Spatial Clusters of High Participation Rates for Specific Health Checkups among Prefectures in Japan and Their Regional Factors

メタデータ	言語: English 出版者: 公開日: 2024-03-06 キーワード (Ja): キーワード (En): 作成者: Mayumi Mizutani, 水谷, 真由美, Ritsuko Nishide, 西出, りつ子, Nanako Saeki, 佐伯, 南々子, Susumu Tanimura, 谷村, 晋 メールアドレス: 所属:
URL	https://doi.org/10.34414/0002000139

―― 原　著 ――

Spatial Clusters of High Participation Rates for Specific Health Checkups among Prefectures in Japan and Their Regional Factors

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Objective：This study aimed to investigate：(1) prefectural-level clusters with high participation rates of age-standardized specific health checkups (SHC) during 2009-2019；(2) clusters with improved rates over the 10-year period；(3) regional factors associated with the rates；and (4) regional variations in the magnitude of the association.

Methods：This ecological study used publicly available data from 47 prefectures in Japan regarding the SHC rate, income, unemployment rate, unmarried rate, nurse-to-population density, and public health nurse-to-population density. We performed spatial cluster analyses using flexible spatial scan statistics to detect the prefectural-level clusters. We specified the association using the ordinary least squares model (OLS), spatial autoregressive model (SAR), and spatial error model (SEM) to identify the regional factors associated with SHC rates. We applied geographically weighted regression (GWR) to assess geographical variations in the magnitude of the association.

Results：The cluster with high age-standardized SHC rate increased from 2009 to 2019. The numbers of prefectures in the cluster in both years were one for males and eight for females. The clusters with improved SHC rates over the 10-year period were located in 12 prefectures for males and 14 prefectures for females. OLS, SAR, and SEM showed positive correlations between the current SHC rates and public health nurse density (males：B = 1.00-1.11, p = 0.028-0.035；females：B = 2.05-2.27, p < 0.001). For females, GWR revealed a regional variation in the magnitude of the association (B = 1.47-3.79). For males, SEM revealed a positive correlation between the rates of changes in SHC over the 10-year period and nurse density (B = 0.42, p = 0.035).

Conclusion：The public health nurse and nurse densities were associated with high and improved SHC rates, and the magnitude of the association showed a regional variation. Further larger sample studies using city- and town-level data are needed to better assess the association.

Key words：specific health checkup, ecological research, spatial clusters, spatial regression

Ⅰ. Introduction

Fifteen years have passed since the specific health checkup (SHC), a nationwide screening program for the prevention of metabolic syndrome, was initiated in 2008 by the Ministry of Health, Labour and Welfare of Japan (Ministry of Health, Labour and Welfare of Japan, 2021b). This program mandates all healthcare insurers to conduct SHC for all enrollees aged 40-74 years per the Act on Assurance of Medical Care for the Elderly. The SHC participation rate has been steadily increasing. However, the national average has not reached the target value set by the government (Ministry of Health, Labour and Welfare of Japan, 2021a), and there were regional disparities at the prefectural-level (Cabinet Office of Japan, 2019；Ministry of Health, Labour and Welfare of Japan, 2022). To increase the national average and mitigate regional disparities in the SHC partici-

受付日：2023年4月23日/受理日：2023年9月25日
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pation rate, it is necessary to identify prefectures with better outcomes and mechanisms that cause the regional disparities. However, there is little evidence of the existence of spatial clusters with high and improved SHC rates and their regional factors per spatial analyses. In contrast to the empirical non-statistical approach, the advantage of our spatial cluster analysis is that it provides statistically significant evidence on regions with high or improved SHC rates. Moreover, we found that identifying factors associated with high or improved SHC rates, which can contribute to the development of nationwide public health strategies and public health nursing activities suitable for each region, is important.

Some studies have reported factors associated with SHC rates. An ecological study found an association between the prefecture-level health checkup rate and income and unemployment rates (Tamon et al., 2011). A quantitative study found an association between individual participation in SHC and recommendations from public health nurses, medical professionals, and family members (Sonoda et al., 2022). Another qualitative study reported the relationship of mutual trust between public health nurses and residents (Kakumori et al., 2021). However, the strength of the association between the SHC rates and each variable may vary depending on the geographical environment. In other words, the assumption that the strength of the association is geographically invariant may not be valid. Spatial epidemiology, a methodology that visualizes geographic distributions and examines health risks and associated factors by utilizing spatial statistics, is one strategy to overcome this problem through a proper assessment of the association that entails adjusting for spatial effects.

The overarching purpose of this study was to identify the spatial and temporal variations in high and improved SHC rates, which can help to clearly understand SHC from a geographic perspective. By utilizing spatial analyses, this study aimed to identify the following: (1) spatial clusters with high participation rates of age-standardized SHC at the prefectural-level in Japan between 2009 and 2019; (2) clusters that improved these rates over the 10-year period; (3) regional factors associated with the SHC rates (particularly factors that were modifiable by nursing approach); and (4) regional variations in the magnitude of the association. The findings of this study will be evidence to strengthen future public health policy and public health nursing practices based on regional characteristics.

Ⅱ. Methods

1. Design

This was an ecological study based on data from 47 prefectures in Japan. This study uses publicly available prefectural-level data that does not contain personally identifiable information, which is not applicable to the "Scope of Application" of the Ethical Guidelines for Medical and Biological Research Involving Human Subjects (Ministry of Education, Culture, Sports, Science and Technology, Ministry of Health, Labour and Welfare, Ministry of Economy, Trade and Industry of Japan, 2022). Therefore, ethical approval was waived by the institutional review board.

2. Data sources and data collection

Prefectural-level data on objective and explanatory variables were accessed from the website of the Statistics Bureau of Japan (Statistics Bureau of Japan, n. d.), and the Ministry of Health, Labour and Welfare of Japan (Ministry of Health, Labour and Welfare of Japan, n. d.). We retrieved prefectural-level geospatial vector data from the R package "Nippon Map" (Tanimura, 2018).

Objective variables were (1) the age-standardized SHC rate of each prefecture in 2019 and (2) the SHC change rate between 2009 and 2019. To calculate the age-standardized SHC rate of each prefecture in 2019, we first calculated the age-specific SHC rates for each five-year age group by dividing the number of people who underwent SHC by the corresponding general population and then multiplying the quotient by 100%. Then, we multiplied each of the age-specific rates by the proportion of the 2015 population belonging to the particular age group. Finally, we added the products. To calculate the rate of change of SHC (SHC improvement rate) between 2009 and 2019, we first subtracted the baseline age-standardized SHC rate in 2009 from the current rate in 2019. Thereafter, we divided the difference by the baseline rate in 2009 and multiplied the quotient by 100%.

Explanatory variables at the prefectural-level were income levels (million yen per capita) in 2008 and 2018, unemployment rates in 2010 and 2020, unmarried rates in 2010 and 2020, nurse-to-population densities (per 10,000 people) in 2008 and 2018, and public health nurse-to-population densities (per 10,000 people) in 2008 and 2018. The unemployment rate was calculated by dividing the number of completely unemployed people aged≥15 years by the working population among people aged≥15 years and then multiplying the quotient by 100%. The unmarried rate was calculated by dividing the number of unmarried people aged 40–74 years by the total number of people aged 40–74 years and then multiplying the quotient by 100%. The nurse-to-population density (per 10,000 people) was calculated by dividing the number of nurses by the total population and then multiplying the quotient by 10,000 people. Similarly, we calculated the public health nurse-to-population density (per 10,000 people). We also calculated the rate of change over the 10-year period for each explanatory variable. For each variable, we subtracted the baseline value (the value 10 years earlier) from the current value, divided the difference by the baseline value, and multiplied the quotient by 100%.

3. Data analysis and visualization

First, we performed spatial cluster analysis, which is a restricted flexibly-shaped spatial scan test (Tango et al., 2012), using the R package "smerc" (French, 2022) to identify arbitrarily-shaped spatial clusters with high SHC rates and improved SHC rates over the 10-year period (2009–2019). We defined prefectures sharing the same prefectural border as neighbors. Prefectures with statistically higher SHC rates than other prefectures were considered prefectures with high SHC rates. We set the maximum number of regions to be included in a potential cluster as 24. Second, an ordinary least squares model (OLS) was specified to assess the association between SHC and potential factors. We calculated the statistical power of the models to determine whether our sample size was large enough to answer the research question (Tanimura, 2023). Third, we performed spatial regression analysis. The traditional OLS model assumes that every observation is spatially independent; thus, violations of this assumption can lead to biased and incorrect results. Meanwhile, spatial regression models incorporate the spatial dependence of the variables (Anselin, 2003), enabling the appropriate estimation of the coefficients. There is no golden rule for selecting the correct model specification; however, the spatial autoregressive (SAR) model and spatial error model (SEM) are the most commonly used (Ward & Gleditsch, 2019). The SAR assumes spatial dependence among the dependent variables, whereas the SEM assumes spatial dependence among the error terms (Anselin, 2003). Thus, we used a spatial autoregressive model (SAR) and a spatial error model (SEM) to detect spatially adjusted factors using a k-nearest neighbor approach. We defined each prefecture's nearest three prefectures as its neighbors. Using Akaike's information criterion (AIC), a statistic for assessing model fitness, the model with the lowest AIC was singled out as the best-fit model. Finally, to assess the geographical variation in the regression coefficients of the explanatory variables, we conducted geographically weighted regression (GWR). GWR assumes that there is spatial variation in relationships (Fotheringham et al., 1998). In other words, the traditional OLS assumes that coefficients are identical across a study area, whereas GWR assumes that the coefficients significantly vary in an area. GWR was used in our study to calculate prefecture-specific coefficients. For all analyses, p-values of $<$ 0.05 were considered statistically significant. All data processing, analyses, and visualizations were performed using R version 4.2.3 (R Core Team, 2023).

Ⅲ. Results

1. SHC rates of 47 prefectures between 2009 and 2019

Table 1 shows the characteristics of prefectures. Figure 1 shows the SHC rates of 47 prefectures. The lightest colors represent low SHC rates, while dark colors represent high SHC rates. For males, the mean SHC rate among the 47 prefectures increased from 40.0% in 2009 (SD: 4.5; range: 32.6–55.9) to 54.5% in 2019 (SD: 3.7; range: 46.1–64.0). The rate of change of SHC between 2009 and 2019 was 37.3% (SD: 8.9; range: 8.2–55.2). For females, the mean SHC rate increased from 32.1% in 2009 (SD: 5.0; range: 21.9–44.9) to 45.6% in 2019 (SD: 4.5; range: 34.7–57.5). The rate of change of SHC between 2009 and 2019 was 43.5% (SD: 11.4; range: 17.7–80.1).

In Figure 2-A and 2-B, the darkest color represents clusters of high SHC rates. For males, the cluster was located only in Tokyo in 2009 (Figure 2-A). Then, the cluster expanded to 15 prefectures in the Tohoku, North-Kanto, South-Kanto, Hokuriku, Tokai, and Kinki regions in 2019 (the centroid of the cluster: Iwate prefecture, the maximum intercentroid distance between all the regions in the cluster: 714.99 km) (Figure 2-B). For females, the cluster was concentrated in nine prefectures in the Tohoku, North-Kanto, and Hokuriku regions in addition to Tokyo in 2009 (the centroid of the cluster: Miyagi prefecture, the maximum intercentroid distance between all the regions in the cluster: 383.33 km) (Figure 2-A). Then, the cluster expanded to 14 prefectures including the Tokai and Kinki regions in 2019 (the centroid of the cluster: Iwate prefecture, the

Table 1　Characteristics of Prefectures　　*N*=47

	Observation								Change rate			
	Start				End							
	2009				2019				2009-2019			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Age-standardized SHC rates (male, %)	40.0	4.6	32.6	55.9	54.5	3.7	46.1	64.0	37.3	9.0	8.2	55.2
Age-standardized SHC rates (female, %)	32.1	5.0	22.0	44.9	45.6	4.6	34.8	57.5	43.5	11.6	17.7	80.1
	2010				2020				2010-2020			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Unemployment rate (male, %)	7.7	1.4	5.6	13.1	4.4	0.6	3.2	6.3	−42.8	4.3	−51.6	−34.7
Unemployment rate (female, %)	4.9	0.9	3.2	8.2	3.1	0.4	2.1	4.5	−35.9	4.5	−46.9	−27.6
Unmarried rate (male, %)	13.9	2.0	9.9	20.2	18.5	1.6	15.0	21.8	34.4	9.8	0.5	50.9
Unmarried rate (female, %)	7.4	1.7	4.6	13.7	10.7	1.6	7.6	15.3	46.8	11.3	11.3	73.4
	2008				2018				2008-2018			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Income (million yen/capita)	2.7	0.5	1.9	5.5	3.0	0.5	2.4	5.4	13.3	5.8	−0.9	26.2
Nurse/10,000 people	76.5	14.7	44.4	102.9	108.2	19.8	69.4	151.1	41.9	5.5	28.7	56.4
Public health nurse/10,000 people	4.1	1.0	2.0	6.1	5.2	1.3	2.4	7.9	25.1	7.7	9.5	43.7

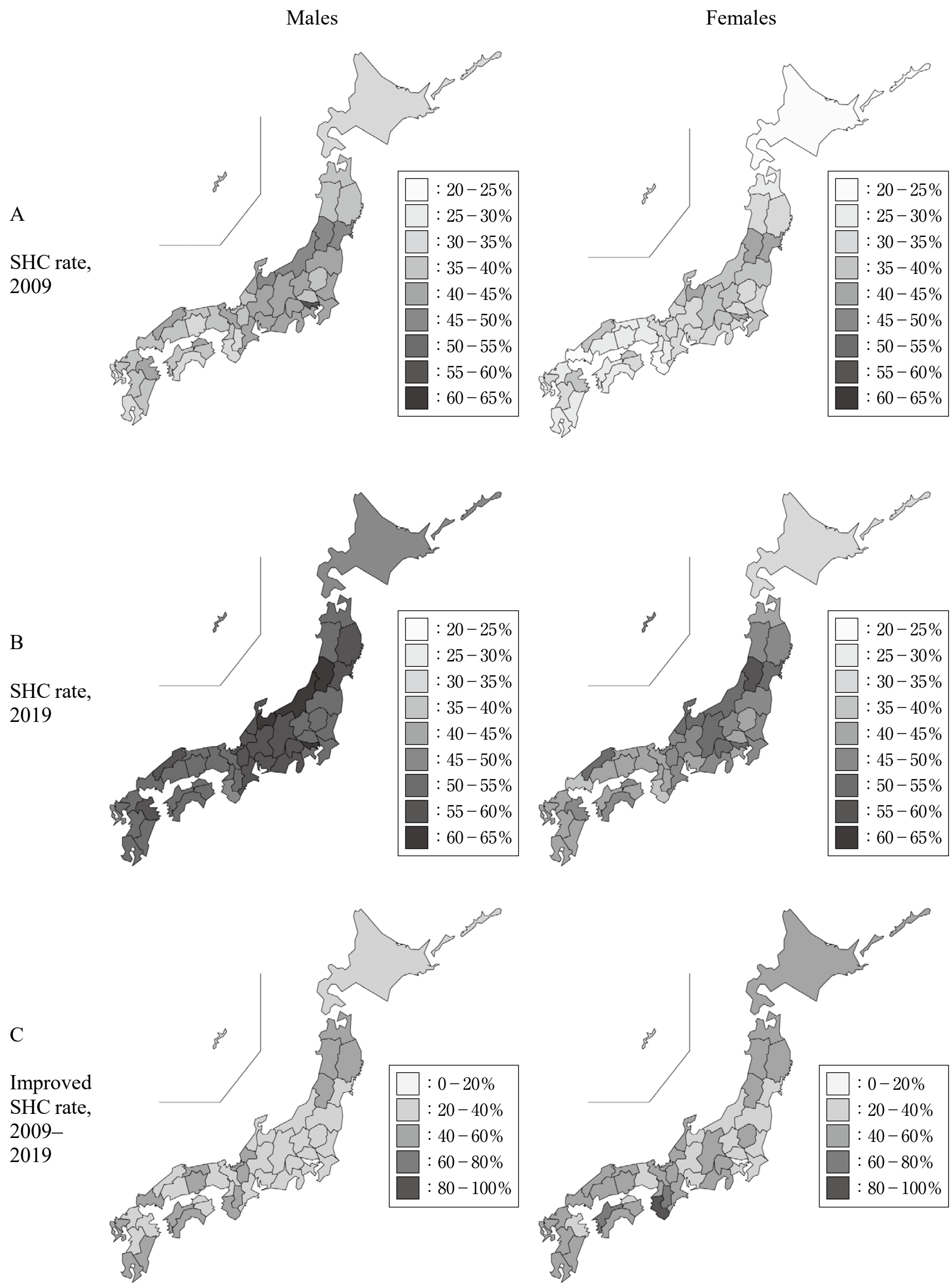
Note. SHC : specific health checkups.

maximum intercentroid distance between all the regions in the cluster : 714.99 km) (Figure 2-B). Combining the results, there were eight prefectures for females (Miyagi, Yamagata, Fukushima, Tokyo, Niigata, Toyama, Yamanashi, and Nagano) and one prefecture for males (Tokyo), which was inside the cluster for both 2009 and 2019.

In Figure 2-C, the darkest color represents the clusters that improved the SHC rate over the 10-year period (2009-2019). For males, the cluster was concentrated in 12 prefectures in the North-Kanto, South-Kanto, Hokuriku, and Tokai regions (the centroid of the cluster : Ibaraki prefecture, the maximum intercentroid distance between all the regions in the cluster : 410.45 km). These were Ibaraki, Tochigi, Saitama, Kanagawa, Toyama, Ishikawa, Fukui, Nagano, Gifu, Shizuoka, Mie, and Shiga. For females, the cluster was located in 14 prefectures in the North-Kanto, South-Kanto, Hokuriku, Tokai, and Kinki regions (the centroid of the cluster : Ibaraki prefecture, the maximum intercentroid distance between all the regions in the cluster : 514.63 km). These were Ibaraki, Tochigi, Saitama, Kanagawa, Ishikawa, Fukui, Yamanashi, Nagano, Shizuoka, Aichi, Mie, Shiga, Nara, and Wakayama.

2. Association between high and improved SHC rates and regional factors

Table 2 depicts the results of OLS and spatial regression models to assess the association between the SHC rate in 2019 and potential regional factors. For males, the unemployment rate had a negative association with the SHC rate in the models. The best-fit model for males was OLS with the lowest AIC (241.4). A 1% increase in the unemployment rate was associated with a 2.87% decrease in the SHC rate. For females, income had a positive association with the SHC rate in the models. The best-fit model for males was OLS with the lowest AIC (260.8). A one million yen increase in income per capita was associated with a 4.29% increase in the SHC rate. For both males and females, the public health nurse density had a positive association with the SHC rate in the models. The best-fit models were OLS with the lowest AICs. One more public health nurse per 10,000 people was associated with a 1.11% increase in the SHC rate for males and a 2.27% increase in the SHC rate for females. The statistical power ($1-\beta$) of

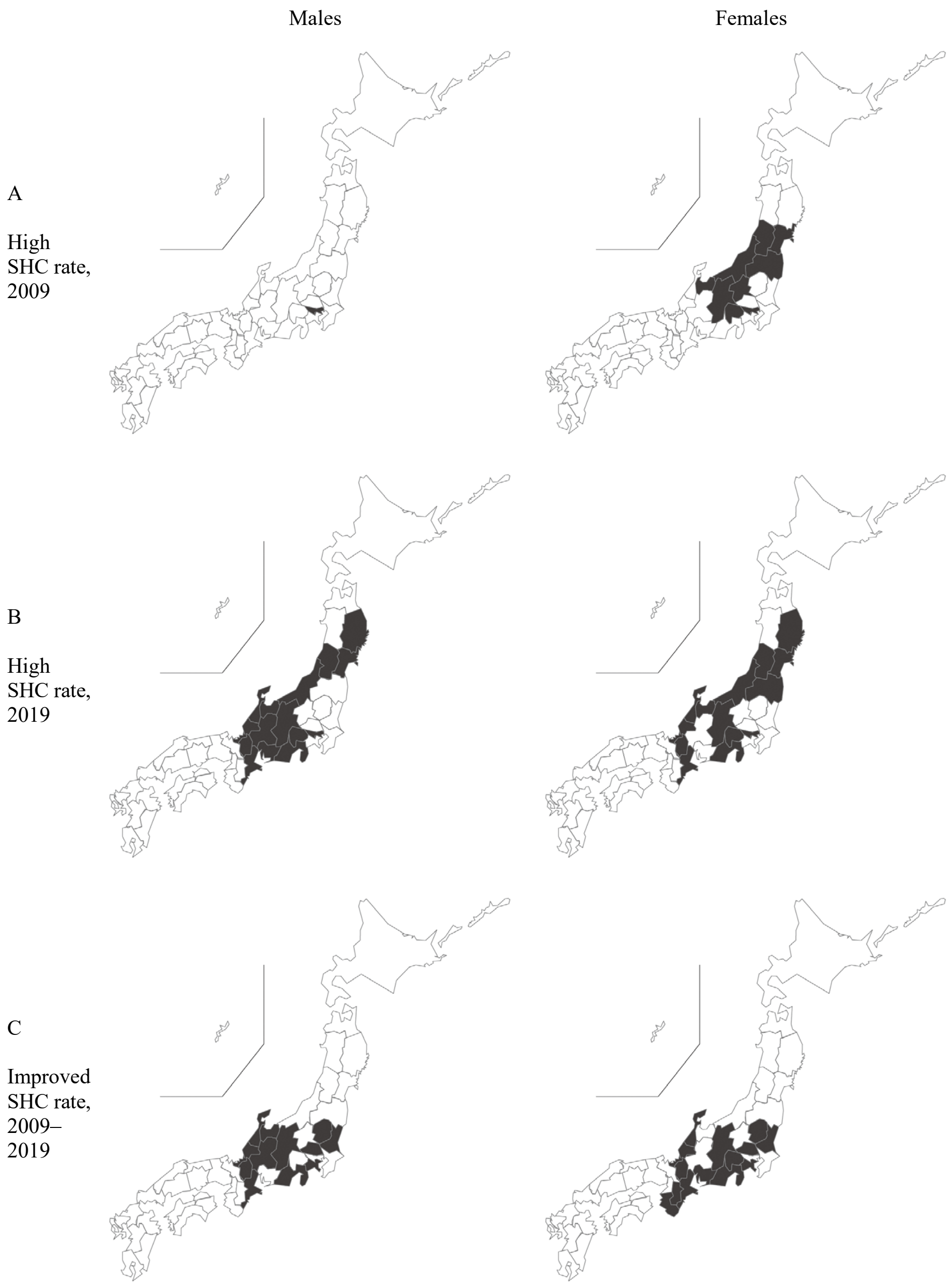


Note. SHC: specific health checkups.

Figure 1　Age-Standardized SHC Rates in 47 Prefectures in 2009-2019

both models was 0.99.

Table 3 depicts the results of OLS and spatial regression models to assess the association between the rate of change of SHC in 2009-2019 and potential regional factors. For males, the rates of change of the unemployment and unmarried rates had associations with the SHC rate in the models. The best-fit models were OLS with the lowest AIC (330.6). A 1% increase in the rate of change of the unemployment rate was associated with a 0.80% decrease in the rate of change of SHC over the 10-year period. A 1% increase in the rate of change of the unmarried rate was associated with a 0.30% increase in the rate of change of SHC. Although no significant association was found in OLS, the nurse density had a positive association with the rate of change of SHC in SEM ($B = 0.42$, $p = 0.035$). One more nurse per 10,000 people was associated a 0.42% increase in the rate of change of SHC. For females, no significant association was found in any model. The statistical power ($1-\beta$) of the male model was 0.99, while that of the female model was 0.39.



Note. SHC: specific health checkups.

Figure 2　Prefectural-Level Clusters With High and Improved SHC Rates in 2009–2019

3. Regional variability in the relationship between the SHC rate and factors

Figure 3 presents the regression coefficients of the SHC rate in 2019 and the public health nurse density in 2018 based on GWR. For females, the magnitude of the association between the SHC rate and the public health nurse density was stronger in the southern areas, such as the Kyushu, Shikoku, and Chugoku regions. In the area with the highest magnitude of the association, one more public health nurse per 10,000 people was associated with a 3.79% increase in the SHC rate. However, in the area with the lowest magnitude of the association, one more public health nurse per 10,000 people was associated with a 1.47% increase in the SHC rate. For males, there was little geographical variation in the magnitude of the association（B＝1.10–1.12）.

Figure 4 presents regression coefficients of the rates of change of SHC and nurse density. For both males and females, there was little geographical variation in the magnitude of the association（male：B＝0.40–0.45, female：B＝0.41–0.46）.

Table 2　Association Between the SHC Rate in 2019 and Potential Regional Factors

	Male						Female					
	OLS		SAR		SEM		OLS		SAR		SEM	
	B	*p*	B	*p*	B	*p*	B	*p*	B	*p*	B	*p*
Income (million yen/capita) (2018)	1.99	0.122	2.02	0.085	2.05	0.079	4.29	**0.011**	4.15	**0.005**	4.33	**0.004**
Unemployment rate (%) (2020)	−2.87	**0.005**	−2.72	**0.004**	−2.90	**0.002**	−0.01	0.995	−0.15	0.942	−0.17	0.936
Unmarried rate (%) (2020)	0.22	0.513	0.19	0.550	0.22	0.480	−0.61	0.312	−0.56	0.311	−0.61	0.279
Nurse/10,000 pop (2018)	−0.06	0.087	−0.05	0.164	−0.06	0.083	−0.06	0.195	−0.05	0.322	−0.06	0.226
Public health nurse/10,000 pop (2018)	1.11	**0.035**	1.00	**0.036**	1.05	**0.028**	2.27	**<0.001**	2.05	**<0.001**	2.13	**<0.001**
ρ			0.17	0.413					0.21	0.277		
λ					0.105	0.689					0.14	0.608
Adjusted R^2	0.39						0.39					
F Statistic (df = 5 ; 41)	6.99	**<0.001**					6.76	**<0.001**				
AIC	241.4		242.7		243.2		260.8		261.6		262.5	
f^2	0.85						0.82					
$1-\beta$	0.99						0.99					

Note. SHC : specific health checkups, OLS : ordinary least squares model, SAR : spatial autoregressive model, SEM : spatial error model, AIC : Akaike's information criterion. Boldface indicates statistical significance.

Ⅳ. Discussion

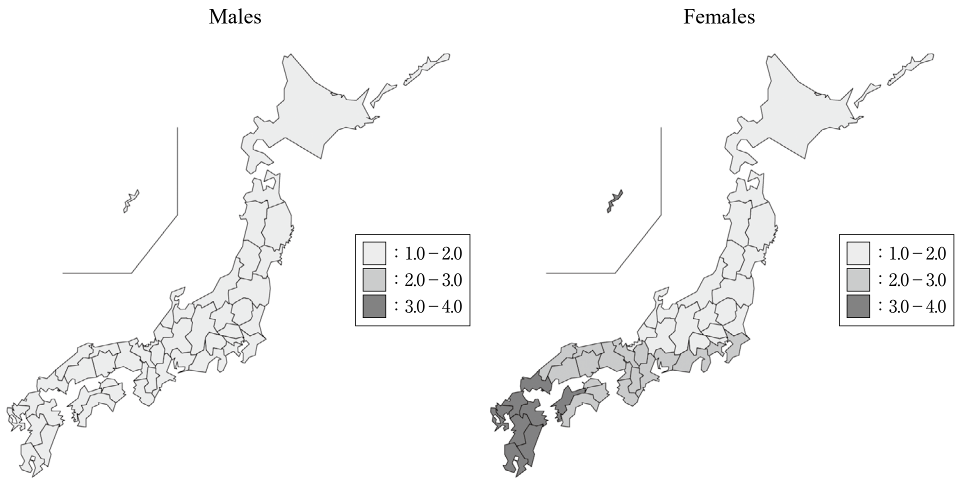
To our knowledge, this study is the first to explore the importance of spatial detection of prefecture-level clusters with a high current age-standardized SHC rate and an improved SHC rate in the 10-year period in Japan. First, we found that the number of prefecture-level clusters with a high age-standardized SHC rate has increased from 2009 (males : one prefecture ; females : nine prefectures) to 2019 (males : 15 prefectures ; females : 14 prefectures) (Figure 2). Combining the results, there were eight prefectures (Miyagi, Yamagata, Fukushima, Tokyo, Niigata, Toyama, Yamanashi, and Nagano) for females and one prefecture (Tokyo) for males that were inside the cluster for both 2009 and 2019. In these prefectures, there might be a key strategy to sustain a high SHC rate in the 10-year period.

One of the possible reasons why the prefectures achieved the current high SHC rate might be the public health nurse density. The results of regression models showed a positive association between the high SHC rate and public health nurse density both in males and females, even after adjusting for the spatial effect. The strengths of the association differed with greater coefficients in females than in males (B = 2.05–2.27 vs. B = 1.00–1.11) and in the southern regions (Table 2, Figure 3). Public health nurses working for local governments are the ones who support insured persons of National Health Insurance to receive SHC. Among 16.2 million males and 13.6 million females aged 40–74 who underwent SHC in 2019, the percentage of females who were insured persons of the National Health Insurance was higher than that of males (29.7% vs. 18.6%) (Ministry of Health, Labour and Welfare of Japan, n. d.). Among 531,875 males and 277,240 females aged 40–74 who were insured persons of the National Health Insurance and needed to receive specific health guidance in 2019, the completion rate for the specific health guidance was higher among females than among males (32.9% vs. 27.5%) (Ministry of Health, Labour and Welfare of Japan, n. d.). Thus, females are more likely to participate in health programs provided in a community and are more likely to be impacted by public health nurses. Our findings provided more evidence that the appropriate allocation of public health nurses in the population might be the key to achieving high SHC rates at the prefectural-level. More particularly, the impact might

Table 3　Association Between the SHC Change Rate in 2009-2019 and Potential Regional Factors

	Male						Female					
	OLS		SAR		SEM		OLS		SAR		SEM	
	B	*p*	B	*p*	B	*p*	B	*p*	B	*p*	B	*p*
Income change rate (2008-2018)	0.26	0.279	0.24	0.275	0.06	0.795	0.19	0.617	0.23	0.481	0.25	0.461
Unemployment rate change rate (2010-2020)	−0.80	**0.008**	−0.87	**0.002**	−1.06	**<0.001**	−0.55	0.185	−0.42	0.248	−0.32	0.383
Unmarried rate change rate (2010-2020)	0.30	**0.020**	0.31	**0.008**	0.32	**0.001**	−0.01	0.971	0.02	0.912	0.00	0.984
Nurse/10,000 pop change rate (2008-2018)	0.42	0.060	0.40	0.055	0.42	**0.035**	0.43	0.201	0.46	0.112	0.48	0.099
Public health nurse/10,000 pop change rate (2008-2018)	−0.07	0.705	−0.05	0.759	0.02	0.905	−0.25	0.347	−0.25	0.282	−0.21	0.334
ρ			−0.11	0.612					0.38	**0.044**		
λ					−0.50	0.184					0.39	0.052
Adjusted R^2	0.30						0.00					
F Statistic (df = 5 ; 41)	4.99	**<0.001**					0.97	0.447				
AIC	330.6		332.4		330.9		371.3		369.3		369.5	
f^2	0.60						0.12					
$1-\beta$	0.99						0.39					

Note. SHC : specific health checkups, OLS : ordinary least squares model, SAR : spatial autoregressive model, SEM : spatial error model, AIC : Akaike's information criterion. Boldface indicates statistical significance.

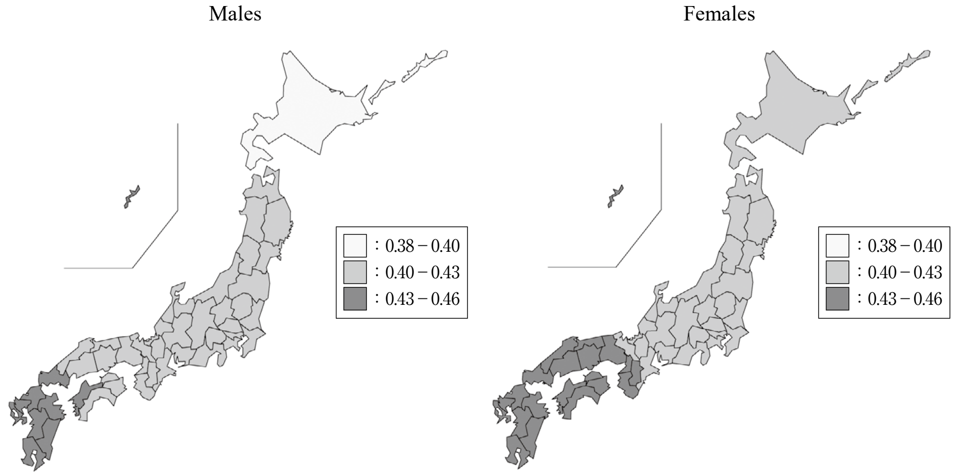


Note. SHC: specific health checkups. The Figure demonstrates the local regression coefficients of the public health nurse density (2018) against the SHC rate (2019) after adjusting for covariates (i.e., income (million yen per capita) in 2018, unemployment rate in 2020, unmarried rate in 2020, and number of nurses per 10,000 people in 2018).

Figure 3　Regression Coefficients of the Public Health Nurse Density (2018) Against the SHC rate (2019)

be greater for females and in the southern area.

We also identified a cluster with an improved SHC rate over the 10-year period (2009-2019). These were 12 prefectures for males (Ibaraki, Tochigi, Saitama, Kanagawa, Toyama, Ishikawa, Fukui, Nagano, Gifu, Shizuoka, Mie, and Shiga) and 14 prefectures for females (Ibaraki, Tochigi, Saitama, Kanagawa, Ishikawa, Fukui, Yamanashi, Nagano, Shizuoka, Aichi, Mie, Shiga, Nara,



Note. SHC: specific health checkups. The Figure demonstrates the local regression coefficients of the nurse density change rate (2008–2018) against the SHC rate change rate (2009–2019) adjusted by covariates (i.e., income change rate in 2008–2018, unemployment rate change rate in 2010–2020, unmarried rate change rate in 2010–2020, and public health nurse per 10,000 people change rate in 2008–2018).

Figure 4　Regression Coefficients of the Nurse Density Change Rate (2008-2018) Against the SHC Rate Change Rate (2009-2019)

and Wakayama) (Figure 2). In these prefectures, there might be a clue strategy to improve the SHC rate in the 10-year period.

One of the possible reasons why the prefectures achieved improved SHC rates might be the nurse density. For males, only a spatial regression model revealed that the improved SHC rate over the 10-year period was associated with a higher rate of change in the nurse density (Table 3). Our findings provided more evidence that the spatial analysis enables us to appropriately assess the association between the rates of change of the SHC rate and the nurse density. In the past 15 years, the basic nursing education system has changed drastically. The number of universities has increased by 152.9% (from 104 universities in 2003 to 263 universities in 2018) and the percentage of universities among all the nursing schools has also increased from 9.4% in 2003 to 24.7% in 2018 (Ministry of Education, Culture, Sports, Science and Technology of Japan, n. d.). Thus, more nurses have undergone university education. To explain the quantitative mechanism of the association between improved SHC rates and the rate of change of nurse density, a qualitative mechanism to determine the quality of nurses may intervene. The appropriate allocation of nurses in the population may contribute significantly to improving the SHC rate in the prefecture. Further studies are needed to explore the qualitative mechanism involved.

This study has certain limitations. First, it was an ecological study, which are potentially susceptible to ecological fallacies (Wakefield, 2008). Additionally, the statistical power of the female model in Table 3 (39%) was less than 80% due to the relatively small sample size. Therefore, there might have been associations that could not be detected. Future studies including city-level and town-level of data in Japan need to be conducted as the findings of such studies would allow data-driven and specific decision-making to optimize health interventions aimed to improve and sustain the SHC rate in each local government of Japan.

Ⅴ. Conclusion

The spatial clusters with high age-standardized SHC rates in Japan, both in 2009 and 2019, were one prefecture for males and eight prefectures for females. Regression models showed that the current higher SHC rate was associated with a higher public health nurse density both for males and females, with the associations in females and the southern regions being stronger. The clusters in which the SHC rate improved over the 10-year period (2009-2019) were 12 prefectures for males and 14 prefectures for females. Only a spatial regression model revealed that the improvement in the SHC rate over the 10-year period was associated with a higher rate of change in the nurse density for males. To improve and sustain the SHC rate in Japan, it is considered important to have an adequate number of nurses and public health nurses per population across all prefectures.

Conflicts of interest

The author (s) declare no potential conflicts of interest with respect to the research and/or publication of this article.

Acknowledgments

This work was supported by the 2022 Nursing Science Research Grant of St. Luke's Society for Nursing Research.

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和文抄録

空間疫学を援用した特定健康診査の高受診率地域クラスターの検出とその地域要因

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目的：(1) 2009年と2019年における年齢調整特定健診受診率が高い地域クラスター，(2) 10年間の受診率の変化率が高い地域クラスター，(3) 受診率の高値と向上に関連する地域要因，(4) その関連強度における地域変動を明らかにすることを目的とした．

方法：47都道府県の公開データを用いる生態学的研究である．特定健診受診率，所得，失業率，未婚率，看護師数，保健師数などのデータを収集した．クラスターを特定するために flexible spatial scan 法による地域集積性の検定を行った．受診率の高値と向上に関連する要因を明らかにするために，最小二乗モデル，空間自己回帰モデル，空間誤差モデルにより分析した．関連強度の地域変動を明らかにするために地理加重回帰モデルをデータに当てはめた．

結果：年齢調整特定健診受診率が高い地域クラスター数は2009年から2019年に増加した．2009年および2019年ともクラスター内であった県は，男性１県，女性８県であった．10年間の受診率の変化率が高いクラスターは，男性12県，女性14県であった．回帰モデルにより，2019年の受診率と人口当たり保健師数との間に正の関連が示された（男性：B＝1.00–1.11，p＝0.028–0.035；女性：B＝2.05–2.27，p＜0.001）．地理加重回帰モデルにより，女性ではその関連強度に地域差がみられた（B＝1.47–3.79）．空間誤差モデルにより，男性では，受診率の10年間の変化率と人口当たり看護師数の変化率の間に正の関連が見られた（B＝0.42，p＝0.035）．

結論：人口当たりの保健師数や看護師数が年齢調整特定健診受診率の高値と向上に関連すること，関連強度に地域差があることが示された．今後，関連性をより正確に評価するために，市町村レベルのデータを用い，より大きなサンプルサイズによる研究が必要である．

キーワード：特定健康診査，生態学的研究，地域集積性，空間回帰分析