Effectiveness of mask in COVID-19 pandemic in Japan

Junko Kurita[1*], Tamie Sugawara[2], Yasushi Ohkusa[2]

1. Department of Nursing, Daitobunka University, Itabashi, Tokyo, Japan
2. National Institute of Infectious Diseases, Tokyo, Japan

Correspondence to:
Junko Kurita,
e-mail: kuritaj@ic.daito.ac.jp

Conflict of Interest:

No author has any conflict of interest, financial or otherwise, to declare in relation to this study.

ICMJE Statement

Contributors JK was responsible for the coordination of the study and responsible for the data setting. YO developed the model and TS illustrated the results. All authors contributed to the writing of the final manuscript.

Abstract

Background: The government of Japan had stopped to recommend to wear mask on March 13, 2023.

Object: The object of this study was to estimate effectiveness of mask to prevent for COVID-19 infection through comparison among before and after the stopping date.

Method: The effective reproduction number(R(t)) was regressed on dummy variable for after the stopped date as well as vaccine coverage, vaccine coverage with some delay, temperature, humidity, mobility, share of the mutated strains, counter measures including Go To Travel Campaign and an Olympic Games. The study period was February, 2020 through April 14, 2023, as of May 7, 2023.

Results: We selected the specification with 90 days lag of waning. In this specification, the second to the fourth vaccination coverage, the first to the third emergency of status, Goto Travel Campaign and Olympic games and the share of other minor mutated strains were significantly negative. Conversely, share of the alpha, delta, and BA2, BA5, and XBB.1.5 sublineage of omicron variant strain,

The estimated coefficient of after the stopped date for recommendation to wear mask was negative but insignificant.

Discussion: The obtained estimated results showed that mask may not have effectiveness to reduce infection of COVID-19. However, it might suggest that the most of Japanese have continued to wear mask without the government did not recommend after the stopped date.

Keywords: SARS-CoV-2, effective reproduction number, mask, , vaccine coverage, waning in vaccine effectiveness

1. Introduction

Since emerging SARS-CoV-2, the Japanese government had recommended to wear mask to prevent for infection. It had ceased on March 12, 2023. Japan was one of the latest country in which cancelled recommendation to wear mask. At the same time, in Japan, people was recommended to wear mask by the government, however, wearing mask has never been legally enforced. Even without enforcement, the most Japanese had wearied mask during pandemic, and many Japanese have kept to wear mask even after March 12, 2023. Therefore,

Wearing mask may be effective to reduce infectivity of SARS-CoV-2 by many observational study [1-12] . Moreover, one experimental study found partially effectiveness[13]. Conversely, one randomized clinical trial found no effective[14], though placebo for mask . Therefore, definitive conclusions about effectiveness of wearing mask might not be reached, yet.

The object of this study was to examine how mask reduced infectivity of SARS-CoV-2 in Japan. So as to do it, we regressed the effective reproduction number, R(t), on mask policy, which was one in the period before the stopped date and zero after the stopped date, as well as other situation such as vaccine coverage, the mutated strain, counter measures or climate condition.

2. Methods

This study examined the numbers of patients including asymptomatic patients reported by the Ministry of Health, Labour and Welfare (MHLW) from February 1, 2020 to April 14, 2023 published [3] as of May 7, 2023.

Estimation procedure for effective reproduction number was the same as previous study [4]. In short, let f(t) was the empirical distribution of incubation period and g(t) was the empirical distribution of the period from onset to be reported in public. Both were indicated in the previous study [4]. Then, $\Sigma_{s=1}g(s)x(t+s)$ should be estimated the number of patients whose onset date was t where x(t) was newly confirmed symptomatic patients on date t. x(t) was assumed to be constant proportion of total of newly confirmed symptomatic patients including asymptomatic cases, which were reported in public. Now, $\Sigma_{k=1}\Sigma_{s=1}f(k)g(s)x(t+s+k)$ should be estimated the number of patients who were infected on date t. On the other hand, let h(t) was distribution of infectivity power defined in the previous study [4]. Then,

$\Sigma_{k=1}\Sigma_{s=1}h(k)g(s)x(t+s+k)$ was sum of infectivity on date t. Therefore,

$R(t)=\Sigma_{k=1}\Sigma_{s=1}f(k)g(s)x(t+s+k) / \Sigma_{k=1}\Sigma_{s=1}h(k)g(s)x(t+s+k)$. Note that proportion of asymptomatic cases does not affect R(t) if it was constant.

The dummy variable for mask policy was one for before March 13, 2023, the stopped date, and was zero for after the stopped date.

Data indicating the shares of mutated variants among all cases were published by the Tokyo Metropolitan Government. Unfortunately, detailed information about mutated strains has not been published for the entirety of Japan. We used four measures for the mutant strain shares in Tokyo, Japan: alpha, delta, BA.1, BA.2, BA.5 and XBB.1.5. sublineage of omicron variant strains [5].

We use average temperature and relative humidity data for Tokyo during the day as climate data because national average data are not available. We obtained data from the Japan Meteorological Agency (https://www.data.jma.go.jp/gmd/risk/obsdl/index.php). Temperatures were measured in degrees Celsius.

Additionally, we identified several remarkable countermeasures in Japan: four state-of-emergency declarations, a travel campaign, and school closure and voluntary event cancellation (SCVEC). The latter, SCVEC, extended from February 27 through March in 2020: this countermeasure required school closure and cancellation of voluntary events, and even cancellation of private meetings. The first state of emergency was declared on April 7, 2020. It ceased at the end of May. It required school closures, shutting down of some businesses, and voluntary restriction against going out. To subsidize travel and shopping at tourist destinations, the "Go To Travel Campaign (GTTC)" started on July 22, 2020. It was halted at the end of December 2020.

The second state of emergency was declared on January 7, 2021 for the 11 most-affected prefectures. This countermeasure required restaurant closure at 8:00 p.m., with voluntary restrictions against going out, but it did not require school closure. It continued until March 21, 2021. The third state of emergency was declared on April 25, 2021 for four prefectures: Tokyo, Osaka, Hyogo, and Kyoto. Later, the application areas were extended gradually. They never covered the entirety of Japan.

To clarify associations among R(t) and mask policy in addition to current and the past vaccine coverage, the mutant strains, climate, mobility, the Olympic Games, and countermeasures, we used ordinary least squares regression to regress the daily R(t) on daily current vaccine coverage and daily past vaccine coverage as well as dummy variables for the Games, weekly shares of variant strains, daily climate, mobility, and dummy variables for countermeasures.

Because mobility data provided by Apple Inc. or Google Inc. had been ceased to provide to public in March 13, 2022 and October 15, 2022, we could not used mobility data. Thus we discard mobility to estimate for the effective reproduction number in this study even before date of ceased to release, though the previous studies used these information [4].

Information about vaccine coverage was provided Prime Minister's office [6]. We examined the current vaccine coverage of the second to fifth dose without delay. As of the end of year 2022, fifth dose of vaccination had been started. However, its coverage was not high o the end of study period as shown in Figure 1. If a vaccine perfectly protects the recipient from infection, then the estimated coefficient of vaccine coverage would be -0.01 if one assumes an average of R(t) with no vaccination in the study period. That would indicate that vaccine coverage increased by one percentage point could be expected to reduce R(t) by 0.01. If the estimated coefficient of vaccine coverage were larger than -0.01, then it might reflect imperfect personal prevention. Conversely, if the estimated coefficients of vaccine coverage were smaller than -0.01, then herd immunity might be supposed to have contributed to prevention of infection among non-recipients.

Waning of vaccine effectiveness was measured by the estimated coefficient of vaccine coverage in the past. Particularly, we examined every 30 days prior until 150 days prior. Note that the waning of the fifth vaccination may not be identified with longer lag because it had started recently. We expected the estimated coefficient to be positive if waning was occurring. If its estimated coefficient was positive but smaller than the absolute value of the estimated coefficient of current vaccine coverage, then waning was presumed to be partially occurring. Vaccination was presumed to be effective even if a part of effectiveness was waning. If the estimated coefficient of vaccine coverage in the past was positive and almost equal to the absolute value of the estimated coefficient of current vaccine coverage, then waning was presumed to be complete. We might not expect vaccine effectiveness until that time. Conversely, if the estimated coefficient of vaccine coverage in the past was positive and larger than the absolute value of the estimated coefficient of current vaccine coverage, then the vaccine might raise infectivity eventually. We supposed waning of vaccine effectiveness in the second and third vaccination because the fourth vaccination had just started in the study period. We also estimate it without any vaccine coverage in the past which implies to be no waning of vaccine effectiveness. We selected length of lag in vaccine coverage in the past trough adjusted coefficient of determinant which was a measure of goodness of fit when the number of explanatory variables were not the same.

We specified major variant strains as alpha and delta, and BA.1, BA.2, BA.5 and XBB.1.5 sublineage of omicron variant strain and other minor sublineages of omicron variant strain of omicron such as BF.7, BA2.75 or BQ1.1. The other minor sublineages of omicron variant strain was represented by dummy variables for November, 2021 and after period. Because the original Wuhan strain had disappeared until October, 2021, we added this dummy variables for November, 2021. Its estimated coefficients might represent average infectivity among the other minor sublineages of omicron variant strain comparison with the original Wuhan strain. On the other hand, constant term represents infectivity of the original Wuhan strain.

We expected the sign of the explanatory variables as follows: mask was expected to reduced infectivity. Also, vaccine coverage in any time reduced infectivity, however, its lag was supposed to be raise infectivity due to waning. The mutated strains were supposed to raise infectivity. Counter measure as the emergency status or SCVEC were supposed to decline the infectivity. Conversely, Olympic Games and/or GTTC which enhanced to mover persons might raise infectivity. We adopted 5% as the significance level.

3. **Results**

Figure 1 depicts vaccine coverage second and third dose with a 14-day delay. It showed the alpha variant strain emerged in March, 2021 and reached peak on May, 2021. The delta variant strain emerged April, 2021 and reached peak on November, 2021. The micron BA.1, 2, and 5 emerged in December, 2021, February and May, 20211, respectively. The former two variant strains reached peak on February and May, 2022. The latest proportion of XBB.1.5. in Figure 1 was around 40%.

The complete rate for the second vaccination had started in increasing since April, 2021 and it surpassed 80% in November, 2021 but it changed to b almost flat. The third vaccination had started in December, 2021, and it reached 65% in July, 2022.

Figure 2 depicts R(t) during the study period. The highest was around 9 in December, 2021 when the Delta variant strain dominated. The second highest was around in March, 2020 before the first emergency state declared. In other period, it fluctuated around one and less than three at highest.

Table 1 presents estimation results. We selected the specification with 90 days lag of waning of the second and third dose vaccination. In this specification, vaccine coverage except for the fifth dose and those with lag, and proportion of alpha and delta, and BA.2 and BA.5 sublineage of omicron variant strain, the first to third emergency status were significant with the expected sign. Conversely, SCVEC and the fourth emergency status were significant but with unexpected sign. Goto Travel Campaign and Olympic games were significantly negative and thus these events reduced infectivity. The estimated coefficient of mask was negative, but not significant. XBB.1.5 sublineage of omicron variant strain was insignificant.Other minor sublineages of omicron variant strain was significantly negative and thus these minor sublineages had lower infectivity than the original Wuhan strain. This result might be consistent with these sublineage could not be major sublineage.

Discussion

The obtained estimated results showed that wearing mask might not reduce infectivity. However, we have to remind that the period without mask was very short, just a one month. Therefore, estimation result about effectiveness of mask might change over time. Moreover, after the stopped date, all Japanese did not necessarily cease to wear mask on the stopped date. Quite a few Japanese might continue to wear mask after the stopped date. Unfortunately, proportion of wearing mask day by day was not available. If majority of Japanese had continued to wear mask after the stopped date, our estimation procedure cannot find out some effectiveness of mask.

XBB.1.5 may not have higher infectivity than BA.1, BA.2, BA.5 or the other minor sublineage of omicron variant strains. Note that basic reproduction number, R, for the mutated strain was probably impossible because vaccination was prevailed, and other counter measures was activated, and we cannot exclude these effect completely. Conversely, R(t) can always be calculated as described above because it depends these several factors affected infectivity as well as R. Therefore, this study focused R(t) instead of R and then examined how several factors affected it. Therefore, the obtained result in this study might be more reliable than the previous study. Actually, in Figure 2, the last peak caused by XBB.1.5. was not much higher than other peak such as the high peak around the end of 2021 caused by BA.1. or peaks in 2020 caused by the original strain.

We found that waning of the second to fourth dose vaccine with 90 days prior was the most appropriate specification. This duration may be comparable with earlier studies of waning [6,7], which reached their conclusions based on antibody titer or test negative design. Readers must be reminded that waning estimated for the present study might include behavioral changes among the vaccinated persons to adoption of more risky behavior that is prone to exacerbating infectivity. Such behaviors and the vaccine itself affect waning results, but they are not separately discernible based on results of this study. Weakening of immunoreaction and behavioral change are separate factors, but their mutual effects might be the most important for management of public health.

Limitations

First, we assumed implicitly that epidemiological characteristics including incubation period or delay in reports were the same among the original strain, alpha, delta, and sublineages of omicron variant strains. However, results of one study indicated that the delta variant strain has a shorter incubation period than either original strain [15].

Secondly, readers must be reminded when interpreting the obtained results that they do not indicate causality. Even thou it was not significant, the obtained results of this study demonstrated that a negative association exists between mask and infectivity. That finding does not necessarily mean that mask wearing reduced infectivity. The lower infectivity might have caused or might have even simply coincided with mask wearing.

Conclusion

The obtained estimated results showed that mask may not have effectiveness to reduce infection of COVID-19. Because the length of the period after the stopped date was too short, data accumulation should be necessarily to consider this problem.

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

Acknowledgments

We acknowledge the great efforts of all staff at public health centers, medical institutions, and other facilities fighting COVID-19.

Ethical considerations

All information used for this study was from official data published on the internet. There is therefore no ethical issue related to this study.

References

1. Wang Y, Tian H, Zhang L, Zhang M, Guo D, Wu W, et al. Reduction of secondary transmission of SARS-CoV-2 in households by face mask use, disinfection and social distancing: a cohort study in Beijing, China. BMJ Glob Health 2020;5:e002794.
2. Hendrix MJ, Walde C, Findley K, Trotman R. Absence of apparent transmission of SARS-CoV-2 from two stylists after exposure at a hair salon with a universal face covering policy . Springfield, Missouri, May 2020. MMWR Morb Mortal Wkly Rep 2020;69:930-2.
3. Hendrix MJ, Walde C, Findley K, Trotman R. Absence of Apparent Transmission of SARS-CoV-2 from Two Stylists After Exposure at a Hair Salon with a Universal Face Covering Policy - Springfield, Missouri, May 2020. MMWR Morb Mortal Wkly Rep 2020;69:930-2. doi: 10.15585/mmwr.mm6928e2.
4. Nir-Paz R, Grotto I, Strolov I, Salmon A, Mandelboim M, Mendelson E, et al. Absence of in-flight transmission of SARS-CoV-2 likely due to use of face masks on board. J Travel Med 2020;27:taaa117.
5. Payne DC, Smith-Jeffcoat SE, Nowak G, Chukwuma U, Geibe JR, Hawkins RJ, et al. SARS-CoV-2 infections and serologic responses from a sample of U.S. Navy Service

members . USS Theodore Roosevelt, April 2020. Morb Mortal Wkly Rep 2020;69:714.-1.

6. Chen J, He H, Cheng W, Liu Y, Sun Z, Chai C, et al. Potential transmission of SARS-CoV-2 on a flight from Singapore to Hangzhou, China: An epidemiological investigation. Travel Med Infect Dis 2020;36:101816.
7. Schwartz KL, Murti M, Finkelstein M, Leis JA, Fitzgerald-Husek A, Bourns L, et al. Lack of COVID-19 transmission on an international flight. CMAJ 2020;192:E410.
8. Hong L, Lin A, He Z, Zhao H, Zhang J-G, Zhang C, et al. Mask wearing in pre-symptomatic patients prevents SARS-CoV-2 transmission: An epidemiological analysis. Travel Med Infect Dis 2020;36:101803.
9. Wu Y, Song S, Kao Q, Kong Q, Sun Z, Wang B. Risk of SARS-CoV-2 infection among contacts of individuals with COVID-19 in Hangzhou, China. Public Health 2020;185:57-9.
10. Doung-ngern P, Suphanchaimat R, Panjangampatthana A, Janekrongtham C, Ruampoom D, Daochaeng N, et al. Case-control study of use of personal protective measures and risk for SARS-CoV 2 infection, Thailand. Emerg Infect Dis 2020;26:2607-16.
11. Freedman DO, Wilder-Smith A. In-flight transmission of SARS-CoV-2: A review of the attack rates and available data on the efficacy of face masks. J Travel Med 2020;27:taaa178.

12. Ueki H, Furusawa Y, Iwatsuki-Horimoto K, Imai M, Kabata H, Nishimura H, et al. Effectiveness of face masks in preventing airborne transmission of SARS-CoV-2. mSphere 2020;2-6.

13. Greenhalgh T. Will COVID-19 be evidence-based medicine's nemesis? PLOS Med. 2020;17(6):e1003266.

14. European Centre for Disease Prevention and Control. Epidemiological update: SARS-CoV-2 Omicron sub-lineages BA.4 and BA.5. https://www.ecdc.europa.eu/en/news-events/epidemiological-update-sars-cov-2-omicron-sub-lineages-ba4-and-ba.5. [accessed on January 22, 2023]

15. National Institute of Infectious Diseases. Updated Situation of COVID-19 Outbreak (July 13,2022) https://www.niid.go.jp/niid/ja/2019-ncov/11309-covid19-ab90th.html (in Japanese) [accessed on January 20, 2023]

16. Ministry of Health, Labour and Welfare. Visualizing the data: information on COVID-19 infections. https://covid19.mhlw.go.jp/en/ [accessed on February 17, 2023]Kurita J, Sugawara T, Ohkusa Y. Estimating Event Ban Effects on COVID-19 Outbreak in Japan. Journal of Health Science and Development 2021. 4: https://www.innovationinfo.org/articles/JHSD/JHSD-137.pdf

17. Tokyo metropolitan Government. Data of COVID-19 monitoring meeting in metropolitan Tokyo. *https://www.bousai.metro.tokyo.lg.jp/taisaku/saigai/1013388/index.html* (in Japanese) [accessed February 21,2023].

18. Prime Minister of Japan and His Cabinet. COVID-19 Vaccines. https://japan.kantei.go.jp/ongoingtopics/vaccine.html [accessed on February 17, 2023]

19. Levin EG, Lustig Y, Cohen C, *et al.* Waning Immune Humoral Response to BNT162b2 Covid-19 Vaccine over 6 Months. N Engl J Med 2021:NEJMoa2114583.

20. Chemaitelly H, Tang P, Hasan MR, *et al*. Waning of BNT162b2 Vaccine Protection against SARS-CoV-2 Infection in Qatar. N Engl J Med. 2021:NEJMoa2114114.

21. Polack FP, Thomas SJ, Kitchin N, *et al.* Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine. N Engl J Med. 2020;383:2603-15.

22. Chung H, He S, Nasreen S, *et al*. Effectiveness of BNT162b2 and mRNA-1273 covid-19 vaccines against symptomatic SARS-CoV-2 infection and severe covid-19 outcomes in Ontario, Canada: test negative design study. BMJ 2021;374.

23. Dagan N, Barda N, Kepten E, Miron O, Perchik S, Katz MA, Hernan MA, Lipsitch M, Reis B, Balicer RD. BNT162b2 mRNA Covid-19 vaccine in a nationwide mass vaccination setting. N Engl J Med 2021;384:1412-23.

24. Vasileiou E, Simpson CR, Shi T, *et al*. Interim findings from first-dose mass COVID-19 vaccination roll-out and COVID-19 hospital admissions in Scotland: a national prospective cohort study. Lancet 2021;397:1646-57.

25. Bernal JL, Andrews N, Gower C, Robertson C, Stowe J, Tessier E, Simmons R, Cottrell S, Roberts R, O'Doherty M, Brown K, Cameron C, Stockton D, McMenamin J, Ramsay

M. Effectiveness of the Pfizer–BioNTech and Oxford–AstraZeneca vaccines on Covid-19 related symptoms, hospital admissions, and mortality in older adults in England: test negative case-control study. BMJ 2021;373:n1088.

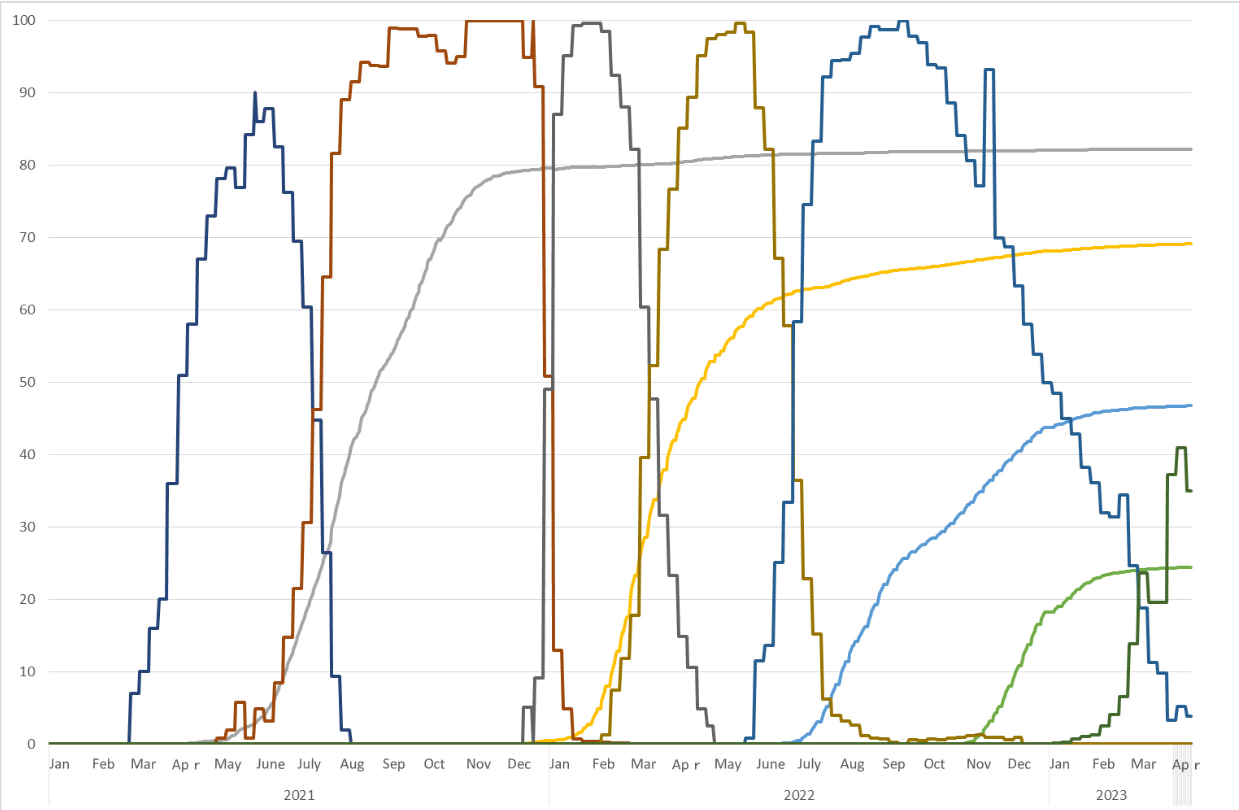
26. Bjork J, Inghammar M, Moghaddassi M, Rasmussen M, Malmqvist U, Kahn F. Effectiveness of the BNT162b2 vaccine in preventing COVID-19 in the working age population: first results from a cohort study in southern Sweden. Infect Dis (Lond) 2021;1-6.

27. Pawlowski C, Lenehan P, Puranik A, Agarwal V, Venkatakrishnan AJ, Niesen MJM, O'Horo JC, Virk A, Swift MD, Badley AD, Halamka J, Soundararajan V. FDA-authorized COVID-19 vaccines are effective per real-world evidence synthesized across a multi-state health system. Med (N Y) 2021;2:979-92.e8.

28. Li B, Deng A, Li K, et al. Viral infection and transmission in a large, well-traced outbreak caused by the SARS-CoV-2 Delta variant. medRxiv 2021.07.07.21260122; doi: https://doi.org/10.1101/2021.07.07.21260122

Figure 1: Vaccine coverage and shares of alpha and delta variant strains in 2021 until April 14, 2023.

(%)

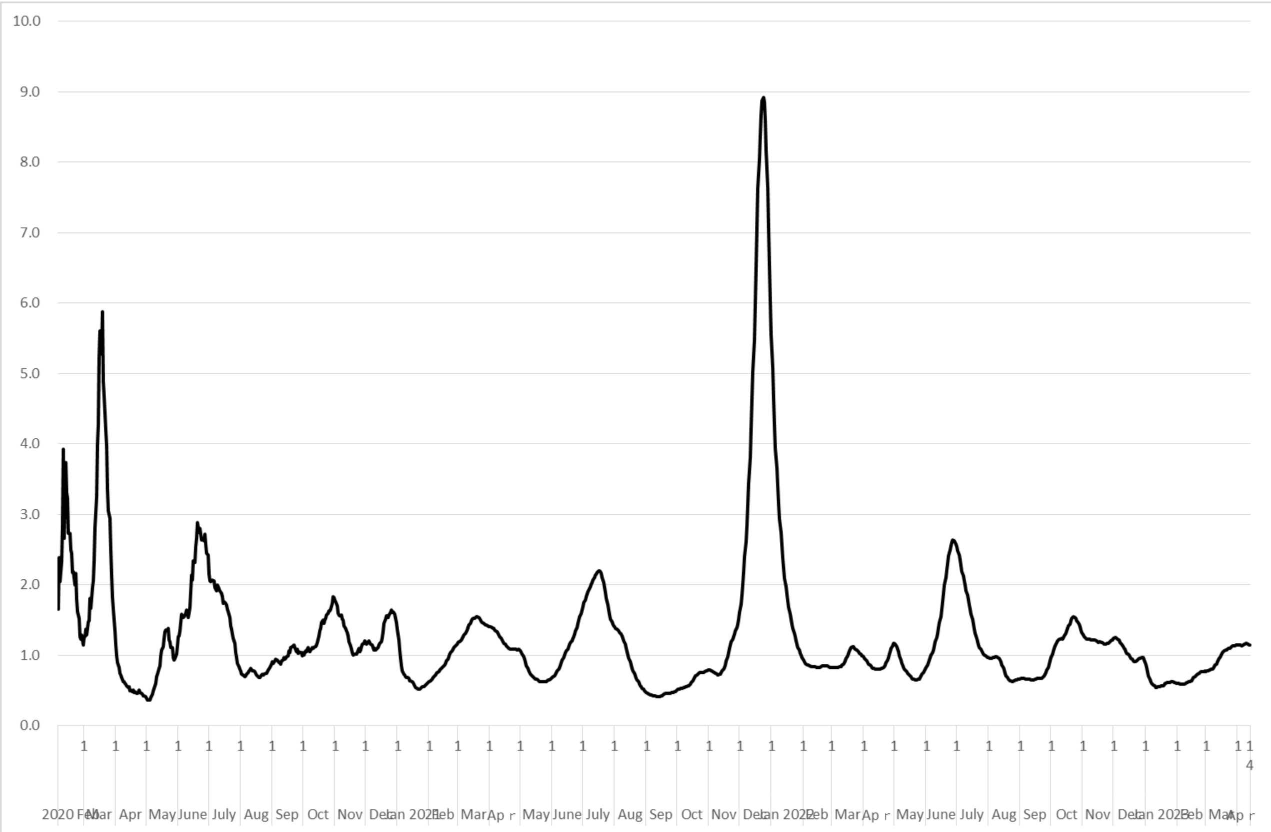


(date)

Note: Five lines with chevron shape and dark green increasing line started since September, 2022 indicates proportion of variant strains. The most left dark blue line with chevron shape indicates alpha variant strain, and orange line was delta variant strain. Following three lines were BA.1, BA.2 and BA.5.sublineage of omicron variant strain. Dark green increasing line started sinceJanuary, 20223indicates XBB.1.5 sublineage of omicron variant strain. Monotonically increasing four line except for dark green increasing line started since September, 2022 indicates vaccine coverage rate. Gray increasing line indicates vaccine coverage of second dose, yellow increasing line was the third dose, and blue increasing line was the fourth dose. Light green increasing line started since November, 2022 indicates vaccine coverage of the fifth doze.

Figure 2: Effective reproduction number from February, 2020 through April 14, 2023

R(t)



(date)

Note: The line represents the effective reproduction number in Japan from February, 2020 through April 4, 2023, as of the Mat 7, 2023. Calculation procedures are explained in the main text.

Table 1: Estimation results of R(t) on wearing mask, vaccine coverage, prevalence of the variant strains, and Olympic Games with the climate condition, and countermeasures.

Lag of waning (days)	Without waning		30		60	
Explanatory variable	Estimated coefficient	*p*-value	Estimated coefficient	*p*-value	Estimated coefficient	*p*-value
Mask	-0.2464	0.461	-0.38074	0.237	-0.40667	0.161
Temperature	-0.02076	0	-0.01131	0.043	-0.00123	0.806
Humidity	-0.00215	0.247	-0.00119	0.504	0.000951	0.552
SCVEC	0.812375	0	0.892072	0	0.984042	0
1st State of emergency	-1.10841	0	-1.09469	0	-1.08184	0
GTTC	-0.6385	0	-0.64972	0	-0.66562	0
2nd State of emergency	-1.10132	0	-1.01657	0	-0.90239	0
3rd State of emergency	-0.80946	0	-1.23766	0	-1.49257	0
4th State of emergency	-0.16575	0.343	0.653678	0.001	2.108386	0

Olympic Games	0.405953	0.084	0.979412	0	0.584988	0.004
Vaccine coverage of the second dose(%)	-0.02602	0	-0.10221	0	-0.20939	0
Vaccine coverage of the second dose with lag (%)			0.103125	0	0.22143	0
Vaccine coverage of the third dose(%)	0.017037	0.17	-0.07128	0	-0.06695	0
Vaccine coverage of the third dose with lag (%)			0.061777	0	0.039942	0

Vaccine coverage of the fourth dose(%)	-0.034	0	-0.13781	0	-0.07304	0
Vaccine coverage of the fourth dose with lag (%)			0.115788	0	0.084662	0
Vaccine coverage of the fifth dose(%)	-0.01382	0.507	0.002085	0.94	-0.00378	0.841
Vaccine coverage of the fifth dose with lag (%)			-0.00405	0.87	-0.02129	0.224

Share of alpha variant strain (%)	-0.00058	0.8	0.006706	0.007	0.01208	0
Share of delta variant strain (%)	0.00705	0.075	0.000544	0.917	0.039499	0
Share of BA.1 sublineage of omicron variant strain (%)	-0.01055	0.004	-0.01577	0.001	-0.00484	0.175
Share of BA.2 sublineage of omicron variant strain (%)	-0.02371	0.001	-0.01369	0.072	0.012392	0.086

Share of BA.5 sublineage of omicron variant strain (%)	-0.01411	0.065	-0.00324	0.721	0.013995	0.083
Share of XBB.1.5sublineage of omicron variant strain (%)	0.002404	0.838	-0.00138	0.919	0.010105	0.437
Other minor sublineage of omicron variant strain	2.558108	0	1.650689	0	-0.16053	0.483
Constant	2.569967	0	2.464329	0	2.156395	0
Adjusted R^2	0.3461		0.4082		0.521	

Notes: The dependent variable was R(t), effective reproduction number; GTTC stands for "Go To Travel Campaign"; SCVEC denotes school closure and voluntary event cancellation. The sample period was February 1, 2021 through April 14 2023, as of May 7, 2023. Number of observations was 1168. Yellow markers indicate significant except for constant term.

(cont.)

Lag of waning(days)	90		120		150	
Explanatory variable	Estimated coefficient	*p*-value	Estimated coefficient	*p*-value	Estimated coefficient	*p*-value
Mask	-0.40099	0.268	0.322583	0.35	-0.46104	0.129
Temperature	-0.00403	0.408	-0.01033	0.042	-0.0102	0.049
Humidity	-5.2E-05	0.973	-0.00169	0.302	-0.00217	0.194
SCVEC	0.953756	0	0.887228	0	0.907865	0
1st State of emergency	-1.08693	0	-1.10164	0	-1.07804	0
GTTC	-0.66193	0	-0.65809	0	-0.63388	0

2nd State of emergency	-0.92837	0	-1.0043	0	-0.98503	0
3rd State of emergency	-1.12537	0	-0.85535	0	-0.79955	0
4th State of emergency	1.280828	0	-0.56675	0	-1.58278	0
Olympic Games	-0.53779	0.008	-0.31224	0.139	-0.43737	0.046
Vaccine coverage of the second dose(%)	-0.19167	0	-0.107	0	-0.11821	0
Vaccine coverage of the second dose with lag (%)	0.25483	0	0.157661	0	0.176541	0
Vaccine coverage of	-0.18161	0	-0.10208	0	-0.0786	0

the third dose(%)						
Vaccine coverage of the third dose with lag (%)	0.134595	0	0.23112	0	-0.17779	0
Vaccine coverage of the fourth dose(%)	-0.07236	0	-0.23592	0	0.271068	0
Vaccine coverage of the fourth dose with lag (%)	0.095956	0	0.07737	0.279	0.049666	0.038
Vaccine coverage of the fifth dose(%)	-0.02405	0.255	-0.0761	0.365	-0.14118	0.003

Vaccine coverage of the fifth dose with lag (%)	-0.0215	0.623	-0.00148	0.973	-0.06968	0.646
Share of alpha variant strain (%)	0.006132	0.002	0.000535	0.79	-0.00024	0.908
Share of delta variant strain (%)	0.0647	0	0.052727	0	0.071927	0
Share of BA.1 sublineage of omicron variant strain (%)	-0.00345	0.307	-0.01015	0.002	-0.00718	0.062
Share of BA.2 sublineage of	0.061337	0	0.014336	0.056	-0.01823	0.008

omicron variant strain (%)						
Share of BA.5 sublineage of omicron variant strain (%)	0.023212	0.004	-0.04647	0	0.012107	0.15
Share of XBB.1.5 sublineage of omicron variant strain (%)	0.007506	0.68	-0.04552	0.009	0.008566	0.534
Other minor sublineage of omicron	-2.89005	0	-0.86875	0.001	0.668418	0.002

variant						
strain						
Constant	2.274261	0	1.787472	0	2.579917	0
Adjusted R^2	0.5442		0.4951		0.46440.4708	