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Worsening Sufficiency and Equity in the Geographic Distribution of Physicians in Japan

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Worsening Sufficiency and Equity in the Geographic Distribution of Physicians in Japan

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Worsening Sufficiency and Equity in the Geographic Distribution of Physicians in Japan

Abstract

Objectives

The objective of this study was to examine longitudinally the geographic distribution of physicians in Japan with adjustment for healthcare demand according to changes in population age structure.

Methods

We examined trends in the number of physicians per 100 000 population in Japan's secondary medical areas (SMAs) from 2000 to 2014. Healthcare demand was adjusted using health expenditure per capita. Trends in Gini coefficient and the number of SMAs with a low physician supply were analysed. A sub-group analysis was also conducted where SMAs were divided into four groups according to urban-rural classification and initial physician supply.

Results

The time-based changes in both Gini coefficient and the number of SMAs with a low physician supply indicated that the equity in physician distribution had worsened throughout the study period. The number of physicians per 100 000 population had seemingly increased in all groups, with increases of 22.9% and 34.5% in urban groups with higher and lower initial physician supply, respectively. However, after adjusting healthcare demand, physician supply decreased by 1.3% in the former group and increased by 3.5% in the latter group; decreases were also observed in the rural groups.

Conclusions

Although the total number of physicians increased in Japan, when healthcare demand was adjusted, physician supply decreased in recent years in all areas except for urban areas with a lower initial physician supply. In addition, the equity of physician distribution had consistently deteriorated since 2000. The results indicate the need for major reform of Japan's healthcare system to improve physician distribution.

Strengths and limitations of this study

- This study longitudinally examines the geographic distribution of physicians in Japan with adjustment for healthcare demand according to changes in population age structure.

- The trends in sufficiency and equity in Japan's physician supply changed after adjusting healthcare demand, indicating that healthcare demand should be considered when examining the geographic distribution of physicians. This adjustment will become increasingly important as the age structure of the Japanese population continues to change.
- The primary limitation of this study is that it was a retrospective study and, as such, does not provide estimates on future physician supply and healthcare demand.

Keywords
Japan; physicians; geographic distribution; sufficiency; equity; healthcare demand

Introduction

The inequitable geographic distribution of physicians is a pressing issue in many countries [1-4]. There are at least two reasons why this issue attracts social and political attention. The reason comes from the issue of equity and social justice, that is, a citizen's right to access healthcare equally. The other is rooted in the belief in linkages between physician availability and health status [5].

Studies that address this topic frequently use the number of physicians per population as an indicator of physician supply. However, this simple calculations may present an oversimplification of findings due to its reliance on simple head counts that ignore differences within a population [5]. In particular, healthcare demand is likely to differ substantially among the age strata as elderly people tend to require more health care. As many parts of the world are experiencing accelerated population ageing, it is becoming increasingly important to consider the differences in age-dependent healthcare demand when examining physician supply.

Population ageing has become a key policy issue throughout the world [6]. Japan currently has the highest proportion of people aged 65 years or older, and became one of the first "super-aged" societies when this proportion exceeded 21% in 2007 [7]. In addition, Japan's rate of population ageing is unprecedented: the rise in the proportion of people aged 65 years or older from 10% to 20% occurred within 20 years. In contrast, the UK had almost 79 years and the US had almost 59 years to adapt to this shift in population age structure. Furthermore, Japan's proportion of elderly people is predicted to rise to 33.4% in 2035 and 39.9% in 2060 [8], indicating that its population is still undergoing rapid changes.

In Japan, the issue of the number of physicians has been changing from a shortage to a surplus. Japan faced a shortage of physicians in the 1960s and 1970s [9]. During that period, the country experienced a massive increase in population from 94 million to 117 million people. The government at that time aimed to ensure a minimum of 150 physicians for every 100 000 people, and doubled medical school enrolments in the 1970s to increase physician supply. The target number of physicians was achieved in 1984, and has since continued to increase. Due to the ageing and projected decrease of the Japanese population, the possible surplus of physicians is an issue that needs to be addressed. Although the government-sanctioned reduction of enrolments in medical schools has been proposed as a possible measure to control physician numbers, this measure is controversial and has been met with resistance from several interest groups [10]. Detailed and accurate information on physician supply that accounts for age-dependent healthcare demand is needed to support this decision-making process.

Although previous studies have examined trends in physician geographic distribution using healthcare demand-adjusted populations [11 12], there is currently no standardized method for adjusting healthcare demand. Furthermore, the trends in physician supply in a super-aged society such as Japan have yet to be investigated. In this study, we conducted a longitudinal examination of the geographic distribution of physicians with adjustment for healthcare demand according to the changing age structure of the Japanese population.

Methods

Data sources

The number of physicians was obtained from the National Physician Census, which is conducted biennially by the Ministry of Health, Labour and Welfare. The census data included the type and location (municipality) of workplace for each physician. Population data were collected from the National Basic Resident Register, which is published annually by the Ministry of Internal Affairs and Communications. We collected national health expenditure data from the Ministry of Health, Labour and Welfare, and calculated the expenditure per capita for each age group in 2014. Although national health expenditure includes various types of health care, we only used general treatment medical fees for our analysis because the other types of care were deemed to have little direct relevance to the number of physicians.

Medical consultation rates were collected from the 2014 Patient Survey conducted by the Ministry of Health, Labour and Welfare. Population density was calculated by dividing the number of people residing in each secondary medical area (SMA, described below) by the area (km^2). The area of each region was obtained from statistical reports on land areas of prefectures and municipalities by the Geospatial Information Authority of Japan.

Physicians and population

Practicing physicians at all Japanese clinics and hospitals were included in analysis, whereas registered physicians working in non-clinician roles (e.g., basic researchers or government officials) were excluded. Physician numbers were calculated for both the raw (unadjusted) population and the healthcare demand-adjusted population; the former included all Japanese citizens and the latter included all Japanese citizens adjusted for age-dependent healthcare demand. The population was stratified into 5-year age groups, with the initial group comprising persons aged 0 to 4 years and the final group comprising persons aged 80 years or older.

Secondary medical areas

The SMA was used as the geographic unit of analysis. The Japanese government has designated medical service administration areas throughout the country, and these areas are categorized into primary, secondary, and tertiary medical areas. Primary medical areas are set at the municipal level, and generally represent areas that are capable of providing basic primary care to residents. Tertiary medical areas are generally set at the prefectural level, and generally represent areas that are capable of providing the most advanced and specialized medical treatments. SMAs, which are between these two levels, generally supply and manage the majority of primary care and emergency medical services to regional communities. Therefore, SMAs are arguably the most important of the three geographic units with regard to implementing health policies. The geographic boundaries of the primary and tertiary medical areas are based on existing regional borders, whereas SMAs are demarcated by the prefectural governments based on healthcare provision capabilities. As a result, SMAs are directly relevant to the functional aspects of healthcare administration. Previous studies on physician geographic distribution in Japan have been conducted at the municipal level [9 13], although recent studies have also focused on SMAs [4 14 15]. SMA boundaries can be modified by prefectural governments in response to changing healthcare requirements.

In this study, we analysed the 349 designated SMAs in 2012.

Analysis of physician distribution

First, we calculated the healthcare demand-adjusted population using adjustment coefficients that were derived according to the health expenditure per capita for each age group. The health expenditure for each age group was divided by the overall mean health expenditure of the population, and the obtained quotients were used as age group-specific adjustment coefficients. We applied the adjustment coefficients to the raw population to obtain the healthcare demand-adjusted population. The numbers of physicians per 100 000 population in the SMAs were calculated for both the raw and demand-adjusted populations, and these values were used in the following analyses. In addition, we assessed the robustness of the adjustment coefficients by comparing them with alternative coefficients based on medical consultation rates instead of health expenditure, and also examined the annual changes in the adjustment coefficients by age group during the study period.

Next, we assessed the equity of the geographic distribution of physicians. The Gini coefficient was used as the indicator of equity, and has been widely used in similar analyses [2 4 16-18]. This coefficient measures the degree of departure from a uniform distribution known as the Lorenz curve, and takes a value between 0 (indicating perfect equality) and 1 (indicating perfect inequality). The Lorenz curve for the SMAs was plotted based on the number of physicians per 100 000 population.

We then examined the time-based trends in the number of SMAs with a low physician supply. SMAs were categorized into quartiles according to the number of physicians per 100 000 raw population in 2000, and the SMAs in the first quartile were specified as having a low physician supply. We examined the changes in the proportions of SMAs that fulfilled this criterion throughout the study period.

Finally, we divided SMAs into four groups according to two criteria: whether they were rural or urban, and whether they had a lower or higher initial physician supply at the start of the study period. Using an approach described previously in [14] the degree of urbanization was determined using the population density in 2000 as a proxy variable, and the initial physician supply was indicated using the number of physicians per 100 000 population in 2000. We divided the SMAs according to the median values of each variable to obtain four groups: Group 1 comprised urban SMAs with a higher initial physician supply, Group 2 comprised rural SMAs with a higher initial physician supply, Group 3 comprised rural areas with a lower initial physician supply, and Group 4 comprised urban areas with a lower initial physician supply. The changes in physician numbers were compared among these groups. All analyses were performed using R statistical software (version 3.2.2).

Results

As shown in Table 1, the adjustment coefficients for the age groups ranged from 0.22 (15–24 years) to 3.33 (80 years or older). The adjustment coefficient of the elderly population (65 years or older) was approximately four times that of the younger population (10–39 years). The results of robustness testing indicated that our adjustment coefficient was consistent with the results of the alternative coefficient based on medical consultation rates, with a high level of correlation (correlation coefficient: 0.99) between the primary adjustment coefficients and medical consultations rates by age group. Furthermore, our coefficient also appeared robust to time-based changes from 2000 to 2014 (data not shown).

Table 2 shows the temporal trends in the number of physicians and population from 2000 to 2014 at 2-year intervals. The number of physicians consistently increased by approximately 6000 to 8000 every two years, and was 1.22 times higher in 2014 than in 2000. The raw population generally remained unchanged throughout the study period. In contrast, the healthcare demand-adjusted population was 1.23 times higher in 2014 than it was in 2000. Hence, the increase rate of the demand-adjusted population slightly exceeded the increase rate of physicians.

Table 3 summarizes the descriptive statistics for the 349 SMAs. The mean number of physicians and demand-adjusted population had increased between 2000 and 2014. Figure 1 illustrates the temporal changes in Gini coefficient for the number of physicians per 100 000 population (both raw and demand-adjusted) at the SMA level, and indicates that the equity in physician numbers had worsened in both populations. In particular, equity had deteriorated more (higher Gini coefficient) in the healthcare demand-adjusted population.

Figure 2 shows the changes in the proportion of SMAs with a low physician supply across the study period. In the raw population, the proportion consistently decreased from 24.9% to 13.2% (with a brief increase between 2006 and 2008). In contrast, the same proportion in the healthcare demand-adjusted population consistently increased from 24.9% to 35.0% (with a brief decrease between 2000 and 2002); notably, there was a relatively large increase of 4.5% between 2006 and 2008 in the demand-adjusted population.

Table 4 presents the changes in the absolute numbers of physicians and physicians per 100 000 population in Groups 1 to 4 between 2000 and 2014. There were 100 SMAs in Group 1, 75 SMAs in Group 2, 99 SMAs in Group 3, and 75 SMAs in Group 4. The absolute numbers of physicians showed considerable increases in Groups 1 and 4, whereas the increases were smaller in the other two groups. In the raw population, all groups (including the rural areas) exhibited increases in the number of physicians per 100 000 population. In contrast, the number of physicians per 100 000 healthcare demand-adjusted population was observed to decrease in all groups except Group 4.

Discussion

We conducted a longitudinal examination of the geographic distribution of physicians in Japan that accounted for changes in age-dependent healthcare demand in accordance with the changing age structure of the Japanese population. Our study produced two major findings: First, the equity in physician geographic distribution for the demand-adjusted population had worsened throughout the study period when analysing the time-based trends of both Gini coefficient and the number of SMAs with a low physician supply. Second, the number of physicians per 100 000 healthcare demand-adjusted population decreased in all types of areas except for urban areas with a lower initial physician supply.

Although the number of physicians per population has been widely used as an indicator of physician supply, it does not account for intra-population variations in healthcare demand. Healthcare demand differs among the age strata because elderly people tend to utilize more health care. As Japan is undergoing unprecedented population ageing, changes in age structure and healthcare demand should be considered when examining the geographic distribution of physicians.

In fact, the changes in the number of physicians per raw population in each group were markedly different from the changes in the demand-adjusted population. The number of physicians per 100 000 raw population had seemingly increased in all types of areas, especially in the urban groups: there was an increase of 22.9% in Group 1 and 34.5% in Group 4. However, after adjusting healthcare demand, the number decreased by 1.3% in Group 1, and increased by 3.5% in Group 4; the number of physicians also decreased in the rural groups. The disparity in results indicates that it is necessary to adjust healthcare demand when analysing physician supply. Furthermore, this adjustment will become increasingly important in the future as the age structure of the Japanese population continues to change.

Despite the consistent nationwide increase in the absolute number of physicians, this increase was not accompanied by improved equity in physician distribution. It has been previously proposed that increasing the overall number of physicians may resolve uneven physician distribution as competitive forces play a major role in determining distribution patterns [19 20]. However, studies in Japan have reported that increases in overall physician numbers have not been able to improve the regional disparity in physician supply [4 9 21]. Similarly, our results indicate that this disparity has not been resolved in recent years. In fact, the problem appears to have worsened when physician supply was analysed in the healthcare demand-adjusted population. We surmise that equity in physician supply will continue to worsen without the prompt development and implementation of appropriate measures.

The number of SMAs with a low physician supply had appeared to decrease throughout the study period in the raw population, but adjusting for age-dependent healthcare demand revealed that these SMAs had actually increased. We posit that these conflicting results may be attributed to the higher increase rate of the demand-adjusted population relative to the increase rate of physicians. An earlier study found that physician supply had increased in SMAs with small populations due to the larger effects of reductions in population size [4]. However, our study was able to detect reductions in the number of physicians in SMAs with similarly small populations when healthcare demand was adjusted. Although population numbers have been decreasing in rural areas, their demand for health care is increasing due to the rising proportion of elderly persons.

Although physician supply had appeared to increase in Group 1 (urban SMAs with a higher initial physician supply), our study showed that the supply had actually decreased after healthcare demand was adjusted. This discovery is interesting in that it contradicts the convention that physician supply tends to increase in urban areas, and indicates that healthcare demand has rapidly increased in these regions. Many countries are experiencing population ageing; the OECD has reported an increase of 23.8% in elderly populations in urban areas from 2001 to 2011, whereas the increase was lower in rural areas at 18.2% [22]. It is therefore evident that physician shortages are not limited to rural areas, and should also be actively addressed as an urban issue. On the other hand, our study also found that physician supply had increased in Group 4 (urban SMAs with lower initial physician supply) after adjusting healthcare demand. Many SMAs in Group 4 are composed of suburban areas with large populations and relatively small numbers of physicians. Despite the increase in physician supply in Group 4, the number of physicians per 100 000 demand-adjusted population was almost half that of Group 1 in 2014.

Our findings are also important in the context of the study setting: Japan has gained worldwide attention as it addresses the challenges of a super-aged society [23]. Due to the lengthy training periods and declining birth rate in Japan, it will be difficult to quickly increase the number of physicians if needed. We therefore propose that there is a need for major reform of the healthcare delivery system that does not rely on increasing physician numbers. For example, possible measures include establishing and enhancing the roles of medical teams to improve physician productivity or promoting the utilization of information and communications technology, such as telemedicine.

Several studies have previously attempted to account for healthcare demand through the use of variables such as patient age, sex, and health status [11 12 24]. In this study, we elected to use health expenditure per capita as the adjustment coefficient to represent healthcare demand. This indicator was chosen based on the assumption that expenditure per capita is reflective of the general workload of healthcare providers across regions and provider types [12]. Japan's healthcare system is characterized by universal health coverage, and hospital reimbursements for medical services are uniform throughout the nation [25]. Hence, health expenditure provides a standardized indicator that reflects the vast majority of healthcare services provided (with the exception of cosmetic, advanced, or experimental care not covered under insurance), and generally indicates the same workload regardless of where patients receive healthcare services. Furthermore, we consider that medical health expenditure per capita more accurately reflects the degree of workload than medical consultation rates because the former accounts for variations in patient health status.

These findings should be interpreted in the context of several limitations. First, this was a retrospective study and, as such, does not provide estimates on future physician supply and healthcare demand. Next, the long-term generalizability of our adjustment coefficient may be susceptible to changes in population structure. However, our study showed that the coefficient remained essentially unchanged from 2000 to 2014, and it is not likely to undergo major changes in the near future. In addition, the coefficient itself cannot be applied to other countries, but the adjustment method may have applications outside of Japan.

Conclusions

The number of physicians per 100 000 raw population had seemingly increased in both urban and rural areas in Japan. After healthcare demand was adjusted, however, physician supply was observed to decrease in all types of areas except for urban areas with lower initial physician supply. In addition, physician distribution had consistently become less equitable in recent years. These results indicate the need for major reform of Japan's healthcare system.

List of abbreviations

SMA, secondary medical area

Footnotes

Acknowledgements

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Contributors

KH contributed to the study conception and design, data collection, analysis, interpretation, and drafting. TO and SK contributed to the data collection and the data management. YI contributed to the study design, data acquisition, and interpretation. All authors critically revised the article, and approved the final version.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

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Figure titles

Figure 1: Temporal changes in Gini coefficients of the number of physicians per 100 000 population in secondary medical areas

Figure 2: Temporal changes in the proportion of secondary medical areas with a low physician supply

Figure legend

Figure2: SMA, Secondary medical area

SMAs with a low physician supply were defined as those in the first quartile according to the number of physicians per 100 000 population in 2000; the y-axis shows the proportion of SMAs defined according to this criterion to all 349 SMAs.

Table 1: Adjustment coefficients of healthcare demand by age group based on health expenditure per capita

Age group	Expenditure per capita (US dollars*)	Adjustment coefficient
All Patients	1881.7	Reference
0–4 years	1532.5	0.81
5–9 years	629.2	0.33
10–14 years	505.8	0.27
15–19 years	411.7	0.22
20–24 years	423.3	0.22
25–29 years	556.7	0.30
30–34 years	661.7	0.35
35–39 years	725.0	0.39
40–44 years	825.8	0.44
45–49 years	1031.7	0.55
50–54 years	1329.2	0.71
55–59 years	1726.7	0.92
60–64 years	2260.8	1.20
65–69 years	2892.5	1.54
70–74 years	3821.7	2.03
75–79 years	4777.5	2.54
≥80 years	6266.0	3.33

* An exchange rate of US$1 = 120 Yen was used.

Table 2: Trends in the absolute number of physicians and population in Japan

Year	2000	2002	2004	2006	2008	2010	2012	2014
The number of physicians	243 201	249 574	256 668	263 540	271 897	280 431	288 850	296 845
	(100)	(102.6)	(105.5)	(108.4)	(111.8)	(115.3)	(118.8)	(122.1)
Raw population	126 071 305	126 478 672	126 824 166	127 055 025	127 066 178	127 057 860	126 659 683	126 434 634
	(100)	(100.3)	(100.6)	(100.8)	(100.8)	(100.8)	(100.5)	(100.3)
Demand-adjusted population*	102 426 743	106 236 098	110 121 313	113 627 296	117 265 790	120 684 904	123 445 680	125 991 667
	(100)	(103.7)	(107.5)	(110.9)	(114.5)	(117.8)	(120.5)	(123.0)

*Population numbers were rounded up to the nearest whole number.

The values in parentheses represent the proportional increases in numbers relative to the initial number in 2000, which was given a value of 100.

Table 3: Descriptive statistics of the secondary medical areas (n=349)

Year	2000					2014				
	Min	Median	Max	Mean	SD	Min	Median	Max	Mean	SD
Number of physicians	27.0	333.0	7527.0	696.9	967.2	27.0	374.0	9841.0	850.6	1237.4
Population										
Raw population	25 527.0	23 2582.0	2 471 100.0	361 235.8	366 575.6	21 204	215 770	2 551 482	362 276.9	390 804.1
Demand-adjusted population	28 133.4	200 105.6	2 023 140.0	293 486.4	277 230.4	27 965.9	227 926.4	2 467 691	361 007.6	362 612.6
Area (km^2)	41.9	261.0	3908.0	350.0	322.8	41.9	261.0	3908.0	350.0	322.8
Population density (per km^2)	51.4	757.6	15 609.5	1638.9	2468.8	46.9	703.6	16 582.0	1679.5	2685.8

SD, standard deviation

Table 4: Temporal changes in physician numbers for the four groups of secondary medical areas

Year	2000	2014	Increase rate (%)
Absolute number of physicians			
Group 1	153 602	188 842	22.9
Group 2	26 367	28 331	7.4
Group 3	17 260	17 823	3.3
Group 4	45 972	61 849	34.5
Physicians per 100 000 raw population			
Group 1	247.0	297.9	20.6
Group 2	194.2	225.6	16.2
Group 3	124.3	142.0	14.2
Group 4	126.2	163.0	29.1
Physicians per 100 000 demand-adjusted population			
Group 1	309.3	305.1	-1.3
Group 2	211.5	202.1	-4.4
Group 3	137.4	127.0	-7.6
Group 4	165.8	171.6	3.5

Group 1: urban areas with higher initial physician supply, Group 2: rural areas with higher initial physician supply,

Group 3: rural areas with lower initial physician supply, Group 4: urban areas with lower initial physician supply

Figure 1

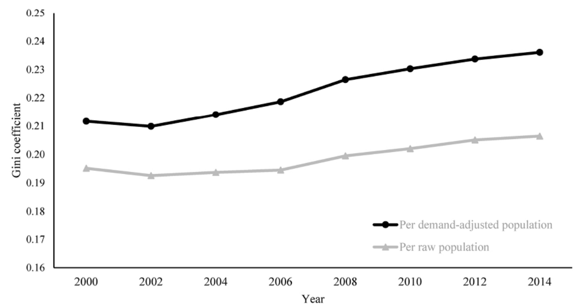

Figure 1: Temporal changes in Gini coefficients of the number of physicians per 100 000 population in secondary medical areas

209x148mm (300 x 300 DPI)

Figure 2

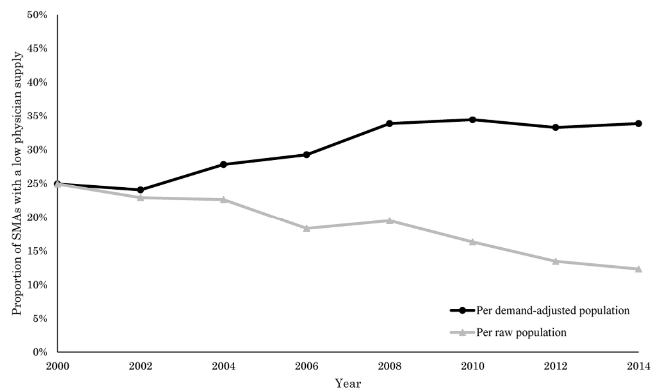

Figure 2: Temporal changes in the proportion of secondary medical areas with a low physician supply
Figure2: SMA, Secondary medical area
SMAs with a low physician supply were defined as those in the first quartile according to the number of physicians per 100 000 population in 2000; the y-axis shows the proportion of SMAs defined according to this criterion to all 349 SMAs.

209x148mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract -p2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found – p2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported -p3-4
Objectives	3	State specific objectives, including any prespecified hypotheses – p4
Methods		
Study design	4	Present key elements of study design early in the paper – p6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection –p4-5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants – p4-6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable – p5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group –p5-6
Bias	9	Describe any efforts to address potential sources of bias –not applicable
Study size	10	Explain how the study size was arrived at – p5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – p5-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding –not applicable
		(*b*) Describe any methods used to examine subgroups and interactions –p6-7
		(*c*) Explain how missing data were addressed –not applicable
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy –not applicable
		(*e*) Describe any sensitivity analyses –not applicable

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed –p7
		(b) Give reasons for non-participation at each stage –not applicable
		(c) Consider use of a flow diagram – no use
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders –not applicable
		(b) Indicate number of participants with missing data for each variable of interest –not applicable
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures –p7-8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included –not applicable
		(*b*) Report category boundaries when continuous variables were categorized –not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses –p8
Discussion		
Key results	18	Summarise key results with reference to study objectives – p8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias –p11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence –p8-11
Generalisability	21	Discuss the generalisability (external validity) of the study results –p10
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based –p12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Examining sufficiency and equity in the geographic distribution of physicians in Japan: a longitudinal study

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Keywords:	Japan, Physicians, geographic distribution, sufficiency, healthcare demand, equity

Examining sufficiency and equity in the geographic distribution of physicians in Japan: a longitudinal study

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Examining sufficiency and equity in the geographic distribution of physicians in Japan: a longitudinal study

Abstract

Objectives

The objective of this study was to longitudinally examine the geographic distribution of physicians in Japan with adjustment for healthcare demand according to changes in population age structure.

Methods

We examined trends in the number of physicians per 100 000 population in Japan's secondary medical areas (SMAs) from 2000 to 2014. Healthcare demand was adjusted using health expenditure per capita. Trends in Gini coefficient and the number of SMAs with a low physician supply were analysed. A sub-group analysis was also conducted where SMAs were divided into four groups according to urban-rural classification and initial physician supply.

Results

The time-based changes in both Gini coefficient and the number of SMAs with a low physician supply indicated that the equity in physician distribution had worsened throughout the study period. The number of physicians per 100 000 population had seemingly increased in all groups, with increases of 22.9% and 34.5% in urban groups with higher and lower initial physician supply, respectively. However, after adjusting healthcare demand, physician supply decreased by 1.3% in the former group and increased by 3.5% in the latter group. Decreases were also observed in the rural groups, where the number of physicians decreased by 4.4% in the group with higher initial physician supply and 7.6% in the group with lower initial physician supply.

Conclusions

Although the total number of physicians increased in Japan, demand-adjusted physician supply decreased in recent years in all areas except for urban areas with a lower initial physician supply. In addition, the equity of physician distribution had consistently deteriorated since 2000. The results indicate that failing to adjust healthcare demand will produce misleading results, and that there is a need for major reform of Japan's healthcare system to improve physician distribution.

Strengths and limitations of this study

- This study longitudinally examines the geographic distribution of physicians in Japan with adjustment for healthcare demand according to changes in population age structure.
- The use of medical health expenditure per capita for the adjustment of healthcare demand enabled a more accurate reflection of the degree of workload than medical consultation rates.
- The primary limitation of this study is that it was a retrospective study and, as such, does not provide estimates on future physician supply and healthcare demand.
- Although the adjustment methodology itself may have international applications, the adjustment coefficient values that we used must undergo further examination and modification before their application to other countries.

Keywords
Japan; physicians; geographic distribution; sufficiency; equity; healthcare demand

Introduction

The inequitable geographic distribution of physicians is a pressing issue in many countries [1-4]. There are at least two reasons why this issue attracts social and political attention. The first reason comes from the issue of equity and social justice, that is, a citizen's right to access healthcare equally. The other is rooted in the belief in linkages between physician availability and health status [5].

Studies that address this topic frequently use the number of physicians per population as an indicator of physician supply. However, this simple calculation may present an oversimplification of findings due to its reliance on simple head counts that ignore differences within a population [5]. In particular, healthcare demand is likely to differ substantially among the age strata as elderly people tend to require more health care. As many parts of the world are experiencing accelerated population ageing, it is becoming increasingly important to consider the differences in age-dependent healthcare demand when examining physician supply.

Population ageing has become a key policy issue throughout the world [6]. Japan currently has the highest proportion of people aged 65 years or older, and became one of the first "super-aged" societies when this proportion exceeded 21% in 2007 [7]. In addition, Japan's rate of population ageing is unprecedented: the proportion of people aged 65 years or older rose from 10% to 20% within 20 years. In contrast, the UK had almost 79 years and the US almost 59 years to adapt to this shift in population age structure. Furthermore, Japan's proportion of elderly people is predicted to rise to 33.4% in 2035 and 39.9% in 2060 [8], indicating that its population is still undergoing rapid changes.

In Japan, the issue concerning the number of physicians has shifted from a shortage to a surplus. Japan faced a shortage of physicians in the 1960s and 1970s [9]. During that period, the country experienced a massive increase in population from 94 million to 117 million people. The government at that time aimed to ensure a minimum of 150 physicians for every 100 000 people, and doubled medical school enrolments in the 1970s to bolster physician supply. The target number of physicians was achieved in 1984, but has since continued to increase. Due to the ageing and projected decrease of the Japanese population, the possible surplus of physicians is an issue that needs to be addressed. Although the government-sanctioned reduction of enrolments in medical schools has been proposed as a possible measure to control physician numbers, this measure is controversial and has been met with resistance from several interest groups [10]. Detailed and accurate information on physician supply that accounts for age-dependent healthcare demand is needed to support this decision-making process.

Although previous studies have examined trends in physician geographic distribution using healthcare demand-adjusted populations [11 12], there is currently no standardised method for adjusting healthcare demand. Furthermore, the trends in physician supply in a super-aged society such as Japan have yet to be investigated. In this study, we conducted a longitudinal examination of the geographic distribution of physicians with adjustment for healthcare demand according to the changing age structure of the Japanese population.

Methods

Data sources

The number of physicians was obtained from the National Physician Census, which is conducted biennially by Japan's Ministry of Health, Labour and Welfare (MHLW). The census data included the type and location (municipality) of workplace for each physician. Population data were collected from the National Basic Resident Register, which is published annually by the Ministry of Internal Affairs and

Communications. We collected data on national health expenditure per capita according to patient age in 2014 from the MHLW. Although national health expenditure includes various types of health care, we only used general treatment medical fees for our analysis because the other types of care were deemed to have little direct relevance to the number of physicians. Medical consultation rates were collected from the 2014 Patient Survey conducted by the MHLW. Population density was calculated by dividing the number of people residing in each secondary medical area (SMA, described below) by the area (km^2). The area of each region was obtained from statistical reports on land areas of prefectures and municipalities by the Geospatial Information Authority of Japan.

Physicians and population

Practicing physicians at all Japanese clinics and hospitals were included in analysis, whereas registered physicians working in non-clinician roles (e.g., basic researchers or government officials) were excluded. Physician densities were calculated for both the raw (unadjusted) population and the healthcare demand-adjusted population; the former included all Japanese citizens and the latter included all Japanese citizens adjusted for age-dependent healthcare demand. The population was stratified into 5-year age groups, with the initial group comprising persons aged 0 to 4 years and the final group comprising persons aged 80 years or older.

Secondary medical areas

The SMA was used as the geographic unit of analysis. The Japanese government has designated medical service administration areas throughout the country, and these areas are categorised into primary, secondary, and tertiary medical areas. Primary medical areas are set at the municipal level, and generally represent areas that are capable of providing basic primary care to residents. Tertiary medical areas are generally set at the prefectural level, and generally represent areas that are capable of providing the most advanced and specialised medical treatments. SMAs, which are between these two levels, supply and manage the majority of primary care and emergency medical services to regional communities. Therefore, SMAs are arguably the most important of the three geographic units with regard to implementing health policies. The geographic boundaries of the primary and tertiary medical areas are based on existing regional borders, whereas SMAs are demarcated by the prefectural governments based on healthcare provision capabilities. As a result, SMAs are directly relevant to the functional aspects of healthcare administration. Previous studies on physician geographic distribution in Japan have been conducted at the municipal level [9 13], although recent studies have also focused on SMAs [4 14 15]. SMA boundaries can be modified by prefectural governments in response to changing healthcare requirements. In this study, we analysed the 349 designated SMAs in 2012.

Analysis of physician distribution

First, we calculated the healthcare demand-adjusted population using adjustment coefficients that were derived according to the health expenditure per capita for each age group. The health expenditure for each age group was divided by the overall mean health expenditure of the population, and the obtained quotients were used as age group-specific adjustment coefficients. We then applied the adjustment coefficients to the raw population to obtain the healthcare demand-adjusted population. The numbers of physicians per 100 000 population in the SMAs were calculated for both the raw and demand-adjusted populations, and these values were used in the following analyses. In addition, we assessed the robustness of the adjustment coefficients by comparing them with alternative coefficients based on medical consultation rates instead of health expenditure, and also examined the annual changes in the adjustment coefficients by age group during the study period.

Next, we assessed the equity of the geographic distribution of physicians. The Gini coefficient was used as the indicator of equity, and has been widely used in similar analyses [2 4 16-18]. This coefficient measures the degree of departure from a uniform distribution known as the Lorenz curve, and takes a value between 0 (indicating perfect equality) and 1 (indicating perfect inequality). The Lorenz curve for the SMAs was plotted based on the number of physicians per 100 000 population.

We then examined the time-based trends in the number of SMAs with a low physician supply. SMAs were categorised into quartiles according to the number of physicians per 100 000 raw population or 100 000 healthcare demand-adjusted population in 2000, and the SMAs in the first quartiles were specified as having a low physician supply. We examined the changes in the proportions of SMAs that fulfilled this criterion throughout the study period.

Finally, we divided SMAs into four groups according to two criteria: whether they were rural or urban, and whether they had a lower or higher initial physician supply at the start of the study period. Using an approach described in an earlier study [14], the degree of urbanization was determined using the population density in 2000 as a proxy variable. We divided the SMAs according to the median value of the population density in 2000 to obtain two groups: SMAs with population densities above the median value were designated urban areas, whereas SMAs with population densities below the median value were designated rural areas. Similarly, the initial physician supply was calculated using the number of physicians per 100 000 population in 2000. We divided the SMAs according to the median values of the initial physician supply to obtain two groups: SMAs with initial physician densities above the median value were designated as having higher initial physician supply, whereas SMAs with initial physician densities below the median value were designated as having lower initial physician supply. Based on a combination of these two criteria, the SMAs were divided into four groups: Group 1 comprised urban SMAs with a higher initial physician supply, Group 2 comprised rural SMAs with a higher initial physician supply, Group 3 comprised rural areas with a lower initial physician supply, and Group 4 comprised urban areas with a lower initial physician supply. The changes in physician numbers were compared among these groups. All analyses were performed using R statistical software (version 3.2.2).

Results

As shown in Table 1, the adjustment coefficients for the age groups ranged from 0.22 (15–24 years) to 3.33 (80 years or older). The adjustment coefficient of the elderly population (65 years or older) was approximately four times that of the younger population (10–39 years). The results of robustness testing indicated that our adjustment coefficient was consistent with the results of the alternative coefficient based on medical consultation rates, with a high level of correlation (correlation coefficient: 0.99) between the primary adjustment coefficients and medical consultations rates by age group. Furthermore, our coefficient also appeared robust to time-based changes from 2000 to 2014 (data not shown).

Table 2 shows the temporal trends in the number of physicians and population from 2000 to 2014 at 2-year intervals. The number of physicians consistently increased by approximately 6000 to 8000 every two years, and was 1.22 times higher in 2014 than in 2000. The raw population generally remained unchanged throughout the study period. In contrast, the healthcare demand-adjusted population was 1.23 times higher in 2014 than it was in 2000. Hence, the increase rate of the demand-adjusted population slightly exceeded the increase rate of physicians.

Table 3 and Table 4 summarize the descriptive statistics for the 349 SMAs and the four groups, respectively. Table 3 shows that the mean number of physicians and demand-adjusted population had increased between 2000 and 2014. Figure 1 illustrates the temporal changes in Gini coefficient for the number of physicians per 100 000 population (both raw and demand-adjusted) at the SMA level, and indicates that the equity in physician numbers had worsened in both populations. In particular, equity had deteriorated more (higher Gini coefficient) in the healthcare demand-adjusted population.

Figure 2 shows the changes in the proportion of SMAs with a low physician supply across the study period. In the raw population, the proportion consistently decreased from 24.9% to 13.2% (with a brief increase between 2006 and 2008). In contrast, the same proportion in the healthcare demand-adjusted population consistently increased from 24.9% to 35.0% (with a brief decrease between 2000 and 2002); notably, there was a relatively large increase of 4.5% between 2006 and 2008 in the demand-adjusted population.

Table 5 presents the changes in the absolute numbers of physicians and physicians per 100 000 population in Groups 1 to 4 between 2000 and 2014. There were 100 SMAs in Group 1, 75 SMAs in Group 2, 99 SMAs in Group 3, and 75 SMAs in Group 4. The absolute numbers of physicians showed considerable increases in Groups 1 and 4, whereas the increases were smaller in the other two groups. In the raw population, all groups (including the rural areas) exhibited increases in the number of physicians per 100 000 population. In contrast, the number of physicians per 100 000 healthcare demand-adjusted population was observed to decrease in all groups except Group 4.

Discussion

We conducted a longitudinal examination of the geographic distribution of physicians in Japan that accounted for changes in age-dependent healthcare demand in accordance with the changing age structure of the Japanese population. Our study produced two major findings: First, the equity in physician geographic distribution for the demand-adjusted population had worsened throughout the study period when analysing the time-based trends of both Gini coefficient and the number of SMAs with a low physician supply. Second, the number of physicians per 100 000 healthcare demand-adjusted population decreased in all types of areas except for urban areas with a lower initial physician supply.

Although the number of physicians per population has been widely used as an indicator of physician supply, it does not account for intra-population variations in healthcare demand. Healthcare demand differs among the age strata because elderly people tend to utilize more health care. As Japan is undergoing unprecedented population ageing, changes in age structure and healthcare demand should be considered when examining the geographic distribution of physicians.

Notably, the changes in the number of physicians per raw population in each group were markedly different from the changes in the demand-adjusted population. The number of physicians per 100 000 raw population had seemingly increased in all types of areas, especially in the urban groups: there was an increase of 22.9% in Group 1 and 34.5% in Group 4. However, after adjusting healthcare demand, the number decreased by 1.3% in Group 1, and increased by 3.5% in Group 4. Furthermore, decreases were also observed in the rural groups, where the number decreased by 4.4% in Group 2 and by 7.6% in Group 3. The disparity in results indicates that it is necessary to adjust healthcare demand when analysing physician supply. Furthermore, this adjustment will become increasingly important in the future as the age structure of the Japanese population continues to change.

Despite the consistent nationwide increase in the absolute number of physicians, this was not accompanied by improved equity in physician distribution. It has been previously proposed that increasing the overall number of physicians may resolve uneven physician distribution as competitive forces play a major role in determining distribution patterns [19 20]. However, studies in Japan have reported that increases in overall physician numbers have not been able to improve the regional disparity in physician supply [4 9 21]. Similarly, our results indicate that this disparity has not been resolved in recent years. In fact, the problem appears to have worsened when physician supply was analysed in the healthcare demand-adjusted population. We surmise that equity in physician supply will continue to worsen without the prompt development and implementation of appropriate measures.

The number of SMAs with a low physician supply had appeared to decrease throughout the study period in the raw population, but adjusting for age-dependent healthcare demand revealed that these SMAs had actually increased. We posit that these conflicting results may be attributed to the higher increase rate of the demand-adjusted population relative to the increase rate of physicians. An earlier study found that physician supply had increased in SMAs with small populations due to the larger effects of reductions in population size [4]. However, our study was able to detect reductions in the number of physicians in SMAs with similarly small populations when healthcare demand was adjusted. Although population numbers have been decreasing in rural areas, their demand for health care is growing due to the rising proportion of elderly persons.

Although physician supply had appeared to increase in Group 1 (urban SMAs with a higher initial physician supply), our study showed that the supply had actually decreased after healthcare demand was adjusted. This discovery is interesting in that it contradicts the convention that physician supply tends to increase in urban areas, and indicates that healthcare demand has rapidly increased in these regions. Many countries are experiencing population ageing; the OECD has reported an increase of 23.8% in elderly populations in urban areas from 2001 to 2011, whereas the increase was lower in rural areas at 18.2% [22]. It is therefore evident that physician shortages are not limited to rural areas, and should also be actively addressed as an urban issue. On the other hand, our study also found that physician supply had increased in Group 4 (urban SMAs with lower initial physician supply) after adjusting healthcare demand. Many SMAs in Group 4 are composed of suburban areas with large populations and relatively small numbers of physicians. Despite the increase in physician supply in Group 4, the number of physicians per 100 000 demand-adjusted population was almost half that of Group 1 in 2014.

Our findings are also important in the context of the study setting: Japan has gained worldwide attention as it addresses the challenges of a super-aged society [23]. Although the adjustment methodology itself may have international applications, our results are not generalisable to other countries in their current form. Nevertheless, these results have substantial implications on the importance of demand adjustment on physician supply. Due to the lengthy physician training periods and declining birth rate in Japan, it will be difficult to quickly increase the number of physicians if needed. We therefore propose that there is a need for major reform of the healthcare delivery system that does not rely on increasing physician numbers. Possible measures include establishing and enhancing the roles of medical teams to improve physician productivity or promoting the utilization of information and communications technology, such as telemedicine.

Since 2007, the Japanese government has implemented several measures aimed at improving the geographic distribution and availability of physicians in rural areas. For example, all prefectures in Japan have established a regional medical support center tasked with resolving the inequities in physician geographic distribution and incentivizing the move of physicians to less urban areas. These centers usually provide banking services and career development support for young physicians working in areas with an insufficient physician supply. In addition, the government has expanded the "*Chiikiwaku"* system, which sets regional quotas for medical school students and grants scholarships with stipulations on future rural practice. These efforts are fairly recent, and their effects on physician supply remain unclear [24].

Several studies have previously attempted to account for healthcare demand through the use of variables such as patient age, sex, and health status [11 12 25]. In this study, we elected to use health expenditure per capita as the adjustment coefficient to represent healthcare demand. This indicator was chosen based on the assumption that expenditure per capita is reflective of the general workload of healthcare providers across regions and provider types [11]. The Nuffield Trust—a charitable trust in the UK that also predicts future health expenditure—has reported a relationship between healthcare demand and health expenditure [26]. In addition, Japan's healthcare system is characterised by universal health coverage, and hospital reimbursements for medical services are uniform throughout the nation [27]. Hence, health expenditure provides a standardised indicator that reflects the vast majority of healthcare services (with the exception of cosmetic, advanced, or experimental care not covered under insurance), and generally indicates the same workload regardless of where patients receive healthcare services. Furthermore, we consider that medical health expenditure per capita more accurately reflects the degree of workload than medical consultation rates because the former accounts for variations in patient health status.

These findings should be interpreted in the context of several limitations. First, this was a retrospective study and, as such, does not provide estimates on future physician supply and healthcare demand. Although future physician supply estimates are beyond the scope of this study, they should be addressed in future research. Second, it is possible that a small number of physicians who work in Japanese clinics and hospitals do not participate in the National Physician Census, which may introduce a degree of sampling bias. However, because all physicians in Japan are legally required to participate in the census, the number of non-participating physicians is likely to be too small to have a discernible effect on our results. Third, it is possible that individual health expenditure may not reflect the degree of physician workload. On the other hand, at a macro level, using health expenditure is better than medical consultation rates because the latter are unadjusted and therefore completely unweighted for physician workload. Fourth, SMAs may be divided into groups using various other criteria. In this study, we adopted a simple approach based on an earlier study[14], and were able to obtain distinctly different results among the groups. Fifth, the long-term generalizability of our adjustment coefficient may be susceptible to changes in population structure. However, our study showed that the coefficient remained essentially unchanged from 2000 to 2014, and it is not likely to undergo major changes in the near future. Finally, the adjustment coefficient in its current form cannot be applied to studies in other countries, but the adjustment method may have applications outside of Japan.

Conclusions

The number of physicians per 100 000 raw population had seemingly increased in both urban and rural areas in Japan. After healthcare demand was adjusted, however, physician supply was observed to decrease in all types of areas except for urban areas with lower initial physician supply. In addition, physician distribution had consistently become less equitable in recent years. These results indicate that failure to adjust healthcare demand will produce misleading results when examining physician supply, and that there is a need for major reform of Japan's healthcare system.

List of abbreviations

MHLW, Ministry of Health, Labour and Welfare

SMA, secondary medical area

Footnotes

Acknowledgements

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Contributors

KH contributed to the study conception and design, data collection, analysis, interpretation, and drafting the manuscript. TO and SK contributed to the data collection and data management. YI contributed to the study design, data acquisition, and interpretation. All authors critically revised the manuscript, and approved the final version.

Ethics approval

Ethics committee approval was waived for this study because all of the data are publicly available online and comprise only aggregate values without any personally identifiable information.

Consent for publication

Not applicable

Data sharing

No additional data

Reference

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Figure titles

Figure 1 Temporal changes in Gini coefficients of the number of physicians per 100 000 population in secondary medical areas

Figure 2 Temporal changes in the proportion of secondary medical areas with a low physician supply

Figure legend

Figure2

Secondary medical areas (SMAs) with a low physician supply were defined as those in the first quartile according to the number of physicians per 100 000 population in 2000; the y-axis shows the proportion of SMAs defined according to this criterion to all 349 SMAs.

Table 1 Adjustment coefficients of healthcare demand by age group based on health expenditure per capita

Age group	Expenditure per capita (US dollars*)	Adjustment coefficient
All Patients	1881.7	Reference
0–4 years	1532.5	0.81
5–9 years	629.2	0.33
10–14 years	505.8	0.27
15–19 years	411.7	0.22
20–24 years	423.3	0.22
25–29 years	556.7	0.30
30–34 years	661.7	0.35
35–39 years	725.0	0.39
40–44 years	825.8	0.44
45–49 years	1031.7	0.55
50–54 years	1329.2	0.71
55–59 years	1726.7	0.92
60–64 years	2260.8	1.20
65–69 years	2892.5	1.54
70–74 years	3821.7	2.03
75–79 years	4777.5	2.54
≥80 years	6266.0	3.33

* An exchange rate of US$1 = 120 Yen was used.

Table 2 Trends in the absolute number of physicians and population in Japan

Year	2000	2002	2004	2006	2008	2010	2012	2014
Number of physicians	243 201	249 574	256 668	263 540	271 897	280 431	288 850	296 845
	(100)	(102.6)	(105.5)	(108.4)	(111.8)	(115.3)	(118.8)	(122.1)
Raw population	126 071 305	126 478 672	126 824 166	127 055 025	127 066 178	127 057 860	126 659 683	126 434 634
	(100)	(100.3)	(100.6)	(100.8)	(100.8)	(100.8)	(100.5)	(100.3)
Demand-adjusted population*	102 426 743	106 236 098	110 121 313	113 627 296	117 265 790	120 684 904	123 445 680	125 991 667
	(100)	(103.7)	(107.5)	(110.9)	(114.5)	(117.8)	(120.5)	(123.0)

*Population numbers were rounded up to the nearest whole number.

The values in parentheses represent the proportional increases in numbers relative to the initial number in 2000, which was given a value of 100.

Table 3 Descriptive statistics of the secondary medical areas (n=349)

Year	2000					2014				
	Min	**Median**	**Max**	**Mean**	**SD**	**Min**	**Median**	**Max**	**Mean**	**SD**
Number of physicians	27.0	333.0	7527.0	696.9	967.2	27.0	374.0	9841.0	850.6	1237.4
Population										
Raw population	25 527.0	232 582.0	2 471 100.0	361 235.8	366 575.6	21 204	215 770	2 551 482	362 276.9	390 804.1
Demand-adjusted population	28 133.4	200 105.6	2 023 140.0	293 486.4	277 230.4	27 965.9	227 926.4	2 467 691	361 007.6	362 612.6
Area (km^2)	41.9	261.0	3908.0	350.0	322.8	41.9	261.0	3908.0	350.0	322.8
Population density (per km^2)	51.4	757.6	15 609.5	1638.9	2468.8	46.9	703.6	16 582.0	1679.5	2685.8

SD, standard deviation

Table 4 Descriptive statistics of the four groups of secondary medical areas in 2000

Urban / Rural	Urban		Rural	
Group	Group 1	Group 4	Group 2	Group 3
	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)
Number of physicians	1 536(1 409.7)	613(433.9)	351.6(293.3)	174.3(127.6)
Population				
Raw population	621 865.5(458 098.5)	485 630.2(341 335.1)	181 059.2(124 327.1)	140 232.9(100 955.2)
Demand-adjusted population	496 662.1(352 362.3)	369 774.9(244 619.1)	166 237.4(103 118.1)	126 864.8(85 236)
Area (km^2)	311.5(221.5)	242.1(140.5)	370.8(252.1)	454.8(485.6)
Population density (per km^2)	3 023.7(3 403.4)	2 567.2(2 502.6)	510.2(144.9)	391.9(184)

Group 1 and Group 2: Higher initial physician supply,

Group 3 and Group 4: Lower initial physician supply

Table 5 Temporal changes in physician numbers for the four groups of secondary medical areas

Year	2000	2014	Increase rate (%)
Absolute number of physicians			
Group 1	153 602	188 842	22.9
Group 2	26 367	28 331	7.4
Group 3	17 260	17 823	3.3
Group 4	45 972	61 849	34.5
Physicians per 100 000 raw population			
Group 1	247.0	297.9	20.6
Group 2	194.2	225.6	16.2
Group 3	124.3	142.0	14.2
Group 4	126.2	163.0	29.1
Physicians per 100 000 demand-adjusted population			
Group 1	309.3	305.1	-1.3
Group 2	211.5	202.1	-4.4
Group 3	137.4	127.0	-7.6
Group 4	165.8	171.6	3.5

Group 1: Urban areas with higher initial physician supply, Group 2: Rural areas with higher initial physician supply,

Group 3: Rural areas with lower initial physician supply, Group 4: Urban areas with lower initial physician supply

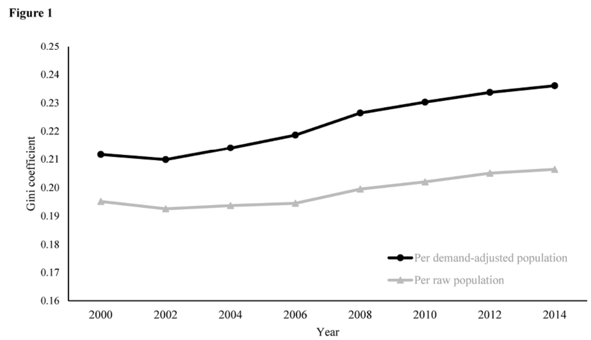

Figure 1 Temporal changes in Gini coefficients of the number of physicians per 100 000 population in secondary medical areas

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Figure 2

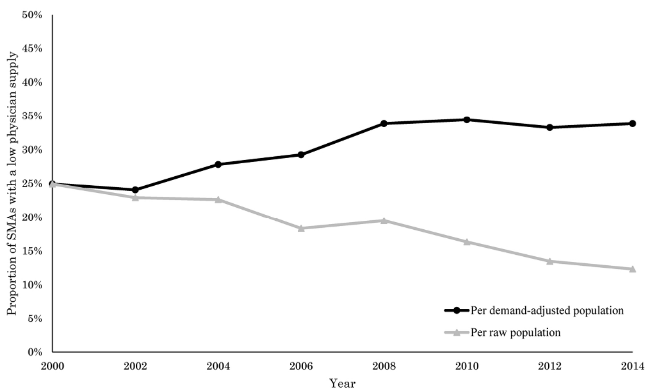

Figure 2 Temporal changes in the proportion of secondary medical areas with a low physician supply

209x148mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract -p2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found – p2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported -p3-4
Objectives	3	State specific objectives, including any prespecified hypotheses – p4
Methods		
Study design	4	Present key elements of study design early in the paper – p6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection –p4-5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants – p4-6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable – p5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group –p4-7
Bias	9	Describe any efforts to address potential sources of bias –p12
Study size	10	Explain how the study size was arrived at – p5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – p5-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding –not applicable
		(*b*) Describe any methods used to examine subgroups and interactions –p6-7
		(*c*) Explain how missing data were addressed –not applicable
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy –not applicable
		(*e*) Describe any sensitivity analyses –not applicable

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed –p7, Table 2,4
		(b) Give reasons for non-participation at each stage –not applicable
		(c) Consider use of a flow diagram – no use
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders –Table 3
		(b) Indicate number of participants with missing data for each variable of interest –not applicable
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures –p7-8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included –not applicable
		(*b*) Report category boundaries when continuous variables were categorized –not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses –p8
Discussion		
Key results	18	Summarise key results with reference to study objectives – p8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias –p11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence –p8-11
Generalisability	21	Discuss the generalisability (external validity) of the study results –p10
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based –p13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.