LESSONS LEARNED FROM THE COVID-19 PANDEMIC: AN ANALYSIS OF REGIONAL PHILIPPINE DATA AND COVID-19 OUTCOMES

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KEY WORDS: COVID-19; Case Fatality Rate; Incidence Rate; Hospitalization Rate; Philippines; Regions; Delta; Omicron.

ABSTRACT:

Variations in indicators which may affect COVID-19 outcomes exist among regions in the Philippines. These variations suggest that the impacts of the pandemic differ not only between countries but also within regions and local areas in a country. This study aims to investigate COVID-19 outcomes (case fatality rate or CFR, incidence rate and hospitalization rate) over time and their correlation with regional healthcare and population factors during different phases of the pandemic across the 17 regions of the Philippines. These outcomes were chosen because they are readily available from government data sources, and are simple to work with. We mark five 100-day time periods of the COVID-19 pandemic in the country. The COVID-19 dataset was based on data maintained by the Department of Health (DOH). Spearman's rank correlation coefficient analysis was used to examine the link between COVID-19 outcomes region-specific indicators referring to population and access to health care resources. Despite their higher vaccination coverage, regions with greater access to health care resources may still be susceptible to future COVID-19 outbreaks due to their urban and densely populated nature. However, vaccines remain effective in reducing COVID-19 hospitalizations in these regions. Therefore, it is crucial to focus on increasing vaccination coverage in rural, underserved regions and implement targeted outbreak control measures in densely populated areas.

1. INTRODUCTION

Due to its notably young population with a median age of 25.0 in 2023 (Worldometer, 2023), the Philippines has achieved a relatively favorable performance in comparison to many other countries concerning COVID-19 deaths per million individuals. This achievement is noteworthy considering that the global median age stands at around 30 years. Refer to Figure 1 where the researchers specifically examined data from "Our World in Data" for the daily confirmed COVID-19 deaths per million of Philippines (25.0 years), the global average (30 years), Chile (35.3 years), and Italy (47.3 years) (Our World In Data, 2023).

Bongolan et al. posits this hypothesis in their study (Bongolan, Minoza, & de Castro, 2021), putting forward the notion that median age serves as a meaningful indicator for predicting mortality rates.

(PHEIC) on May 9, 2023 (WHO, 2023), it remains crucial to comprehend the dynamics of COVID-19 and the potential implications of future variants in the Philippines. In fact, it gives us a perfect chance to dissect what happened in the study area, now using COVID-19 outcomes, and see how health services may be improved in the future.

There were significant variations among the regions in the Philippines regarding region-specific factors such as population density, Gross Regional Domestic Product (GRDP), proportion of elderly in population, hospital-to-population ratio, bed-to-population ratio, and estimated vaccination coverage that could potentially influence COVID-19 outcomes. Region 1 (Ilocos

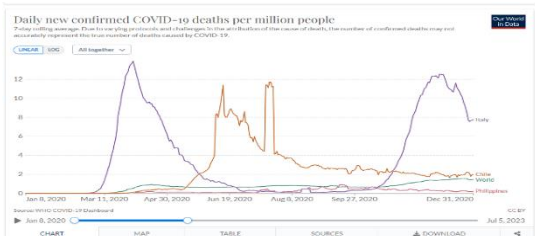

Figure 1: Daily new confirmed COVID-19 deaths per million according to Our World In Data (2023)

Despite the official declaration by the World Health Organization (WHO) that the COVID-19 pandemic no longer qualifies as a Public Health Emergency of International Concern Region) and Region 6 (Western Visayas) have the highest proportion of elderly individuals in their populations, at 7%; while the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) has the lowest percentage, at 2% (PSA, 2022).

In terms of population density, the National Capital Region (NCR) has the highest density with 21,765 persons per sq. km of land, while the Cordillera Administrative Region (CAR) is the least dense with 91 persons per sq. km. of land (PSA, 2021). Moreover, due to an initially limited vaccine supply, the DOH implemented a distribution strategy that prioritized regions based on their COVID-19 burden (DOH, 2021). The National Capital

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Region (NCR) became the hotspot of the disease during COVID-19's first wave, which meant its prioritization in terms of vaccine allocation.

As of July 2021, a week before the first Delta variant case was announced in the country, the NCR had achieved the highest vaccination rate in the country at the time, with 10% of its eligible population fully vaccinated. Conversely, the BARMM had the lowest vaccination rate, with 0.5% of its eligible population vaccinated (DOH, 2023a).

Other prioritization strategies were under discussion well before the rollout of vaccines in late 2020. The anticipation was that fatalities would peak among the elderly, while infections would be most prevalent among the working population. Bongolan et al. suggested that, specifically for the study area of Quezon City, prioritizing the low-income demographic could be an effective approach to minimize fatalities. This is due to the potential for overlapping vulnerabilities; for instance, an individual could belong to both the low-income group and the elderly category, compounding their risk (Bongolan et al., 2021).

These variations may indicate that the impacts of the crisis differ not only among countries but also within regions and local areas. This falls under heterogeneity as we mainly explore socioeconomic factors as indicators (Rivieccio et al., 2020).

This study aims to analyze the variations in the following COVID-19 outcomes across all 17 regions in the country: case fatality rate, incidence rate, and hospitalization rate; and their association with region-specific factors related to healthcare resources and population, divided into five distinct 100-day phases of the pandemic: Period A, pre-vaccination (20 July–28 October 2020); Period B, start of vaccination (1 March–9 June 2021) (Tomacruz, 2021); Period C, the emergence of the Delta variant (20 July–28 October 2021) (Al Jazeera, 2021); Period D, the emergence of the Omicron variant and start of booster doses (1 December 2021–11 March 2022) (Deiparine, 2021; Cabico, 2021); and Period E, latest surge in cases (22 December 2022–1 April 2023).

2. METHODOLOGY

2.1. Data Sources

2.1.1. COVID-19 Data: The study used the COVID-19 dataset maintained and published by the Department of Health (2023c). The dataset was divided into respective time periods using the date field indicating the collection of test samples. To maintain data quality, records with missing age group values (0.29% of the dataset) and missing region of residence values (0.09% of the dataset) were excluded from the analysis. Additionally, entries for Returning Overseas Filipinos (ROFs) as region values, which do not correspond to geographic locations within the Philippines, were also excluded from the analysis. Data from five 100-day time periods were analyzed namely: Period A, prior to the availability of vaccination (20 July–28 October 2020); Period B, when vaccination started (1 March–9 June 2021) (Tomacruz, 2021); Period C, the emergence of the Delta variant (20 July–28 October 2021) (Al Jazeera, 2021); Period D, the emergence of the Omicron variant and start of booster doses (1 December 2021–11 March 2022) (Deiparine, 2021; Cabico, 2021); and Period E, latest surge in cases (22 December 2022–1 April 2023).

2.1.2. Correlation Analysis Variables: The analysis includes demographic and economic indicators: population density, Gross Regional Domestic Product (GRDP), and the proportion of the elderly (60 years old and above) in the population. Data for these variables was sourced from Philippine Statistics Authority Reports (PSA, 2021, 2022, and 2023).

Health care resource indicators examined are the hospital-to-population ratio, bed-to-population ratio, and estimated vaccination coverage at the end of each time period. Data for health care resources were sourced from the DOH (PSA, 2023) while data for vaccination coverages were taken from the reports of the National Task Force on COVID-19 during the "Talk to the People" broadcasts and DOH published data (DOH, 2023a and 2023c; RTVMalacanang, 2021; GMA Integrated News, 2021). Hospital-to-population and bed-to-population ratios were calculated per 100,000 population such as in the equation below:

$$Bed-to-population\ ratio = \frac{Number\ of\ COVID-19\ allotted\ beds}{Population\ size} \times 100{,}000 \quad (1)$$

$$Hospital-to-population\ ratio = \frac{Number\ of\ public\ and\ private\ hospitals}{Population\ size} \times 100{,}000 \quad (2)$$

For each time period, the COVID-19 outcomes were calculated for each region. The case fatality rate (CFR) is defined as the ratio of COVID-19 fatalities to the total count of confirmed COVID-19 cases (Porta et al., 2014). The incidence rate reflects how quickly a disease occurs in a population indicating the speed at which new cases emerge in the population in each time period (Porta et al., 2014). The hospitalization rate signifies the proportion of COVID-19 cases which required hospitalization (Lui and Wallace, 2021). As age was found to be a confounding factor in several studies (Garcia-Calavaro et al., 2021; Green et al., 2020; Hong et al., 2021), age standardization was performed for each outcome as follows:

$$CFR_{std}(\%) = 100 \times \sum_{i=1}^{n} w_i \frac{d_i}{c_i} \quad (3)$$

$$Hospitalization_{std}(\%) = 100 \times \sum_{i=1}^{n} w_i \frac{h_i}{c_i} \quad (4)$$

$$Incidence_{std} = 10{,}000 \times \sum_{i=1}^{n} x_i \frac{c_i}{p_i} \quad (5)$$

Where $i = 1, \ldots, n$ represents each age group in the population, w_i is the proportion of the total number of cases in the ith age group, x_i is the proportion of the standard population in the ith age group, d_i is the number of COVID-19 deaths in the ith age group, c_i is the number of cases in the ith age group, p_i is the population of the ith age group, and h_i is the number of hospitalizations due to COVID-19 in the ith age group.

2.2. Statistical Analysis

The normality of variables was evaluated using the Shapiro-Wilk test. The analysis revealed that only the CFRs and the hospital-to-population ratio exhibited a normal distribution, and the standardized values showed lower standard deviations across all COVID-19 outcomes. This indicates a tighter "grouping" around the mean. Given the non-normal distributions observed for the remaining variables, Spearman's rank correlation coefficients were computed for each time period (Mukaka, 2012; Schober et al., 2018). This was used to analyze the associations between the standardized COVID-19 outcomes and region-specific factors namely, the log-transformed population density, log-transformed gross regional domestic product (GRDP), proportion of elderly (60 years old and above), ratio of COVID-19 beds per 100,000 population, and ratio of healthcare facilities per 100,000 population.

All analyses were performed using the pandas and scipy.stats libraries in Python with a significance level set at α = 0.05.

3. RESULTS

3.1. Change in COVID-19 Outcomes Between Periods

Figure 1 illustrates the trend of COVID-19 outcomes in the country. It can be observed that case incidence did not decrease until Period C. Despite the increase in incidence from Period A to C, there was a simultaneous reduction in CFR and hospitalization rates. The hospitalization rate and CFR steadily declined throughout the pandemic, reaching their lowest average rates in Period E. Table 1 presents the standardized COVID-19 outcomes for all time periods.

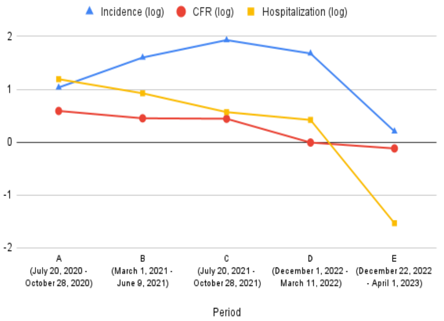


Figure 1: Average COVID-19 outcomes (log-transformed)

3.1.1. Period A to Period B (pre-vaccination to start of vaccination): From Period A to Period B, 12 of the 17 regions experienced a decrease in CFR, with Region 10 (Northern Mindanao) having the highest decrease at 65%. Region 4B (MIMAROPA), Region 2 (Cagayan Valley), Region 8 (Eastern Visayas), and the Cordillera Administrative Region (CAR) observed an increase in CFR, with MIMAROPA showing the largest increase at 49%. Incidence rate increased in all regions with a mean increase of 269%. Region 2 (Cagayan Valley) had the highest increase at 1532%. Hospitalization rate decreased in 15 regions, with Region 10 (Northern Mindanao) having the largest decrease at 97%, while Region 2 (Cagayan Valley) and Region 4A (CALABARZON) experienced increases, with CALABARZON showing the highest increase at 104%. Notably, Region 2 (Cagayan Valley) saw an increase in all COVID-19 outcomes from Period A to Period B.

3.1.2. Period B to Period C (start of vaccination to Delta variant): From Period B to Period C, there was a marginal decline in CFR, with mean decrease of 2%. Among the 17 regions, 10 witnessed a decrease in CFR, with Region 10 (Northern Mindanao) having the largest decrease at 38%. In contrast, Region 7 (Central Visayas) experienced the highest increase in CFR at 73%. The incidence rate continued to rise, with a mean increase of 114%, and Region 1 (Ilocos Region) exhibited the largest increase at 340%. Hospitalization rates continued to decrease with a mean decrease of 96% except for Region 12 (SOCCSKSARGEN), which saw a 53% increase in COVID-19 hospitalizations.

3.1.3. Period C to Period D (Delta to Omicron variants): During the transition from Period C to Period D, all regions saw a decrease in CFR, with a mean decrease of 65%. BARMM had the highest decrease at 76%. Incidence rate also declined, with a mean decrease of 52%, and only the NCR showed a 1% increase. Hospitalization rate increased in 9 regions, with Region 3 (Central Luzon) showing a 48% increase in COVID-19 hospitalizations.

3.1.4. Period D to Period E (Omicron variant to latest surge): Period D to E exhibited an average decrease in all COVID-19 outcomes. However, 8 regions had an increase in CFR, with Region 4A (CALABARZON) showing the highest increase at 104%. Incidence rate continued to decrease with a mean decrease of 96%, and hospitalization rate showed an average decrease of 99%.

3.2. COVID-19 Outcomes Across Regions

Figure 2 depicts the CFR trends across regions, highlighting initial high CFRs in Period A followed by a decline in Period B. Notably, there was a significant increase in CFR during Period C, particularly in Region 7 (Central Visayas). Region 11 (Davao Region) had the highest CFRs in Periods A and B (5.80 and 3.98, respectively). Central Visayas maintained the highest CFR from Period C (5.33) until Period D (1.79). In Period E, Region 1 (Ilocos Region) had the highest CFR at 1.86. Figure 5 shows the CFRs across the country at different time periods. It can be observed that in Period A (Figure 5.a), high CFRs are concentrated in the Visayas and Mindanao regions, and in Period B (Figure 5.b), high CFRs are shown to occur in North Luzon and Western and Central Visayas. Western and Central Visayas will continue to show high CFRs in Periods C (Figure 5.c) and D (Figure 5.d).

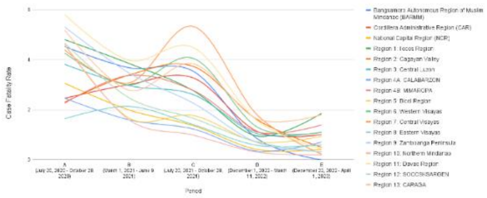


Figure 2: Case fatality rates (CFRs) of Philippine regions throughout the periods

Figure 3 displays the incidence rate across regions, indicating a relatively low nationwide incidence during Period A, with the National Capital Region (NCR) having the highest incidence at 55 new cases per 10,000 population. As the analysis progresses to Period B, the NCR maintains its status as the region with the highest incidence rate. However, in Period C, the Cordillera Administrative Region (CAR) surpasses NCR, exhibiting an incidence rate of 215 new cases per 10,000 population. Incidence rates rose during Period B, reaching a peak during Period C for most regions, except for NCR, which experienced its peak in Period D and regaining its position as the region with the highest incidence rate with 162 cases per 10,000 population. This would persist until Period E (5 cases per 10,000 population).

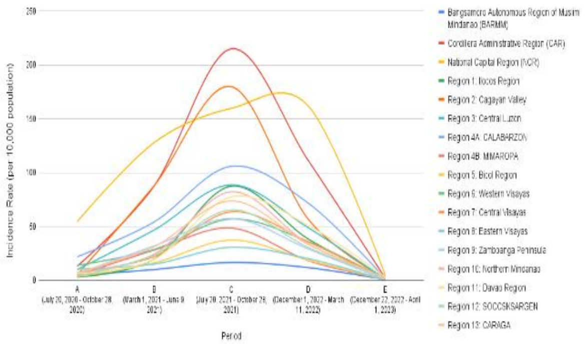


Figure 3: Incidence rates (per 10,000 population) of Philippine regions throughout the periods

Figure 4 portrays the hospitalization rates across regions, highlighting the initially high rates during Period A, particularly in Region 4B (MIMAROPA), which then declined except for some regions in Period D. Notably, MIMAROPA consistently showed the highest hospitalization rates from Period A to D. In Period E, 12 out of 17 regions recorded 0 COVID-19 hospitalizations, with the highest rate being recorded in Region 13 (CARAGA) with a 0.23% hospitalization rate.

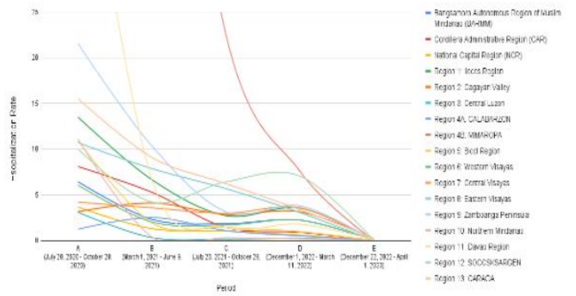


Figure 4: Hospitalization rates of Philippine regions throughout the periods

3.3. Correlation Analysis Results

Table 1 displays the correlation analyses results. In Period B, hospitalization rate was negatively correlated with Gross Regional Domestic Product (GRDP) and log-transformed population density, while incidence rate showed a positive correlation with vaccination coverage. In Period C, hospitalization rate continued to exhibit negative associations with GRDP and log-transformed population density, and also showed a negative correlation with vaccination coverage. Conversely, incidence rate maintained a positive correlation with vaccination coverage and health care resource factors such as bed-to-population and hospital-to-population ratios. These associations persisted in Period D with stronger magnitudes of the correlation coefficients. Hospitalization rate only showed negative associations with GRDP and vaccination coverage during this period. It was only in Period E that CFR displayed associations with certain factors, particularly positive associations with the proportion of the elderly and bed-to-population ratio. Incidence rate only demonstrated a positive association with hospital-to-population ratio in this period.

Factor	COVID-19 Outcome	Period A	Period B	Period C	Period D	Period E
Gross Regional Domestic Product (GRDP) (log)	CFR	0.107	-0.422*	-0.407	-0.409	0.051
	Incidence	0.343	0.230	0.255	0.434*	0.132
	Hospitalization	-0.323	-0.566**	-0.615***	-0.532**	0.088
Population density (log)	CFR	0.154	-0.324	-0.245	-0.252	0.005
	Incidence	0.345	0.140	0.235	0.431	0.039
	Hospitalization	-0.428*	-0.539**	-0.524**	-0.400	0.071
Proportion of elderly	CFR	-0.255	0.203	0.358	0.451*	0.583**
	Incidence	0.032	-0.017	0.042	0.125	-0.267
	Hospitalization	0.002	0.199	0.123	0.137	-0.166
Vaccination Coverage^	CFR	-	-0.316	0.039	-0.208	0.400
	Incidence	-	0.672***	0.760***	0.819***	0.439*
	Hospitalization	-	0.113	-0.610***	-0.591**	0.336
Ratio of COVID-19 allotted beds	CFR	-0.343	0.218	0.189	0.294	0.525**
	Incidence	0.25	0.458*	0.498**	0.566**	0.353
	Hospitalization	-0.137	0.167	-0.037	-0.022	0.232
Ratio of hospitals	CFR	0.014	-0.115	-0.120	-0.049	-0.267
	Incidence	0.267	0.382	0.684***	0.716***	0.627***
	Hospitalization	-0.294	-0.318	-0.377	-0.297	0.136

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

^ Vaccination coverage for Period B is as of July 5, 2021; Period C is as of October 18, 2021; Period D is as of March 21, 2022, including booster doses; Period E is as of March 19, 2023, including booster doses

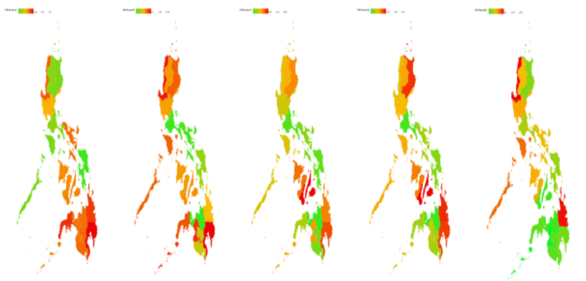
Table 1: Spearman rank correlation coefficients between COVID-19 outcomes and regional factors

4. DISCUSSION

In this study, the dynamics of COVID-19 was shown by analyzing the COVID-19 outcomes of the Philippine regions and its association with different factors throughout different phases of the pandemic in the country.

The pre-vaccination Period A (20 July–28 October 2020) had the highest average case fatality and hospitalization rates, while the incidence rate during this period was the second lowest on average, with Period E having the lowest average incidence rate. Figure 5 shows the CFRs across the country at different periods. In Period A, high CFRs can be seen concentrated in Mindanao and Western and Central Visayas. At this stage, the country relied on non-pharmaceutical interventions such as quarantines, lockdowns, and physical distancing since there was no available vaccination yet. Initially, the national government prioritized implementing COVID-19 measures in Luzon, such as declaring an enhanced community quarantine on March 16, 2020 (Aguilar, 2020), and conducting mass testing in specific areas, particularly in Valenzuela and Quezon City, the latter being "ground zero" for Covid (Ramos and Valenzuela, 2020). The responsibility for implementing COVID-19 measures, including quarantine or lockdown protocols, was later transferred to the Local Government Units (LGUs) depending on the COVID-19 situation in their regions and rural areas (COVID-19 IATF Resolution, 2021). This combination of practices and their varying timing of implementations may have had a compounding impact on the outcomes observed.

Moreover, these interventions alone may not have been effective in reducing disease transmission among the regions as evidenced by the country's increasing incidence rate from Period A to Period C (20 July–28 October 2021). However, this trend is accompanied by decreasing hospitalization and case fatality rates which may imply that although these interventions were not effective in curbing the spread of the disease, they were effective in lowering COVID-19 related hospitalizations and deaths. This is further supported by the results of the correlation analyses in Periods B to D (1 December 2021–11 March 2022), where vaccination coverage showed a negative association with hospitalization rate in Periods C and D, despite showing positive associations with incidence rate. Incidence rate also showed positive associations with health care resource factors such as hospital and bed to population ratios. Interestingly, it was only in Period E (22 December 2022–1 April 2023) where a moderate positive association was found between the CFR and the proportion of the elderly in the population.



a)Period A **b)** Period B **c)** Period C **d)** Period D **e)** Period E

Several studies have shown that higher incidence of COVID-19 cases are observed in areas characterized by high population and population densities, making urban areas hotspots of the disease (Cuadros et al., 2022; Herlihy et al., 2021). High population numbers and density increases the chances of contact between individuals, raising the risk of disease transmission (Hamidi, Sabouri, and Ewing, 2020). In densely populated areas, close proximity leads to prolonged exposure to potentially infected individuals, further facilitating disease spread. These urban areas also tend to have higher workplace and transport mobility, as well as a higher concentration of COVID-19 testing labs and facilities, leading to a higher number of reported cases (Wesley and Peterson, 2017; Buhat et al., 2021). This is the well-known "street light effect." Further, these areas are often centers of tourism and business, making them entry points for the virus and were particularly affected in the early stages of the pandemic (Organisation for Economic Co-operation and Development, 2020). In the Philippines, urban areas such as NCR and CALABARZON, are characterized by higher population numbers and, consequently, tend to have better vaccination coverage. Moreover, these urban areas have greater access to healthcare resources, including hospitals and COVID-19 beds (DOH, 2023c). In line with DOH's vaccine distribution plan, the allocation of vaccines is targeted towards these urban areas as well, especially during the initial stages of the pandemic, due to their higher case incidence and high population (DOH, 2021).

While vaccination does not prevent disease transmission, it plays a role in reducing COVID-19 hospitalizations and, the worst effect, death. Additionally, hospitalization rates were consistently found to have negative associations with population density and GRDP, suggesting that: a) densely populated regions had lower hospitalization rates and b) regions with stronger economies generally experience lower hospitalization rates.

This, along with the association between incidence rate and regions with greater access to health care resource factors (hospital and bed to population ratios) which are mostly highly urbanized areas, implies that although such regions may experience greater COVID-19 cases, they also tended to have lower hospitalization rates, which may be attributed to greater access to other health care resources, reducing the need for hospital care in COVID-19 cases. These findings are consistent with similar studies conducted in various countries worldwide, where an increase in COVID-19 cases has been observed, even in countries with high vaccination rates (Cuadros et al., 2022; Nesteruk and Rodionov, 2021 and 2022). Thus, the health impact of the pandemic may not solely depend on demographic factors alone but also on the interplay between these demographic factors and access to healthcare resources.

The course of the COVID-19 pandemic has been influenced by various control measures, including non-pharmaceutical interventions and the distribution of vaccines, as well as the emergence of new variants with varying patterns of transmission. It is observed that most of the regions saw a peak in its case incidence during Period C, the emergence of the Delta variant, while NCR saw its peak in case incidence in Period D, during the emergence of the Omicron variant. Further, the average CFR and median hospitalization and incidence rates are lower in Period D (Omicron), compared to Period C (Delta). However, a higher positive correlation between incidence and vaccination coverage in Period D compared to Period C suggests that the relationship between these two factors became stronger during the Omicron variant's prevalence. This could mean that as the Omicron variant emerged, regions with higher vaccination coverage experienced a relatively higher incidence of COVID-19 cases. This finding may indicate that the Omicron variant was able to spread more easily even in areas with a high number of vaccinated individuals, possibly due to its unique characteristics or immune evasion capabilities (Tian et al., 2022). This shows that the Omicron variant has different transmission dynamics, and caused less severe illness compared to the Delta variant in the country.

The findings of this study emphasizes that highly populated and densely crowded areas are more susceptible to future COVID-19 outbreaks, despite having higher vaccination coverages. Thus, it is crucial to prioritize vaccinating regions with low vaccination coverage, considering the findings that indicate lower hospitalization rates in regions with higher vaccination coverage. Additionally, results of the study sheds light on COVID-19 variants which may play a significant role in increasing disease transmissibility, particularly in these densely populated areas.

To the best of our knowledge, this study is the first to examine the relationship between COVID-19 outcomes and demographic and socioeconomic factors in the Philippine regions during different phases of the pandemic. Due to limited data, certain factors that could influence the COVID-19 outcomes were not included in the analysis, such as changes in age distribution and population, population immunity (vaccination rate), and a hypothesized virus evolution towards reduced virulence. Data collection biases and variations in testing policies and reporting delays can also affect the comparability of COVID-19 outcomes between regions. While correlation analysis provides a summary of relationships, they are associations and not causal. Further research is needed to address data-related challenges and investigate these causal relationships.

5. CONCLUSION

The objective was to examine the variations in COVID-19 outcomes in the Philippine regions (case fatality, hospitalization, and incidence rates), and their relationship with region-specific factors related to healthcare resources and population, across five 100-day phases of the pandemic.

The results of our study indicate that the incidence rate showed consistent positive associations with healthcare resources such as COVID-19 allotted beds and hospitals, which are typically found in regions with larger populations. Additionally, hospitalization rate showed a negative association with the log-transformed Gross Regional Domestic Product (GRDP) and the log-transformed population density, indicating that urban regions with stronger economies and higher population densities had lower hospitalization rates. Vaccination coverage showed a negative association with hospitalization rate during the Delta and Omicron periods, suggesting that regions with higher vaccination rates experienced a decrease in COVID-19 hospitalizations despite having higher incidence rates. Overall, the case fatality rate (CFR) and hospitalization rate decreased over the course of the pandemic, while the incidence rate initially remained low and then peaked during the emergence of the Delta variant before decreasing up to the present time.

Given the results, we recommend the following:

- Increase vaccination coverage in rural underserved regions especially in Visayas and Mindanao, targeting the vulnerable populations in these communities
- Allocate more health care resources, facilities, and physicians in rural underserved regions
- Efforts should be made to evaluate the duration of immunity provided by initial vaccine doses and additional booster shots
- Implement targeted outbreak control measures in highly populated regions

We hope policymakers make insights and related measures from this study.

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