the relatively low recovery numbers in Oceania likely indicate successful containment strategies, underscoring that healthcare infrastructure is just one piece of the puzzle in pandemic response.

5. Conclusion

In addition to expected relationships between healthcare capacity and COVID-19 outcomes, analysis of the charts reveals several patterns. Regions with larger numbers of doctors and nurses per person, such as Europe and North America, show higher rates of confirmed cases and deaths, suggesting they may be more susceptible to rapid virus transmission due to factors like urban density and global connectivity. In contrast, less developed areas, such as Africa, report fewer cases and deaths, likely due to limited testing and significant underreporting rather than lower actual infection rates. The study concludes that a country's ability to effectively manage the pandemic involves more than just healthcare resources—multiple social, structural, and policy-level factors also play crucial roles.

High-resource regions reported more confirmed cases and deaths, which may reflect both better testing capacity and greater virus exposure. Urban density and global connectivity in healthcare-rich regions likely contributed to the local spread of the virus. Significant underreporting in lower-resource regions could mean the true burden of the pandemic is seriously underestimated. Healthcare capacity alone did not guarantee better outcomes; early intervention and public health measures were also critical. Unequal global healthcare infrastructure contributed to varied pandemic responses and outcomes across regions.

Despite advanced healthcare systems, high-resource regions experienced more cases and deaths due to factors such as greater urbanization, older populations more vulnerable to severe outcomes, and increased global mobility, which accelerated virus transmission. Economic disparities played a significant role, as wealthier nations could afford widespread testing and comprehensive healthcare responses, while lower-income countries struggled with limited resources, leading to unreported cases and deaths. Public compliance with lockdowns and health guidelines also made a difference; regions with stricter measures often saw better outcomes. These findings emphasize the need to address not only healthcare infrastructure but also broader social, economic, and demographic factors that contribute to pandemic vulnerability.

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