

Preplanned Studies

Comparative Analysis of Vaccine Inequity and COVID-19 Transmission Amid the Omicron Variant Among Countries — Six Countries, Asia-Pacific Region, 2022

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Summary

What is already known about this topic?

The coronavirus disease 2019 (COVID-19) persists as a significant global public health crisis. The predominant strain, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), notably the Omicron variant, continues to undergo mutations. While vaccination is heralded as the paramount solution to cease the pandemic, challenges persist in providing equitable access to COVID-19 vaccines.

What is added by this report?

The distribution of vaccine coverage exhibited disparities between high-income and middle-income countries, with middle-income countries evidencing lower levels of vaccination. The data further suggested that countries with lesser vaccination levels tended to display a higher case fatality rate. Findings indicated that an increase in population-wide vaccination was effective in mitigating COVID-19 related mortalities.

What are the implications for public health practice?

The findings of this research underscore the pressing necessity for equitable access to vaccines to effectively mitigate the COVID-19 pandemic within the Asia-Pacific region.

Coronavirus disease 2019 (COVID-19) has emerged as a global public health crisis, with equitable access to vaccines representing a significant challenge. Our study aimed to investigate vaccine inequity and the relationship between vaccination and COVID-19 transmission during the Omicron variant period, focusing specifically on six countries within the Asia-Pacific region. We applied Joinpoint regression modeling to analyze the transmission trends of COVID-19, and the beta regression model was employed to explore the impacts of vaccination on daily mortality, morbidity, case fatality rate (CFR), and mortality fatality index (MFI). As of October 18,

2022, the fully vaccinated population percentages in Singapore, Australia, Malaysia, Thailand, Indonesia, and Vietnam were 93.90%, 84.04%, 81.95%, 74.70%, 62.38%, and 86.42%, respectively. When compared with countries boasting a full vaccination coverage rate exceeding 90%, those countries with rates below 70% exhibited increased mortality by an average of 11.88%, morbidity by 19.85%, MFI by 3.06%, and CFR by 1.34%. Clearly, vaccine coverage is uneven throughout the Asia-Pacific region. Elevated levels of population vaccination have been shown to be effective in preventing COVID-19-related deaths. Thus, our findings underscore the pressing need for more uniform vaccine access to efficiently manage and mitigate the ongoing COVID-19 pandemic.

The dataset used in our study is sourced from Our World in Data ([1](https://ourworldindata.org/)). The analysis focuses on six Asia-Pacific countries with relatively comprehensive data at various income levels: Australia and Singapore (high-income), Thailand and Malaysia (upper-middle-income), and Indonesia and Vietnam (lower-middle-income). The study spans from the establishment of the Omicron variant's 100% share in each country to October 18, 2022. Abstraction of definitions pertaining to COVID-19 vaccination, COVID-19 outcomes, and governmental response can be obtained from the [Supplementary Methods](https://weekly.chinacdc.cn/) (available in <https://weekly.chinacdc.cn/>). A beta regression model was adopted to investigate the association between full vaccination and variables such as daily mortality, morbidity, CFR, and MFI using the logit link model. Both the beta coefficients (β) and the 95% confidence interval (95% *CI*) were calculated. Model accuracy was ensured by assessing the distribution of residuals. The joinpoint regression model was utilized to discern trends over a period of time.

Statistical significance was defined by a two-sided test with *P* values less than 0.05. All statistical computations were performed using R software (version 4.1.3; R Foundation for Statistical

Computing, Vienna, Austria) and the NCI Joinpoint Regression Program (version 4.9.1.0; National Cancer Institute: Rockville, MD, USA).

Supplementary Table S1 (available in <https://weekly.chinacdc.cn/>) delineates the distribution of cases, deaths, and full vaccinations. Throughout the designated COVID-19 period (**Table 1**), Singapore was the inaugural country to initiate vaccinations, while Vietnam and Thailand were the last.

As of October 18, 2022, the percentage of the population that had received the complete vaccination protocol in Singapore, Australia, Malaysia, Thailand, Indonesia, and Vietnam was 93.92%, 84.04%, 81.96%, 74.70%, 62.41%, and 86.57%, respectively. The highest fully vaccinated rate was reported in Singapore, and the lowest in Indonesia (**Figure 1A**). According to **Supplementary Table S2** (available in <https://weekly.chinacdc.cn/>), Indonesia demonstrated the greatest increase in full vaccination rates amongst the six countries. Government response indicators

shone brightest in Malaysia, whereas Australia showed the lowest (**Figure 1B**).

As outlined in **Figure 1**, Australia and Singapore observed lower CFR but higher morbidity and mortality, whereas the inverse trend was noted in Indonesia and Thailand. Additionally, Thailand, Indonesia, and Australia reported higher MFI while Singapore, Malaysia, and Vietnam reported lower MFI.

Increasing trends in cumulative morbidity, mortality, CFR, and MFI were noted across these six countries (**Supplementary Tables S3–S6**, available in <https://weekly.chinacdc.cn/>).

We employed residual simulation and the Akaike information criterion to evaluate model fitness. Compared with level 1 at full vaccination (**Table 2**), mortality increased by an average of 10.55%, 5.33%, and 11.88%, morbidity increased by an average of 4.97%, 4.54%, and 19.85%, CFR increased by an average of 0.36%, 0.48%, and 1.34%, MFI increased

TABLE 1. Distribution of vaccination rates over time, by country.

Variables	High income		Upper middle income		Lower middle income	
	Singapore	Australia	Malaysia	Thailand	Indonesia	Vietnam
One vaccination						
0%	Dec-20 (+0 m)	Feb-21 (+0 m)	Feb-21 (+0 m)	Mar-21 (+0 m)	Jan-21 (+0 m)	Mar-21 (+0 m)
20%	Apr-21 (+4 m)	June-21 (+4 m)	July-21 (+4 m)	Aug-21 (+5 m)	Aug-21 (+7 m)	Sep-21 (+6 m)
40%	May-21 (+5 m)	Aug-21 (+6 m)	July-21 (+4 m)	Sep-21 (+6 m)	Oct-21 (+9 m)	Oct-21 (+7 m)
60%	June-21 (+6 m)	Sep-21 (+7 m)	Aug-21 (+5 m)	Nov-21 (+8 m)	Jan-22 (+12 m)	Nov-21 (+8 m)
80%	Aug-21 (+8 m)	Jan-22 (+11 m)	Jan-22 (+11 m)	–	–	Jan-22 (+10 m)
18 Oct 2022	94.65%	86.58%	83.72%	79.62% (+19 m)	74.62% (+21 m)	92.37%
Full vaccination						
0%	Jan-21 (+1 m)	Feb-21 (+0 m)	Feb-21 (+0 m)	Mar-21 (+0 m)	Jan-21 (+0 m)	Apr-21 (+1 m)
20%	May-21 (+5 m)	Aug-21 (+6 m)	July-21 (+5 m)	Sep-21 (+6 m)	Oct-21 (+9 m)	Oct-21 (+7 m)
40%	July-21 (+7 m)	Sep-21 (+7 m)	Aug-21 (+6 m)	Oct-21 (+7 m)	Dec-21 (+11 m)	Dec-21 (+9 m)
60%	Aug-21 (+8 m)	Oct-21 (+8 m)	Sep-21 (+7 m)	Dec-21 (+9 m)	Apr-22 (+15 m)	Dec-21 (+9 m)
80%	Nov-21 (+11 m)	Mar-22 (+13 m)	May-22 (+15 m)	–	–	Apr-22 (+13 m)
18 Oct 2022	93.92%	84.04%	81.96%	74.70% (+19 m)	62.41% (+21 m)	86.57%
Boosters						
0%	Sep-21 (+9 m)	Oct-21 (+8 m)	Sep-21 (+7 m)	Aug-21 (+5 m)	Feb-22 (+13 m)	Feb-22 (+11 m)
20%	Nov-21 (+11 m)	Jan-22 (+11 m)	Jan-22 (+11 m)	Jan-22 (+10 m)	July-22 (+18 m)	–
40%	Dec-21 (+12 m)	Feb-22 (+12 m)	Feb-22 (+12 m)	Jun-22 (+20 m)	–	Mar-22 (+14 m)
60%	Feb-22 (+14 m)	–	–	–	–	June-22 (+15 m)
80%	Aug-22 (+20 m)	–	–	–	–	–
18 Oct 2022	81.13%	55.03% (+20 m)	49.92% (+20 m)	44.89% (+19 m)	23.30% (+21 m)	71.62% (+19 m)

Note: The distribution of time is represented in terms of months since the initiation of the vaccine rollout. “–” means unavailable; “m” means month.

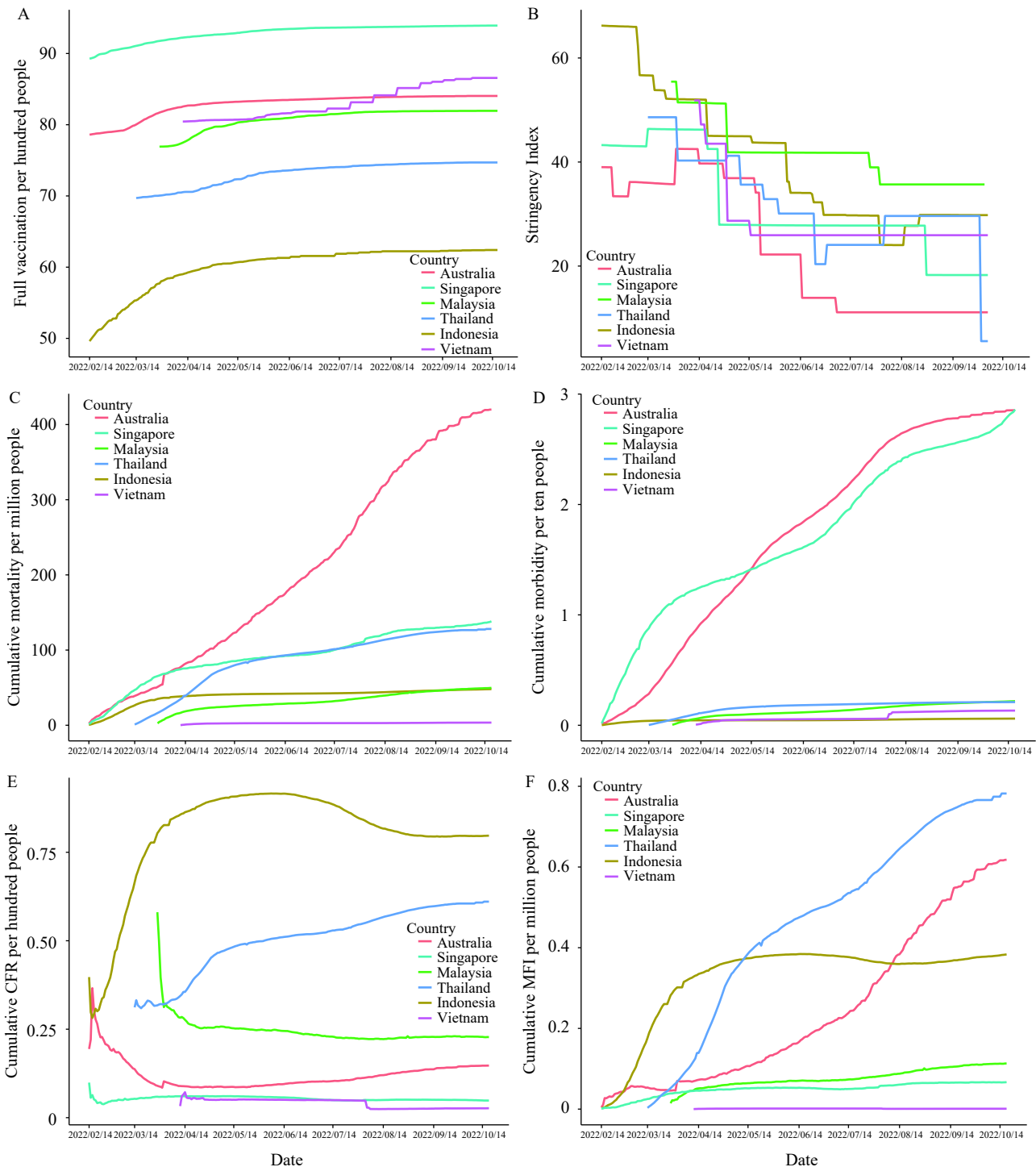


FIGURE 1. Trends by country during the Omicron period. (A) Full vaccination; (B) Stringency Index; (C) mortality; (D) morbidity; (E) case fatality rate (CFR); (F) mortality fatality index (MFI).

by an average of 4.98%, 2.12%, and 3.06% in levels 2-4, respectively.

DISCUSSION

In this study, six representative countries from the

Asia-Pacific region categorized by economic tiers were analyzed to investigate the correlation between immunization and COVID-19 results. The findings suggest that countries with high-income scales exhibit higher rates of complete vaccination, early commencement of vaccination programs, and lower

TABLE 2. Association between full vaccination status and measures of disease severity including MFI, CFR, mortality, and morbidity during the Omicron variant period.

Full vaccination	Beta coefficients		Average marginal effects	
	β (95% CI)	P-value	AME (95% CI), %	P-value
Mortality fatality index				
Level 1	Reference	–	Reference	–
Level 2	0.94 (0.60, 1.28)	<0.001	4.98 (3.31, 6.65)	<0.001
Level 3	0.55 (0.13, 0.97)	0.001	2.12 (0.82, 3.41)	0.001
Level 4	0.68 (0.11, 1.25)	0.019	3.06 (0.57, 2.55)	0.016
Case fatality rate				
Level 1	Reference	–	Reference	–
Level 2	1.00 (0.68, 1.33)	<0.001	0.36 (0.22, 0.49)	<0.001
Level 3	1.26 (0.88, 1.64)	<0.001	0.48 (0.29, 0.66)	<0.001
Level 4	1.46 (0.99, 1.93)	<0.001	1.34 (0.66, 2.02)	<0.001
Mortality				
Level 1	Reference	–	Reference	–
Level 2	2.05 (1.78, 2.33)	<0.001	10.55 (7.61, 13.49)	<0.001
Level 3	1.71 (1.34, 2.07)	<0.001	5.33 (2.45, 8.22)	<0.001
Level 4	2.18 (1.63, 2.73)	<0.001	11.88 (4.65, 19.10)	0.001
Morbidity				
Level 1	Reference	–	Reference	–
Level 2	1.47 (1.26, 1.69)	<0.001	4.97 (3.86, 6.09)	<0.001
Level 3	1.55 (1.25, 1.85)	<0.001	4.54 (3.12, 5.96)	<0.001
Level 4	2.47 (1.94, 2.99)	<0.001	19.85 (13.00, 26.71)	<0.001

Note: 1) The model has been adjusted for factors including a 28-day lag for full vaccination, a 14-day lag for Stringency Index, booster shots, population density, gross domestic product, the number of hospital beds per thousand, the proportion of the population aged 65 years and older, and the reproduction rate. 2) The full vaccination rate is regarded as a categorical variable that is divided into four levels. Level 1 signifies a full vaccination rate higher than 90%, level 2 denotes a rate between 80% and 90%, level 3 indicates a rate from 70% to 80%, and level 4 represents a full vaccination rate below 70%.

“–” means unavailable.

Abbreviation: CFR=case fatality rate; MFI=mortality fatality index; AME=average marginal effects; β =beta coefficients; CI=confidence interval.

CFR. Additionally, a notable increase in both CFR and MFI was seen in countries with lower vaccination rates in comparison to the country with the highest rate of full vaccination.

The Omicron variant of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) demonstrates greater transmissibility, increased upper respiratory tract prevalence, and lower disease severity compared to previous variants (2). Despite the decrease in disease severity, Omicron's rapid transmission rates persist as a significant obstacle to pandemic control. The administration of booster doses has been shown to enhance defense against severe COVID-19 during the Omicron surge, with elevated antibody levels sustained for the initial four months post-vaccination (3). Yet, the effectiveness of vaccines appears to diminish over time (4). In summary, while vaccines have significantly

curtailed the severity and death rate from COVID-19, they do not offer absolute protection from infection, with cases of “long COVID” prevalent even amidst those who experienced mild or asymptomatic cases of the virus (5). Particularly vulnerable to severe outcomes, including hospitalization and death from COVID-19, are older adults, especially those contending with multiple chronic illnesses, notably cardiovascular or respiratory conditions, or dementia (6).

This study reveals that lower-income countries exhibit lower rates of complete vaccination and later initiation of the vaccination process. This highlights the disparity in vaccine coverage within the Asia-Pacific region and underscores the urgent need for rectification. Our models indicate that by raising the full vaccination rate from less than 70% to more than

90% as accomplished in Indonesia, the MFI decreased by 19.90% and the CFR declined by 8.02%. Consistent with our findings, Watson et al. (7) pointed out that COVID-19 vaccinations have significantly influenced the pandemic's trajectory. However, limited vaccine accessibility in economically disadvantaged countries has restricted its benefits, reinforcing the urgency for global vaccine equality and comprehensive coverage. The primary global objective should remain focused on amplifying vaccination coverage across the world's eligible populace, giving special regard to individuals at an elevated risk of severe illness, such as older demographics, cardiac patients, and individuals with dementia (8). This is a significant global concern as stated by COVAX, the World Health Organization's initiative promoting global equality of COVID-19 vaccine access, which maintains that until all individuals are protected, no one is truly safe (9). Several stratagems to ensure equalized COVID-19 vaccine coverage have been proposed, including expansion of the COVAX facility, waivers for intellectual property rights, amplified manufacturing capabilities within economically disadvantaged nations, reinforced and improved health infrastructure, and implementation of extensive COVID-19 vaccination initiatives (10). In the future, prioritizing and enhancing routine vaccination schedules within high-risk areas of low- and mid-income nations will abet improved control of future pandemics by addressing vaccine scarcity and unequal accessibility.

In the present study, the severity of COVID-19 across six representative countries was evaluated using an array of outcome measures, including mortality, morbidity, CFR, and MFI. An infectious disease's burden is not solely determined by its case and death counts but also significantly impacted by the total population. Mortality is assessed based on both the number of deaths and the total target population, while CFR factors in the number of cases and deaths. The MFI, a more comprehensive indicator developed for this study, integrates case and death counts with the total targeted population to evaluate COVID-19's severity. As a general metric, the MFI presents a valuable tool for evaluating and comparing the burden of COVID-19 across various regions. The data analyzed in this study pertain to a period when the Omicron variant represented 100% of COVID-19 cases, thus presenting a picture of the ongoing prevalence of this variant relative to studies featuring earlier variants.

However, some limitations warrant consideration.

First, given that reporting of the SARS-CoV-2 variant appears every two weeks, the timing of Omicron's dominance may be inaccurately represented. Second, the disparity in vaccine types and disease surveillance reporting systems across different countries could potentially bias the results. Third, the beta regression model displayed some underdispersion — an inherent trait of such models — which, while not significantly detracting from our conclusions, invites a more conservative interpretation of hypothesis tests. Furthermore, the existing study lacks data from asymptomatic, mild, moderate, severe, critical, and fatal cases, a spectrum that future research should consider in order to enhance the MFI's efficiency and accuracy. Despite controlling for potential confounding variables, some factors not accounted for in this research, such as vaccine type, could potentially impact COVID-19 transmission. Thus, caution must be exercised when interpreting the study results.

Conflicts of interest: No conflicts of interest.

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REFERENCES

- Mathieu E, Ritchie H, Rod s-Guirao L, Appel C, Giattino C, Hasell J, et al. Coronavirus pandemic (COVID-19) our world in data. 2020. <https://ourworldindata.org/coronavirus>. [2023-1-13].
- Zhang ZC, Hao M, Zhang XC, He YF, Chen XS, Taylor EW, et al. Potential of green tea EGCG in neutralizing SARS-CoV-2 Omicron variant with greater tropism toward the upper respiratory tract. *Trends Food Sci Technol* 2023;132:40 – 53. <http://dx.doi.org/10.1016/j.tifs.2022.12.012>.
- Higdon MM, Baidya A, Walter KK, Patel MK, Issa H, Esp   E, et al. Duration of effectiveness of vaccination against COVID-19 caused by the omicron variant. *Lancet Infect Dis* 2022;22(8):1114 – 6. [http://dx.doi.org/10.1016/S1473-3099\(22\)00409-1](http://dx.doi.org/10.1016/S1473-3099(22)00409-1).
- Feikin DR, Higdon MM, Abu-Raddad LJ, Andrews N, Araos R,

- Goldberg Y, et al. Duration of effectiveness of vaccines against SARS-CoV-2 infection and COVID-19 disease: results of a systematic review and meta-regression. *Lancet* 2022;399(10328):924 – 44. [http://dx.doi.org/10.1016/S0140-6736\(22\)00152-0](http://dx.doi.org/10.1016/S0140-6736(22)00152-0).
5. Ledford H. Do vaccines protect against long COVID? What the data say. *Nature* 2021;599(7886):546 – 8. <http://dx.doi.org/10.1038/d41586-021-03495-2>.
 6. Yang JL, McClymont H, Wang LP, Vardoulakis S, Hu WB. Epidemic features of COVID-19 and potential impact of hospital strain during the omicron wave - Australia, 2022. *China CDC Wkly* 2023;5(7):165 – 9. <http://dx.doi.org/10.46234/ccdcw2023.029>.
 7. Watson OJ, Barnsley G, Toor J, Hogan AB, Winskill P, Ghani AC. Global impact of the first year of COVID-19 vaccination: a mathematical modelling study. *Lancet Infect Dis* 2022;22(9):1293 – 302. [http://dx.doi.org/10.1016/S1473-3099\(22\)00320-6](http://dx.doi.org/10.1016/S1473-3099(22)00320-6).
 8. Leung K, Jit M, Leung GM, Wu JT. The allocation of COVID-19 vaccines and antivirals against emerging SARS-CoV-2 variants of concern in East Asia and Pacific region: A modelling study. *Lancet Reg Health West Pac* 2022;21:100389. <http://dx.doi.org/10.1016/j.lanwpc.2022.100389>.
 9. WHO. COVAX: Working for global equitable access to COVID-19 vaccines. <https://www.who.int/initiatives/act-accelerator/covax>. [2023-1-13].
 10. Kunyenje CA, Chirwa GC, Mboma SM, Ng'ambi W, Mnjowe E, Nkhoma D, et al. COVID-19 vaccine inequity in African low-income countries. *Front Public Health* 2023;11:1087662. <http://dx.doi.org/10.3389/fpubh.2023.1087662>.

SUPPLEMENTARY MATERIAL

Methods

Sources of Data and the Study Population

The Our World in Data project, overseen by the Global Change Data Lab registered in England and Wales, maintains the dataset related to coronavirus disease 2019 (COVID-19) (1). The Oxford COVID-19 Government Response Tracker (OxCGRT), which relies on publicly available information, provided the indicators of government response data that we gathered (2). Given that our analysis focused on routinely collected, publicly available de-identified data, the approval of an ethics committee was deemed unnecessary.

In this study, we utilized the World Bank's classification to determine the income levels of various countries (3). The research includes a selection of six countries in the Asia-Pacific region, chosen based on the relative completeness of their data. These countries represented high-income (Australia and Singapore), upper-middle-income (Thailand and Malaysia), and lower-middle-income tiers (Indonesia and Vietnam). However, the study only includes countries within these specific income level classifications due to insufficient reporting of COVID-19 data from low-income nations in the Asia-Pacific region. Our analysis encompassed data gathered from the date each country reported a 100% Omicron variant prevalence up to October 18, 2022. Data collection commenced on different dates for each country: Australia, Singapore, and Indonesia began on February 14, 2022, Malaysia on March 28, 2022, Thailand on March 14, 2022, and Vietnam on April 11, 2022.

COVID-19 Vaccination and Government Responses

In this study, "full vaccination" is identified as the proportion of individuals who have received all doses required by the preliminary vaccination protocol, per hundred individuals in the overall population. "One vaccination" refers to the proportion of individuals who have obtained at least one dose of the vaccine, per hundred individuals in the total population. Booster vaccination is described as the percentage of individuals who have received supplemental booster doses, exceeding the doses dictated by the initial vaccination protocol, per hundred individuals in the total population.

The OxCGRT government response indicators consist of nine policies, each rated on an ordinal scale. These include school and workplace closures, public event cancellations, public gathering restrictions, public transportation closures, stay-at-home requirements, public information campaigns, internal movement restrictions, and international travel controls. The Stringency Index, a measure used to gauge governmental restrictions, is an aggregate of these nine indicators. Its value ranges from 0 to 100, with 100 indicating the severest government response and 0 signifying a lack of government response (2).

COVID-19 Outcomes

The outcomes of COVID-19 evaluated in this study encompass daily and cumulative morbidity, mortality, CFR, and MFI. These were calculated as follows:

$$\text{Daily morbidity} = \frac{\text{Number of new confirmed cases}}{\text{Total population}} \times 1,000,000$$

$$\text{Daily mortality} = \frac{\text{Number of new confirmed deaths}}{\text{Total population}} \times 1,000,000$$

$$\text{Daily CFR} = \frac{\text{Number of new confirmed deaths}}{\text{Number of new confirmed cases 10 days earlier}} \times 100$$

$$\text{Daily MFI} = \frac{\text{Number of new confirmed deaths}^2}{\text{Number of new confirmed cases 10 days earlier} \times \text{Total population}} \times 1,000,000$$

$$\text{Cumulative morbidity} = \frac{\text{Number of total confirmed cases}}{\text{Total population}} \times 1,000,000$$

$$\text{Cumulative mortality} = \frac{\text{Number of total confirmed deaths}}{\text{Total population}} \times 1,000,000$$

$$\text{Cumulative CFR} = \frac{\text{Number of total confirmed deaths}}{\text{Number of total confirmed cases}} \times 100$$

$$\text{Cumulative MFI} = \frac{\text{Number of total confirmed deaths}^2}{\text{Number of total confirmed cases 10 days earlier} \times \text{Total population}} \times 1,000,000$$

In the present study, the daily CFR was computed utilizing the number of newly confirmed cases from 10 days prior, as documented by *Our World in Data* (1). Moreover, the term ‘death’ used in the aforementioned formulas represents the reported fatalities attributed to COVID-19. Given that both the morbidity rate and the CFR impact the overall burden of COVID-19, a MFI was formulated. This index incorporates confirmed COVID-19 cases, associated fatalities, and the concurrent population size to provide a more comprehensive assessment of the disease’s severity (4).

Statistical Analyses

Descriptive statistics were utilized to analyze the count of cases, mortality, and vaccination rates. A beta regression model (5) was conducted to investigate the relationship between full vaccination status and daily CFR and MFI using a logit link. The beta coefficients (b) and 95% confidence intervals (95% CI) were determined. The model accounted for variables such as 28-day lag time for full vaccination, 14-day lag time for the Stringency Index, booster presence, population density, gross domestic product, hospital beds per capita, proportion of the population aged 65 and older, and reproduction rate. Full vaccination status was treated as either a categorical variable split into four levels (Level 1–4). Level 1 represented a full vaccination rate above 90%, level 2, between 80% and 90%; level 3, between 70% and 80%; and level 4, less than 70%. Missing data was addressed using the listwise deletion technique (6). To correct for temporal variations in full vaccination coverage and the Stringency Index, varying lag times (0, 1, 2, 3, and 4 weeks) were implemented to adjust for lagged effects. When referencing a 1-week lag, the beta regression model utilized vaccination rates (Stringency Index) a week prior. The most suitable lag periods were selected based on the Akaike information criterion (AIC) of each model, with the lowest AIC indicating the most optimal model. Finally, the residual distribution was evaluated to ascertain the fit of the beta regression model.

The Joinpoint regression model was employed to investigate the temporal trends of full vaccination, cumulative morbidity, mortality, CFR, and MFI in each country. This model measured both the average weekly percentage change (AWPC) over the complete observation duration and the weekly percentage change (WPC) for each identified linear trend segment. All computations were executed using the default method and parameters in the Joinpoint statistical software (7).

Two-sided test with *P* values <0.05 was considered statistically significant. All statistical analyses were completed using R version 4.1.3 software (R Foundation for Statistical Computing, Vienna, Austria) and the NCI Joinpoint Regression Program version 4.9.1.0 (National Cancer Institute: Rockville, MD, USA, 2022).

SUPPLEMENTARY TABLE S1. Cases, deaths, and full vaccination rates by country as of the date when the Omicron variant reached 100% prevalence on October 18, 2022.

Variables	High-income levels		Upper-middle-income levels		Lower-middle-income levels	
	Singapore	Australia	Malaysia	Thailand	Indonesia	Vietnam
Start time	February 14, 2022	February 14, 2022	March 28, 2022	March 14, 2022	February 14, 2022	April 11, 2022
Total population*	5,453,600	25,921,089	33,573,874	71,601,103	273,753,191	97,468,028
Stringency Index	28 (18, 46)	22(11, 43)	42(36, 56)	30 (6, 49)	34 (24, 66)	26 (26, 52)
Cases, per 100 people						
N1	8.78	11.36	12.37	4.48	1.77	10.52
N2	37.21	39.79	14.51	6.55	2.36	11.79
DPC	0.118	0.118	0.011	0.010	0.002	0.007
Deaths, per 10,000 people						
N1	1.66	1.80	10.38	3.32	5.31	4.39
N2	3.03	5.98	10.85	4.59	5.78	4.43
DPC	0.006	0.017	0.002	0.006	0.002	0
Full vaccination, per 100 people						
N1	89.28	78.60	76.92	69.71	49.61	80.43
N2	93.90	84.04	81.95	74.70	62.38	86.42
DPC	0.019	0.023	0.025	0.024	0.053	0.033

Note: N1, Number at 100% share of Omicron variant in all analyzed sequences in the preceding two weeks; N2, Number at 18/10/2022. The acronym DPC stands for Daily Percent Change. Stringency Index, Median (Min, Max).

* Source of total population: https://github.com/owid/covid-19-data/blob/485449bc78681595a553320eaa0c95c139207280/scripts/input/un/population_latest.csv.

SUPPLEMENTARY TABLE S2. Trends in full vaccination across various countries during the Omicron phase in 2022.

Full vaccination	High income		Upper middle income		Lower middle income	
	Singapore	Australia	Malaysia	Thailand	Indonesia	Vietnam
Start to October 18	93.90	84.04	81.95	74.70	62.38	86.42
AWPC (95% CI)	0.02 (0.02, 0.02)	0.03 (0.03, 0.03)	0.03 (0.03, 0.04)	0.03 (0.03, 0.03)	0.09 (0.09, 0.10)	0.04 (0.03, 0.05)
Period-1						
Time	February 14–28	February 14–March 6	March 27–April 10	March 13–April 17	February 14–28	April 10–July 10
WPC (95% CI)	0.09 (0.08, 0.10)	0.04 (0.03, 0.04)	0.06 (0.03, 0.09)	0.04 (0.04, 0.04)	0.45 (0.41, 0.48)	0.02 (0.02, 0.03)
Period-2						
Time	February 28–April 3	March 6–27	April 10–May 1	April 17–May 29	February 28–March 27	July 10–September 11
WPC (95% CI)	0.05 (0.05, 0.05)	0.15 (0.15, 0.16)	0.15 (0.12, 0.18)	0.09 (0.08, 0.09)	0.32 (0.30, 0.34)	0.08 (0.07, 0.09)
Period-3						
Time	April 3–May 29	March 27–April 17	May 1–July 24	May 29–July 3	March 27–April 24	September 11–October 18
WPC (95% CI)	0.02 (0.02, 0.02)	0.06 (0.05, 0.06)	0.03 (0.02, 0.03)	0.03 (0.02, 0.03)	0.14 (0.12, 0.16)	0.01 (–0.01, 0.04)
Period-4						
Time	May 29–June 26	April 17–May 8	July 24–October 18	July 3–August 28	April 24–May 22	
WPC (95% CI)	0.01 (0.01, 0.02)	0.02 (0.02, 0.03)	0 (0, 0)	0.01 (0.01, 0.02)	0.05 (0.04, 0.07)	
Period-5						
Time	June 26–October 18	May 8–August 7		August 28–October 18	May 22–August 7	
WPC (95% CI)	0 (0, 0)	0.01 (0.01, 0.01)		0 (0, 0.01)	0.02 (0.02, 0.03)	
Period-6						
Time		August 7–October 18			August 7–October 18	
WPC (95% CI)		0 (0, 0)			0.01 (0, 0.01)	

Note: The AWPC and the WPC exhibit significant deviations from zero at an alpha level of 0.05.

Abbreviation: AWPC=average weekly percentage change; WPC=weekly percentage change.

SUPPLEMENTARY TABLE S3. Trends in the cumulative morbidity of COVID-19 in various countries during the Omicron period in 2022.

Morbidity	High income		Upper middle income		Lower middle income	
	Singapore	Australia	Malaysia	Thailand	Indonesia	Vietnam
Start to October 18	2.86	2.85	0.22	0.21	0.06	0.13
AWPC (95% CI)	2.06 (1.86, 2.26)	2.21 (2.08, 2.34)	1.87 (1.75, 2.00)	1.86 (1.78, 1.95)	1.44 (1.35, 1.54)	1.60 (1.51, 1.68)
Period-1						
Time	February 14–28	February 14–28	March 27–April 10	March 13–27	February 14–28	April 10–24
WPC (95% CI)	30.31 (25.86, 34.92)	18.53 (16.47, 20.63)	21.13 (18.93, 23.37)	22.35 (21.11, 23.60)	24.51 (22.47, 26.59)	15.24 (14.49, 16.00)
Period-2						
Time	February 28–October 18	February 28–April 10	April 10–October 18	Mar 27–1	February 28–October 18	April 24–July 24
WPC (95% CI)	0.56 (0.52, 0.61)	4.60 (4.19, 5.01)	0.58 (0.54, 0.61)	2.64 (2.32, 2.98)	0.19 (0.17, 0.21)	0.20 (0.16, 0.23)
Period-3						
Time		April 10–July 17		May 1–October 18		July 24–August 14
WPC (95% CI)		0.93 (0.84, 1.03)		0.16 (0.14, 0.18)		3.65 (2.97, 4.33)
Period-4						
Time		July 17–October 18				August 14–October 18
WPC (95% CI)		0.19 (0.10, 0.28)				0.12 (0.06, 0.18)

Note: The WPC and AWPC are statistically significant at an alpha level of 0.05, indicating significant differences from zero.

Abbreviation: COVID-19=coronavirus disease 2019; AWPC=average weekly percentage change; WPC=weekly percentage change.

SUPPLEMENTARY TABLE S4. Trends in cumulative mortality due to COVID-19 by country during the Omicron variant period in 2022.

Mortality	High income		Upper middle income		Lower middle income	
	Singapore	Australia	Malaysia	Thailand	Indonesia	Vietnam
Start to October 18	135.14	416.07	49.09	126.41	47.70	3.50
AWPC (95% CI)	1.77 (1.67, 1.88)	2.12 (1.94, 2.30)	1.43 (1.34, 1.52)	2.18 (2.09, 2.28)	1.76 (1.70, 1.82)	1.42 (1.33, 1.50)
Period-1						
Time	February 14–28	February 14–28	March 27–April 10	March 13–27	February 14–28	April 10–24
WPC (95% CI)	20.74 (19.18, 22.32)	18.34 (15.00, 21.77)	14.94 (13.43, 16.46)	21.98 (20.57, 23.40)	25.12 (24.13, 26.13)	18.26 (16.90, 19.65)
Period-2						
Time	February 28–March 27	February 28–May 15	April 10–October 18	Mar 27–1	February 28–March 27	April 24–October 18
WPC (95% CI)	3.48 (2.81, 4.16)	2.03 (1.80, 2.26)	0.49 (0.47, 0.52)	3.91 (3.53, 4.29)	3.33 (2.92, 3.74)	0.18 (0.15, 0.20)
Period-3						
Time	March 27–October 18	May 15–October 18		May 1–October 18	March 27–October 18	
WPC (95% CI)	0.35 (0.33, 0.37)	0.81 (0.74, 0.88)		0.34 (0.31, 0.36)	0.11 (0.10, 0.12)	

Note: The WPC and AWPC are statistically significant at an alpha level of 0.05, indicating significant differences from zero.

Abbreviation: COVID-19=coronavirus disease 2019; AWPC=average weekly percentage change; WPC=weekly percentage change.

SUPPLEMENTARY TABLE S5. Trends in the cumulative CFR by country during the Omicron period of 2022.

CFR	High income		Upper middle income		Lower middle income	
	Singapore	Australia	Malaysia	Thailand	Indonesia	Vietnam
Start to October 18	491.28	1,464.25	2,289.61	6,079.1	7,960.66	264.25
AWPC (95% CI)	-0.23 (-0.36, -0.11)	-0.12 (-0.20, -0.04)	-0.44 (-0.51, -0.36)	0.30 (0.27, 0.34)	0.34 (0.24, 0.44)	-0.15 (-0.19, -0.11)
Period-1						
Time	February 14–28	February 14–28	March 27–April 10	March 13–April 3	February 14–March 27	April 10–24
WPC (95% CI)	-4.68 (-6.20, -3.14)	-0.16 (-1.13, 0.82)	-5.12 (-6.18, -4.04)	0.09 (-0.06, 0.24)	2.20 (1.80, 2.60)	2.89 (2.57, 3.20)
Period-2						
Time	February 28–March 27	February 28–March 27	April 10–October 18	April 3–May 1	March 27–May 29	April 24–July 24
WPC (95% CI)	1.31 (0.50, 2.12)	-2.75 (-3.23, -2.28)	-0.08 (-0.10, -0.06)	1.28 (1.12, 1.43)	0.16 (-0.09, 0.42)	-0.08 (-0.10, -0.07)
Period-3						
Time	March 27–October 18	March 27–May 15		May 1–22	May 29–October 18	July 24–August 14
WPC (95% CI)	-0.13 (-0.16, -0.11)	-0.16 (-0.33, 0)		0.37 (0.07, 0.68)	-0.13 (-0.20, -0.07)	-3.39 (-3.68, -3.10)
Period-4						
Time		May 15–October 18		May 22–July 17		August 14–October 18
WPC (95% CI)		0.38 (0.36, 0.41)		0.12 (0.08, 0.16)		0.20 (0.17, 0.23)
Period-5						
Time				July 17–September 4		
WPC (95% CI)				0.23 (0.18, 0.28)		
Period-6						
Time				September 4–October 18		
WPC (95% CI)				0.07 (0.01, 0.12)		

Note: The WPC and AWPC are statistically significant at an alpha level of 0.05, indicating significant differences from zero.

Abbreviation: CFR=case fatality rate; AWPC=average weekly percentage change; WPC=weekly percentage change.

SUPPLEMENTARY TABLE S6. Trends in the cumulative MFI by country during the Omicron period in 2022.

MFI	High income		Upper middle income		Lower middle income	
	Singapore	Australia	Malaysia	Thailand	Indonesia	Vietnam
Start to October 18	0.07	0.61	0.11	0.77	0.38	<0.01
AWPC (95% CI)	1.52 (1.40, 1.65)	1.98 (1.75, 2.21)	0.99 (0.88, 1.10)	2.50 (2.39, 2.60)	2.07 (1.98, 2.17)	1.20 (0.61, 1.79)
Period-1						
Time	February 14–28	February 14–28	March 27–April 10	March 13–27	February 14–28	April 10–24
WPC (95% CI)	14.67 (13.51, 15.85)	15.00 (10.48, 19.71)	9.06 (7.29, 10.85)	22.44 (20.77, 24.13)	25.70 (24.59, 26.82)	23.28 (13.78, 33.56)
Period-2						
Time	February 28–March 20	February 28–October 18	April 10–October 18	March 27–May 8	February 28–March 20	April 24–October 18
WPC (95% CI)	5.60 (4.52, 6.68)	1.24 (1.19, 1.29)	0.41 (0.39, 0.44)	4.34 (4.02, 4.66)	7.37 (6.43, 8.33)	−0.39 (−0.54, −0.23)
Period-3						
Time	March 20–April 24			May 8–October 18	March 20–May 1	
WPC (95% CI)	1.06 (0.73, 1.39)			0.46 (0.43, 0.49)	0.84 (0.64, 1.04)	
Period-4						
Time	April 24–July 24				May 1–October 18	
WPC (95% CI)	0.02 (−0.05, 0.08)				−0.01 (−0.03, 0.01)	
Period-5						
Time	July 24–August 21					
WPC (95% CI)	0.80 (0.29, 1.32)					
Period-6						
Time	August 21–October 18					
WPC (95% CI)	0.07 (−0.05, 0.18)					

Note: Both the AWPC and the WPC significantly deviate from zero at the $\alpha=0.05$ level.

Abbreviation: MFI=mortality fatality index; AWPC=average weekly percentage change; WPC=weekly percentage change.

REFERENCES

- Mathieu E, Ritchie H, Rod s-Guirao L, Appel C, Giattino C, Hasell J, et al. Coronavirus pandemic (COVID-19) our world in data. 2020. <https://ourworldindata.org/coronavirus>. [2023-1-13].
- Hale T, Angrist N, Goldszmidt R, Kira B, Petherick A, Phillips T, et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nat Hum Behav* 2021;5(4):529 – 38. <http://dx.doi.org/10.1038/s41562-021-01079-8>.
- The World Bank. Countries and economies. Washington, DC: The World Bank. <https://data.worldbank.org/country>. [2013-1-13].
- Yang JL, McClymont H, Wang LP, Vardoulakis S, Hu WB. Epidemic features of COVID-19 and potential impact of hospital strain during the omicron wave - Australia, 2022. *China CDC Wkly* 2023;5(7):165 – 9. <http://dx.doi.org/10.46234/ccdcw2023.029>.
- Ferrari S, Cribari-Neto F. Beta regression for modelling rates and proportions. *J Appl Stat* 2004;31(7):799 – 815. <http://dx.doi.org/10.1080/0266476042000214501>.
- Yang JL, Al Mosabbir A, Raheem E, Hu WB, Hossain MS. Demographic characteristics, clinical symptoms, biochemical markers and probability of occurrence of severe dengue: A multicenter hospital-based study in Bangladesh. *PLoS Negl Trop Dis* 2023;17(3):e0011161. <http://dx.doi.org/10.1371/journal.pntd.0011161>.
- Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med* 2000;19(3):335 – 51. [http://dx.doi.org/10.1002/\(SICI\)1097-0258\(20000215\)19:3<335::AID-SIM336>3.0.CO;2-Z](http://dx.doi.org/10.1002/(SICI)1097-0258(20000215)19:3<335::AID-SIM336>3.0.CO;2-Z).