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Spatial accessibility of home visiting nursing: An exploratory ecological study

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Abstract

Background and Aims: Japan is one of the oldest societies worldwide and manages a system of care for older adults in the community. In the 2000s, a community-based integrated care system was introduced to enable older adults to live in their neighborhoods. Home visiting nursing (HVN) is a crucial component of this system; however, the current and future shortage of home visiting nurses is a concern. Thus, HVN services may not be available in some areas; however, no indicators of the accessibility of HVN services have been developed. Developing accessibility indicators will serve as a standard for considering the allocation of health care resources and supporting future nursing policies that improve regional disparities.

Methods: We estimated the population-weighted spatial accessibility index (PWSAI) of HVN services in Hokkaido, using the two-step floating catchment area method (2SFCA). The 2SFCA comprised population, location of HVN agencies, number of home visiting nurses, and travel time. A multivariate regression model was run for the number of HVN users in each municipality as the objective variable to test the validity of the PWSAI; the number of home care support clinics, home care support hospitals, HVN agencies, home visiting nurses, home visiting nurses (24/7), total beds in health care facilities for older adults, and nursing homes for older adults were included as other explanatory variables.

Results: The PWSAI was median 9.0 [interquartile range: 6.2–11.8]. The distribution of the PWSAI was mapped to visualize the existence of regional differences. As a result of the conditional autoregressive model, PWSAI and home visiting nurses (24/7) were significant, Exp(β) and 95% credible interval were 1.043 [1.015–1.076] and 1.021 [1.006–1.036], respectively.

Conclusion: The PWSAI was positively correlated with the number of HVN users in each municipality and can serve as an indicator for assessing the accessibility of HVN.

KEYWORDS

health care, home visiting nursing, nursing policies, spatial accessibility

1 | INTRODUCTION

As of 2020, the aging population in Japan was 28.8% and the older adult population (over 65 years) was approximately 36 million people.[1] Japan faces the challenge of an aging society earlier than any other country. To adapt to an aging society, a community-based integrated care system was introduced in the 2000s.[2] The goal of this system is to achieve a society in which older adults can live in their own neighborhoods until the end of their lives.[3] Home visiting nursing (HVN), which provides home and medical care, is an important component of a community-based integrated care system. HVN service costs in long-term care insurance doubled from 145 billion yen (FY2010) to 333.3 billion yen (FY2020), accounting for approximately 15% of home visit service costs in FY2020.[4]

The government has estimated that 110,000–120,000 home-visit nurses will be required to meet the demand for HVN services by 2025.[5] However, the number of home visit nurses in 2020 was approximately 60,000, indicating a significant shortage. Furthermore, this situation will continue as the older adult population (over 65 years) increases slowly until 2040, reaching approximately 39 million.[6] Although the number of home-visiting nurses and HVN agencies has consistently increased over the last decade,[7,8] accessibility to HVN services from a user perspective is unclear. Indicators of the spatial accessibility of HVN services can help assess and correct regional disparities. In a literature review on the accessibility of HVN services,[9] reported that the utilization of HVN services was higher among older adults living in municipalities with high population coverage within 10 min of an HVN agency. Additionally, despite people's wishes, most people in Japan often die in the hospital[10]; however, in municipalities with a population comprising of more home-visiting nurses, more people were able to die at their own homes.[11] In other words, municipalities with more home-visiting nurses and home health care resources increased the utilization of HVN services, indicating effects such as the realization of death at home.

The number of health care resources per population in an area (provider-population ratio, PPR) is widely used as an indicator of the spatial accessibility of health care services.[12] PPR is a straightforward indicator; however, because HVN can provide services by moving from the office to the user's home beyond the municipality boundaries, conventional PPR cannot properly evaluate the accessibility of municipalities without HVN agencies.[9] Naruse et al. addressed this problem by setting a travel range of 10 min[9]; however, many HVN agencies also provide services to users' homes that are more than 10 min away.[13] Thus, expanding the range of HVN service areas could advance this topic. Another limitation is that the population coverage rate does not consider supply and demand. To overcome this limitation, the two-step floating catchment area method (2SFCA) is widely used to evaluate accessibility in the medical field[14,15] and has been applied in many areas, such as primary care and emergency medicine[14,16–18] also applied 2SFCA to the service area defined by HVN agencies as one unit and evaluated the spatial accessibility of HVN. This study only indicates spatial disparities and differences; the relevance of the indicators developed in these studies to the actual utilization of HVN services is uncertain. Therefore, by identifying the relationship between the spatial accessibility index (SAI) and the spatial disparities of utilization of HVN services, we can propose a reasonable index for the future construction of HVN provision systems and contribute to the evaluation and planning of health care policies.

Therefore, the aims of this study are as follows: (1) to evaluate the spatial accessibility and disparity of HVN and (2) to identify whether SAI can be a factor explaining spatial differences in the utilization of HVN services.

Key points

- The demand for home health care is increasing, however, there are no spatial access indicators available to measure it.
- The study's spatial accessibility index indicates that areas with higher scores had a greater number of people utilizing home nursing services.
- Spatial accessibility is crucial for the development of equitable home visiting nursing services.

2 | MATERIALS AND METHODS

2.1 | Study design

This cross-sectional ecological study using public data was conducted to develop an index for quantitatively evaluating the utilization of HVN services. This study employed a geographic information system to provide more realistic information regarding the accessibility of HVN services based on the location of both the HVN agency and the user.

2.2 | Study area

The targeted area involved 156 municipalities that administer long-term care insurance in Hokkaido prefecture, Japan. Although Hokkaido consisted of 179 municipalities, the municipalities that jointly administered long-term care insurance were handled as one municipality. Hokkaido has the lowest population density in Japan (67 persons/km^2); furthermore, Hokkaido is characterized by an uneven population distribution, with approximately 50% of the population living only in three cities.[19] We add the population density distribution in Supporting Information S1: Figure 1 (Additional file 1).

2.3 | Measurement of spatial accessibility

We used the 2SFCA to measure the spatial accessibility of HVN.[15] First, we defined the estimated older adult population (over 65 years) in 2025 as demand because approximately 80% of HVN users were

over 65 years old in 2019.[20] Next, we identified the number of nurses visiting homes at each HVN agency as supply and designated an area reachable within 110 min by car from HVN agencies as the service area. Population data with location information were obtained from the National Land Numerical Information Download Service (https://nlftp.mlit.go.jp/ksj/) as 500*500 m grid data. Home visiting nurses and HVN agencies, including location data (March 2022) for measuring spatial accessibility, were obtained from a Health care Market Analysis Platform (https://caremap.jp/). Following a previous survey,[13] we defined the maximum service area as 110 min and set the decay function to reduce the impact by 50% in 30 min (Supporting Information S1: Figure 2, Additional file 1). The SAI was calculated using Equations 1–4. Equation 1 calculates the supply/demand ratio for each HVN agency. Equation 2 sums all the supply/demand ratios calculated in Equation 1 across all grids. Equation 3 represents the decay function. Equation 4 calculates the population-weighted SAI (PWSAI) to expand the A_i calculated in Equation 2 to the municipal level.[21] The SAI at the mesh level can be treated as the SAI at the municipal level by the PWSAI. The PWSAI can be interpreted as the number of nurses visiting homes per 10,000 older adults (over 65 years) without the limitation of the administrative area.

(Equation 1):

$$r_j = \frac{S_j}{\sum_{d_{ij} \in d_0} (D_i / 10000) * f(d_{ij})}$$

(Equation 2)

$$A_i = \sum_{d_{ik} \in d_0} r_k * f(d_{ik})$$

(Equation 3)

$$f(d_{ij}) = \begin{cases} e^{-\frac{1}{2}\left(\frac{dij}{\theta}\right)^2}, & d_{ij} < d_0 \\ 0, & d_{ij} \geq d_0 \end{cases}$$

(Equation 4)

$$PWSAI = \frac{\sum_{i \in I} D_i * A_i}{\sum_{i \in I} D_i}$$

where i is the grid, k and j are the HVN agencies, r is the supply/demand ratio, S is the number of nurses visiting homes in the HVN agency, D is the older adult population (over 65 years), d_{ij} is the travel time between i and j, A_i is the SAI on the grid, and d_0 and θ are defined as 110 and 25.5, respectively.

2.4 | Variables

To achieve Objective (2) of this study, a regression model was designed that included the PWSAI. The objective variable is the average number of HVN users per month (April 2021 to March 2022) in each municipality. Explanatory variables include PWSAI, number of home care support clinics (2021), number of home care support hospitals (2021), number of HVN agencies (2021), number of home visit nurses (2021), number of home visit nurses at HVN agencies open 24/7 (2021), and total beds in health care facilities and nursing homes for older adults (2021). All variables, except the PWSAI, were measured per 10,000 older adults (over 65 years). The number of HVN users was obtained from the Status report on Long-term Care Insurance.[22] Exploratory variables excluded the PWSAI, and population data were obtained from Regional Data for Home Health Care data provided by the Ministry of Health, Labor, and Welfare (2021).

2.5 | Statistical analysis

All continuous variables are presented as medians [interquartile ranges]. In this study, three regression models were used. Model 1 was a generalized linear model (distribution: negative binomial) with all variables. At this time, we excluded the number of home visiting nurses that showed multicollinearity, a variance inflation factor of >5. In Model 2, variables were reduced using the least absolute shrinkage and selection operator (LASSO).[23] The hyperparameter in LASSO was λ (λ = 0.17), which maximized the value of the logarithmic likelihood by k-fold cross-validation (k = 10). Model 3 employed the same variables as Model 2 and added a random term to account for spatial autocorrelation. Model 3 was adjusted for variables with similar characteristics in neighboring municipalities. We used a conditional regression model (CAR) following[24] in Model 3. The adjacencies between municipalities required for the CAR model were defined by the type of queen, and remote islands were assumed to be adjacent to ferry routes. The CAR model was estimated in a Bayesian setting using Markov chain Monte Carlo (MCMC). The prior distribution for τ^2 was given as inverse-gamma (1, 0.01); the prior distribution for ρ was given as Uniform (0, 1). The settings were as follows: chain: 4, burn in: 20,000, sampling 1,020,000, thining: 100; total: 40,000 samples. The convergence of MCMC was determined using the Gelman-Rubin potential scale reduction factor < 1.1.[25] All models included the older adult population as the offset variable. The spatial autocorrelation in the residuals of each model was confirmed by Moran's I test,[26] a two-sided test, with $p < 0.05$ to be significant. The coefficients of the parameters in the regression analysis were shown to be exponentially transformed, and 95% confidence intervals (CI) or 95% credible intervals were shown. The travel time between the HVN agency and the center of the grid was calculated using ArcGIS Pro 3.1 (Esri) and the ArcGIS Geo Suite Road Network 2021 (ESRI Japan). All other analyzes were performed with R ver. 4.1.1 and R studio 2021.09.0.[27,28]

2.6 | Sensitivity analysis

This study had a high uncertainty due to the various assumptions made in the process of calculating the PWSAI. Therefore, to increase the robustness of the results, a sensitivity analysis was performed in Model 3, assuming multiple service areas, such as 30, 60, and 90 min.

Additionally, multiple prior distributions were applied as a sensitivity analysis to the MCMC to confirm the influence of the prior distribution. All the analyses yielded the same results as those of the main analysis. All results are shown in Supporting Information S1: Table 1 (Additional file 1).

3 | RESULTS

3.1 | Describe the characteristics of municipalities

The number of HVN users per month was 23.7 [11.2–86.6] per person. The PWSAI was 9.0 [6.2–11.8]. Home care support clinics and hospitals scored 0 [0–1.8] and 0 [0–0], respectively. Half of the municipalities did not have facilities. The HVN agency, home visit nurses, and home visit nurses at HVN agencies open 24/7 were 0 [0–3.2], 0 [0–13.5], and 0 [0–10.1], respectively. The total number of beds in older adults' health care facilities and nursing homes was 335.2 [248.1-466.7] (Table 1). Figure 1 shows the distribution of the number of HVN users per older adult population (over 65 years) in municipalities. Figure 2 shows the distribution of the PWSAI, areas with a relatively high supply are shown in black, and areas with a low supply are shown in yellow.

3.2 | Results of the regression model analysis

First, the number of nurses visiting homes was excluded from the model due to multicollinearity. In Model 1, where all variables were included, the PWSAI and home visitor nurse (24/7) showed a positive correlation with the number of HVN users, Exp(β) and the 95% CI were 1.036 [1.016–1.056], 1.019 [1.007–1.032], respectively. Next, in Model 2, the variables were reduced by LASSO. Consequently, the PWSAI, home care support clinics, and home visiting nurses (24/7) were selected. Similarly to Model 1, the PWSAI and home visiting nurses (24/7) were significant variables; Exp(β) and 95%CI were 1.036 [1.017–1.055] and 1.019 [1.007–1.030], respectively. Finally, Model 3, applying the CAR model, expresses a similar result to Models 1 and 2. The PWSAI and home visiting nurses (24/7) were significant; Exp(β) and 95% credible intervals were 1.043 [1.015–1.076] and 1.021 [1.006–1.036]. The residuals of all the models did not show spatial autocorrelation according to Moran's

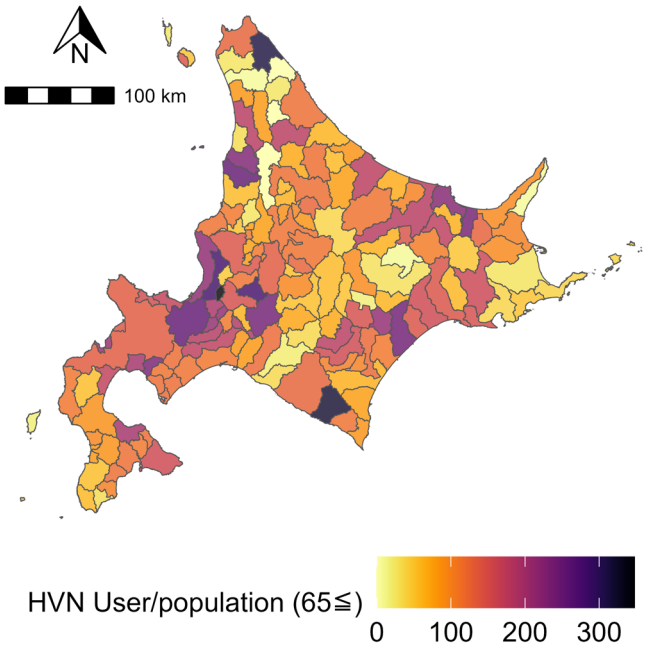

FIGURE 1 Distribution of the number of HVN users per 10,000 older adult population. Figure 1 shows the distribution of the number of HVN users per 10,000 older adult population. A gradation from yellow to black means an increase in the number of HVN users. HVN, home visiting nursing.

TABLE 1 Characteristics of each municipality.

Variable	Median	Interquartile range (Q1–Q3)	Range (Min–Max)
HVN users (person per month)	23.7	11.2–86.6	0–13,868.8
PWSAI	9.0	6.2–11.8	0–31.1
The number of home care support clinics[a]	0	0-1.8	0–17.5
The number of home care support hospitals[a]	0	0–0	0–5.7
The number of HVN agencies[a]	0	0–3.2	0–15.3
The number of home-visiting nurses[a]	0	0–13.5	0-60.9
The number of home-visiting nurses (24/7)[a]	0	0-10.1	0–52.9
The number of total beds in health care facilities and nursing homes[a]	335.2	248.1–466.7	0–2144.8
Population (over 65 years)	2555	1400–6867	218–541,195

Abbreviations: HVN, home visiting nursing; PWSAI, population-weighted spatial accessibility index.
[a]Per 10,000 population (over 65 years).

I statistics (Table 2). The trends of the coefficients were similar for all models.

3.3 | Sensitivity analysis

The process of calculating PWSAI involves some uncertainties. Therefore, in Model 3, we calculated the PWSAI for each service area (ordinary 110 min) for 30, 60, and 90 min and evaluated the impact on the results. In all analyses, the coefficients of the PWSAI showed the same trend (Supplementary File).

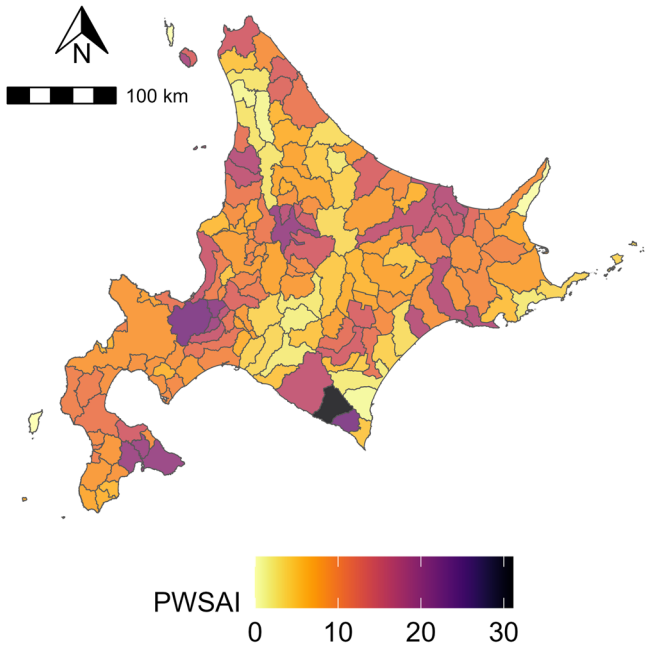

FIGURE 2 Distribution of PWSAI in Hokkaido, Japan. Figure 2 shows the distribution of PWSAI in Hokkaido. The yellow area has lower access, while the black area has higher access for HVN services. HVN, home visiting nursing; PWSAI, population-weighted spatial accessibility index.

4 | DISCUSSION

We demonstrate the validity of the PWSAI as an accessibility index for HVN in municipalities. This is the first study to explore the relationship between HVN accessibility and the number of HVN users. Municipalities with higher PWSAI scores had more HVN users. Therefore, this area is estimated to be one in which more people can receive HVN services. The Exp(β) of the regression model was approximately 1.04. This reflects an increase of 4% in HVN users per unit of PWSAI. However, the number of home visiting nurses needed to increase the PWSAI by one unit in each municipality, which varies with the population (over 65 years)or the number of home visiting nurses in the neighborhood. In other words, increasing the PWSAI in areas with a large population requires many nurses visiting homes, but in municipalities with small population sizes, even a small number of visiting nurses can improve the PWSAI. The strength of the PWSAI, which is based on the 2SFCA, lies in its ability to capture health care resources beyond municipal boundaries. Even considering its strengths, the PWSAI still differs between municipalities and Figure 2 shows the geographical differences. The areas indicated in yellow are those where HVN resources are relatively scarce. Kilinc et al.[17] proposed accessibility scores for home health care. They set an area as a service area when calculating the scores because they assumed that each home care agency provides service on a regional basis rather than on a travel-time basis. We also quantified the potential accessibility considering demand, supply, and service areas. Their study highlighted disparities in home health care access according to ZIP codes in Arkansas, USA. However, the actual utilization gap and accessibility scores have not yet been verified. In this study, we created a regression model that included the PWSAI

TABLE 2 Result of each regression model.

Variable	Model 1		Model 2		Model 3	
	Exp(β)	95% CI	Exp(β)	95% CI	Exp(β)	95% Cr
PWSAI	1.036	1.016–1.056	1.036	1.017–1.055	1.043	1.015–1.076
The number of home care support clinics[a]	1.028	0.996–1.062	1.028	0.996–1.061	1.020	0.985–1.057
The number of home care support hospitals[a]	1.010	0.932–1.100				
The number of HVN agencies[a]	1.003	0.961–1.047				
The number of home-visiting nurses (24/7)[a]	1.019	1.007–1.032	1.019	1.010–1.030	1.021	1.006–1.036
The number of total beds in health care facilities and nursing homes[a]	1.000	1.000–1.000				
AIC	1337.7		1331.8			
Moran's I	0.05	$p = 0.33$	0.04	$p = 0.34$	−0.08	$p = 0.14$

Abbreviations: AIC, Akaike information criterion; HVN, home visiting nursing; PWSAI, population-weighted spatial accessibility index.
[a]Per 10,000 population (over 65 years).

with the number of HVN users as the objective variable and confirmed a significant relationship with the number of HVN users. Our findings show that estimates such as the PWSAI are significantly correlated with the actual utilization of services, showing evidence that the 2SFCA method is effective in measuring the accessibility of HVN services by validating the potential accessibility scores proposed by.[17] Although home visiting nurses (24/7) per population was also a significant variable, this was zero in half of the municipalities. Therefore, this indicator does not quantify accessibility in areas without nurses visiting homes. Furthermore, this limitation became more pronounced when evaluating smaller areas, but the PWSAI overcame this limitation.

Next, we discuss the background of the association between the PWSAI, number of nurses visiting homes (24/7), and use of HVN, which are significant variables in our models. Both variables capture the supply-to-demand ratio. Therefore, it is reasonable to assume that both variables are positively correlated with the objective variable. The PWSAI reflects the HVN system, which travels and provides services to the homes of users. In a previous survey,[13] 80% of businesses used cars for transportation, and the median travel time to the closest customer's home was 30 min. This means that they do not provide services to areas that are more than a certain distance from their locations. In this study, we applied the same distance decay function to all agencies because obtaining information on each office's actual service area was difficult. Once the data availability challenge is overcome, a better accessibility indicator can be established.

When visiting nurses are used, their availability 24 h a day is important. For example, users with conditions that are likely to change rapidly or those in the terminal stage can spend their time at home with peace of mind thanks to the 24-h service. A previous survey reported that more than 40% of HVN users expected 24-h service from HVN agencies.[29] Additionally, according to a survey conducted by the Japanese government, 60% or more of the Japanese population want to die at home.[30] Despite such hopes, 64.5% of people die in hospitals (FY2022).[31] In fact, it is easier to achieve death at home in municipalities with many service workers at home.[32] To overcome this situation, the government enabled remote death diagnosis through collaboration between nurses and doctors in 2017.[33] Consequently, doctors can diagnose death without being directly present at the time of the patient's death. On behalf of doctors, nurses visit patients on the verge of death and use an mobile device with the information and communication technology to support doctors in diagnosing them. However, as a natural process, the time of death cannot be controlled and requires a 24-h response. Therefore, an increase in the number of home visiting nurses can help realize a community where people live at home until the end of their lives.

This study had several limitations. First, an ecological fallacy is inevitable because this study used regional data. Therefore, further studies are required using individual-level data to determine whether the PWSAI applies at the individual level. Second, our findings did not show causal associations because the study design was a cross-sectional analysis. Third, a modifiable areal unit problem should be considered. The results may vary if larger prefectures or smaller regions are analyzed. However, the long-term care insurer is the basic unit in the long-term care insurance system and can be said to be the regional unit that should be considered first when creating an environment for the use of home-visit nursing services. As municipalities and long-term care insurers are the basic units in establishing home medical care, the classification chosen in this study is valid. Fourth, the HVN user data used in this study also included visits by physical and occupational therapists. However, current official statistics could not distinguish between them. Therefore, this result may underestimate the supply in some areas. Finally, there is a potential for improvement in the precision of each variable in the future. Not all HVN agencies update information promptly. Although our data acquisition date was March 2022, the average data update date for each HVN agency was January 2021. Therefore, a system that accumulates and updates data promptly is required to promote data-based health care care policies. However, it is important not to increase the workload of the HVN agencies.

5 | IMPLICATIONS FOR NURSING MANAGEMENT

The spatial indicator suggested in this study can help reduce the inequality in accessing HVN services, thus contributing to nursing policy. HVN services are becoming more prevalent worldwide due to the growing demand for home health care. However, in certain regions, HVN services are unavailable due to a shortage of home visiting nurses. These challenges can be resolved by correcting the imbalance between the location of HVN agencies and home visiting nurses, resulting in more equitable access.

6 | CONCLUSION

The PWSAI captures the accessibility of HVN in municipalities based on the resources available in neighboring municipalities, even if the municipality itself does not have resources. Greater the PWSAI and home visiting nurses (24/7) per 10,000 older adults, the greater the positive association with the number of HVN service users at the municipality. The development of accessibility indicators of reliability will help establish an equitable system for the provision of HVN.

AUTHOR CONTRIBUTIONS

Kazuki Ohashi: Conceptualization; methodology; software; data curation; writing—review and editing; writing—original draft; funding acquisition; visualization; project administration. **Miho Sato**: Writing—review and editing. **Kensuke Fujiwara**: Methodology; conceptualization; writing—review and editing. **Takumi Tanikawa**: Methodology; writing—review and editing; software; resources. **Yasuhiro Morii**: Methodology; writing—review and editing. **Katsuhiko Ogasawara**: Writing—review and editing; methodology; resources; funding acquisition; supervision.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

ETHICS STATEMENT

This study was a secondary use of publicly available data and did not include personal information.

TRANSPARENCY STATEMENT

The lead author Katsuhiko Ogasawara affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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