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Paper:

Excess Mortality Probably Attributable to COVID-19 in Tokyo, Japan During August and October 2020

Junko Kurita*, **Tamie Sugawara****,†, **and Yasushi Ohkusa****

*Department of Nursing, Tokiwa University
1-430-I Miwa, Mito, lbaraki 310-8585, Japan
**Infectious Disease Surveillance Center, National Institute of Infectious Diseases (NIID), Tokyo, Japan
†Corresponding author, E-mail: tammy@nih.go.jp
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Background: By March, 2021, the COVID-19 outbreak had reached its highest peak at the end of December, 2020. Nevertheless, no remarkable excess mortality attributable to COVID-19 has been observed. Object: We sought to quantify excess mortality in April using the National Institute of Infectious Diseases (NIID) model. Method: We applied the NIID model to deaths of all causes from 1987 through February, 2021 for all of Japan and through October for Tokyo. Results: Results obtained for Japan show very few excess mortality cases in August and October, 2020, estimated respectively as 12 and 104. However, in Tokyo, 595 cases of excess mortality were detected during August and October: they were, respectively, 3.1% and 1.7% of baseline numbers. Discussion and Conclusion: We detected considerable excess mortality in Tokyo but not throughout Japan. Continued careful monitoring of excess mortality of COVID-19 is expected to be important.

Keywords: excess mortality, COVID-19, all cause death, stochastic frontier estimation, NIID model

1. Introduction

To date, excess mortality has been used mainly to assess the social effects of influenza activity [1–6]. However, since the emergence of COVID-19, excess mortality attributable to COVID-19 has attracted attention [7] as a measure of overall disease effects because it can reflect cases that have remained unidentified as polymerase chain reaction (PCR) positive. Especially in Japan, few PCR tests have been administered per capita. Therefore, concern has arisen that some deaths caused by COVID-19 might have remained unrecognized. Moreover, excess mortality related to COVID-19 might be expected to contribute to evaluation of vaccine effects. For these evaluations, the estimated excess mortality without vaccine effects should be regarded as a baseline. Nevertheless, no such trial to ascertain excess mortality has been undertaken to date. This study might be the first trial to measure that quantity in Japan.

By the end of February 2021, the COVID-19 outbreak had shown its highest peak on the end of December 2020. In Japan, approximately 433 thousand patients have been reported from the outbreak, and about eight thousand deaths. Although Japan has about one-third of the population of the U.S., these figures are vastly different in scale from those reported for the U.S.: 28.6 million cases of morbidity and 512 thousand cases of mortality [8]. In light of the much lower number of patients in Japan, some criticism has arisen that low PCR testing rates might have led to the lower number of documented patients [9]. In this sense, one might regard the number of deaths as reflecting the actual situation in Japan, but with no testing-related bias.

Regarding deaths, the case-fatality rate (CFR) is about 5%. In fact, the CFRs in both countries are not much different. The lower relative frequency of PCR testing in Japan might be related to some difficulties. Therefore, we specifically examined excess mortality attributable to COVID-19 in Japan, irrespective of the cause of death.

In Japan, excess mortality was estimated using the National Institute of Infectious Diseases (NIID) model [10], which has been the official procedure for more than a decade. It was applied to two data sources: the national monthly deaths of all causes and the respective weekly pneumonia and influenza deaths in the 21 largest cities and their total. The latter is published regularly in Japanese during the influenza season (https://www.niid.go.jp/niid/ja/flu-m/2112-idsc/jinsoku/131-flu-jinsoku.html). Unfortunately, that publication ceased in March 2020 because it was intended for influenza. The first peak in Japan was April 3 [11]: excess mortality cannot be detected until March. Instead, we applied the NIID model to all causes of death throughout Japan during April–December 2020.

2. Method

Excess mortality is defined as the difference between the actual number of deaths and an epidemiological threshold. The epidemiological threshold is defined as the upper bound of the 95% confidence interval (CI) of the baseline. The baseline is defined as the number of deaths that are likely to have occurred if an influenza outbreak had not occurred. Therefore, excess mortality is not inferred if the actual deaths are fewer than the epidemiological threshold.

The data used for this study were monthly deaths of all causes from 1987 through February 2021 [12]. For the NIID model, the Stochastic Frontier Estimation [13–19] is

$$\log D_t = \alpha + \beta T_t + \gamma T_t^2 + \sum \eta_i M_{it} + \varepsilon_t, \quad . \quad . \quad . \quad (1)$$

and

$$\varepsilon_t = \nu_t + |\omega_t|, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where D_t represents all causes of death in month/year t, T_t denotes the linear time trend, and M_{it} is the dummy variable for a month. Its value is one if t is the i-th month and zero otherwise. Moreover, ν_t and ω_t are stochastic variables respectively expressing $\nu_t \sim N(0,\mu^2)$ and $\omega_t \sim N(0,\xi^2)$; they are mutually independent. Although ν_t represents stochastic disturbances, ω_t denotes non-negative deaths attributable to influenza. These disturbance terms in this model are parameterized by two parameters: ξ/μ and $\sqrt{\mu^2+\xi^2}$. If the null hypothesis $\xi/\mu = 0$ is not rejected, then the Stochastic Frontier Estimation model is inappropriate.

Study areas were the whole of Japan and its capital, Tokyo. The study period for estimation was from 1987 through February 2021 for the whole of Japan and up through October for Tokyo. We inferred significance for results with $p < 0.05$.

3. Results

Table 1 presents estimation results obtained for the whole of Japan. **Table 2** shows those for Tokyo. **Table 1** shows that almost all coefficients were significant except for the square term of the time trend and dummy for March. **Table 2** shows that almost all coefficients were significant except for dummies for May or November. Some insignificant monthly dummies mean that the impacts of the month were not significantly different from December as reference. For the case of the whole of Japan in **Table 1**, deaths in January were significantly more numerous than in December, those in March were not significantly different from those in December, and those in other months were significantly fewer than in December. By contrast, ξ/μ in both tables were significantly different from zero. That finding proved the validity of using stochastic frontier method for these data.

Figure 1 presents observed deaths, the estimated baseline, and its threshold in Japan. It shows a clearly upward trend with periodic fluctuation: it was high in winter and low in summer. However, some peaks of the actual number of deaths exceeded its threshold and revealed excess mortality. Although a large degree of excess mortality was found mainly in winter, a small degree of excess mortality was found even in summer.

Figure 2 specifically portrays results obtained for the

Table 1. Estimation results of NIID model for excess mortality in all causes from 1987 through February 2021 throughout Japan.

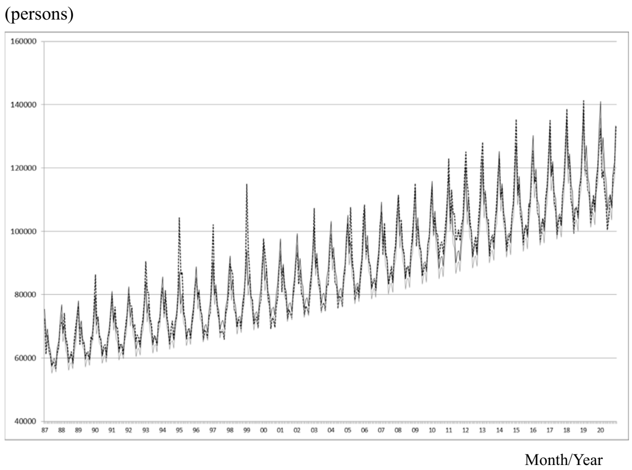
Explanatory variable	Estimated coefficient	p-value
Constant	11.12	$<$ .0004
Time trend	0.001537	$<$ .0004
Time trend ^{2}	$-0.9763*10^{-7}$	.423
January	0.07075	$<$ .0004
February	−0.05631	$<$ .0004
March	−0.01671	.053
April	−0.1027	$<$ .0004
May	−0.1247	$<$ .0004
June	−0.2126	$<$ .0004
July	−0.1776	$<$ .0004
August	−0.1710	$<$ .0004
September	−0.2083	$<$ .0004
October	−0.1197	$<$ .0004
November	−0.08768	$<$ .0004
ξ/μ	2.386	$<$ .0004
$\sqrt{\mu^2+\xi^2}$	0.04934	$<$ .0004

Note: For the 410 observations, the log likelihood was 914.529. ξ^2 denotes the variance of the non-negative disturbance term. μ^2 represents the variance of the disturbance term.

Table 2. NIID Model estimation results from 1987 until October 2020 in Tokyo.

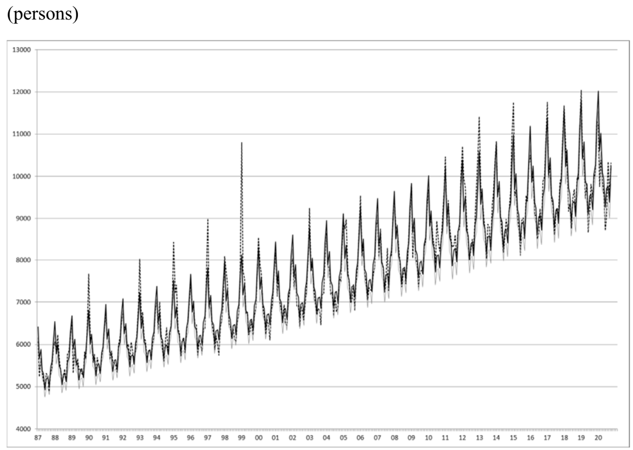
Explanatory variable	Estimated coefficient	p-value
Constant	8.55	$<$ .0004
Time trend	0.00186	$<$ .0004
Time trend ^{2}	$-0.726*10^{-6}$	.001
January	0.0759	$<$ .0004
February	0.137	$<$ .0004
March	0.0292	.015
April	0.0479	$<$ .0004
May	−0.0271	.111
June	−0.0584	$<$ .0004
July	−0.111	$<$ .0004
August	−0.0664	$<$ .0004
September	−0.0719	$<$ .0004
October	−0.108	$<$ .0004
November	−0.0253	.102
ξ/μ	2.44	$<$ .0004
$\sqrt{\mu^2+\xi^2}$	0.0684	$<$ .0004

Note: For the 406 observations, the log likelihood was 887.758. ξ^2 denotes the variance of the non-negative disturbance term. μ^2 represents the variance of the disturbance term.



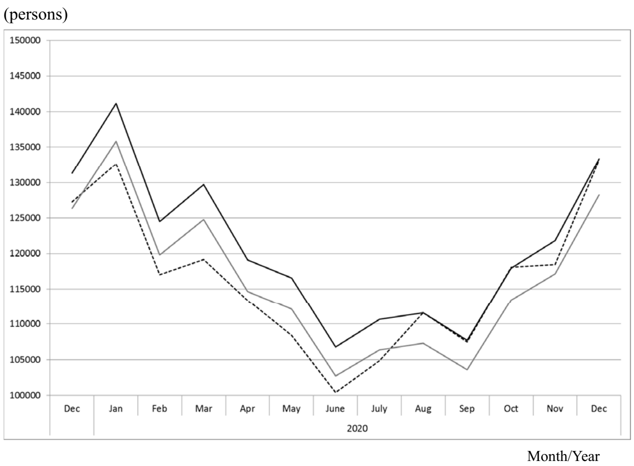
Note: Broken line represents observations of all deaths. Gray represents the estimated baseline based on **Table 1**. Black shows the threshold.

Fig. 1. Observations for all deaths, estimated baseline and threshold by NIID model from 1987 through February 2021 in Japan.



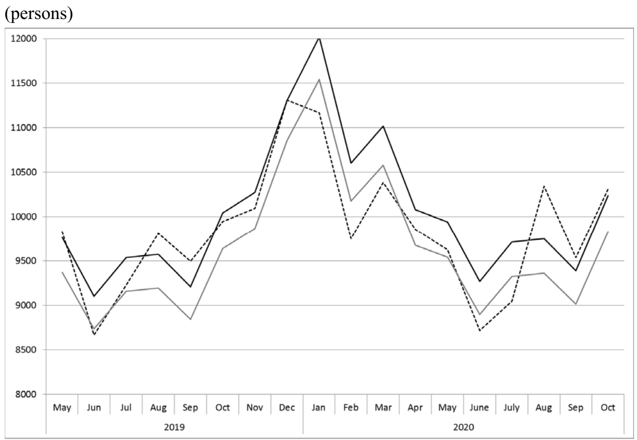
Note: Broken line represents observations of all deaths. Gray represents the estimated baseline based on **Table 2**. Black shows the threshold.

Fig. 3. Observations of all deaths, the estimated baseline, and threshold by NIID model from 1987 through October 2020 in Tokyo.



Note: Broken represents observations of all deaths. Gray represents the estimated baseline based on **Table 1**. Black shows its threshold.

Fig. 2. Observations for all deaths, baseline and threshold by NIID model since January 2020 in Japan.



Note: Broken represents observations of all deaths. Gray represents the estimated baseline based on **Table 2**. Black shows the threshold.

Fig. 4. Observations of all deaths, estimated baseline and threshold by NIID model from May 2019 through October 2020 in Tokyo.

period of 2020. It was difficult to recognize the black line visually, which was the actual number of deaths. Deaths were more numerous than the threshold based on the estimation result shown in **Table 1** in August and October 2020. Therefore, some excess mortality was found in these two months. In September, black and broken lines were almost identical, but broken line was not higher than black line. Differences between the black line and the broken line in the case of that broken line was higher than black line as defined in *Methods* revealed 12 and 104 cases of excess mortality in August and October 2020, which were respectively 0.01 and 0.1% of the baseline.

Figures 3 and **4** portray the estimated results for Tokyo. The pattern of fluctuation in the numbers of all deaths in Tokyo was similar to that for the whole of Japan, except for its level. We found 595 cases of excess mortality in August, 150 cases of excess mortality in September, and 76 in October, which were respectively 3.1, 1.7, and 0.8% of the baseline. **Fig. 4** also showed some excess mortality in August and September in 2019, similarly to 2020.

4. Discussion

This study applied the NIID model to all causes of death to detect excess mortality attributable to COVID-19. We found 12 and 104 cases of excess mortality respectively in August and October, 2020 throughout Japan.

Moreover, we found 821 ($= 595 + 150 + 76$) cases of excess mortality in August and October in Tokyo which corresponded to approximately 0.8 and 3.1% of the baseline. It might not be slight excess mortality. It might be increasing after October, especially in winter, even though these data were not available in Tokyo and even though cases of excess mortality for the whole of Japan were not found at least until February 2021, as shown in **Fig. 2**. Although **Fig. 4** also showed some excess mortality in August and September in 2019, similarly to 2020, it should not result from COVID-19. It might be associated with insolation.

About 5800 mortality cases caused by COVID-19 were confirmed throughout Japan by PCR testing and reported by the MHLW officially as of February 2021 [12]. Therefore, even if COVID-19 actually caused external mortality, neither the NIID model nor another statistical model would be able to detect significant effects attributable to COVID-19. Some deaths from COVID-19 might not have been tested and might have been excluded from these official numbers of mortality cases. However, deaths in all causes, which were analyzed in the present study, include deaths without diagnosis as COVID-19. They are not included with deaths in COVID-19, but are actually associated with COVID-19. The slight mortality from all causes found from the present study suggests that such unrecognized deaths associated with COVID-19 were not significantly numerous, even if they occurred.

Some researchers in Japan have emphasized considerable excess mortality from all causes of death through October of around 19 thousand at maximum because of COVID-19 [20] when using the Farrington algorithm [21] and EuroMOMO [22], which was more than approximately 3.3 times greater than the number of deaths confirmed by PCR testing. This study measured excess mortality as the gap separating observations and the baseline, not a threshold as in prefectures where observations was more numerous than the threshold. Therefore, their estimated huge excess mortality might severely mislead the risk participation for COVID-19 among the general population.

Particularly in Tokyo, although they found 18 cases of excess mortality in May 2020, it was not found in the present study, as shown in **Fig. 4**. That finding suggests that their adopted procedure has an upward bias for excess mortality compared with the NIID model, which has been suggested logically [23].

Because we found that the total deaths were fewer than the baseline nationwide until July and because we found very little excess mortality in August and October shown in **Fig. 2**, we might emphasize negative excess mortality. Such negative excess mortality might be attributable to precautions adopted widely among people such as wearing masks, washing hands with alcohol, and maintaining social distance, all of which reduce the infection risk not only of COVID-19 and of other infectious diseases such as influenza and pharyngoconjunctival fever. Therefore, the total number of deaths decreased, completely offsetting COVID-19 effects.

Using pneumonia death data instead of total death data might be better to evaluate excess mortality caused by COVID-19. However, the application rules of the International Classification of Diseases were revised in January 2017, after which pneumonia deaths decreased by approximately 25%. April 2020 was the fourth April since 2017. Moreover, because the COVID-19 outbreak might have spurred precautions for pneumonia in general, it might have decreased pneumonia and deaths attributable to pneumonia from causes other than COVID-19. If so, the number of pneumonia deaths attributable to COVID-19 might be offset partially or completely by the decreased number of pneumonia deaths attributable to infectious diseases other than COVID-19.

5. Conclusion

Results of this study show considerable excess mortality since the outbreak of COVID-19 emerged in Tokyo between August and October, as shown in **Fig. 4**. Excess mortality might have increased rapidly in the winter. Continued careful monitoring of excess mortality of COVID-19 is expected to be important.

Notes:

The present study is based on the authors' opinions: it does not reflect any stance or policy of their professionally affiliated bodies.

Conflict of interest: The authors have no conflict of interest to declare.

Ethical considerations: All information used for this study was published on the web site of MHLW [12]. Therefore, no ethical issue is presented.

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Name:
Junko Kurita

Affiliation:
Department of Nursing, Tokiwa University
Address:
1-430-1 Miwa, Mito, Ibaraki 310-8585, Japan
Brief Career:
2019 Received Master of Nursing from Ibaraki Prefectural Medical University
2020- Junior Associate Professor, Department of Nursing, Tokiwa University
Selected Publications:
• J. Kurita, T. Sugawara, and Y. Ohkusa, "Estimated effectiveness of school cIosure and voluntary event cancellation as COVID-19 countermeasures in Japan," J. lnfect. Chemother, Vol.27, No.1, pp. 62-64, 2021.

Name:
Tamie Sugawara

Affiliation:
National lnstitute of lnfectious Diseases (NIID)
Address:
1-23-1 Toyama, Shinjuku-ku, Tokyo 162-8640, Japan
Brief Career:
2006 Received Ph.D. degree of Human Health Care from University of Tsukuba
2015- Senior Researcher, Infectious Disease Surveillance Center, NIID
Selected Publications:
• T. Sugawara, Y. Ohkusa, K. Taniguchi, C. Miyazaki, M. Momoi, and N. Okabe, "Association of severe abnormal behavior and acetaminophen with/without neuraminidase inhibitoors," J. lnfect Chemother, Vol.25, No.6, pp. 423-426, 2019.

Name:
Yasushi Ohkusa

Affiliation:
National lnstitute of lnfectious Diseases (NIID)
Address:
1-23-1 Toyama, Shinjuku-ku, Tokyo 162-8640, Japan
Brief Career:
2001 Received Ph.D. degree of Economics, Osaka University
2005 Received Ph.D. degree of Medical, University of Tsukuba
2003- Senior Researcher, Infectious Disease Surveillance Center, NIID
Selected Publications:
• Y. Sugishita, J. Kurita, T. Sugawara, and Y. Ohkusa, "Effects of voluntary event cancellation and school closure as countermeasures against COVID-19 outbreak in Japan," PLoS One, Vol.15, No.12, doi: 10.1371/journal.pone.0239455, 2020.