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The Estimation of Excess Mortality during the COVID-19 Pandemic in Jakarta, Indonesia

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Abstract

Indonesia is among the countries affected by the coronavirus disease 2019 (COVID-19) pandemic, and DKI Jakarta Province recorded the highest number of deaths. This study aimed to analyze the excess mortality across five administrative cities in Jakarta stratified by gender to assess the pandemic impact on mortality. The monthly mortality data from January 2018 to December 2020 was obtained through government sources. This data helped to measure excess mortality by estimating the baseline mortality had the COVID-19 pandemic not occurred. The analysis used a linear mixed model because of its ease and flexibility in forecasting subject-specific mortality. The results showed 13,507 or 35% excess deaths in Jakarta [95% CI: 11,636 to 15,236] between June and December 2020. The excess numbers were found relatively higher among men than women. Furthermore, Jakarta has underreported the COVID-19 deaths at least seven times higher than the reported number of confirmed deaths.

Keywords: baseline mortality, COVID-19, excess mortality, linear mixed model, subject-specific

Introduction

The coronavirus disease 2019 (COVID-19) caused global havoc. This pandemic started in Wuhan City, China, on December 31, 2019 and continued to spread worldwide. Indonesia was also affected by the rising COVID-19 cases, which announced the first case of COVID-19 at the beginning of March 2020. The number of positive cases reached 743,198, with 22,138 deaths on December 31, 2020.[1] Additionally, *Daerah Khusus Ibukota* (DKI) Jakarta was the most affected province, with 25% positive cases and 15% deaths nationwide. The number of reported cases was affected by test coverage, and some infected patients died without being tested or showing a false negative. Therefore, the test-confirmed deaths underestimated the actual death toll from the pandemic, specifically in countries such as Indonesia with low testing capacities.[2]

Beyond the deaths caused by the COVID-19 disease itself, the pandemic could have an indirect effect that can potentially increase the number of deaths caused by second mortality, such as delayed health care access and resources diverted towards the situation. The lockdown or large-scale social restrictions (LSRR)/*Pembatasan Sosial Berskala Besar* (PSBB) by DKI Jakarta's Provincial Government may also affect mortality rates. In order to understand the impact of the pandemic, measuring excess mortality is essential as the pandemic is causing more deaths than expected in a given period. The mortality numbers due to COVID-19 may be under-reported and also may be indirectly responsible for additional deaths.

The excess mortality estimations follow various perfectly curated and suitable mathematical models for effective results. However, modeling is not straightforward for estimating the deaths due to different factors that need to be considered for accurate results.[3] Time series analysis-based prediction model is generally adopted by exploiting the serial correlation in the historical mortality data,[4,5] but this approach relies on a solid assumption such as stationarity. Another approach is a linear mixed model, offering the flexibility to model longitudinal data with the inclusion of mean and variability structures.[6] The estimation model flexibility is crucial due to the dynamic variations in the coronavirus spread. The variations should be understood and integrated into the model on a real-time basis for effective balancing roles.

The linear mixed model has been demonstrated to outperform the commonly used monthly or weekly po-

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pulation averaging to forecast mortality at the baseline level.[7] Therefore, the objective of this study was to utilize a linear mixed model to forecast the subject-specific baseline mortality, obtaining excess deaths estimation using the public forum's data. Specific analyses by gender and administrative cities were also covered in more detail. The analysis also fixed the reasons for the excess deaths and pinpointed the areas that could improve the system. Also, it would ensure that the readers can get the complete estimation figures and be vigilant in anticipating the upcoming challenges effectively.

Method

The all-cause mortality data in previous years were retrieved from Jakarta's Open Data,[8] providing the number of deaths by gender for five administrative cities in DKI Jakarta Province (South Jakarta, East Jakarta, Central Jakarta, West Jakarta, and North Jakarta). Due to the limitation of data sources, the analysis was based on monthly data from January 2018 to December 2020. The number of deaths reported as COVID-19 was obtained from the Department of Communication, Informatics, and Statistics of DKI Jakarta Province,[1] on a monthly basis from March 2020, when COVID-19 was officially declared to have transmitted in Indonesia, to December 2020.

The statistical analysis used a similar approach studied by Verbeeck *et al.*,[7] The monthly mortality data from January 2018 to February 2020 was modeled using a linear mixed model. Only the first two months of 2020 were considered in building the model since the pandemic was confirmed to spread in March 2020, and the remaining months in 2020 were forecasted. The model was expressed in Formula 1 where $\varepsilon_{tj} \sim N(0,\sigma^2)$, $b_j \sim N(0,D)$ and ε_{tj} and b_j were mutually independent. The response variable y_{tj} denoted mortality data for a given administrative city j in month t, β_0 and β_1 were the common intercepts and b_j was the administrative city-specific random intercepts. To account for the time effect, a function of time t, f(t), was considered in the model. Three different functions, f(t), were used, e.g., (1) a linear term for time, (2) a cubic smoothing spline to describe monthly mortality variations,[9] and (3) yearly Fourier series,[7] to account for cyclical pattern that might present in the data. If necessary, additional random or fixed effects can be easily included in the linear mixed model. Model parameters estimation used restricted maximum likelihood (REML) as it showed to perform better by removing finite-sample bias than ML estimators (Formula 2).[10]

The model's appropriateness was examined using several statistics. The likelihood ratio test compared two nested models by calculating and comparing likelihoods for the two models, measured as the deviance.[11,12] Information criteria such as Akaike Information Criteria

$$y_{tj} = \begin{cases} \beta_0 + b_j + f(t) + \varepsilon_{tj} & ,if\ male \\ \beta_1 + b_j + f(t) + \varepsilon_{tj} & ,if\ female \end{cases}$$

Formula 1. Linear Mixed Model of Monthly Mortality Data from Januari 2018 - February 2020

$$RMSE\% = \frac{\frac{1}{n}\sqrt{\Sigma(y_{tj}-\hat{y}_{tj})^2}}{\frac{1}{n}\Sigma y_{tj}} \times 100$$

Formula 2. Model Evaluation with Root Mean Square Error Percentage (RMSE%)[10]

(AIC) and Bayesian Information Criteria (BIC) were alternative model selection procedures by allowing non-nested models comparison. It used deviance to measure fit by adding a penalization for a more complex model.[13] The root means square error percentage (RMSE%) was also considered to evaluate the forecasting accuracy of the models.[7]

The data were first explored to gain insight into the mortality trend over time and determine appropriate time functions in the linear mixed model. Formula 1 was built using training data, which consisted of monthly mortality data from January 2018 to February 2020. The fitted model was then used to estimate the expected mortality in the absence of COVID-19 based on the pattern of all-cause mortality in prior years through forecasting from March to December 2020. The excess number was computed by subtracting observed all-cause mortality (total death) in the same forecasted period from the corresponding expected mortality in each administrative city across gender. The total excess number for DKI Jakarta Province (from now on referred to as "Jakarta") was calculated by combining the excess of five administrative cities numbers.

It should be noted that the accumulated total excess mortality in 2020 was based on the calculation from June 2020. The mortality data before June 2020 appeared to be outliers as they showed unusual behavior with a substantial decrease, particularly in March 2020 (Formula 1). This situation was caused by the implemented lockdown and LSRR for the first time, according to Government Regulation No. 21 of 2020. It affected people staying at home and only being able to report death cases in the following months. Therefore, the excess calculation excluded outlier months to improve forecast accuracy.

Similarly, the fraction of death (% excess) was computed for each administrative city across gender. The excess mortality ratio to the reported COVID-19 deaths was also calculated as an undercount of COVID-19 deaths.[14] To account for uncertainty in the excess estimates, the empirical 95% confidence interval was calculated using a parametric bootstrap approach. Specifically, 1,000 bootstrap samples (y^*_{tj}) were generated from a random sample $\varepsilon^*_{tj} \sim N(0,\sigma^2)$ and $b^*_j \sim N(0,D)$. A linear mixed model was fitted to the bootstrap data for each simulation, and the predictions for all-cause mortality in the absence of COVID-19 were derived. Finally, the crude excess death rates (excess deaths divided by population multiplied by 100,000 people,[15]) were calculated in five administrative cities of DKI Jakarta Province, separately in men and women. The data were analyzed in RStudio 4.0.3 using lmer4 package,[16] to fit linear mixed model and spline package,[17] to perform cubic smoothing splines.

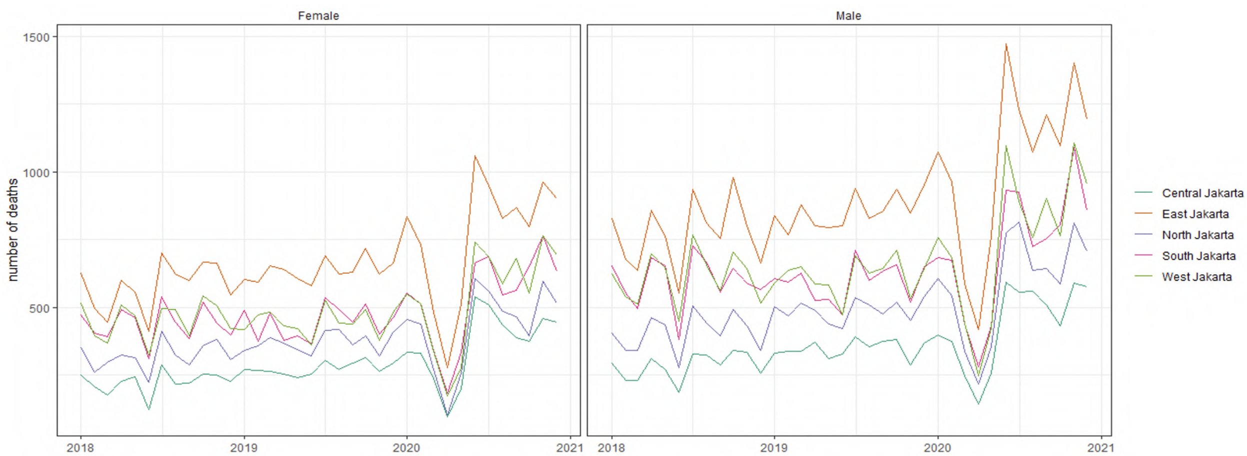

Figure 1. Mortality Trend from 2018 to 2020 by Gender and Administrative Cities in Jakarta

Table 1. Estimation of Excess Death Associated with COVID-19 Pandemic (95% Confidence Interval) from June-December 2020

	Total Deaths	Expected Death	Excess Deaths (a)	% Excess	Total Reported COVID-19 Deaths (b)	Difference between (a) and (b)	Undercount of COVID-19 Deaths
Total							
Central Jakarta	6,964	4,898	2,052 (1,648 to 2,455)	42%	240	1,812 (1,408 to 2,215)	8.55
East Jakarta	15,045	10,881	4,182 (3,779 to 4,602)	39%	561	3,621 (3,218 to 4,041)	7.45
North Jakarta	8,599	6,510	2,104 (1,671 to 2,527)	32%	250	1,854 (1,421 to 2,277)	8.42
South Jakarta	10,591	8,194	2,380 (1,959 to 2,821)	29%	419	1,961 (1,540 to 2,402)	5.68
West Jakarta	11,176	8,382	2,789 (2,358 to 3,208)	33%	411	2,378 (1,947 to 2,797)	6.79
Jakarta	52,375	38,865	13,507 (11,636 to 15,236)	35%	1,881	11,626 (9,755 to 13,355)	7.18
Male							
Central Jakarta	3,815	2,692	1,116 (878 to 1,344)	41%	129	987 (749 to 1,215)	8.65
East Jakarta	8,680	6,194	2,505 (2,269 to 2,748)	41%	329	2,176 (1,940 to 2,419)	7.61
North Jakarta	4,978	3,632	1,354 (1,111 to 1,577)	37%	143	1,211 (968 to 1,434)	9.47
South Jakarta	6,085	4,609	1,459 (1,223 to 1,686)	32%	255	1,204 (968 to 1,431)	5.72
West Jakarta	6,475	4,715	1,746 (1,511 to 1,985)	37%	248	1,498 (1,263 to 1,737)	7.04
Jakarta	30,033	21,842	8,180 (7,229 to 9,102)	37%	1,104	7,076 (6,125 to 7,998)	7.41
Female							
Central Jakarta	3,149	2,206	936 (716 to 1,167)	42%	111	825 (605 to 1056)	8.43
East Jakarta	6,365	4,687	1,677 (1,448 to 1,913)	36%	232	1,445 (1,216 to 1,681)	7.23
North Jakarta	3,621	2,878	750 (529 to 968)	26%	107	643 (422 to 861)	7.01
South Jakarta	4,506	3,585	921 (706 to 1,149)	26%	164	757 (542 to 985)	5.62
West Jakarta	4,701	3,666	1,043 (822 to 1,257)	29%	163	880 (659 to 1094)	6.40
Jakarta	22,342	17,022	5,327 (4,371 to 6,251)	31%	777	4,550 (3,594 to 5,474)	6.86

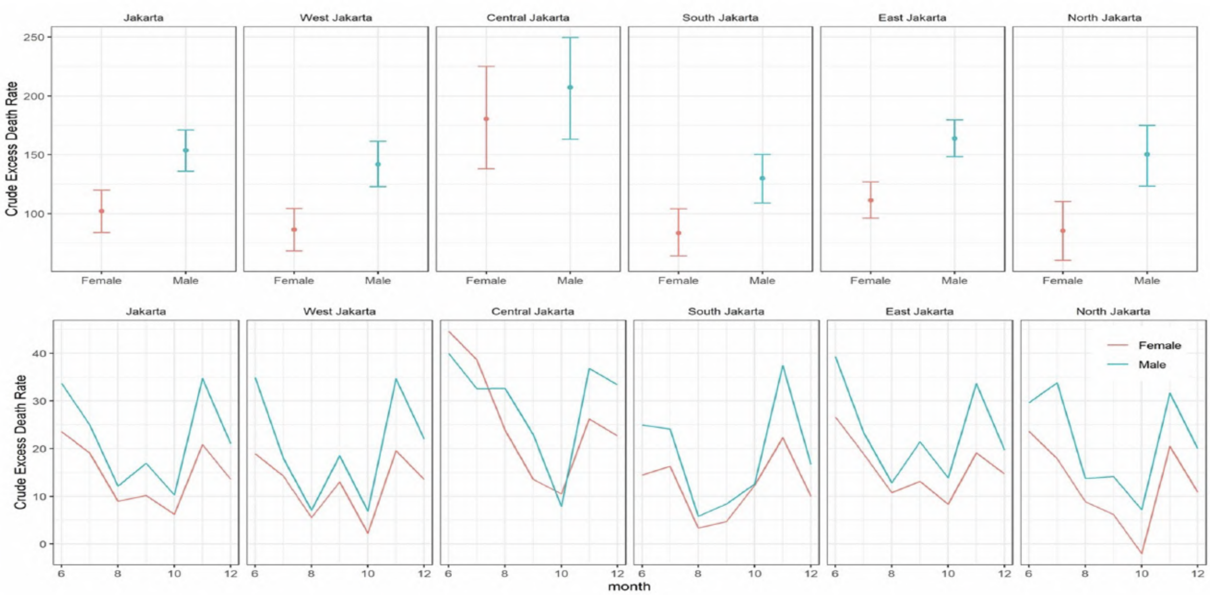

Figure 2. Accumulated Crude Excess Death Rate (Top Panel) and Trend in Crude Excess Death Rate from June-December 2020 (Bottom Panel)

Results

All-cause mortality during the study period displayed fluctuating upward trend (Figure 1). The five administrative cities had similar mortality trends over the years, with notes that East Jakarta showed more deaths and Central Jakarta showed the lowest. Additionally, mortality was generally higher among men than women. Different functions of time were adapted in the linear mixed models to account for time trend effects.

The linear mixed model with a linear term for time outperformed the other models, reporting the lowest BIC value and the lowest forecasting accuracy (AIC = 2723.3; BIC = 2747.7; %RMSE = 8.46). A linear mixed model with cubic smoothing splines with 5 degrees of freedom yielded AIC = 2732.1, BIC = 2760.0, and %RMSE = 8.56. The linear mixed model with yearly Fourier series had AIC = 2719.7; BIC = 2758.0, and %RMSE = 8.59. Adding additional random effects (such as random slope for time) to the model led to a singular fit, indicating the random-effects structure was too complex to be supported by data. Allowing both genders to have different evolution over time or including an interaction term between gender and time also did not improve the fitted model due to insignificant likelihood ratio test at 5% level (χ^2 (1) = 0.7502, p-value = 0.386). Additionally, the model's AIC and BIC statistics with interaction term were higher, e.g., 2724.6 and 2752.4, respectively, than without interaction.

From the period of June to December 2020, a total of 52,375 deaths were recorded in Jakarta, with estimated excess deaths of 13,507 (95% CI = 11,636 to 15,236) or approximately 35% higher than the expected baseline number when accounting for a linear time trend in the calculation (Table 1). East Jakarta had the highest absolute number of excesses, with an estimated increase of 4,182 (95% CI = 3,779 to 4,602). In terms of excess percentage, Central Jakarta had the highest increase with 42% than the number of expected deaths, despite having the lowest absolute number of excesses at 2,052 (95% CI = 1,648 to 2,455) than other administrative cities. Men consistently had a higher estimated number of excess deaths than women across administrative cities. They had an increase of 8,180 (95% CI = 7,229 to 9,102), corresponding to 37% increase. In contrast, the women had an increase of 5,327 (95% CI = 4,371 to 6,251), corresponding to 31% increase.

A total of 1,881 death cases due to COVID-19 were reported in Jakarta from June to December 2020. This number was then compared to the estimated excess deaths, as shown in Table 1. The results indicated that the number of excess deaths exceeded the official COVID-19 recorded deaths by Jakarta's Government by 11,626 (95% CI = 9,755 to 13,355). This was significantly higher among men (7,076; 95% CI = 6,125 to 7,998) than women (4,550; 95% CI = 3,594 to 5,474). Breakdown by administrative cities, East Jakarta, showed the largest difference at 3,621 (95% CI = 3,218 to 4,041) than the other four.

Jakarta experienced an undercount of COVID-19 deaths similar to most countries since the ratio was above one.[18] The ratio was higher among men at 7.41 than women at 6.86. Central and North Jakarta had the highest ratio above of the five administrative cities.[8] These large undercount ratios suggested that the number of COVID-19 deaths in Jakarta was inaccurate and more likely to have been significantly underreported.

Figure 2 shows the crude excess death rate (excess deaths divided by population multiplied by 100,000 people,[18]) in Jakarta and administrative cities, separately in men and women. It is evident from the plot that there is a significant difference in the excess death rate between men and women in Jakarta. The estimated crude excess death rate among men per 100,000 people was 154 (95% CI = 136–171), higher than women with 102 (95% CI = 84–120). Central Jakarta had the highest crude death rate but lacked a significant difference between men (207, 95% CI = 163–250) and women (180, 95% CI = 138–225).

The crude excess death rate trend between June and December 2020 by gender and administrative cities indicated similar risk trends across gender, but men had consistently higher rates than women. For Jakarta, there was a higher excess rate in June which decreased until October 2020 and increased in November 2020. It supported the reported number of COVID-19 transmissions in Jakarta, which increased at the beginning of November. The government then instructed to implement lockdown or LSRR, and there was a decreasing excess rate in the following month of December.

Discussion

Most studies measured mortality using time series models,[19-21] or methods of averaging the 5-year historical mortality data,[22,23] and a few utilized linear mixed models. The linear mixed model has the advantage over traditional analysis procedures, conducting simultaneous inferences for multiple outcomes by introducing random effects in the model.[24] This method gives forecast values with minor variance than the time series model.[7]

The result revealed an excess number of 13,507 deaths in overall Jakarta, which was far higher than the official record of 1,881 deaths related to COVID-19 in 2020. Stratified analysis by gender and administrative cities indicated an excess numbers variation. Men experienced higher excess mortality with a 37% increase from the expected baseline number, while women experienced a 31% increase. Other studies noted these discrepancies, indicating that most countries reported gender mortality inequality with higher excess among men than women.[19,25,26]

The excess to the reported COVID-19 death ratio revealed that Jakarta had an undercount ratio of 7.18. The data followed other countries' analysis as many had ratios above one.[14,27] However, various European and American countries had ratios below three. Countries like Belgium and France reported a ratio below one, indicating a very accurate report on COVID deaths,[28] and that all excess deaths were directly due to COVID-19.[29] The most extreme undercount ratios were above 30 in Uzbekistan, Nicaragua, and Tajikistan. However, the performance of the DKI Jakarta Provincial Government in handling this issue cannot be compared to other provinces and cities in Indonesia since no recent studies reported excess mortality in different cities.

A high undercount ratio above one suggested that Jakarta misclassified COVID-19 deaths.[27] This discrepancy was driven by inadequate testing or treatment access and the fact that diagnostic COVID-19 testing was not widely available at the pandemic's beginning. Indonesia's testing rate was 247 tests per million people since its first case in March 2020, placing in the second-lowest in Southeast Asia.[30] Therefore, the reported death numbers underestimated the accurate picture.

Secondary mortality caused a high undercount ratio in Jakarta. Indonesia was known for having a high prevalence of non-communicable diseases in previous years, such as hypertension, diabetes mellitus, chronic kidney disease, cancer, and stroke. When the pandemic took place, health care facilities were mainly diverted to provide services for the COVID-19 patients, limiting public (non-COVID patients) health systems access.[31] People were afraid of visiting the hospital to avoid the virus infection, delaying chronically ill patient's treatment and care. A cross-sectional study had similar findings identifying people's health services access barriers during the pandemic in Indonesia.[31] It indicated that fear of infection was one of the most influential barriers. The discrepancy was also due to poor contact tracing, resulting from the stigma around COVID-19 prompting expulsion fears in the communities. Hence, people provided incomplete data. Low testing rate and poor contact tracing caused incorrect identification of deaths attributed to COVID-19 and, at the same time, increased death rates.

Central Jakarta showed the most considerable rise in percentage of excess death at 42%, and the highest undercount of COVID-19 deaths at 8.55. A recent study identified Central Jakarta as the most affected administrative city in terms of distribution of COVID-19 cases.[32] This can be expected as it is among the busiest cities with high human mobility. In September 2020, the DKI Jakarta Provincial Government reported that Central Jakarta had more red zones than other administrative cities.[33]

Conclusion

This study assessed all-cause mortality in Jakarta during the COVID-19 pandemic from June to December 2020 across population subgroups. The excess deaths were estimated to be far higher than the official record related to COVID-19. The pandemic results increased deaths, not only those who have died directly from COVID-19, but also those from all other causes. Limited diagnostic testing, weakened healthcare systems, and improper treatment for chronically ill patients caused the excess numbers. Men had higher excess mortality than women, and Central Jakarta appeared to be more severely affected in excess deaths than other administrative cities. The findings illustrated that the deaths estimation from all-cause mortality excess were more reliable than the government's official reported deaths. This study recommended that the provincial government monitor excess mortality as a critical tool to evaluate the effects of the ongoing pandemic.

Limitations and Recommendations

Government should implement nodal agencies to apply these data estimations to prepare and sync their arrangements with the requirements as and when needed. The analysis must be verified with the raw data figures to ensure the reliability of the data. The excess deaths data can also help handle the upcoming COVID-19 waves in a more prepared and efficient manner. Precise death estimations have various benefits, including the required doctor's engagement and daily medical supplies during the pandemic. These issues must be appropriately analyzed so that the correct trend of the pandemic can be gauged and there are no issues of unawareness or lack of knowledge with unavailable data.

This study had several important caveats. The preferred mortality data were collected by date of death for analysis. However, the public data only provided monthly data organized by the registration date, causing weekly or monthly spurious drops with public holidays, particularly during national lockdowns in March and April 2020. The problem of incomplete all-cause mortality data in the early COVID-19 pandemic may lead to underestimating the number of excesses that occurred in 2020. These issues can be resolved for better results when additional information and data related to the COVID-19 pandemic are released.

Despite the limitations, the estimated total excess mortality during a COVID-19 outbreak in Jakarta better perceives the mortality burden. The results confirmed that COVID-19 had a high mortality impact. In order to manage future outbreaks, this finding facilitated appropriate resource allocation for public health priorities. If COVID-19 is known to be the source of death, it must be correctly reported to make an accurate assessment of the pandemic's effects and properly direct public health response. Continuous monitoring of excess mortality will provide an important tool to evaluate the effects of an ongoing pandemic and enable better government management. Future work is required to understand the impact of age, socioeconomic status, and vaccination programs on excess mortality in Jakarta and in Indonesia. It will help people learn from the experience to mitigate any future issues.

Abbreviations

COVID-19: coronavirus disease 2019; DKI: *Daerah Khusus Ibukota*; LSRR: Large-Scale Social Restrictions; PSBB: *Pembatasan Sosial Berskala Besar*; REML: Restricted Maximum Likelihood; ML: Maximum Likelihood; AIC: Akaike Information Criteria; BIC: Bayesian Information Criteria; RMSE%: Root Means Square Error Percentage; CI: Confidence Interval.

Ethics Approval and Consent to Participate

Not applicable.

Competing Interest

The author declares that there are no significant competing financial, professional, or personal interests that might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

The dataset is publicly available at Open Data Jakarta and the Department of Communication, Informatics, and Statistics of DKI Jakarta Province.

Authors' Contribution

MYW is the only contributor to data collection, statistical analysis, and article writing.

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