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Short communication

Incidence and length of outbreak period of COVID-19 and population density in comparison with seasonal influenza in Japan

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ABSTRACT

Objectives: There is no consensus regarding the impact of population density on the transmission of respiratory viral infections such as COVID-19 and seasonal influenza. Our study aimed to determine the correlation between population density and the incidence and duration of COVID-19 transmission.
Methods: Publicly available data for confirmed COVID-19 cases in Japan, from January 2020 through November 2021, were retrospectively collected. The average numbers of seasonal influenza cases reported in the national database from 2013–2014 through 2019–2020 were identified. Using data for COVID-19 and seasonal influenza population density and incidence rates (age-adjusted), the Pearson's correlation coefficient was determined.
Results: A significant positive correlation between log population density and length of outbreak period was observed for COVID-19 (r = 0.734; p < 0.001) but not for seasonal influenza. Additionally, a significant linear correlation was observed between population density and age-adjusted incidence rate for COVID-19 (r = 0.692; p < 0.001) but not for seasonal influenza.
Conclusions: In Japan, areas with high population density experienced a prolonged and more intense COVID-19 outbreak compared with areas with low population density. This was not observed with seasonal influenza, suggesting that public health measures against COVID-19 should be tailored according to population density.

People in densely populated areas are theoretically more likely to contract infectious diseases, which accounts for the higher incidences found in urban areas compared with rural areas, with more diffuse outbreaks observed in densely populated areas. While there is growing evidence that population density is associated with overall incidence of COVID-19 (Kodera et al., 2020; Smith et al., 2021), other studies have reported that population density is not correlated with the incidence of, or deaths due to, COVID-19 (Carozzi et al., 2020). Since these differences may involve a number of factors, including human behavior, environment, viral and host characteristics, and public health interventions (Chen et al., 2021), identifying reasons for heterogeneous geographic spread can help establish effective public health measures against COVID-19, and could inform policymakers on the need for appropriate modifications. Therefore, our study analyzed the correlation between population density and the incidence and duration of COVID-19 transmission in Japan, and compared these patterns with those of seasonal influenza.

Data on confirmed COVID-19 cases between January 15, 2020 and November 13, 2021 were retrospectively collected from local government websites using a standardized format and used to construct a unified database for real-time data analysis, risk assessment, and research (Furuse et al., 2020). Publicly available national data on seasonal influenza were also obtained, which were provided as aggregated weekly case numbers from approximately 5000 sentinel sites (https://www.niid.go.jp/niid/en/). Population density data were obtained from the Statistics Bureau of Japan (https://www.stat.go.jp/english/data/kokusei/2015/poj/mokuji.html).

The duration of community transmission was defined as the sum of weeks recording more than one case per 100 000 population for COVID-19 or 10 cases per sentinel site for seasonal influenza, as this is the minimum rate at which a warning for community transmission of influenza is issued. Further, for seasonal influenza, the average numbers of cases reported for seasons 2013–2014 through 2019–2020 were used. Using these data on population density and incidence rates of COVID-19 (age-adjusted) and seasonal influenza, the Pearson's correlation coefficient was calculated, with statistical significance determined at $p < 0.05$. To assess the robustness of the findings, sensitivity analyses were performed using population densities of densely inhabited areas, along with

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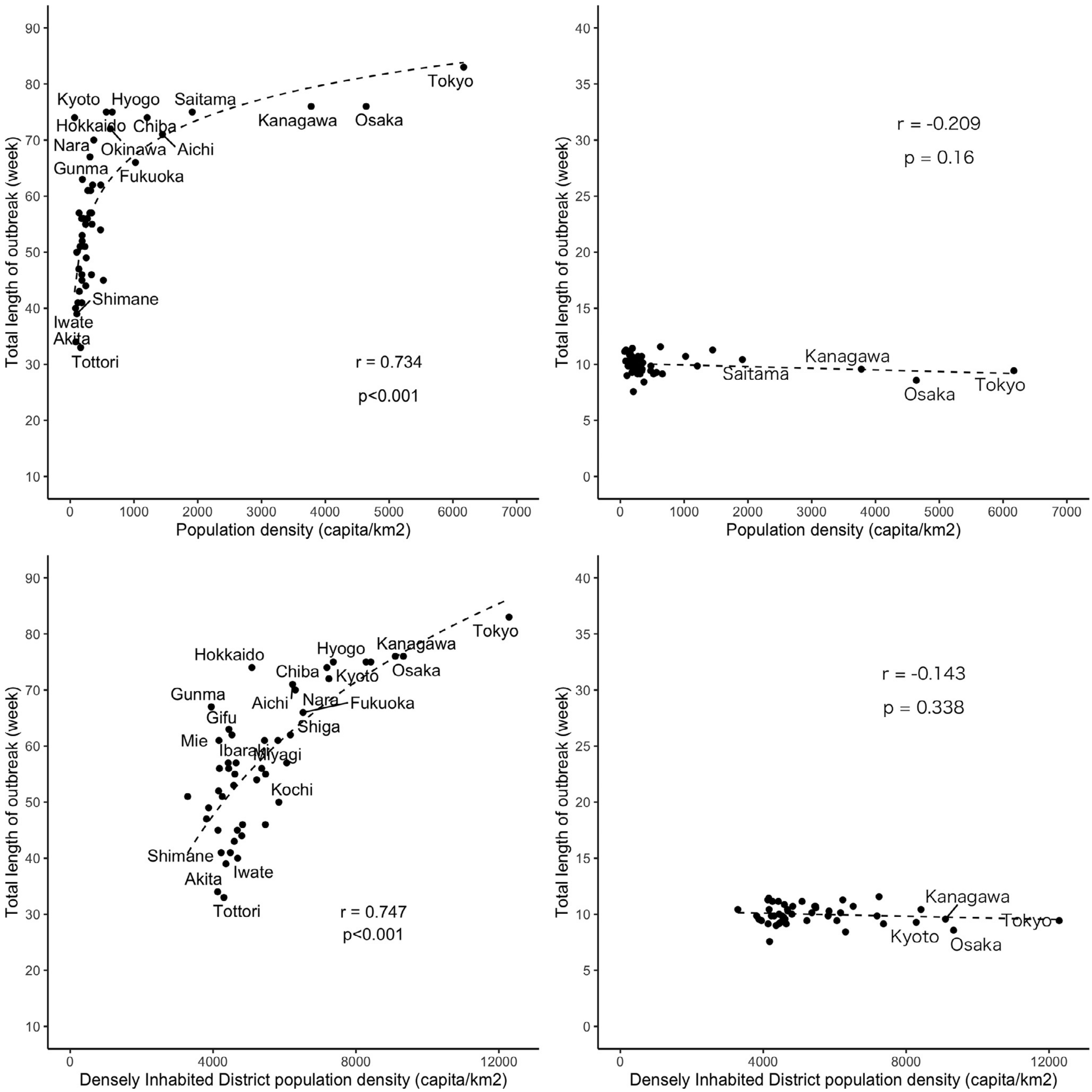

Figure 1. Scatter plots with fitted curves showing length of outbreak period versus population density across 47 prefectures in Japan, for COVID-19 (top left) and seasonal influenza (top right). The data periods were from January 2020 to November 2021 for COVID-19 and the 2013–2014 through 2019–2020 seasons for influenza. A logarithmic increasing trend was evident for COVID-19 (r = 0.734), whereas there was no correlation for seasonal influenza (r = −0.209). This trend persisted even in areas with high population densities (bottom panels).

a COVID-19 outbreak threshold of five cases per 100,000 population, which was also stratified into outbreak waves. The analysis was also performed by modifying the outbreak threshold for seasonal influenza. Finally, the trends were analyzed using data for the H1N1 influenza pandemic period (week 28, 2009 through week 10, 2010).

Incidences of COVID-19 and seasonal influenza in all prefectures are presented in Supplementary Table 1. Overall, Japan experienced the highest incidence in the fifth wave. Generally, areas of higher population density tended to have higher COVID-19 incidence, although such trends were not observed with seasonal influenza. Regarding the length of outbreak periods, a significant positive correlation was observed between log of population density and length of outbreak period for COVID-19 (r = 0.734; p < 0.001; Figure 1); in contrast, no significant correlation was seen for seasonal influenza (r = −0.209; p = 0.160). In addition, a significant linear correlation was observed between population density and age-adjusted incidence rate for COVID-19 (r = 0.692; p < 0.001) but not for seasonal influenza (r = −0.088; p = 0.558; Figure 2). Okinawa prefecture showed a higher incidence rate for both COVID-19 and seasonal influenza despite a low population density, and maintained this trend even when different thresholds were applied and analyses were performed for different outbreak waves (Supplementary Figures 1 and 2). Sensitivity analyses also revealed a weak correlation (r = 0.490; p < 0.001) during the fourth wave (weeks 9–24, 2021) (Supplementary Figure 2).

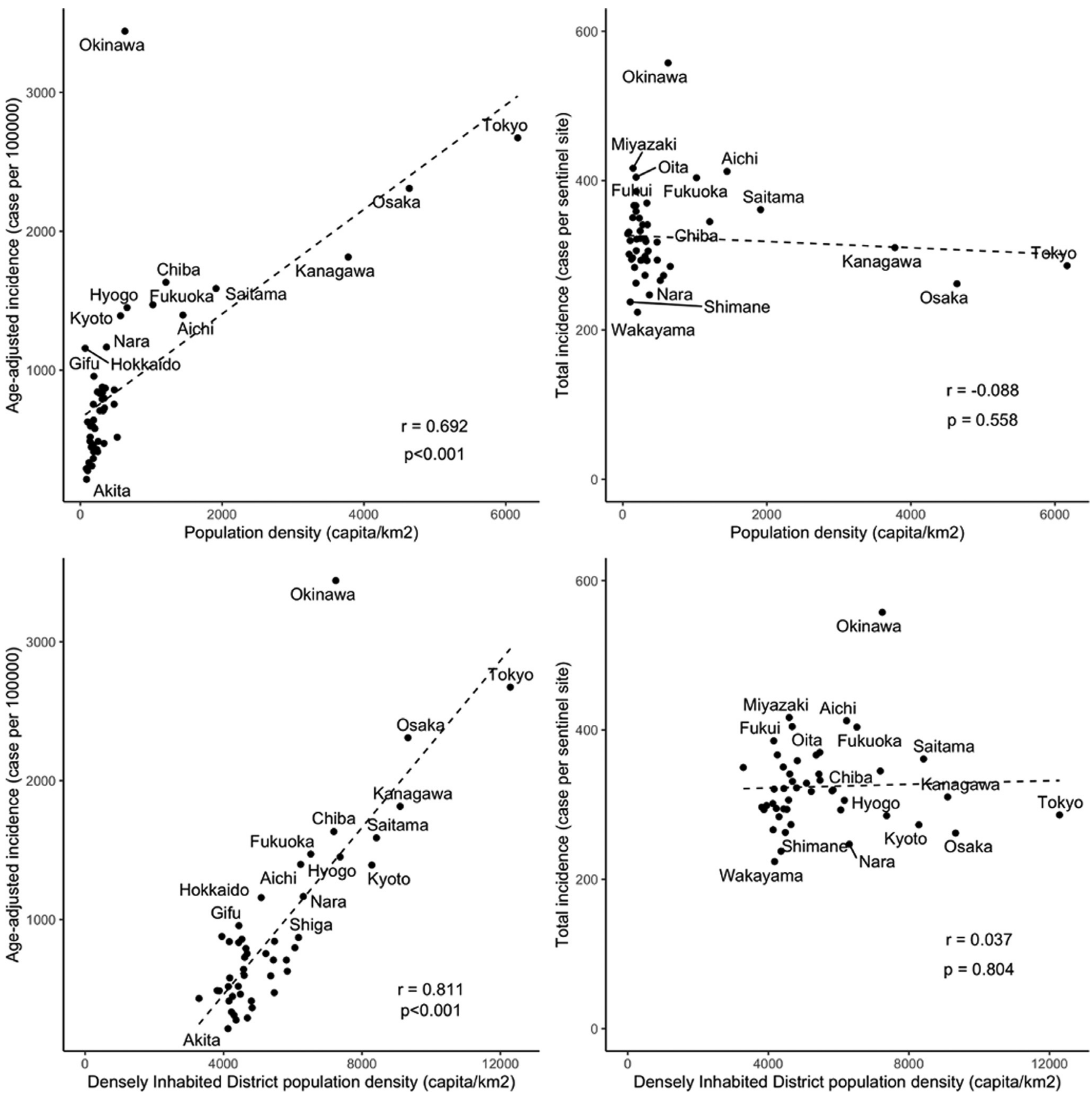

Figure 2. Scatter plots with fitted curves showing incidence proportion versus population density across 47 prefectures in Japan, for COVID-19 (top left) and seasonal influenza (top right). The data periods were from January 2020 to November 2021 for COVID-19 and the 2013–2014 through 2019–2020 seasons for influenza. A linear increasing trend was evident for COVID-19 ($r = 0.692$), whereas no correlation was observed for seasonal influenza ($r = -0.088$). This trend persisted in data from densely inhabited districts (bottom panels).

The overall trend for seasonal influenza did not alter with different thresholds (Supplementary Figure 3), while the H1N1 pandemic strain spread uniformly irrespective of population density (Supplementary Figure 4).

These results indicate that, in Japan, areas with a high population density experienced a more prolonged and intense COVID-19 outbreak when compared with areas of low population density. The weak correlation in the fourth wave was most likely because most cases were identified mainly in Osaka and adjacent areas with lower population density. Okinawa was an outlier, presenting a high COVID-19 incidence despite a low population density. Okinawa is a southern island in Japan, which attracts many tourists from all over Japan. Hence, we suggest that the high COVID-19 incidence rate in Okinawa was mainly due to the large volume of people traveling to the island from densely populated areas with a higher incidence of COVID-19. Moreover, the prefecture was also an outlier for seasonal influenza patterns and during the H1N1 pandemic period. It is possible that the subtropical climate and relatively high proportion of younger individuals might have also contributed to these differences in disease patterns.

Even though population density might be a factor that contributes to variations in epidemiological patterns between COVID-19 and seasonal influenza, a critical epidemiological characteristic of COVID-19 is the overdispersion of secondary transmission, wherein only a small proportion of infected individuals spreads the infection to a large number of individuals, resulting in superspreading events (Endo et al., 2020). On the other hand, seasonal and pandemic influenza are transmitted relatively uniformly (Chen et al., 2021). This explains both the intense and prolonged COVID-19 transmission in densely populated areas and the relatively homogeneous spread of seasonal influenza, regardless of population density. In contrast, a previous study reported that seasonal influenza was characterized by persistent community transmission in a densely populated community in the USA (Dalziel et al., 2018), which has a relatively similar socioeconomic distribution to that of Japan. This may have been due to variations in data collection, as the Japanese seasonal flu surveillance cases were diagnosed by physicians from sentinel healthcare facilities, whereas Dalziel et al. employed a broader definition of influenza-like diseases to estimate incidence.

The observed correlation between population density and COVID-19 transmission in Japan may also be due to heterogeneity in the nature and effectiveness of interventions, as the country has been applying a cluster-based approach since the beginning of the outbreak. This strategy focuses on revealing superspreader events through prospective and retrospective contact tracing to identify a common source of infections (Oshitani, 2020). Since this approach requires substantial human resource input from public health authorities (Imamura et al., 2020), effective implementation is challenging in authorities with a high caseload, especially in areas with a high population density. Generally, detection and control of COVID-19 cases are more convenient in areas with a low population density. Furthermore, while no specific public health measures have been implemented to mitigate the transmission of seasonal influenza, except for the reactive suspension of schools, COVID-19 has spread extensively, even in places with low population density. Moreover, routine sentinel surveillance was examined for case numbers per sentinel site, not per population, as validated methods for assessing incidence from surveillance have not yet been elucidated (Hashimoto et al., 2003).

Although a causal association cannot be inferred from this ecological study, our results indicate that public health measures against COVID-19 should be tailored according to population density, for example restrictions on intra-prefectural mobility dependent not only on the trend of local COVID-19 spread, but also on population density (Hazarie et al., 2021). Future studies should investigate factors associated with the sustained community transmission of COVID-19 and other respiratory infections, in order to establish more effective measures for reducing the impact.

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Ethical approval

As this study involved secondary analysis of publicly available, deidentified data, it was exempt from the requirement for ethical approval from an institutional review board.

Author contributions

HA and KJ contributed equally to this report. All authors conceived the presented idea and discussed the results. HA abstracted the data and performed the analysis. HA wrote the first draft, while KJ provided critical feedback and revised the first draft. All authors further edited and finalized the manuscript. HO supervised the project throughout.

Conflicts of interest

None

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijregi.2022.01.003.

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