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Complete List of Authors:	Hara, Koji; Kyoto University, Department of Healthcare Economics and Quality Management Kunisawa, Susumu; Kyoto University, Department of Healthcare Economics and Quality Management Sasaki, Noriko; Kyoto University, Department of Healthcare Economics and Quality Management Imanaka, Yuichi; Kyoto University, Department of Healthcare Economics and Quality Management
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Failure to improve the inequitable geographic distribution of physicians in Japan: a specialty-specific longitudinal study

Authors:

Koji Hara MA, Susumu Kunisawa, PhD, Noriko Sasaki, PhD, and Yuichi Imanaka, PhD

Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku, Kyoto City, Kyoto, Japan 606-8501

Corresponding author:

Yuichi Imanaka, Professor

Mailing address: Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku, Kyoto City, Kyoto, Japan 606-8501

Tel: +81 75 753 4454

Fax: +81 75 753 4455

Email: imanaka-y@umin.net

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Abstract

Objectives

In this longitudinal study, we examine changes in the geographic distribution of physicians by clinical specialty in Japan with adjustments for healthcare demand based on population structure.

Methods

The Japanese population was adjusted for healthcare demand using health expenditure per capita stratified by age and sex. The numbers of physicians per 100 000 demand-adjusted population in 2000 and 2014 were calculated for sub-prefectural regions known as secondary medical areas. Disparities in the geographic distribution of physicians for each specialty were assessed using the Gini coefficient. A subgroup analysis was conducted by dividing the regions into four groups according to urban-rural classification and initial physician supply.

Results

Over the study period, the number of physicians per 100 000 demand-adjusted population decreased in all clinical specialties (e.g., surgery: 26·0% decrease) excluding pediatrics (33·3% increase) and anesthesiology (21·1% increase). No improvements in geographic disparity were observed in any of

the clinical specialties. In particular, geographic disparity worsened in internal medicine, surgery, and obstetrics and gynecology. Rural areas with lower initial physician supply had the lowest increase (or highest decrease) in physicians per 100 000 demand-adjusted population in all clinical specialties except pediatrics and anesthesiology. In contrast, urban areas with lower initial physician supply had the highest increase (or lowest decrease) in all clinical specialties.

Conclusion

The geographic distribution of physicians has failed to improve in any of the clinical specialties. There is also a growing disparity in physician supply between the urban and rural regions. Urgent measures are needed to reduce the geographic disparities in physician supply and regulate the uneven distribution among clinical specialties.

Article Summary

Strengths and limitations of this study

- This study aimed to longitudinally examine changes in the geographic distribution of physicians by clinical specialty in Japan with adjustments for healthcare demand according to population structure.
- The adjustment method used in this study had been previously verified, and enables adjustment for healthcare demand according to the age strata using health expenditure per capita.
- This study included not only the age strata but also sex in the calculation of the adjustment coefficients in order to increase the accuracy of adjustments.
- There was a lack of information on the physicians' working conditions, such as whether a physician worked full-time or part-time.
- It may be difficult to generalize our adjustment coefficients to other countries as they were calculated using Japanese health expenditure, but the adjustment method itself may have applications in other countries.

Introduction

The presence of inequities in the geographic distribution of physicians is a major social problem in many countries.[1-4] In Japan, the geographic disparity in physician supply has long been recognized as a serious flaw in the healthcare provision system.[5 6] The lack of regulations that dictate where individual physicians work in Japan has led to the concentration of physicians in urban regions and a shortfall in rural areas, thereby resulting in uneven access to health care throughout the country.[5 6] On the other hand, Japan has entered a period of population decline,[7] and an oversupply of physicians is imminent if their numbers continue to increase at current levels. Attempts to control the total number of physicians have been met with resistance from various interest groups.[8]

In addition to the geographic disparity in physician supply, an uneven distribution of physicians among the clinical specialties has also been reported in Japan.[9] Previous studies from the US have also shown that geographic distribution patterns vary according to clinical specialty.[10 11] In Japan, geographic disparities in the number of physicians in pediatrics, obstetrics and gynecology (OB/GYN), and anesthesiology have been documented.[12] However, few studies have longitudinally examined the geographic distribution of physicians according to clinical specialty.

Although the number of physicians per 100 000 population is generally used as an indicator when examining geographic disparities in physician supply, this measure involves a simple head count that does not account for the inherent variations in healthcare demand among the different age strata and sex.[4] Furthermore, Japan's population is aging at an unprecedented rate and has transformed into the world's first "super-aged" society (where more than 21% of a country's population is aged 65 years and older). As a consequence, the population structure in Japan is undergoing dramatic changes, which has invariably resulted in changes to healthcare demand. We have previously reported that Japan's healthcare demand increased by 22% from 2000 to 2014 amid worsening geographic disparity in physician supply.[13] However, studies have yet to be conducted on the disparity in Japan's physician supply according to the different clinical specialties while accounting for the differences in healthcare demand.

This study aimed to longitudinally examine changes in the geographic distribution of physicians by clinical specialty in Japan with adjustments for healthcare demand according to population structure.

Methods

Data source

Data on the number of physicians were obtained from Surveys of Physicians, Dentists, and Pharmacists conducted every two years by the Ministry of Health, Labour and Welfare (MHLW). Population data (age, sex, and location of residence) were extracted from the Annual Report of the National Basic Resident Registration System published by the Ministry of Internal Affairs and

Communications, and the number of births were obtained from the Annual Report of Vital Statistics published by the MHLW. We also acquired data on national health expenditure per capita according to patient age in 2013 from the MHLW. The total area of habitable land was ascertained from statistical reports on land areas of prefectures and municipalities by the Geospatial Information Authority of Japan.

Physicians and population

We targeted physicians working in medical facilities (hospitals and clinics), and excluded physicians working in non-clinical facilities (e.g., research centers and government offices). The following clinical specialties were included in analysis: internal medicine, surgery, orthopedics, OB/GYN, pediatrics, and anesthesiology.

In addition to the total population, we also analyzed population subgroups including the female population, pediatric population (<15 years of age), and the number of births. With the exception of the number of births, all study populations were adjusted for healthcare demand. We calculated the number of OB/GYN specialists per 100 000 female population and per 100 000 births, the number of pediatricians per 100 000 pediatric population, and the number of physicians per 100 000 population for each of the other clinical specialties.

Geographic unit

The geographic unit of analysis was the secondary medical area (SMA). There are three regional levels of healthcare provision designated in Japan. Primary medical areas are geographic units where primary care is provided, and are demarcated by municipal borders. Tertiary medical areas are geographic units that provide advanced medical care, and are demarcated by prefectural borders. SMAs are set between primary and tertiary medical areas, and are regions where general medical care (such as inpatient care) is provided; these areas are composed of multiple municipalities. Each prefectural government stipulates the geographic and demographic range of the SMAs within their prefecture. As a result, the boundaries of each SMA can be altered in response to changes in healthcare demand. SMAs have been previously used to examine the inequity in physician supply in Japan.[6 14] Because the number of SMAs varies slightly over time, our analyses were conducted using the 349 SMAs designated in 2012.

Analytical methods

This retrospective study longitudinally examined the changes in the geographic distribution of the number of physicians by clinical specialty among Japan's SMAs from 2000 to 2014. The population was first adjusted using adjustment coefficients of healthcare demand, which were calculated based on the health expenditure per capita stratified by age and sex through a previously described method.[13] Health expenditure per capita is indicative of the general workload of healthcare providers.[15] These expenditures include those for both inpatient and outpatient services, and account for variations in patient health status.[13] The demand-adjusted population was generated by multiplying the raw population with the adjustment coefficients.

Next, geographic disparity was assessed using the Gini coefficient, which is an indicator widely used to examine disparity in the field of economics and has also been applied to analyze geographic disparity in physician supply.[1 5 16-18] The coefficients, which take a value from 0 (indicating complete equality) to 1 (indicating complete inequality), measure departure from a uniform distribution by drawing Lorenz curves.[17] If the curves of two time points intersect, conclusions cannot be made as to whether or not the inequity of distribution is increasing.[18] Thus, we plotted two Lorenz curves (one each for 2000 and 2014) for each clinical specialty.

Finally, a subgroup analysis was conducted by dividing SMAs into groups according to two regional characteristics. Using the method described in Sasaki et al.,[19] we classified each SMA into one of four groups based on whether the SMA was an urban or rural area, and whether the SMA had a higher or lower initial physician supply in 2000. An SMA was designated an urban area (or a rural area) if its population density was higher (or lower) than the median value in all SMAs. The population density of each SMA was calculated using the total area of habitable land and the population in 2000. Next, an SMA was designated as having a higher (or lower) initial physician supply if the number of physicians per 100 000 population was higher (or lower) than the median number of physicians per 100 000 population in all SMAs. The following four groups were analyzed: Group 1, comprising urban areas with higher initial physician supply; Group 2, comprising rural areas with higher initial physician supply; Group 3, comprising rural areas with lower initial physician supply; and Group 4, comprising urban areas with lower initial physician supply. Data from 2000 were used for both the population and physicians. In this subanalysis, we compared the inter-group changes in the number of physicians per 100 000 population between 2000 and 2014.

All analyses were performed using R statistical software (V.3.2.2).

Results

Figure 1 shows the adjustment coefficients of healthcare demand for the different age strata and sex. These coefficients varied widely among the different categories. In male residents, healthcare demand was lowest (0·2) in those aged in their early twenties and highest (3·83) in those aged 80 years and older; this was more than a 19-fold difference between the two groups. In female residents, healthcare demand was lowest (0·2) in those aged in their late teens and highest (3·23) in those aged 80 years and older; this was more than a 16-fold difference between the two groups. The adjustment coefficients were applied to the raw population to produce the demand-adjusted population.

Table 1 shows the population sizes of the total population, female population, and pediatric population before and after applying the adjustment coefficients in 2000 and 2014. Before adjustment, the population did not substantially change throughout the study period. In contrast, the demand-adjusted total population increased by 23·7% between 2000 and 2014. The number of births, which was not adjusted for healthcare demand, decreased by 15·7%. The pediatric population declined by 11·1% over the study period before and after adjusting for healthcare demand.

Table 2 shows the overall numbers of physicians and the numbers of physicians per 100 000 population in 2000 and 2014. The overall number of all physicians increased by 22·1% over the study period. Similarly, the number of all physicians per 100 000 population increased by 21·7%. However, the number of all physicians per 100 000 demand-adjusted population decreased by 1·3%. Furthermore, the overall numbers of internists, orthopedists and OB/GYN specialists also increased, but the numbers of these specialists per 100 000 demand-adjusted population declined. The number of OB/GYN specialists per 100 000 births increased by 23·1%. The overall number of surgeons decreased by 8·7%, and the number of surgeons per 100 000 demand-adjusted population decreased by 26·6%. The overall number of anesthesiologists showed a large increase of 50·0%, and the number of anesthesiologists per 100 000 demand-adjusted population increased by 21·1%. The overall number of pediatricians increased by 18·4%, and the number of pediatricians per 100 000 demand-adjusted pediatric population increased by 33·3%.

Table 3 shows the trends in Gini coefficients for the number of physicians per 100 000

195 population in the SMAs by clinical specialty. There were no substantial changes in the Gini
196 coefficients for the numbers of orthopedists, pediatricians, and anesthesiologists per 100 000
197 demand-adjusted population. However, inequity had worsened in the geographic distribution of
198 internists, surgeons, and OB/GYN specialists (for both the female population and the number of
199 births). In these three specialties, the Lorenz curves in 2014 also demonstrated a tendency to
200 deteriorate more than the curves in 2000 without intersection between the two curves (figures not
201 shown). When comparing the Gini coefficients before and after adjusting for healthcare demand, the
202 trends in the coefficients were similar for each clinical specialty. However, the post-adjustment Gini
203 coefficients of all clinical specialties (except for pediatrics) were higher than their pre-adjustment
204 values.

205 Table 4 summarizes the numbers of physicians per 100 000 population in the four groups
206 of SMAs in the subanalysis. Detailed descriptive statistics of the four groups are provided in the
207 Appendix. Figure 2 shows the temporal increases (2000 to 2014) in the number of physicians by
208 clinical specialty in each group. The temporal increases in the number of internists and orthopedists
209 were similar to those for all physicians. The overall number of surgeons decreased in all groups
210 except for Group 4, and the number of surgeons per 100 000 demand-adjusted population decreased
211 by 20% to 30% in all groups. As shown in Table 4, the number of surgeons per 100 000
212 demand-adjusted population in Group 3 (11·9) was approximately half of the number in Group 1

(23·2) in 2014. In all groups, the number of OB/GYN specialists per 100 000 demand-adjusted female population decreased, but the number of OB/GYN specialists per 100 000 births increased. The number of pediatricians per 100 000 demand-adjusted pediatric population increased more in the rural SMAs than in the urban SMAs. The number of anesthesiologists per 100 000 demand-adjusted population increased in all groups; in particular, the number in Group 4 increased by more than twice that of the other groups. In all clinical specialties except pediatrics, Group 3 had the lowest increase (or the highest decrease) in the number of physicians per 100 000 demand-adjusted population. The 2014-2000 difference and ratio of the number of physicians per 100 000 demand-adjusted population between Groups 3 and 4 increased in all clinical specialties except pediatrics.

Discussion

The four major findings of this study are as follows: First, the demand-adjusted total population had increased by 23·7% between 2000 and 2014, whereas the demand-adjusted pediatric population had decreased by 11·1%. Second, the number of physicians per 100 000 demand-adjusted population decreased in all clinical specialties except pediatrics and anesthesiology. The largest increase (33·3%) was observed in pediatrics. Third, the geographic disparity in the number of physicians per 100 000 demand-adjusted population had not improved in all clinical specialties, and had in fact deteriorated in internal medicine, surgery, and OB/GYN. Fourth, the rural areas with lower initial physician supply had the lowest increase (or highest decrease) in the number of physicians per 100 000 demand-adjusted population compared with other areas in all clinical specialties except pediatrics and anesthesiology. In contrast, the urban areas with lower initial physician supply had the highest increase (or lowest decrease) in all clinical specialties.

The population used in this study was adjusted for healthcare demand among the different age strata and sex using a previously described method.[13] As seen in Figure 1, there were considerable variations in healthcare demand among the different age strata and sex. Although several papers have examined the demand-adjusted geographic disparity in physician supply,[15 20] there is currently no gold standard for the adjustment method.[20] The method used in this study had been previously verified,[13] and enables adjustment for healthcare demand according to the age strata. In addition, the inclusion of sex in the calculation of the coefficients may increase the accuracy of adjustments.

The number of physicians per 100 000 demand-adjusted population had decreased in internal medicine, surgery, orthopedics, and OB/GYN (per female population). The decline in physician supply was especially notable in surgery and OB/GYN, which corroborates previously reported downward trends in the numbers of physicians in these specialties.[12] The distribution among these specialties is affected by physician preference, experience, and environment. For example, the shortage of surgeons may be influenced by the long working hours, high risk of medical litigation, and low reward for surgical skill.[21] Previous research has also shown that an increase in female physicians has changed the distribution of specialties because they are more likely to choose OB/GYN and pediatrics instead of surgery.[22 23] In order to retain a high number of both female and male physicians, improvements must be made to the working environment, such as a reduction of physician working hours by assigning more duties and responsibilities to other non-physician health professionals.[21]

Our findings detected a decrease in the numbers of internists and orthopedists despite an increase in healthcare demand. On the other hand, the number of pediatricians per 100 000 demand-adjusted pediatric population and OB/GYN specialists per 100 000 births had greatly increased due to a decrease in the pediatrics population and the number of births. The rate of pediatric population decline is expected to eventually exceed the rate of total population decline.[24] It may therefore be more useful to properly allocate physicians instead of simply increasing their overall numbers.

Based on the temporal trends in Gini coefficients, there were no improvements to the geographic disparity in the number of physicians per 100 000 demand-adjusted population in all clinical specialties between 2000 and 2014. In particular, the inequity in physician supply had worsened in internal medicine, surgery, and OB/GYN. The inequity in surgery and OB/GYN may have been influenced by the decrease or lack of increase in the overall number of physicians in these specialties. These findings suggest that the uneven distribution of physicians among the clinical specialties may exacerbate geographic disparities in physician supply. On the other hand, the number of internists had increased at a rate that was comparable to the overall growth rate. The deterioration in geographic disparity may therefore be related to an increasing tendency toward physician specialization in Japan.[25] In fact, although the overall number of general internists had decreased from 74 539 to 61 317 over the study period, there was actually an increase from 21 006 to 48 780 physicians in internal subspecialties such as pulmonary, cardiovascular, and gastrointestinal medicine (data not shown). The geographic disparity in physician supply in these subspecialties is greater than the disparity in general internists.[9]

The rate of increase in the number of physicians per 100 000 demand-adjusted population in the urban areas was generally higher (or the rate of decrease was lower) than in the rural areas. In all clinical specialties except pediatrics, both the difference and ratio in the number of physicians per 100 000 demand-adjusted population between Group 3 and Group 4 in 2014 were larger than the corresponding values in 2000. This indicates that the disparity in physician supply between urban and rural areas had widened over the study period. Group 3 had the lowest initial physician supply, and these regions may be facing a serious physician shortage. This issue should be explored further, and there may be a need for major reforms to ensure adequate physician supply to rural areas. It may also be important to take the initiative in rural areas to improve physician productivity, reduce non-essential workload, and implement technology-based measures such as telemedicine.

Prior to 2004, the vast majority of medical graduates joined a medical specialty department (known as an *Ikyoku*) at their university that secures employment for the new graduates. *Ikyoku* generally dispatch physicians to other affiliated hospitals that are often located in rural areas. In this way, the *Ikyoku* were partly responsible for preventing a shortage of physicians in rural areas. After the implementation of a new post-graduate medical education program in 2004, fewer physicians joined an *Ikyoku*. As a consequence, the graduates, now able to choose their training hospital after graduation, were less likely to select a university hospital for training. Due to the decreasing number of member physicians, it became more difficult for the *Ikyoku* to dispatch physicians to affiliate hospitals.[14] Previous studies have also reported that the new program may have exacerbated the inequity in the geographic distribution of physicians.[14 26] Similarly, this new program may also have contributed to the lack of improvement in geographic disparity observed in this study.

The Japanese government has implemented several measures at the prefectural level aimed at improving the geographic disparities in physician supply. In 2006, a "Council for Regional Medicine" was established in each prefecture, and these councils include representatives of the prefectural and local governments, hospitals, medical associations, universities, and residents. The councils discuss detailed measures for securing medical staff with a variety of hospitals, including university hospitals and public hospitals. Furthermore, a "Support Center for Community Medicine" was established in each prefecture in 2011 to secure and retain physicians. These centers adopt the role of “control towers” to address the uneven distribution of physicians within each prefecture. Specifically, the centers are responsible for supporting career advancement for physicians working in rural areas, acting as general liaisons for engaging new physicians, and providing general work information. In addition, the government has raised the regional quota of medical school admissions from 64 students in 2005 to 1 617 students in 2016. The students are obligated to work in a rural area or a designated specialty (such as OB/GYN) for nine years after graduating in return for financial assistance for their studies.[27] As the program is relatively new, it remains unclear as to whether the increase in quotas will lead to improvements in the geographic disparity of physicians.

There are several limitations in this research. Firstly, the adjustment coefficients may continue to change in the future. However, the coefficients did not change considerably during the study period. In addition, it may be difficult to generalize our adjustment coefficients to other countries as they were calculated using Japanese health expenditure. On the other hand, the adjustment method itself may have applications in other countries. Secondly, there was a lack of information on the physicians' working conditions, such as whether a physician worked full-time or part-time. It may be beneficial for future studies to incorporate mean physician working hours. Finally, there may be other ways to divide the SMAs for the subgroup analysis. However, our subgroup analysis was based on the categorization used in a previous study,[19] and provided an intuitive understanding of the differences in group characteristics.

Conclusion

The geographic distribution of physicians in Japan has failed to improve in any of the clinical specialties. There is also a growing disparity in physician supply between the urban and rural areas. In consideration of the rapidly aging population and the resulting changes in population structure, urgent measures are needed to reduce the geographic disparities in physician supply and regulate the uneven distribution among clinical specialties.

List of abbreviations

OB/GYN, obstetrics and gynecology

MHLW, Ministry of Health, Labour and Welfare

SMA, secondary medical area

Footnotes

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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. SK and NS 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.

Role of the funding source

The funder of the study had no role in study design; collection, analysis, and interpretation of the data; writing of the report; or the decision to submit the paper for publication. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Data Sharing Statement

No additional data available.

Consent for publication

Not applicable.

1. Isabel C, Paula V. Geographic distribution of physicians in Portugal. *European Journal of*

Health Economics 2010;11(4):383-93. doi: 10.1007/s10198-009-0208-8

2. Kanchanachitra C, Lindelow M, Johnston T, et al. Human resources for health in southeast Asia: shortages, distributional challenges, and international trade in health services. *Lancet* 2011;377(9767):769-81. doi: 10.1016/s0140-6736(10)62035-1 [published Online First: 2011/01/29]

3. Ricketts TC. The migration of physicians and the local supply of practitioners: a five-year comparison. *Acad Med* 2013;88(12):1913-8. doi: 10.1097/acm.0000000000000012 [published Online First: 2013/10/17]

4. Pitblado JR, and Raymond W. Pong. Geographic distribution of physicians in Canada. Sudbury, Ontario, Canada: Centre for Rural and Northern Health Research, Laurentian University 1999.

5. Kobayashi Y, Takaki H. Geographic distribution of physicians in Japan. *Lancet* 1992;340(8832):1391-3. [published Online First: 1992/12/05]

6. Tanihara S, Kobayashi Y, Une H, et al. Urbanization and physician maldistribution: a longitudinal study in Japan. *BMC Health Serv Res* 2011;11:260. doi: 10.1186/1472-6963-11-260 [published Online First: 2011/10/11]

7. National Institute of Population and Social Security Research. population projection for Japan:2011-2060 2012 [Available from:

http://www.ipss.go.jp/syoushika/tohkei/newest04/gh2401.pdf accessed 29 Feb 2016.

8. Asano N, Kobayashi Y, Kano K. Issues of intervention aimed at preventing prospective surplus of physicians in Japan. *Med Educ* 2001;35(5):488-94. [published Online First: 2001/05/01]

9. Matsumoto M, Inoue K, Bowman R, et al. Self-employment, specialty choice, and geographical distribution of physicians in Japan: A comparison with the United States. *Health Policy* 2010;96(3):239-44. doi: 10.1016/j.healthpol.2010.02.008 [published Online First: 2010/03/13]

10. Rosenthal MB, Zaslavsky A, Newhouse JP. The geographic distribution of physicians revisited. *Health Serv Res* 2005;40(6 Pt 1):1931-52. doi: 10.1111/j.1475-6773.2005.00440.x [published Online First: 2005/12/13]

11. Schwartz WB, Newhouse JP, Bennett BW, et al. The changing geographic distribution of board-certified physicians. *N Engl J Med* 1980;303(18):1032-8. doi: 10.1056/nejm198010303031803 [published Online First: 1980/10/30]

12. Study group on the supply and demand of physicians of the Ministry of Health LaW. The study group report on the supply and demand of physicians 2006 [Available from: http://www.mhlw.go.jp/shingi/2006/07/dl/s0728-9c.pdf accessed 16 Apr 2017.

13. Hara K, Otsubo T, Kunisawa S, et al. Examining sufficiency and equity in the geographic

distribution of physicians in Japan: a longitudinal study. *BMJ Open* 2017;7(3):e013922. doi: 10.1136/bmjopen-2016-013922 [published Online First: 2017/03/16]

14. Sakai R, Tamura H, Goto R, et al. Evaluating the effect of Japan's 2004 postgraduate training programme on the spatial distribution of physicians. *Hum Resour Health* 2015;13:5. doi: 10.1186/1478-4491-13-5 [published Online First: 2015/01/27]

15. Gravelle H, Sutton M. Inequality in the geographical distribution of general practitioners in England and Wales 1974-1995. *J Health Serv Res Policy* 2001;6(1):6-13. [published Online First: 2001/02/24]

16. Anand S, Fan VY, Zhang J, et al. China's human resources for health: quantity, quality, and distribution. *Lancet* 2008;372(9651):1774-81. doi: 10.1016/s0140-6736(08)61363-x [published Online First: 2008/10/22]

17. Mauguen A, Begg CB. Using the Lorenz Curve to Characterize Risk Predictiveness and Etiologic Heterogeneity. *Epidemiology* 2016;27(4):531-7. doi: 10.1097/ede.0000000000000499 [published Online First: 2016/04/21]

18. Theodorakis PN, Mantzavinis GD, Rrumbullaku L, et al. Measuring health inequalities in Albania: a focus on the distribution of general practitioners. *Hum Resour Health* 2006;4:5. doi: 10.1186/1478-4491-4-5 [published Online First: 2006/03/01]

19. Sasaki H, Otsubo T, Imanaka Y. Widening disparity in the geographic distribution of pediatricians in Japan. *Hum Resour Health* 2013;11:59. doi: 10.1186/1478-4491-11-59 [published Online First: 2013/11/26]

20. Kephart G, Asada Y. Need-based resource allocation: different need indicators, different results? *BMC Health Serv Res* 2009;9:122. doi: 10.1186/1472-6963-9-122 [published Online First: 2009/07/23]

21. Hanazaki K, Tominaga R, Nio M, et al. Report from the Committee for Improving the Work Environment of Japanese Surgeons: survey on effects of the fee revision for medical services provided by surgeons. *Surg Today* 2013;43(11):1209-18. doi: 10.1007/s00595-013-0691-5 [published Online First: 2013/09/06]

22. Fukuda Y, Harada T. Gender differences in specialty preference and mismatch with real needs in Japanese medical students. *BMC Med Educ* 2010;10:15. doi: 10.1186/1472-6920-10-15 [published Online First: 2010/02/13]

23. Jefferson L, Bloor K, Maynard A. Women in medicine: historical perspectives and recent trends. *Br Med Bull* 2015;114(1):5-15. doi: 10.1093/bmb/ldv007 [published Online First: 2015/03/11]

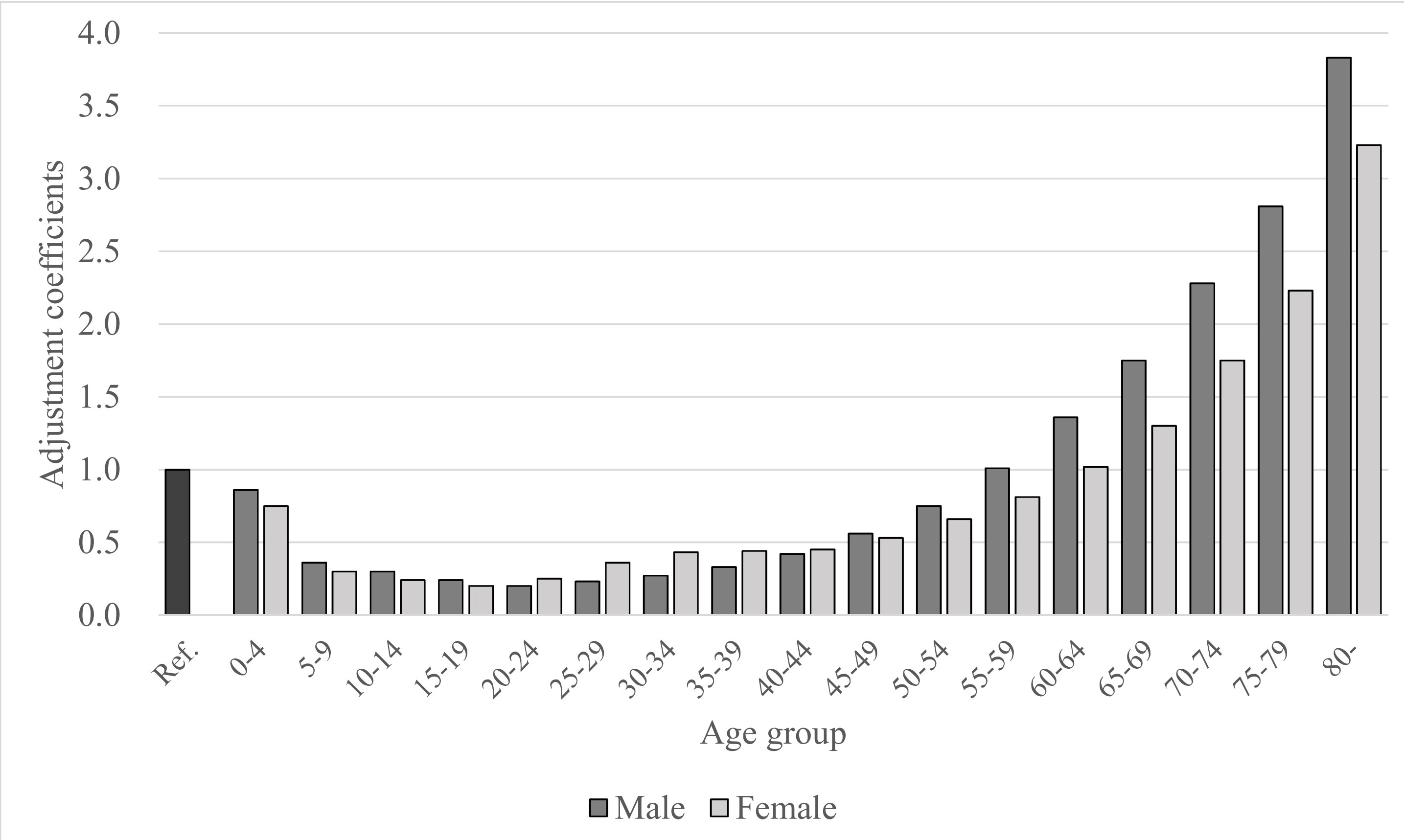
24. National Institute of Population and Social Security Research in Japan. Population Projections for Japan (April 2017) 2017 [cited 2017 Apr 14].

25. Koike S, Matsumoto S, Kodama T, et al. Specialty choice and physicians' career paths in Japan: an analysis of National Physician Survey data from 1996 to 2006. *Health Policy* 2010;98(2-3):236-44. doi: 10.1016/j.healthpol.2010.06.021 [published Online First: 2010/07/29]

26. Toyabe S. Trend in geographic distribution of physicians in Japan. *Int J Equity Health* 2009;8:5. doi: 10.1186/1475-9276-8-5 [published Online First: 2009/03/05]

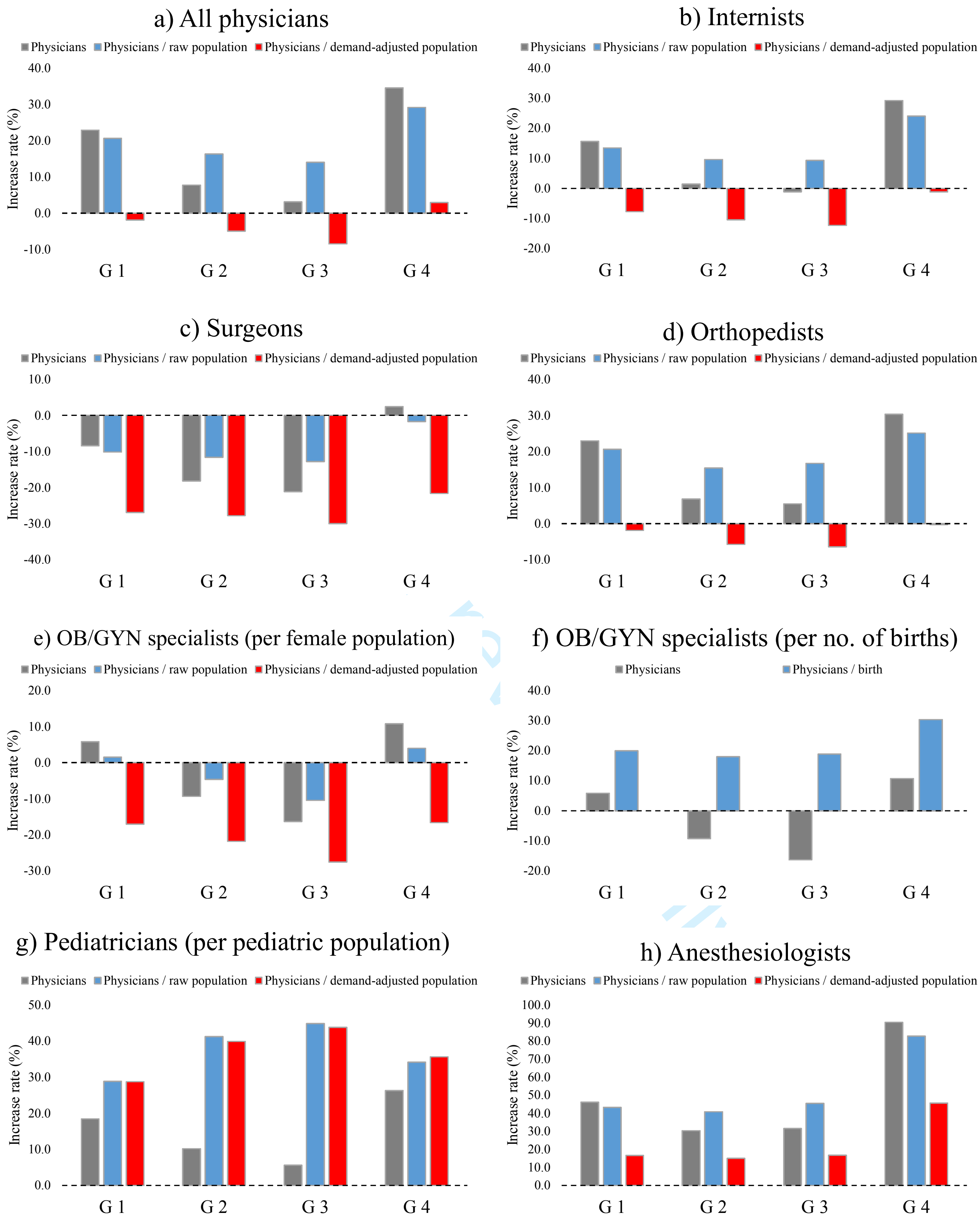
27. Matsumoto M, Takeuchi K, Tanaka J, et al. Follow-up study of the regional quota system of Japanese medical schools and prefecture scholarship programmes: a study protocol. *BMJ Open* 2016;6(4):e011165. doi: 10.1136/bmjopen-2016-011165 [published Online First: 2016/04/17]

Figure 1 Adjustment coefficients of healthcare demand by age strata and sex



Ref.: reference value, which is the mean health expenditure per capita of all patients.

Figure 2 Temporal increases in physician numbers from 2000 to 2014 for the four groups of secondary medical areas



Group 1 (G1): urban areas with higher initial physician supply; Group 2 (G2): rural areas with higher initial physician supply; Group 3 (G3): rural areas with lower initial physician supply; Group 4 (G4): urban areas with lower initial physician supply. * As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown. OB/GYN: obstetrics/gynecology

Table 1 Population sizes in 2000 and 2014 before and after adjustment for healthcare demand

Year	Before adjustment				After adjustment		
	Total population	Female population	Pediatric population [*1]	Number of births [*2]	Total population	Female population	Pediatric population [*1]
2000	126 071 305	55 196 259	18 553 275	1 190 164	101 697 295	48 349 047	8 546 612
2014	126 434 634	56 670 449	16 489 385	1 003 474	125 837 379	60 902 189	7 594 643
Increase in number (%)	363 329 (0·3%)	1 474 190 (2·7%)	-2 063 890 (-11·1%)	-186 690(-15·7%)	24 140 085 (23·7%)	12 553 142 (26·0%)	-951 969 (-11·1%)

Healthcare demand was adjusted by multiplying the raw population with adjustment coefficients that were calculated using health expenditure per capita stratified by age and sex.

[*1] Pediatric population: all residents aged below 15 years.

[*2] The number of births was not adjusted for healthcare demand.

Table 2 Overall numbers of physicians and numbers of physicians per 100 000 population in 2000 and 2014

Year	Specialty							
	All physicians	Internists	Surgeons	Orthopedists	OB/GYN specialists		Pediatricians	Anesthesiologists
Overall number of physicians								
2000	243 201	95 545	25 424	19 225	12 420		14 156	5 751
2014	296 845	110 097	23 223	23 297	12 888		16 758	8 625
Increase in number (%)	53 644 (22·1%)	14 552 (15·2%)	-2 201 (-8·7%)	4 072 (21·2%)	468 (3·8%)		2 602 (18·4%)	2 874 (50·0%)
Number of physicians per 100 000 population								
Population type	Total	Total	Total	Total	Female	Number of births [*1]	Pediatric [*2]	Total
2000	192·9	75·8	20·2	15·2	22·5	1 043·6	76·3	4·6
2014	234·8	87·1	18·4	18·4	22·7	1 284·3	101·6	6·8
Increase in number (%)	41·9 (21·7%)	11·3 (14·9%)	-1·8 (-8·9%)	3·2 (21·1%)	0·2 (0·9%)	240·7 (23·1%)	25·3 (33·2%)	2·2 (47·8%)
Number of physicians per 100 000 demand-adjusted population								
Population type	Total	Total	Total	Total	Female	Number of births [*1]	Pediatric [*2]	Total
2000	239·1	94·0	25·0	18·9	25·7	N/A	165·6	5·7
2014	235·9	87·5	18·5	18·5	21·2	N/A	220·7	6·9
Increase in number (%)	-3·2 (-1·3%)	-6·5 (-6·9%)	-6·5 (-26·0%)	-0·4 (-2·1%)	-4·5 (-17·5%)	N/A	55·1 (33·3%)	1·2 (21·1%)

[*1] As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

[*2] Pediatric population: all residents aged below 15 years.

OB/GYN: obstetrics/gynecology

Table 3 Trends in Gini coefficients for the number of physicians per 100 000 population in secondary medical areas by clinical specialty

Year	2000	2002	2004	2006	2008	2010	2012	2014	2000-2014 changes
Number of physicians per 100 000 population									
All physicians	0·195	0·193	0·194	0·194	0·199	0·202	0·205	0·206	0·011
Internists	0·183	0·179	0·177	0·175	0·177	0·179	0·183	0·181	-0·002
Surgeons	0·204	0·202	0·197	0·190	0·194	0·206	0·210	0·209	0·005
Orthopedists	0·202	0·201	0·196	0·191	0·195	0·193	0·192	0·196	-0·006
OB/GYN specialists (per female population)	0·226	0·218	0·226	0·240	0·260	0·263	0·266	0·270	0·043
OB/GYN specialists (per number of births) *	0·231	0·220	0·227	0·225	0·243	0·243	0·248	0·250	0·019
Pediatricians (per pediatric population)	0·248	0·244	0·239	0·243	0·246	0·244	0·247	0·246	-0·003
Anesthesiologists	0·445	0·435	0·438	0·433	0·434	0·428	0·432	0·429	-0·016
Number of physicians per 100 000 demand-adjusted population									
All physicians	0·212	0·210	0·214	0·219	0·227	0·231	0·234	0·237	0·025
Internists	0·186	0·182	0·185	0·184	0·191	0·194	0·199	0·199	0·013
Surgeons	0·204	0·202	0·198	0·189	0·199	0·213	0·218	0·219	0·015
Orthopedists	0·215	0·212	0·208	0·204	0·211	0·211	0·210	0·213	-0·002
OB/GYN specialists (per female population)	0·254	0·247	0·255	0·272	0·292	0·296	0·299	0·303	0·049
Pediatricians (per pediatric population)	0·244	0·240	0·235	0·240	0·243	0·240	0·243	0·242	-0·002
Anesthesiologists	0·456	0·447	0·451	0·448	0·449	0·445	0·450	0·447	-0·009

* As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

OB/GYN: obstetrics/gynecology

Table 4 Descriptive statistics of the number of physicians per 100 000 population in the four groups of secondary medical areas in 2000 and 2014

	Before adjustment		After adjustment	
	2000	2014	2000	2014
Total number of physicians per 100 000 population				
Group 1	247·0	297·9	311·6	305·7
Group 2	194·8	226·6	213·9	203·3
Group 3	124·6	142·1	138·9	127·0
Group 4	126·3	163·1	166·9	171·9
Number of internists per 100 000 population				
Group 1	95·2	108·0	120·1	110·8
Group 2	79·8	87·5	87·6	78·5
Group 3	54·0	59·1	60·2	52·8
Group 4	49·6	61·4	65·5	64·7
Number of surgeons per 100 000 population				
Group 1	25·2	22·6	31·8	23·2
Group 2	21·8	19·3	24·0	17·3
Group 3	15·3	13·3	17·1	11·9
Group 4	12·9	12·7	17·0	13·3
Number of orthopedists per 100 000 population				
Group 1	18·6	22·4	23·5	23·0
Group 2	16·6	19·2	18·2	17·2
Group 3	10·8	12·6	12·0	11·2
Group 4	10·7	13·4	14·2	14·2
Number of OB/GYN specialists per 100 000 female population				
Group 1	28·4	28·9	33·2	27·5
Group 2	20·2	19·3	20·3	15·8
Group 3	13·9	12·4	14·1	10·2
Group 4	16·3	17·0	20·0	16·7
Number of OB/GYN specialists per 100 000 births *				
Group 1	1316·5	1578·9	N/A	N/A
Group 2	1051·3	1240·3	N/A	N/A
Group 3	714·9	849·8	N/A	N/A
Group 4	702·1	914·7	N/A	N/A
Number of pediatricians per 100 000 pediatric population				

Group 1	49·0	63·1	211·5	272·3
Group 2	35·5	50·2	158·0	221·0
Group 3	22·6	32·7	100·7	144·8
Group 4	27·3	36·7	117·6	159·4
Number of anesthesiologists per 100 000 population				
Group 1	6·6	9·4	8·3	9·7
Group 2	4·4	6·1	4·8	5·5
Group 3	1·9	2·8	2·1	2·5
Group 4	2·2	4·1	2·9	4·3

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.

* As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

N/A: not applicable; OB/GYN: obstetrics/gynecology

Appendix table. 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				
Total physicians	1 536·0(1 409·7)	619·2(433·5)	352·0(295·3)	175·5(127·2)
Internists	592·0(566·4)	242·9(165·3)	144·3(105·2)	76·1(52·0)
Surgeons	156·5(142·1)	63·1(42·2)	39·5(28·4)	21·6(14·2)
Orthopedists	115·8(94·4)	52·6(36·4)	30·0(25·9)	15·2(12·2)
OB/GYN specialists	78·1(71·8)	34·1(26·3)	16·4(15·6)	8·6(6·5)
Pediatricians	88·0(71·9)	40·3(31)	19·1(19·8)	9·6(7·8)
Anesthesiologists	40·9(40·1)	10·9(9·8)	7·9(9·8)	2·7(3·2)
Raw population				
Total population	621 865·5(458 098·5)	490 244·5(341 301·8)	180 718·5(125 140·5)	140 925·7(100 156·8)
Female population	274 615·3(203 154·4)	209 062·4(144 107·6)	81 044·7(54 965·4)	62 047·6(43 331·9)
Pediatric population	89 778·6(62 866·3)	73 620·8(48 171·0)	26 837·6(19 441·3)	21 202·8(15 429·6)
Number of births *	41 599·4(29 459·0)	34 246·1(22 935·5)	12 070·9(8 837·2)	9 497·2(6 971·3)
Demand-adjusted population				
Total population	492 971·0(349 667·3)	370 991·2(242 817·0)	164 585·9(103 001·3)	126 410·8(84 059·2)
Female population	235 594·4(166 553·3)	170 624·5(109 441·9)	80 861·9(49 177·2)	61 184·3(39 965·6)
Pediatric population	41 599·4(29 459·0)	34 246·1(22 935·5)	12 070·9(8 837·2)	9 497·2(6 971·3)

Area (km^2)	311·5(221·5)	242·8(141·4)	360·9(238·5)	458·6(485·8)
Population density (per km^2)	3 023·7(3 403·4)	2 591·6(2 510·6)	514·5(140·9)	393·5(186·9)

Group 1 and Group 2: Higher initial physician supply, Group 3 and Group 4: Lower initial physician supply.

[*] The number of births was not adjusted for healthcare demand.

OB/GYN: obstetrics/gynecology; SD: standard deviation

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Examining changes in the equity of physician distribution in Japan: a specialty-specific longitudinal study

Authors:

Koji Hara MA, Susumu Kunisawa, PhD, Noriko Sasaki, PhD, and Yuichi Imanaka, PhD

Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku, Kyoto City, Kyoto, Japan 606-8501

Corresponding author:

Yuichi Imanaka, Professor

Mailing address: Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku, Kyoto City, Kyoto, Japan 606-8501

Tel: +81 75 753 4454

Fax: +81 75 753 4455

Email: imanaka-y@umin.net

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Examining changes in the equity of physician distribution in Japan: a specialty-specific longitudinal study

Abstract

Objectives

In this longitudinal study, we examined changes in the geographic distribution of physicians in Japan from 2000 to 2014 by clinical specialty with adjustments for healthcare demand based on population structure.

Methods

The Japanese population was adjusted for healthcare demand using health expenditure per capita stratified by age and sex. The numbers of physicians per 100 000 demand-adjusted population in 2000 and 2014 were calculated for sub-prefectural regions known as secondary medical areas. Disparities in the geographic distribution of physicians for each specialty were assessed using Gini coefficients. A subgroup analysis was conducted by dividing the regions into four groups according to urban-rural classification and initial physician supply.

Results

Over the study period, the number of physicians per 100 000 demand-adjusted population decreased in all clinical specialties (e.g., surgery: 26·0% decrease) except pediatrics (33·3% increase) and

anesthesiology (21·1% increase). No reductions in geographic disparity were observed in any of the clinical specialties. Geographic disparity increased substantially in internal medicine, surgery, and obstetrics and gynecology. Rural areas with lower initial physician supply experienced the highest decreases in physicians per 100 000 demand-adjusted population for all clinical specialties except pediatrics and anesthesiology. In contrast, urban areas with lower initial physician supply experienced the lowest decreases in physicians per 100 000 demand-adjusted population in internal medicine, surgery, orthopedics, and obstetrics and gynecology, but the highest increase in anesthesiology.

Conclusion

Between 2000 and 2014, the number of physicians per 100 000 demand-adjusted population in Japan decreased in all specialties except pediatrics and anesthesiology. There is also a growing urban-rural disparity in physician supply in all specialties except pediatrics. Additional measures may be needed to resolve these issues and improve physician distribution in Japan.

Article Summary

Strengths and limitations of this study

- This study longitudinally examined specialty-specific changes in the geographic distribution of Japanese physicians with adjustments for healthcare demand according to population structure.
- The adjustment method used in this study was previously verified, and enables adjustment for healthcare demand according to age strata using health expenditure per capita.
- Both age and sex were included in the calculation of the adjustment coefficients to increase the accuracy of adjustments.
- There was a lack of information on the physicians' working conditions, such as whether a physician worked full-time or part-time.
- It may be difficult to generalize our adjustment coefficients to other countries as they were calculated using Japanese health expenditure, but the adjustment method itself may have applications in other countries.

Introduction

The presence of inequities in the geographic distribution of physicians is a major social problem in many countries.[1-4] In Japan, the geographic disparity in physician supply has long been recognized as a serious flaw in the healthcare provision system.[5 6] The lack of regulations that dictate where individual physicians work in Japan has led to the concentration of physicians in urban regions and a shortfall in rural areas, thereby resulting in uneven access to health care throughout the country.[5 6] On the other hand, Japan has entered a period of population decline,[7] and an oversupply of physicians is imminent if their numbers continue to rise at current rates. Attempts to control the total number of physicians have been met with resistance from various interest groups.[8]

In addition to the geographic disparity in physician supply, Japan also faces issues stemming from an uneven distribution of physicians among the clinical specialties.[9] Previous studies from the US have reported that the geographic distribution of physicians varies according to clinical specialty.[10 11] Similarly, geographic disparities in the number of physicians in pediatrics, obstetrics and gynecology (OB/GYN), and anesthesiology have been documented in Japan.[12] However, few studies have longitudinally examined the geographic distribution of physicians according to clinical specialty.

Although the number of physicians per 100 000 population is generally used as an indicator when examining geographic disparities in physician supply, this measure involves a simple head count that does not account for the inherent variations in healthcare demand among the different age strata and sex.[4] Furthermore, Japan's population is aging at an unprecedented rate, which has resulted in its transformation into the world's first "super-aged" society (where more than 21% of a country's population is aged 65 years and older). As a consequence, the population structure in Japan is undergoing dramatic changes, which has invariably led to changes to healthcare demand. We previously reported that Japan's healthcare demand increased by 22% from 2000 to 2014 amid worsening geographic disparity in physician supply.[13] However, studies have yet to be conducted on the disparity in Japan's physician supply for different clinical specialties while accounting for the differences in healthcare demand.

This study aimed to longitudinally examine specialty-specific changes in the geographic distribution of physicians in Japan from 2000 to 2014 with adjustments for healthcare demand based on population structure.

Methods

Data source

Data on the number of physicians were obtained from the Survey of Physicians, Dentists, and Pharmacists conducted every two years by the Ministry of Health, Labour and Welfare (MHLW). Physicians in Japan are required to participate in this survey, which includes information on each physician's specialty and the type and location (municipality) of their workplace. Population data (age, sex, and location of residence) were extracted from the Annual Report of the National Basic Resident Registration System published by the Ministry of Internal Affairs and Communications, and data on the number of births were obtained from the Annual Report of Vital Statistics published by the MHLW. We also acquired data on national health expenditure per capita according to patient age in 2013 from the MHLW. The total area of habitable land was ascertained from statistical reports on land areas of prefectures and municipalities by the Geospatial Information Authority of Japan.

Physicians and population

We targeted physicians working in clinical facilities (hospitals and clinics), and excluded physicians working in non-clinical facilities (e.g., research centers and government offices). The following clinical specialties were included in analysis: internal medicine, surgery, orthopedics, OB/GYN, pediatrics, and anesthesiology. Internal medicine, surgery, and orthopedics were selected because these departments generally have more physicians than other departments. The remaining three specialties were selected because of their previously reported geographic disparities in physician supply throughout Japan.[12]

In addition to the total population, we also analyzed the female population, pediatric population (<15 years of age), and the number of births. With the exception of the number of births, all study populations were adjusted for healthcare demand. We calculated the number of OB/GYN specialists per 100 000 female population and per 100 000 births, the number of pediatricians per 100 000 pediatric population, and the number of physicians per 100 000 population for each of the other clinical specialties.

Geographic unit

The geographic unit of analysis was the secondary medical area (SMA). The Japanese government has designated three regional levels of healthcare provision. Primary medical areas are geographic units where primary care is provided, and are demarcated by municipal borders. Tertiary medical areas are geographic units that provide advanced medical care, and are demarcated by prefectural borders. SMAs are set between primary and tertiary medical areas, and are regions where general medical care (such as inpatient care) is provided; these areas are composed of multiple municipalities. Each prefectural government stipulates the geographic and demographic range of the SMAs within their prefecture. As a result, the boundaries of each SMA can be altered in response to changes in healthcare demand. SMAs have been previously used to examine the inequities in physician supply in Japan.[6 14] Because the number of SMAs varies slightly over time, this study was conducted using the 349 SMAs designated in 2012.

Analytical methods

This retrospective study longitudinally examined the changes in the geographic distribution of the number of physicians by clinical specialty among Japan's SMAs from 2000 to 2014. The primary outcomes were the overall number of physicians per 100,000 population and the trends in Gini coefficients (indicating geographic disparity) for each specialty during the study period. The secondary outcomes were the changes in physician numbers during the same period for subgroups that were categorized according to regional characteristics (urban-rural classification and initial physician supply).

The population was first adjusted using adjustment coefficients of healthcare demand, which were calculated based on the health expenditure per capita stratified by age and sex through a previously described method.[13] Health expenditure per capita is likely indicative of the general workload of healthcare providers.[15] These expenditures include those for both inpatient and outpatient services, and account for variations in patient health status.[13] The demand-adjusted population was generated by multiplying the raw population with the adjustment coefficients.

Next, geographic disparity was assessed using the Gini coefficient. This indicator, which is widely used to examine disparity in the field of economics, has been applied to analyze geographic disparity in physician supply.[1 5 16-18] We calculated the Gini coefficients for each specialty every two years from 2000 to 2014. The coefficients, which take a value from 0 (indicating complete equality) to 1 (indicating complete inequality), measure departure from a uniform distribution by drawing Lorenz curves.[17] If the curves of two time points intersect, conclusions cannot be made as to whether or not the inequity of distribution is increasing.[18] Thus, we plotted two Lorenz curves (one each for 2000 and 2014) for each clinical specialty.

Finally, a subgroup analysis was conducted by dividing SMAs into groups according to two regional characteristics. Using the method described in Sasaki et al.,[19] we classified each SMA into one of four groups based on whether the SMA was an urban or rural area, and whether the SMA had a higher or lower initial physician supply in 2000. An SMA was designated an urban area (or a rural area) if its population density was higher (or lower) than the median value in all SMAs. The population density of each SMA was calculated using the total area of habitable land and the population in 2000. Next, an SMA was designated as having a higher (or lower) initial physician supply if the number of physicians per 100 000 population was higher (or lower) than the median number of physicians per 100 000 population in all SMAs. The following four groups were analyzed: Group 1, which comprised urban areas with higher initial physician supply; Group 2, which comprised rural areas with higher initial physician supply; Group 3, which comprised rural areas with lower initial physician supply; and Group 4, which comprised urban areas with lower initial physician supply. Data from 2000 were used for both the population and physicians. In this subgroup analysis, we compared the inter-group changes in the number of physicians per 100 000 population between 2000 and 2014.

All analyses were performed using R statistical software (V.3.2.2).

Results

Table 1 shows the population sizes of the total population, female population, and pediatric population before and after applying the adjustment coefficients in 2000 and 2014. The adjustment coefficients for the different age strata and sex are provided Appendix Figure. Before adjustment, the total population did not substantially change throughout the study period. In contrast, the demand-adjusted total population increased by 23·7% between 2000 and 2014. The number of births, which was not adjusted for healthcare demand, decreased by 15·7%. The pediatric population declined by 11·1% over the study period both before and after adjusting for healthcare demand.

Table 2 shows the overall number of physicians and the number of physicians per 100 000 population in 2000 and 2014. The overall number of all physicians increased by 22·1% over the study period. Similarly, the number of all physicians per 100 000 population increased by 21·7%. However, the number of all physicians per 100 000 demand-adjusted population decreased by 1·3%. The number of physicians per 100,000 demand-adjusted population in surgery and OB/GYN declined by 26·0% and 17·5%, respectively. In contrast, the number of OB/GYN specialists per 100,000 births increased by 23·1% due to the declining number of births. The number of physicians

196 per 100,000 demand-adjusted population in pediatrics and anesthesiology increased by 33·3% and
197 21·1%, respectively.

198 Table 3 shows the trends in Gini coefficients for the number of physicians per 100 000
199 population in the SMAs by clinical specialty. There were no substantial changes in the Gini
200 coefficients for the numbers of orthopedists, pediatricians, and anesthesiologists per 100 000
201 demand-adjusted population. However, inequity increased in the geographic distribution of internists,
202 surgeons, and OB/GYN specialists (for both the female population and the number of births). In
203 each of these three specialties, the Lorenz curve in 2014 tended to deteriorate more than the curve in
204 2000 without intersection between the two curves (figures not shown). When comparing the Gini
205 coefficients before and after adjusting for healthcare demand, the trends in the coefficients were
206 similar for each clinical specialty. However, the post-adjustment Gini coefficients for all clinical
207 specialties (except for pediatrics) were higher than their pre-adjustment values.

208 Table 4 summarizes the changes in the numbers of physicians per 100 000 population in
209 the four groups of SMAs. Detailed descriptive statistics of the four groups are provided in the
210 Appendix table. Figure 1 shows the temporal increases (2000 to 2014) in the number of physicians
211 by clinical specialty in each group of SMAs. The temporal increases in the number of internists and
212 orthopedists were similar to those for all physicians. The overall number of surgeons decreased in all
213 groups except for Group 4, and the number of surgeons per 100 000 demand-adjusted population

decreased by 20% to 30% in all groups. As shown in Table 4, the number of surgeons per 100 000 demand-adjusted population in Group 3 (11·9) was approximately half of the corresponding number in Group 1 (23·2) in 2014. In all groups, the number of OB/GYN specialists per 100 000 demand-adjusted female population decreased, but the number of OB/GYN specialists per 100 000 births increased. The number of pediatricians per 100 000 demand-adjusted pediatric population increased more in the rural SMAs than in the urban SMAs. The number of anesthesiologists per 100 000 demand-adjusted population increased in all groups; in particular, the number in Group 4 increased by more than twice that of the other groups. In all clinical specialties except pediatrics and anesthesiology, Group 3 had the highest decrease in the number of physicians per 100 000 demand-adjusted population. The 2014-2000 difference and ratio of the number of physicians per 100 000 demand-adjusted population between Groups 3 and 4 increased in all clinical specialties except pediatrics.

Discussion

The four major findings of this study are as follows: First, the demand-adjusted population increased by 23·7% between 2000 and 2014, whereas the demand-adjusted pediatric population decreased by 11·1%. Second, the number of physicians per 100 000 demand-adjusted population decreased in all clinical specialties except pediatrics and anesthesiology. The largest increase (33·3%) was observed in pediatrics. Third, the geographic disparity in the number of physicians per 100 000 demand-adjusted population did not decline in all clinical specialties, and had in fact increased in internal medicine, surgery, and OB/GYN. Fourth, rural areas with lower initial physician supply had the highest decrease in the number of physicians per 100 000 demand-adjusted population compared with other areas in all clinical specialties except pediatrics and anesthesiology. In contrast, urban areas with lower initial physician supply had the lowest decrease in internal medicine, surgery, orthopedics and OBG/GYN, but the highest increase in anesthesiology.

The population used in this study was adjusted for healthcare demand among the different age strata and sex using a previously described method.[13] Although several studies have examined the demand-adjusted geographic disparity in physician supply,[15 20] there is currently no gold standard method for adjustment.[20] The method used in this study was previously verified,[13] and enables adjustment for healthcare demand according to age strata. In addition, the inclusion of sex in the calculation of the coefficients may increase the accuracy of adjustments.

The number of physicians per 100 000 demand-adjusted population decreased in internal medicine, surgery, orthopedics, and OB/GYN (per female population). The decline in physician supply was particularly large in surgery and OB/GYN, which corroborates previously reported downward trends in the numbers of physicians in these specialties.[12] The distribution among specialties is affected by physician preference, experience, and environment. For example, the shortage of surgeons may be influenced by the long working hours, high risk of medical litigation, and low reward for surgical skill.[21] Previous research has also shown that an increase in female physicians has affected the distribution of specialties because they are more likely to choose OB/GYN and pediatrics instead of surgery.[22 23] In order to ensure a high number of both female and male physicians, we believe that improvements should be made to the working environment, such as a reduction in physician working hours by assigning more duties and responsibilities to non-physician health professionals.[21] On the other hand, there was a large increase in the number of anesthesiologists during the study period. Japan is experiencing an increasing need for anesthesiologists due to the rising number of surgeries conducted, the increasing complexity of surgery owing to advances in surgical techniques and the overall aging of patients, as well as the growing social expectations for safety in anesthesia.[24] Due to the initial shortage of anesthesiologists, the offering of higher salaries may have contributed to attracting more specialists. In addition, the increase in anesthesiologists may have been influenced by the growing number of female physicians. Because anesthesiologists generally do not have their own patients or on-call duties, this specialty may be more compatible with raising families. The increase in female anesthesiologists from 26.7% to 37.6% during the study period is consistent with this possibility.

Our findings detected a decrease in the numbers of internists and orthopedists despite an increase in healthcare demand. On the other hand, the number of pediatricians per 100 000

268 demand-adjusted pediatric population and OB/GYN specialists per 100 000 births greatly increased
269 due to a decline in the pediatrics population and the number of births. The rate of pediatric
270 population decline is expected to eventually exceed the rate of total population decline.[25] It may
271 therefore be more useful to ensure the optimal allocation of physicians instead of simply increasing
272 their overall numbers.

273 Based on the analysis of Gini coefficients, there were no reductions in geographic disparity
274 in the number of physicians per 100 000 demand-adjusted population in all clinical specialties
275 between 2000 and 2014. In particular, the inequity in physician supply increased in internal medicine,
276 surgery, and OB/GYN. The inequity in surgery and OB/GYN may have been influenced by the
277 decrease or lack of increase in the overall number of physicians in these specialties. These findings
278 suggest that the uneven distribution of physicians among the clinical specialties may exacerbate
279 geographic disparities in physician supply. On the other hand, the number of internists increased at a
280 rate that was comparable to the overall growth rate. The increase in geographic disparity may
281 therefore be related to an increasing tendency toward physician specialization in Japan.[26] Although
282 the overall number of general internists decreased from 74 539 to 61 317 over the study period, there
283 was actually an increase from 21 006 to 48 780 physicians in internal subspecialties such as
284 pulmonary, cardiovascular, and gastrointestinal medicine (data not shown). The geographic disparity
285 in physician supply in these subspecialties is greater than the disparity in general internists.[9]

286 The rate of increase in the number of physicians per 100 000 demand-adjusted population
287 in the urban areas was generally higher than in the rural areas. In all clinical specialties except
288 pediatrics, both the difference and ratio in the number of physicians per 100 000 demand-adjusted
289 population between Group 3 and Group 4 in 2014 were larger than the corresponding values in 2000.
290 This indicates that the urban-rural disparity in physician supply widened over the study period.
291 Group 3 had the lowest initial physician supply, and these regions may be facing a serious physician
292 shortage. This issue should be explored further, and there may be a need for major reforms to ensure
293 adequate physician supply to rural areas. It may also be important to implement measures in rural
294 areas to improve physician productivity, reduce non-essential workload, and implement
295 technology-based systems such as telemedicine.

296 Prior to 2004, the vast majority of medical graduates joined a clinical specialty department
297 (known as an *Ikyoku*) at their university that secures employment for the new graduates. *Ikyoku*
298 generally dispatch physicians to other affiliated hospitals that are often located in rural areas. In this
299 way, the *Ikyoku* were partly responsible for preventing a shortage of physicians in rural areas. On the
300 other hand, medical graduates did not receive mandatory clinical training under this system. As a
301 result, few graduates were able to acquire a wide range of medical skills through comprehensive and
302 systematic training.[27] In addition, training assessments were not adequately performed under the
303 *Ikyoku* system.[27] In order to improve the overall quality of clinical training throughout Japan, the

MHLW mandated a standardized 2-year training program in 2004. Furthermore, there was a large increase in the number of non-university hospitals that medical graduates could attend as part of this training program after 2004. As a consequence, the graduates, now able to choose their training hospital after graduation, were less likely to select a university hospital for training. Due to the decreasing number of member physicians, it became more difficult for the *Ikyoku* to dispatch physicians to affiliate hospitals.[14] Previous studies have also reported that the new program may have increased the inequity in the geographic distribution of physicians [14 28]. Similarly, this new program may also have contributed to the lack of reduction in geographic disparity in this study.

The Japanese government has implemented several measures at the prefectural level aimed at reducing the geographic disparity in physician supply. In 2006, a "Council for Regional Medicine" was established in each prefecture, and these councils include representatives of the prefectural and local governments, hospitals, medical associations, universities, and residents. The councils discuss detailed measures for securing medical staff with a variety of hospitals, including university hospitals and public hospitals. Furthermore, a "Support Center for Community Medicine" was established in each prefecture in 2011 to secure and retain physicians. These centers adopt the role of “control towers” to address the uneven distribution of physicians within each prefecture. Specifically, the centers are responsible for supporting career advancement for physicians working in rural areas, acting as general liaisons for engaging new physicians, and providing general work information. In addition, the government has raised the regional quota of medical school admissions from 64 students in 2005 to 1 617 students in 2016. The students are obligated to work in a rural area or a designated specialty (such as OB/GYN) for nine years after graduating in return for financial assistance for their studies.[29] As the program is relatively new, it remains unclear as to whether the increase in quotas will lead to reductions in the geographic disparity of physicians.

There are several limitations in this research. First, the adjustment coefficients may continue to change in the future. However, the coefficients did not fluctuate considerably during the study period. In addition, it may be difficult to generalize our adjustment coefficients to other countries as they were calculated using Japanese health expenditure. Nevertheless, the adjustment method itself may have applications in other countries. Second, there was a lack of information on the physicians' working conditions, such as whether a physician worked full-time or part-time. It may be beneficial for future studies to incorporate mean physician working hours. Finally, there may be other ways to divide the SMAs for the subgroup analysis. However, our subgroup analysis was based on the categorization used in a previous study,[19] and provided an intuitive understanding of the differences in group characteristics.

Conclusion

Between 2000 and 2014, the number of physicians per 100 000 demand-adjusted population in Japan decreased in all specialties except pediatrics and anesthesiology. There is also a growing urban-rural disparity in physician supply in all specialties except pediatrics. In consideration of the rapidly aging population and the resulting changes in population structure, additional measures may be needed to resolve these issues and improve physician distribution in Japan.

List of abbreviations

OB/GYN, obstetrics and gynecology

MHLW, Ministry of Health, Labour and Welfare

SMA, secondary medical area

Footnotes

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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 of the manuscript. SK and NS 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.

Role of the funding source

The funder of the study had no role in study design; collection, analysis, and interpretation of the data; writing of the report; or the decision to submit the paper for publication. The corresponding

author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Data sharing statement

No additional data available.

Consent for publication

Not applicable.

1. Isabel C, Paula V. Geographic distribution of physicians in Portugal. *European Journal of Health Economics* 2010;11(4):383-93. doi: 10.1007/s10198-009-0208-8

2. Kanchanachitra C, Lindelow M, Johnston T, et al. Human resources for health in southeast Asia: shortages, distributional challenges, and international trade in health services. *Lancet* 2011;377(9767):769-81. doi: 10.1016/s0140-6736(10)62035-1 [published Online First: 2011/01/29]

3. Ricketts TC. The migration of physicians and the local supply of practitioners: a five-year comparison. *Acad Med* 2013;88(12):1913-8. doi: 10.1097/acm.0000000000000012 [published Online First: 2013/10/17]

4. Pitblado JR, and Raymond W. Pong. Geographic distribution of physicians in Canada. Sudbury, Ontario, Canada: Centre for Rural and Northern Health Research, Laurentian University 1999.

5. Kobayashi Y, Takaki H. Geographic distribution of physicians in Japan. *Lancet* 1992;340(8832):1391-3. [published Online First: 1992/12/05]

6. Tanihara S, Kobayashi Y, Une H, et al. Urbanization and physician maldistribution: a longitudinal study in Japan. *BMC Health Serv Res* 2011;11:260. doi: 10.1186/1472-6963-11-260 [published Online First: 2011/10/11]

7. National Institute of Population and Social Security Research. population projection for Japan:2011-2060 2012 [Available from: http://www.ipss.go.jp/syoushika/tohkei/newest04/gh2401.pdf accessed 29 Feb 2016.

8. Asano N, Kobayashi Y, Kano K. Issues of intervention aimed at preventing prospective surplus of physicians in Japan. *Med Educ* 2001;35(5):488-94. [published Online First: 2001/05/01]

9. Matsumoto M, Inoue K, Bowman R, et al. Self-employment, specialty choice, and geographical distribution of physicians in Japan: A comparison with the United States. *Health Policy* 2010;96(3):239-44. doi: 10.1016/j.healthpol.2010.02.008 [published Online First: 2010/03/13]

10. Rosenthal MB, Zaslavsky A, Newhouse JP. The geographic distribution of physicians revisited. *Health Serv Res* 2005;40(6 Pt 1):1931-52. doi: 10.1111/j.1475-6773.2005.00440.x [published Online First: 2005/12/13]

11. Schwartz WB, Newhouse JP, Bennett BW, et al. The changing geographic distribution of board-certified physicians. *N Engl J Med* 1980;303(18):1032-8. doi: 10.1056/nejm198010303031803 [published Online First: 1980/10/30]

12. Study group on the supply and demand of physicians of the Ministry of Health LaW. The study group report on the supply and demand of physicians 2006 [Available from: http://www.mhlw.go.jp/shingi/2006/07/dl/s0728-9c.pdf accessed 16 Apr 2017.

13. Hara K, Otsubo T, Kunisawa S, et al. Examining sufficiency and equity in the geographic distribution of physicians in Japan: a longitudinal study. *BMJ Open* 2017;7(3):e013922. doi: 10.1136/bmjopen-2016-013922 [published Online First: 2017/03/16]

14. Sakai R, Tamura H, Goto R, et al. Evaluating the effect of Japan's 2004 postgraduate training programme on the spatial distribution of physicians. *Hum Resour Health* 2015;13:5. doi: 10.1186/1478-4491-13-5 [published Online First: 2015/01/27]

15. Gravelle H, Sutton M. Inequality in the geographical distribution of general practitioners in England and Wales 1974-1995. *J Health Serv Res Policy* 2001;6(1):6-13. [published Online First: 2001/02/24]

16. Anand S, Fan VY, Zhang J, et al. China's human resources for health: quantity, quality, and distribution. *Lancet* 2008;372(9651):1774-81. doi: 10.1016/s0140-6736(08)61363-x [published Online First: 2008/10/22]

17. Mauguen A, Begg CB. Using the Lorenz Curve to Characterize Risk Predictiveness and Etiologic Heterogeneity. *Epidemiology* 2016;27(4):531-7. doi: 10.1097/ede.0000000000000499 [published Online First: 2016/04/21]

18. Theodorakis PN, Mantzavinis GD, Rrumbullaku L, et al. Measuring health inequalities in Albania: a focus on the distribution of general practitioners. *Hum Resour Health* 2006;4:5. doi: 10.1186/1478-4491-4-5 [published Online First: 2006/03/01]

19. Sasaki H, Otsubo T, Imanaka Y. Widening disparity in the geographic distribution of pediatricians in Japan. *Hum Resour Health* 2013;11:59. doi: 10.1186/1478-4491-11-59 [published Online First: 2013/11/26]

20. Kephart G, Asada Y. Need-based resource allocation: different need indicators, different results? *BMC Health Serv Res* 2009;9:122. doi: 10.1186/1472-6963-9-122 [published Online First: 2009/07/23]

21. Hanazaki K, Tominaga R, Nio M, et al. Report from the Committee for Improving the Work Environment of Japanese Surgeons: survey on effects of the fee revision for medical services provided by surgeons. *Surg Today* 2013;43(11):1209-18. doi: 10.1007/s00595-013-0691-5 [published Online First: 2013/09/06]

22. Fukuda Y, Harada T. Gender differences in specialty preference and mismatch with real needs in Japanese medical students. *BMC Med Educ* 2010;10:15. doi: 10.1186/1472-6920-10-15

[published Online First: 2010/02/13]

23. Jefferson L, Bloor K, Maynard A. Women in medicine: historical perspectives and recent trends. *Br Med Bull* 2015;114(1):5-15. doi: 10.1093/bmb/ldv007 [published Online First: 2015/03/11]

24. Tabayashi K, Sai S, Iguchi A, et al. Responding to lack of anesthesiologists thinking about the current situation of anesthesiologists shortage from the standpoint of surgeons [in Japanese]. *Journal of Japanese Association for Operating Room Technology* 2006;27(4):288-91.

25. National Institute of Population and Social Security Research in Japan. Population Projections for Japan (April 2017) 2017 [cited 2017 Apr 14].

26. Koike S, Matsumoto S, Kodama T, et al. Specialty choice and physicians' career paths in Japan: an analysis of National Physician Survey data from 1996 to 2006. *Health Policy* 2010;98(2-3):236-44. doi: 10.1016/j.healthpol.2010.06.021 [published Online First: 2010/07/29]

27. Ministry of Health, Labour and Welfare. A history of post-graduate clinical training system [in Japanese] [Available from: http://www.mhlw.go.jp/topics/bukyoku/isei/rinsyo/hensen/ accessed 1 Sep. 2017].

28. Toyabe S. Trend in geographic distribution of physicians in Japan. *Int J Equity Health* 2009;8:5. doi: 10.1186/1475-9276-8-5 [published Online First: 2009/03/05]

29. Matsumoto M, Takeuchi K, Tanaka J, et al. Follow-up study of the regional quota system of Japanese medical schools and prefecture scholarship programmes: a study protocol. *BMJ Open*

2016;6(4):e011165. doi: 10.1136/bmjopen-2016-011165 [published Online First: 2016/04/17]

Figure titles

Figure 1 Temporal increases in physician numbers from 2000 to 2014 for the four groups of secondary medical areas

Appendix Figure Adjustment coefficients of healthcare demand by age strata and sex

Figure legend

Figure1

Group 1 (G1): urban areas with higher initial physician supply; Group 2 (G2): rural areas with higher initial physician supply; Group 3 (G3): rural areas with lower initial physician supply; Group 4 (G4): urban areas with lower initial physician supply. * As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown. OB/GYN: obstetrics/gynecology

Appendix Figure

Ref.: reference value, which is the mean health expenditure per capita of all patients.

Table 1 Population sizes in 2000 and 2014 before and after adjustment for healthcare demand

Year	Before adjustment				After adjustment		
	Total population	Female population	Pediatric population [*1]	Number of births [*2]	Total population	Female population	Pediatric population [*1]
2000	126 071 305	55 196 259	18 553 275	1 190 164	101 697 295	48 349 047	8 546 612
2014	126 434 634	56 670 449	16 489 385	1 003 474	125 837 379	60 902 189	7 594 643
Increase in number (%)	363 329 (0·3%)	1 474 190 (2·7%)	-2 063 890 (-11·1%)	-186 690(-15·7%)	24 140 085 (23·7%)	12 553 142 (26·0%)	-951 969 (-11·1%)

Healthcare demand was adjusted by multiplying the raw population with adjustment coefficients that were calculated using health expenditure per capita stratified by age and sex.

[*1] Pediatric population: all residents aged below 15 years.

[*2] The number of births was not adjusted for healthcare demand.

Table 2 Overall numbers of physicians and numbers of physicians per 100 000 population in 2000 and 2014

	Specialty							
Year	All physicians	Internists	Surgeons	Orthopedists	OB/GYN specialists		Pediatricians	Anesthesiologists
Overall number of physicians								
2000	243 201	95 545	25 424	19 225	12 420		14 156	5 751
2014	296 845	110 097	23 223	23 297	12 888		16 758	8 625
Increase in number (%)	53 644 (22·1%)	14 552 (15·2%)	-2 201 (-8·7%)	4 072 (21·2%)	468 (3·8%)		2 602 (18·4%)	2 874 (50·0%)
Number of physicians per 100 000 population								
Population type	Total	Total	Total	Total	Female	Number of births [*1]	Pediatric [*2]	Total
2000	192·9	75·8	20·2	15·2	22·5	1 043·6	76·3	4·6
2014	234·8	87·1	18·4	18·4	22·7	1 284·3	101·6	6·8
Increase in number (%)	41·9 (21·7%)	11·3 (14·9%)	-1·8 (-8·9%)	3·2 (21·1%)	0·2 (0·9%)	240·7 (23·1%)	25·3 (33·2%)	2·2 (47·8%)
Number of physicians per 100 000 demand-adjusted population								
Population type	Total	Total	Total	Total	Female	Number of births [*1]	Pediatric [*2]	Total
2000	239·1	94·0	25·0	18·9	25·7	N/A	165·6	5·7
2014	235·9	87·5	18·5	18·5	21·2	N/A	220·7	6·9
Increase in number (%)	-3·2 (-1·3%)	-6·5 (-6·9%)	-6·5 (-26·0%)	-0·4 (-2·1%)	-4·5 (-17·5%)	N/A	55·1 (33·3%)	1·2 (21·1%)

[*1] As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

[*2] Pediatric population: all residents aged below 15 years.

OB/GYN: obstetrics/gynecology

Table 3 Trends in Gini coefficients for the number of physicians per 100 000 population in secondary medical areas by clinical specialty

Year	2000	2002	2004	2006	2008	2010	2012	2014	2000-2014 changes
Number of physicians per 100 000 population									
All physicians	0·195	0·193	0·194	0·194	0·199	0·202	0·205	0·206	0·011
Internists	0·183	0·179	0·177	0·175	0·177	0·179	0·183	0·181	-0·002
Surgeons	0·204	0·202	0·197	0·190	0·194	0·206	0·210	0·209	0·005
Orthopedists	0·202	0·201	0·196	0·191	0·195	0·193	0·192	0·196	-0·006
OB/GYN specialists (per female population)	0·226	0·218	0·226	0·240	0·260	0·263	0·266	0·270	0·043
OB/GYN specialists (per number of births) *	0·231	0·220	0·227	0·225	0·243	0·243	0·248	0·250	0·019
Pediatricians (per pediatric population)	0·248	0·244	0·239	0·243	0·246	0·244	0·247	0·246	-0·003
Anesthesiologists	0·445	0·435	0·438	0·433	0·434	0·428	0·432	0·429	-0·016
Number of physicians per 100 000 demand-adjusted population									
All physicians	0·212	0·210	0·214	0·219	0·227	0·231	0·234	0·237	0·025
Internists	0·186	0·182	0·185	0·184	0·191	0·194	0·199	0·199	0·013
Surgeons	0·204	0·202	0·198	0·189	0·199	0·213	0·218	0·219	0·015
Orthopedists	0·215	0·212	0·208	0·204	0·211	0·211	0·210	0·213	-0·002
OB/GYN specialists (per female population)	0·254	0·247	0·255	0·272	0·292	0·296	0·299	0·303	0·049
Pediatricians (per pediatric population)	0·244	0·240	0·235	0·240	0·243	0·240	0·243	0·242	-0·002
Anesthesiologists	0·456	0·447	0·451	0·448	0·449	0·445	0·450	0·447	-0·009

* As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

OB/GYN: obstetrics/gynecology

Table 4 Descriptive statistics of the number of physicians per 100 000 population in the four groups of secondary medical areas in 2000 and 2014

	Before adjustment		After adjustment	
	2000	2014	2000	2014
Total number of physicians per 100 000 population				
Group 1	247·0	297·9 (20·6%)	311·6	305·7 (-1·9%)
Group 2	194·8	226·6 (16·3%)	213·9	203·3 (-5·0%)
Group 3	124·6	142·1 (14·0%)	138·9	127·0 (-8·6%)
Group 4	126·3	163·1 (29·1%)	166·9	171·9 (3·0%)
Number of internists per 100 000 population				
Group 1	95·2	108·0 (13·4%)	120·1	110·8 (-7·7%)
Group 2	79·8	87·5 (9·6%)	87·6	78·5 (-10·4%)
Group 3	54·0	59·1 (9·4%)	60·2	52·8 (-12·3%)
Group 4	49·6	61·4 (23·8%)	65·5	64·7 (-1·2%)
Number of surgeons per 100 000 population				
Group 1	25·2	22·6 (-10·3%)	31·8	23·2 (-27·0%)
Group 2	21·8	19·3 (-11·5%)	24·0	17·3 (-27·9%)
Group 3	15·3	13·3 (-13·1%)	17·1	11·9 (-30·4%)
Group 4	12·9	12·7 (-1·6%)	17·0	13·3 (-21·8%)
Number of orthopedists per 100 000 population				
Group 1	18·6	22·4 (20·4%)	23·5	23·0 (-2·1%)
Group 2	16·6	19·2 (15·7%)	18·2	17·2 (-5·5%)
Group 3	10·8	12·6 (16·7%)	12·0	11·2 (-6·7%)
Group 4	10·7	13·4 (25·2%)	14·2	14·2 (0·0%)
Number of OB/GYN specialists per 100 000 female population				
Group 1	28·4	28·9 (1·8%)	33·2	27·5 (-17·2%)
Group 2	20·2	19·3 (-4·5%)	20·3	15·8 (-22·2%)
Group 3	13·9	12·4 (-10·8%)	14·1	10·2 (-27·7%)
Group 4	16·3	17·0 (4·3%)	20·0	16·7 (-16·5%)
Number of OB/GYN specialists per 100 000 births *				
Group 1	1316·5	1578·9 (19·9%)	N/A	N/A
Group 2	1051·3	1240·3 (18·0%)	N/A	N/A
Group 3	714·9	849·8 (18·9%)	N/A	N/A
Group 4	702·1	914·7 (30·3%)	N/A	N/A
Number of pediatricians per 100 000 pediatric population				

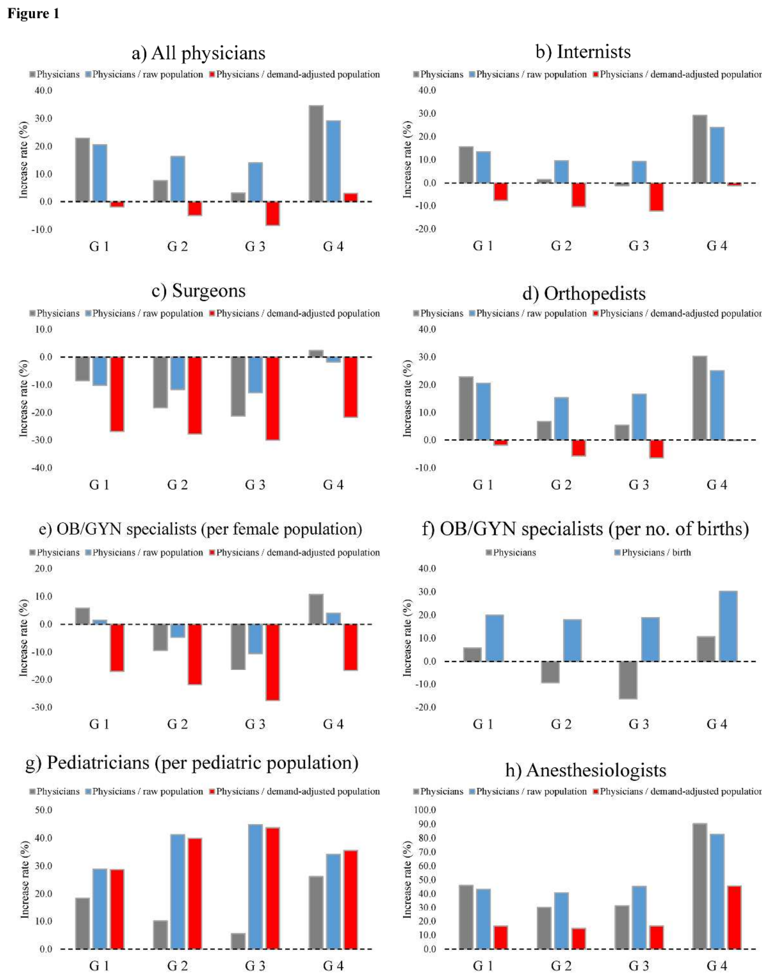
Group 1	49·0	63·1 (28·8%)	211·5	272·3 (28·7%)
Group 2	35·5	50·2 (41·4%)	158·0	221·0 (39·9%)
Group 3	22·6	32·7 (44·7%)	100·7	144·8 (43·8%)
Group 4	27·3	36·7 (34·4%)	117·6	159·4 (35·5%)
Number of anesthesiologists per 100 000 population				
Group 1	6·6	9·4 (42·4%)	8·3	9·7 (16·9%)
Group 2	4·4	6·1 (38·6%)	4·8	5·5 (14·6%)
Group 3	1·9	2·8 (47·4%)	2·1	2·5 (19·0%)
Group 4	2·2	4·1 (86·4%)	2·9	4·3 (48·3%)

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.

* As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

N/A: not applicable; OB/GYN: obstetrics/gynecology

The parenthesis represents the percentage of increase/decrease between 2000 and 2014.



Group 1 (G1): urban areas with higher initial physician supply; Group 2 (G2): rural areas with higher initial physician supply; Group 3 (G3): rural areas with lower initial physician supply; Group 4 (G4): urban areas with lower initial physician supply. * As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown. OB/GYN: obstetrics/gynecology

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Appendix table. 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				
Total physicians	1 536·0(1 409·7)	619·2(433·5)	352·0(295·3)	175·5(127·2)
Internists	592·0(566·4)	242·9(165·3)	144·3(105·2)	76·1(52·0)
Surgeons	156·5(142·1)	63·1(42·2)	39·5(28·4)	21·6(14·2)
Orthopedists	115·8(94·4)	52·6(36·4)	30·0(25·9)	15·2(12·2)
OB/GYN specialists	78·1(71·8)	34·1(26·3)	16·4(15·6)	8·6(6·5)
Pediatricians	88·0(71·9)	40·3(31)	19·1(19·8)	9·6(7·8)
Anesthesiologists	40·9(40·1)	10·9(9·8)	7·9(9·8)	2·7(3·2)
Raw population				
Total population	621 865·5(458 098·5)	490 244·5(341 301·8)	180 718·5(125 140·5)	140 925·7(100 156·8)
Female population	274 615·3(203 154·4)	209 062·4(144 107·6)	81 044·7(54 965·4)	62 047·6(43 331·9)
Pediatric population	89 778·6(62 866·3)	73 620·8(48 171·0)	26 837·6(19 441·3)	21 202·8(15 429·6)
Number of births *	41 599·4(29 459·0)	34 246·1(22 935·5)	12 070·9(8 837·2)	9 497·2(6 971·3)
Demand-adjusted population				
Total population	492 971·0(349 667·3)	370 991·2(242 817·0)	164 585·9(103 001·3)	126 410·8(84 059·2)
Female population	235 594·4(166 553·3)	170 624·5(109 441·9)	80 861·9(49 177·2)	61 184·3(39 965·6)
Pediatric population	41 599·4(29 459·0)	34 246·1(22 935·5)	12 070·9(8 837·2)	9 497·2(6 971·3)

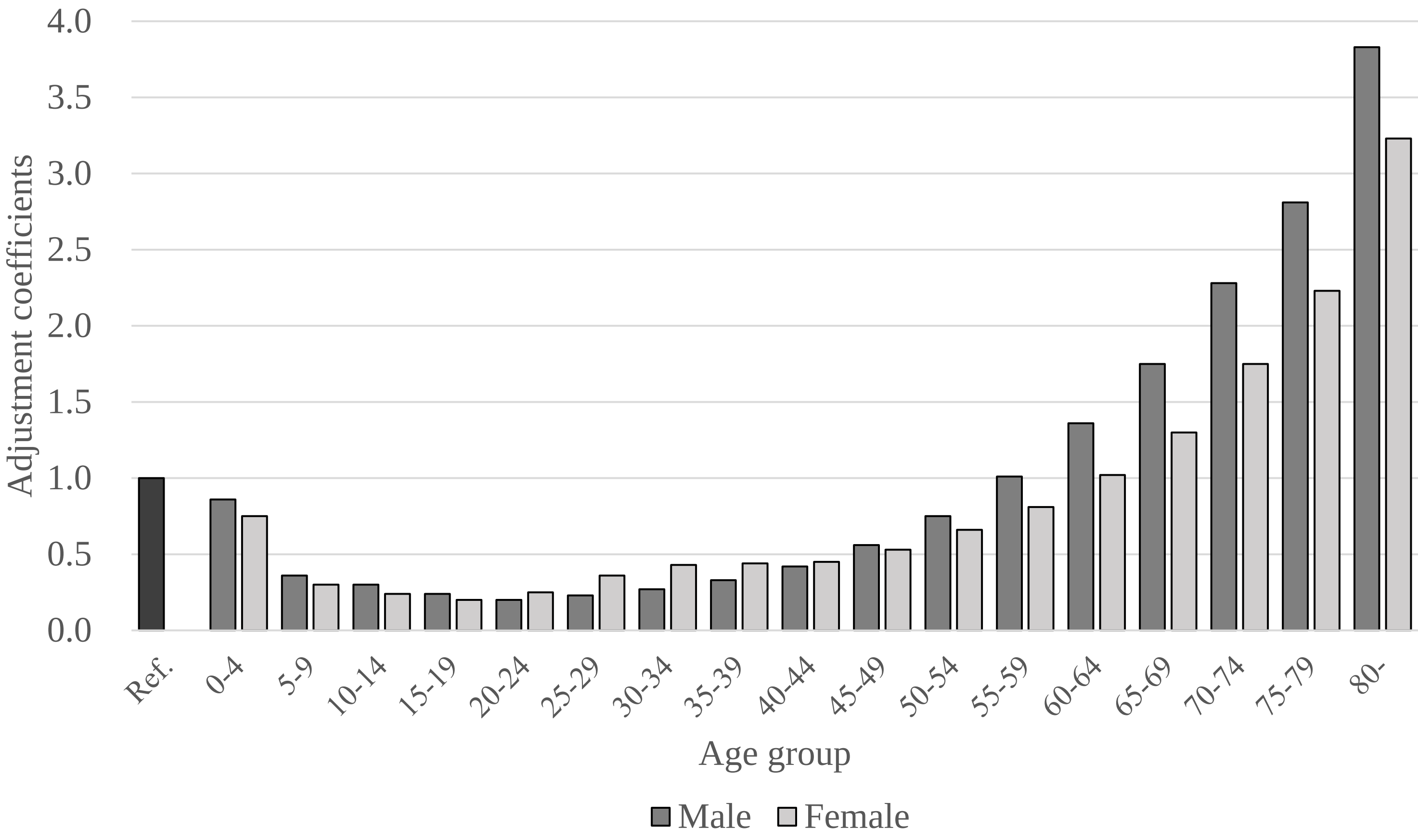
Area (km^2)	311·5(221·5)	242·8(141·4)	360·9(238·5)	458·6(485·8)
Population density (per km^2)	3 023·7(3 403·4)	2 591·6(2 510·6)	514·5(140·9)	393·5(186·9)

Group 1 and Group 2: Higher initial physician supply, Group 3 and Group 4: Lower initial physician supply.

[*] The number of births was not adjusted for healthcare demand.

OB/GYN: obstetrics/gynecology; SD: standard deviation

Appendix Figure.



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 -p3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found – p3-4
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported -p6-7
Objectives	3	State specific objectives, including any prespecified hypotheses – p7
Methods		
Study design	4	Present key elements of study design early in the paper – p10-12
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection –p8-9
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 – p8-9
		(*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 – p10
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 –p7-8
Bias	9	Describe any efforts to address potential sources of bias –p7-8
Study size	10	Explain how the study size was arrived at – p7-9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – p11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding –p10-12
		(*b*) Describe any methods used to examine subgroups and interactions –p11-12
		(*c*) Explain how missing data were addressed –p7-8
		(*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 –p20

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 –Table 1, Table 2, and Table 4
		(b) Give reasons for non-participation at each stage –7-8
		(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 –p8-9
		(b) Indicate number of participants with missing data for each variable of interest –p7-8
		(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 –p12-14
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 –p11
		(*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 –p13-14
Discussion		
Key results	18	Summarise key results with reference to study objectives – p14-15
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 –p20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence –p15-20
Generalisability	21	Discuss the generalisability (external validity) of the study results –p20
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 –p22-23

*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 changes in the equity of physician distribution in Japan: a specialty-specific longitudinal study

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Complete List of Authors:	Hara, Koji; Kyoto University, Department of Healthcare Economics and Quality Management Kunisawa, Susumu; Kyoto University, Department of Healthcare Economics and Quality Management Sasaki, Noriko; Kyoto University, Department of Healthcare Economics and Quality Management Imanaka, Yuichi; Kyoto University, Department of Healthcare Economics and Quality Management

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Examining changes in the equity of physician distribution in Japan: a specialty-specific longitudinal study

Authors:

Koji Hara MA, Susumu Kunisawa, PhD, Noriko Sasaki, PhD, and Yuichi Imanaka, PhD

Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku, Kyoto City, Kyoto, Japan 606-8501

Corresponding author:

Yuichi Imanaka, Professor

Mailing address: Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku, Kyoto City, Kyoto, Japan 606-8501

Tel: +81 75 753 4454

Fax: +81 75 753 4455

Email: imanaka-y@umin.net

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Examining changes in the equity of physician distribution in Japan: a specialty-specific longitudinal study

Abstract

Objectives

In this longitudinal study, we examined changes in the geographic distribution of physicians in Japan from 2000 to 2014 by clinical specialty with adjustments for healthcare demand based on population structure.

Methods

The Japanese population was adjusted for healthcare demand using health expenditure per capita stratified by age and sex. The numbers of physicians per 100 000 demand-adjusted population (DAP) in 2000 and 2014 were calculated for sub-prefectural regions known as secondary medical areas. Disparities in the geographic distribution of physicians for each specialty were assessed using Gini coefficients. A subgroup analysis was conducted by dividing the regions into four groups according to urban-rural classification and initial physician supply.

Results

Over the study period, the number of physicians per 100 000 DAP decreased in all specialties assessed (internal medicine: -6·9%, surgery: -26·0%, orthopedics: -2·1%, obstetrics/gynecology [per

female population]: -17·5%) except pediatrics (+33·3%) and anesthesiology (+21·1%). No reductions in geographic disparity were observed in any of the specialties assessed. Geographic disparity increased substantially in internal medicine, surgery, and obstetrics and gynecology. Rural areas with lower initial physician supply experienced the highest decreases in physicians per 100 000 DAP for all specialties assessed except pediatrics and anesthesiology. In contrast, urban areas with lower initial physician supply experienced the lowest decreases in physicians per 100 000 DAP in internal medicine, surgery, orthopedics, and obstetrics and gynecology, but the highest increase in anesthesiology.

Conclusion

Between 2000 and 2014, the number of physicians per 100 000 DAP in Japan decreased in all specialties assessed except pediatrics and anesthesiology. There is also a growing urban-rural disparity in physician supply in all specialties assessed except pediatrics. Additional measures may be needed to resolve these issues and improve physician distribution in Japan.

Article Summary

Strengths and limitations of this study

- This study longitudinally examined specialty-specific changes in the geographic distribution of Japanese physicians with adjustments for healthcare demand according to population structure.
- The adjustment method used in this study was previously verified, and enables adjustment for healthcare demand according to age strata using health expenditure per capita.
- Both age and sex were included in the calculation of the adjustment coefficients to increase the accuracy of adjustments.
- There was a lack of information on the physicians' working conditions, such as whether a physician worked full-time or part-time.
- It is difficult to generalize our adjustment coefficients to other countries as they were calculated using Japanese health expenditure, but the adjustment method itself may have applications in other countries.

Introduction

The presence of inequities in the geographic distribution of physicians is a major social problem in many countries.[1-4] In Japan, the geographic disparity in physician supply has long been recognized as a serious flaw in the healthcare provision system.[5 6] The lack of regulations that dictate where individual physicians work in Japan has led to the concentration of physicians in urban regions and a shortfall in rural areas, thereby resulting in uneven access to health care throughout the country.[5 6] On the other hand, Japan has entered a period of population decline,[7] and an oversupply of physicians is imminent if their numbers continue to rise at current rates. Attempts to control the total number of physicians have been met with resistance from various interest groups.[8]

In addition to the geographic disparity in physician supply, Japan also faces issues stemming from an uneven distribution of physicians among the clinical specialties.[9] Previous studies from the US have reported that the geographic distribution of physicians varies according to clinical specialty.[10 11] Similarly, geographic disparities in the number of physicians in pediatrics, obstetrics and gynecology (OB/GYN), and anesthesiology have been documented in Japan.[12] However, few studies have longitudinally examined the geographic distribution of physicians according to clinical specialty.

Although the number of physicians per 100 000 population is generally used as an indicator when examining geographic disparities in physician supply, this measure involves a simple head count that does not account for the inherent variations in healthcare demand among the different age strata and sex.[4] Furthermore, Japan's population is aging at an unprecedented rate, which has resulted in its transformation into the world's first "super-aged" society (where more than 21% of a country's population is aged 65 years and older). As a consequence, the population structure in Japan is undergoing dramatic changes, which has invariably led to changes to healthcare demand. We previously reported that Japan's healthcare demand increased by 22% from 2000 to 2014 amid worsening geographic disparity in physician supply.[13] However, studies have yet to be conducted on the disparity in Japan's physician supply for different clinical specialties while accounting for the differences in healthcare demand.

This study aimed to longitudinally examine specialty-specific changes in the geographic distribution of physicians in Japan from 2000 to 2014 with adjustments for healthcare demand based on population structure.

Methods

Data source

Data on the number of physicians were obtained from the Survey of Physicians, Dentists, and Pharmacists conducted every two years by the Ministry of Health, Labour and Welfare (MHLW). Physicians in Japan are required to participate in this survey, which includes information on each

104 physician's specialty and the type and location (municipality) of their workplace. Population data
105 (age, sex, and location of residence) were extracted from the Annual Report of the National Basic
106 Resident Registration System published by the Ministry of Internal Affairs and Communications,
107 and data on the number of births were obtained from the Annual Report of Vital Statistics published
108 by the MHLW. We also acquired data on national health expenditure per capita according to patient
109 age in 2013 from the MHLW. The total area of habitable land was ascertained from statistical reports
110 on land areas of prefectures and municipalities by the Geospatial Information Authority of Japan.
111
112 Physicians and population
113 We targeted physicians working in clinical facilities (hospitals and clinics), and excluded physicians
114 working in non-clinical facilities (e.g., research centers and government offices). The following
115 clinical specialties were included in analysis: internal medicine, surgery, orthopedics, OB/GYN,
116 pediatrics, and anesthesiology. Internal medicine, surgery, and orthopedics were selected because
117 these departments generally have more physicians than other departments. The remaining three
118 specialties were selected because of their previously reported geographic disparities in physician
119 supply throughout Japan.[12]
120 In addition to the total population, we also analyzed the female population, pediatric
121 population (<15 years of age), and the number of births. With the exception of the number of births,

all study populations were adjusted for healthcare demand. We calculated the number of OB/GYN specialists per 100 000 female population and per 100 000 births, the number of pediatricians per 100 000 pediatric population, and the number of physicians per 100 000 population for each of the other clinical specialties.

Geographic unit

The geographic unit of analysis was the secondary medical area (SMA). The Japanese government has designated three regional levels of healthcare provision. Primary medical areas are geographic units where primary care is provided, and are demarcated by municipal borders. Tertiary medical areas are geographic units that provide advanced medical care, and are demarcated by prefectural borders. SMAs are set between primary and tertiary medical areas, and are regions where general medical care (such as inpatient care) is provided; these areas are composed of multiple municipalities. Each prefectural government stipulates the geographic and demographic range of the SMAs within their prefecture. As a result, the boundaries of each SMA can be altered in response to changes in healthcare demand. SMAs have been previously used to examine the inequities in physician supply in Japan.[6,14] Because the number of SMAs varies slightly over time, this study was conducted using the 349 SMAs designated in 2012.

Analytical methods

This retrospective study longitudinally examined the changes in the geographic distribution of the number of physicians by clinical specialty among Japan's SMAs from 2000 to 2014. The primary outcomes were the overall number of physicians per 100,000 population and the trends in Gini coefficients (indicating geographic disparity) for each specialty during the study period. The secondary outcomes were the changes in physician numbers during the same period for subgroups that were categorized according to regional characteristics (urban-rural classification and initial physician supply).

The population was first adjusted using adjustment coefficients of healthcare demand, which were calculated based on the health expenditure per capita stratified by age and sex through a previously described method.[13] Health expenditure per capita is likely indicative of the general workload of healthcare providers.[15] These expenditures include those for both inpatient and outpatient services, and account for variations in patient health status.[13] The demand-adjusted population was generated by multiplying the raw population with the adjustment coefficients.

Next, geographic disparity was assessed using the Gini coefficient. This indicator, which is widely used to examine disparity in the field of economics, has been applied to analyze geographic disparity in physician supply.[1 5 16-18] We calculated the Gini coefficients for each specialty every two years from 2000 to 2014. The coefficients, which take a value from 0 (indicating complete equality) to 1 (indicating complete inequality), measure departure from a uniform distribution by drawing Lorenz curves.[17] If the curves of two time points intersect, conclusions cannot be made as to whether or not the inequity of distribution is increasing.[18] Thus, we plotted two Lorenz curves (one each for 2000 and 2014) for each clinical specialty.

Finally, a subgroup analysis was conducted by dividing SMAs into groups according to two regional characteristics. Using the method described in Sasaki et al.,[19] we classified each SMA into one of four groups based on whether the SMA was an urban or rural area, and whether the SMA had a higher or lower initial physician supply in 2000. An SMA was designated an urban area (or a rural area) if its population density was higher (or lower) than the median value in all SMAs. The population density of each SMA was calculated using the total area of habitable land and the population in 2000. Next, an SMA was designated as having a higher (or lower) initial physician supply if the number of physicians per 100 000 population was higher (or lower) than the median number of physicians per 100 000 population in all SMAs. The following four groups were analyzed: Group 1, which comprised urban areas with higher initial physician supply; Group 2, which comprised rural areas with higher initial physician supply; Group 3, which comprised rural areas with lower initial physician supply; and Group 4, which comprised urban areas with lower initial physician supply. Data from 2000 were used for both the population and physicians. In this subgroup analysis, we compared the inter-group changes in the number of physicians per 100 000 population between 2000 and 2014.

All analyses were performed using R statistical software (V.3.2.2).

Results

Table 1 shows the population sizes of the total population, female population, and pediatric population before and after applying the adjustment coefficients in 2000 and 2014. The adjustment coefficients for the different age strata and sex are provided Appendix Figure. Before adjustment, the total population did not substantially change throughout the study period. In contrast, the demand-adjusted total population increased by 23·7% between 2000 and 2014. The number of births, which was not adjusted for healthcare demand, decreased by 15·7%. The pediatric population declined by 11·1% over the study period both before and after adjusting for healthcare demand.

Table 2 shows the overall number of physicians and the number of physicians per 100 000 population in 2000 and 2014. The overall number of all physicians increased by 22·1% over the study period. Similarly, the number of all physicians per 100 000 population increased by 21·7%. However, the number of all physicians per 100 000 demand-adjusted population decreased by 1·3%. The number of physicians per 100,000 demand-adjusted population in surgery and OB/GYN declined by 26·0% and 17·5%, respectively. In contrast, the number of OB/GYN specialists per 100,000 births increased by 23·1% due to the declining number of births. The number of physicians per 100,000 demand-adjusted population in pediatrics and anesthesiology increased by 33·3% and 21·1%, respectively.

Table 3 shows the trends in Gini coefficients for the number of physicians per 100 000 population in the SMAs by clinical specialty. There were no substantial changes in the Gini coefficients for the numbers of orthopedists, pediatricians, and anesthesiologists per 100 000 demand-adjusted population. However, inequity increased in the geographic distribution of internists, surgeons, and OB/GYN specialists (for both the female population and the number of births). In each of these three specialties, the Lorenz curve in 2014 tended to deteriorate more than the curve in 2000 without intersection between the two curves (figures not shown). When comparing the Gini coefficients before and after adjusting for healthcare demand, the trends in the coefficients were similar for each clinical specialty. However, the post-adjustment Gini coefficients for all clinical specialties (except for pediatrics) were higher than their pre-adjustment values.

Table 4 summarizes the changes in the numbers of physicians per 100 000 population in the four groups of SMAs. Detailed descriptive statistics of the four groups are provided in the Appendix table. Figure 1 shows the temporal increases (2000 to 2014) in the number of physicians by clinical specialty in each group of SMAs. The temporal increases in the number of internists and orthopedists were similar to those for all physicians. The overall number of surgeons decreased in all groups except for Group 4, and the number of surgeons per 100 000 demand-adjusted population decreased by 20% to 30% in all groups. As shown in Table 4, the number of surgeons per 100 000 demand-adjusted population in Group 3 (11·9) was approximately half of the corresponding number in Group 1 (23·2) in 2014. In all groups, the number of OB/GYN specialists per 100 000 demand-adjusted female population decreased, but the number of OB/GYN specialists per 100 000 births increased. The number of pediatricians per 100 000 demand-adjusted pediatric population increased more in the rural SMAs than in the urban SMAs. The number of anesthesiologists per 100 000 demand-adjusted population increased in all groups; in particular, the number in Group 4 increased by more than twice that of the other groups. In all clinical specialties except pediatrics and anesthesiology, Group 3 had the highest decrease in the number of physicians per 100 000 demand-adjusted population. The 2014-2000 difference and ratio of the number of physicians per 100 000 demand-adjusted population between Groups 3 and 4 increased in all clinical specialties except pediatrics.

Discussion

The four major findings of this study are as follows: First, the demand-adjusted population increased by 23·7% between 2000 and 2014, whereas the demand-adjusted pediatric population decreased by 11·1%. Second, the number of physicians per 100 000 demand-adjusted population decreased in all clinical specialties except pediatrics and anesthesiology. The largest increase (33·3%) was observed in pediatrics. Third, the geographic disparity in the number of physicians per 100 000 demand-adjusted population did not decline in all clinical specialties, and had in fact increased in internal medicine, surgery, and OB/GYN. Fourth, rural areas with lower initial physician supply had the highest decrease in the number of physicians per 100 000 demand-adjusted population compared with other areas in all clinical specialties except pediatrics and anesthesiology. In contrast, urban areas with lower initial physician supply had the lowest decrease in internal medicine, surgery, orthopedics and OBG/GYN, but the highest increase in anesthesiology.

The population used in this study was adjusted for healthcare demand among the different age strata and sex using a previously described method.[13] Although several studies have examined the demand-adjusted geographic disparity in physician supply,[15 20] there is currently no gold standard method for adjustment.[20] The method used in this study was previously verified,[13] and enables adjustment for healthcare demand according to age strata. In addition, the inclusion of sex in the calculation of the coefficients may increase the accuracy of adjustments.

The number of physicians per 100 000 demand-adjusted population decreased in internal medicine, surgery, orthopedics, and OB/GYN (per female population). The decline in physician supply was particularly large in surgery and OB/GYN, which corroborates previously reported downward trends in the numbers of physicians in these specialties.[12] The distribution among specialties is affected by physician preference, experience, and environment. For example, the shortage of surgeons may be influenced by the long working hours, high risk of medical litigation, and low reward for surgical skill.[21] Previous research has also shown that an increase in female physicians has affected the distribution of specialties because they are more likely to choose OB/GYN and pediatrics instead of surgery.[22 23] In order to ensure a high number of both female and male physicians, we believe that improvements should be made to the working environment, such as a reduction in physician working hours by assigning more duties and responsibilities to non-physician health professionals.[21] On the other hand, there was a large increase in the number of anesthesiologists during the study period. Japan is experiencing an increasing need for anesthesiologists due to the rising number of surgeries conducted, the increasing complexity of surgery owing to advances in surgical techniques and the overall aging of patients, as well as the growing social expectations for safety in anesthesia.[24] The increase in anesthesiologists may have been influenced by the growing number of female physicians. The increase in female anesthesiologists from 26.7% to 37.6% during the study period is consistent with this possibility.

On the other hand, the number of pediatricians per 100 000 demand-adjusted pediatric population and OB/GYN specialists per 100 000 births increased substantially due to a decline in the pediatrics population and the number of births. The rate of pediatric population decline is expected to eventually exceed the rate of total population decline.[25] It may therefore be more useful to ensure the optimal allocation of physicians instead of simply increasing their overall numbers.

Based on the analysis of Gini coefficients, there were no reductions in geographic disparity in the number of physicians per 100 000 demand-adjusted population in all clinical specialties between 2000 and 2014. In particular, the inequity in physician supply increased in internal medicine, surgery, and OB/GYN. The inequity in surgery and OB/GYN may have been influenced by the decrease or lack of increase in the overall number of physicians in these specialties. These findings suggest that the uneven distribution of physicians among the clinical specialties may exacerbate geographic disparities in physician supply. On the other hand, the number of internists increased at a rate that was comparable to the overall growth rate. The increase in geographic disparity may therefore be related to an increasing tendency toward physician specialization in Japan.[26] Although the overall number of general internists decreased from 74 539 to 61 317 over the study period, there was actually an increase from 21 006 to 48 780 physicians in internal medicine subspecialties such as pulmonary, cardiovascular, and gastrointestinal medicine (data not shown). The geographic disparity in physician supply in these subspecialties is greater than the disparity in general internists.[9] As a supplementary analysis, we calculated the Gini coefficients for general internal medicine and its subspecialties from 2000 to 2014. The results confirmed that the coefficient in the internal medicine subspecialties was consistently more than twice that of general internal medicine (General internal medicine: 0.173 in 2000 to 0.149 in 2014, Internal subspecialties: 0.386 in 2000 to 0390 in 2014).

The rate of increase in the number of physicians per 100 000 demand-adjusted population in the urban areas was generally higher than in the rural areas. In all clinical specialties except pediatrics, both the difference and ratio in the number of physicians per 100 000 demand-adjusted population between Group 3 and Group 4 in 2014 were larger than the corresponding values in 2000. This indicates that the urban-rural disparity in physician supply widened over the study period. Group 3 had the lowest initial physician supply, and these regions may be facing a serious physician shortage. This issue should be explored further, and there may be a need for major reforms to ensure adequate physician supply to rural areas. It may also be important to implement measures in rural areas to improve physician productivity, reduce non-essential workload, and implement technology-based systems such as telemedicine.

Prior to 2004, the vast majority of medical graduates joined a clinical specialty department (known as an *Ikyoku*) at their university that secures employment for the new graduates. *Ikyoku* generally dispatch physicians to other affiliated hospitals that are often located in rural areas. In this way, the *Ikyoku* were partly responsible for preventing a shortage of physicians in rural areas. On the other hand, medical graduates did not receive mandatory clinical training under this system. As a result, few graduates were able to acquire a wide range of medical skills through comprehensive and systematic training.[27] In addition, training assessments were not adequately performed under the *Ikyoku* system.[27] In order to improve the overall quality of clinical training throughout Japan, the

MHLW mandated a standardized 2-year training program in 2004. Furthermore, there was a large increase in the number of non-university hospitals that medical graduates could attend as part of this training program after 2004. As a consequence, the graduates, now able to choose their training hospital after graduation, were less likely to select a university hospital for training. Due to the decreasing number of member physicians, it became more difficult for the *Ikyoku* to dispatch physicians to affiliate hospitals.[14] Previous studies have also reported that the new program may have increased the inequity in the geographic distribution of physicians [14 28]. Similarly, this new program may also have contributed to the lack of reduction in geographic disparity in this study.

The Japanese government has implemented several measures at the prefectural level aimed at reducing the geographic disparity in physician supply. In 2006, a "Council for Regional Medicine" was established in each prefecture, and these councils include representatives of the prefectural and local governments, hospitals, medical associations, universities, and residents. The councils discuss detailed measures for securing medical staff with a variety of hospitals, including university hospitals and public hospitals. Furthermore, a "Support Center for Community Medicine" was established in each prefecture in 2011 to secure and retain physicians. These centers adopt the role of “control towers” to address the uneven distribution of physicians within each prefecture. Specifically, the centers are responsible for supporting career advancement for physicians working in rural areas, acting as general liaisons for engaging new physicians, and providing general work information. In addition, the government has raised the regional quota of medical school admissions from 64 students in 2005 to 1 617 students in 2016. The students are obligated to work in a rural area or a designated specialty (such as OB/GYN) for nine years after graduating in return for financial assistance for their studies.[29] As the program is relatively new, it remains unclear as to whether the increase in quotas will lead to reductions in the geographic disparity of physicians.

There are several limitations in this research. First, the adjustment coefficients may continue to change in the future. However, the coefficients did not fluctuate considerably during the study period. In addition, it may be difficult to generalize our adjustment coefficients to other countries as they were calculated using Japanese health expenditure. Nevertheless, the adjustment method itself may have applications in other countries. Second, there was a lack of information on the physicians' working conditions, such as whether a physician worked full-time or part-time. It may be beneficial for future studies to incorporate mean physician working hours. Third, our analysis had focused on specialties with a large number of physicians and previously reported geographic disparities. This may have introduced selection bias as other specialties may not have experienced the same geographic disparities described in this study. Finally, there may be other ways to divide the SMAs for the subgroup analysis. However, our subgroup analysis was based on the categorization used in a previous study,[19] and provided an intuitive understanding of the differences in group characteristics.

Conclusion

Between 2000 and 2014, the number of physicians per 100 000 demand-adjusted population in Japan decreased in all specialties assessed except pediatrics and anesthesiology. There is also a growing urban-rural disparity in physician supply in all specialties assessed except pediatrics. In consideration of the rapidly aging population and the resulting changes in population structure, additional measures may be needed to resolve these issues and improve physician distribution in Japan.

List of abbreviations

DAP, demand-adjusted population

OB/GYN, obstetrics and gynecology

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 of the manuscript. SK and NS 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.

Role of the funding source

The funder of the study had no role in study design; collection, analysis, and interpretation of the data; writing of the report; or the decision to submit the paper for publication. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Data sharing statement

No additional data available.

Consent for publication

Not applicable.

1. Isabel C, Paula V. Geographic distribution of physicians in Portugal. *European Journal of Health Economics* 2010;11(4):383-93. doi: 10.1007/s10198-009-0208-8

2. Kanchanachitra C, Lindelow M, Johnston T, et al. Human resources for health in southeast Asia: shortages, distributional challenges, and international trade in health services. *Lancet*

2011;377(9767):769-81. doi: 10.1016/s0140-6736(10)62035-1 [published Online First: 2011/01/29]

3. Ricketts TC. The migration of physicians and the local supply of practitioners: a five-year comparison. *Acad Med* 2013;88(12):1913-8. doi: 10.1097/acm.0000000000000012 [published Online First: 2013/10/17]

4. Pitblado JR, and Raymond W. Pong. Geographic distribution of physicians in Canada. Sudbury, Ontario, Canada: Centre for Rural and Northern Health Research, Laurentian University 1999.

5. Kobayashi Y, Takaki H. Geographic distribution of physicians in Japan. *Lancet* 1992;340(8832):1391-3. [published Online First: 1992/12/05]

6. Tanihara S, Kobayashi Y, Une H, et al. Urbanization and physician maldistribution: a longitudinal study in Japan. *BMC Health Serv Res* 2011;11:260. doi: 10.1186/1472-6963-11-260 [published Online First: 2011/10/11]

7. National Institute of Population and Social Security Research. population projection for Japan:2011-2060 2012 [Available from: http://www.ipss.go.jp/syoushika/tohkei/newest04/gh2401.pdf accessed 29 Feb 2016.

8. Asano N, Kobayashi Y, Kano K. Issues of intervention aimed at preventing prospective surplus of physicians in Japan. *Med Educ* 2001;35(5):488-94. [published Online First: 2001/05/01]

9. Matsumoto M, Inoue K, Bowman R, et al. Self-employment, specialty choice, and geographical

410 distribution of physicians in Japan: A comparison with the United States. *Health Policy* 2010;96(3):239-44. doi: 10.1016/j.healthpol.2010.02.008 [published Online First: 2010/03/13]

412 10. Rosenthal MB, Zaslavsky A, Newhouse JP. The geographic distribution of physicians revisited. *Health Serv Res* 2005;40(6 Pt 1):1931-52. doi: 10.1111/j.1475-6773.2005.00440.x [published Online First: 2005/12/13]

415 11. Schwartz WB, Newhouse JP, Bennett BW, et al. The changing geographic distribution of board-certified physicians. *N Engl J Med* 1980;303(18):1032-8. doi: 10.1056/nejm198010303031803 [published Online First: 1980/10/30]

418 12. Study group on the supply and demand of physicians of the Ministry of Health, Labour and Welfare. The study group report on the supply and demand of physicians 2006 [Available from: http://www.mhlw.go.jp/shingi/2006/07/dl/s0728-9c.pdf accessed 16 Apr 2017.

421 13. Hara K, Otsubo T, Kunisawa S, et al. Examining sufficiency and equity in the geographic distribution of physicians in Japan: a longitudinal study. *BMJ Open* 2017;7(3):e013922. doi: 10.1136/bmjopen-2016-013922 [published Online First: 2017/03/16]

424 14. Sakai R, Tamura H, Goto R, et al. Evaluating the effect of Japan's 2004 postgraduate training programme on the spatial distribution of physicians. *Hum Resour Health* 2015;13:5. doi: 10.1186/1478-4491-13-5 [published Online First: 2015/01/27]

427 15. Gravelle H, Sutton M. Inequality in the geographical distribution of general practitioners in England

and Wales 1974-1995. *J Health Serv Res Policy* 2001;6(1):6-13. [published Online First: 2001/02/24]

16. Anand S, Fan VY, Zhang J, et al. China's human resources for health: quantity, quality, and distribution. *Lancet* 2008;372(9651):1774-81. doi: 10.1016/s0140-6736(08)61363-x [published Online First: 2008/10/22]

17. Mauguen A, Begg CB. Using the Lorenz Curve to Characterize Risk Predictiveness and Etiologic Heterogeneity. *Epidemiology* 2016;27(4):531-7. doi: 10.1097/ede.0000000000000499 [published Online First: 2016/04/21]

18. Theodorakis PN, Mantzavinis GD, Rrumbullaku L, et al. Measuring health inequalities in Albania: a focus on the distribution of general practitioners. *Hum Resour Health* 2006;4:5. doi: 10.1186/1478-4491-4-5 [published Online First: 2006/03/01]

19. Sasaki H, Otsubo T, Imanaka Y. Widening disparity in the geographic distribution of pediatricians in Japan. *Hum Resour Health* 2013;11:59. doi: 10.1186/1478-4491-11-59 [published Online First: 2013/11/26]

20. Kephart G, Asada Y. Need-based resource allocation: different need indicators, different results? *BMC Health Serv Res* 2009;9:122. doi: 10.1186/1472-6963-9-122 [published Online First: 2009/07/23]

21. Hanazaki K, Tominaga R, Nio M, et al. Report from the Committee for Improving the Work

Environment of Japanese Surgeons: survey on effects of the fee revision for medical services provided by surgeons. *Surg Today* 2013;43(11):1209-18. doi: 10.1007/s00595-013-0691-5 [published Online First: 2013/09/06]

22. Fukuda Y, Harada T. Gender differences in specialty preference and mismatch with real needs in Japanese medical students. *BMC Med Educ* 2010;10:15. doi: 10.1186/1472-6920-10-15 [published Online First: 2010/02/13]

23. Jefferson L, Bloor K, Maynard A. Women in medicine: historical perspectives and recent trends. *Br Med Bull* 2015;114(1):5-15. doi: 10.1093/bmb/ldv007 [published Online First: 2015/03/11]

24. Tabayashi K, Sai S, Iguchi A, et al. Responding to lack of anesthesiologists thinking about the current situation of anesthesiologists shortage from the standpoint of surgeons [in Japanese]. *Journal of Japanese Association for Operating Room Technology* 2006;27(4):288-91.

25. National Institute of Population and Social Security Research in Japan. Population Projections for Japan (April 2017) 2017 [cited 2017 Apr 14].

26. Koike S, Matsumoto S, Kodama T, et al. Specialty choice and physicians' career paths in Japan: an analysis of National Physician Survey data from 1996 to 2006. *Health Policy* 2010;98(2-3):236-44. doi: 10.1016/j.healthpol.2010.06.021 [published Online First: 2010/07/29]

27. Ministry of Health, Labour and Welfare. A history of post-graduate clinical training system [in Japanese] [Available from: http://www.mhlw.go.jp/topics/bukyoku/isei/rinsyo/hensen/ accessed

1 Sep. 2017].

28. Toyabe S. Trend in geographic distribution of physicians in Japan. *Int J Equity Health* 2009;8:5. doi: 10.1186/1475-9276-8-5 [published Online First: 2009/03/05]

29. Matsumoto M, Takeuchi K, Tanaka J, et al. Follow-up study of the regional quota system of Japanese medical schools and prefecture scholarship programmes: a study protocol. *BMJ Open* 2016;6(4):e011165. doi: 10.1136/bmjopen-2016-011165 [published Online First: 2016/04/17]

Figure titles

Figure 1 Temporal increases in physician numbers from 2000 to 2014 for the four groups of secondary medical areas

Appendix Figure Adjustment coefficients of healthcare demand by age strata and sex

Figure legends

Figure 1

Group 1 (G1): urban areas with higher initial physician supply; Group 2 (G2): rural areas with higher initial physician supply; Group 3 (G3): rural areas with lower initial physician supply; Group 4 (G4): urban areas with lower initial physician supply. * As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown. OB/GYN: obstetrics/gynecology.

Appendix Figure

Ref.: reference value, which is the mean health expenditure per capita of all patients.

Table 1 Population sizes in 2000 and 2014 before and after adjustment for healthcare demand

Year	Before adjustment				After adjustment		
	Total population	Female population	Pediatric population [*1]	Number of births [*2]	Total population	Female population	Pediatric population [*1]
2000	126 071 305	55 196 259	18 553 275	1 190 164	101 697 295	48 349 047	8 546 612
2014	126 434 634	56 670 449	16 489 385	1 003 474	125 837 379	60 902 189	7 594 643
Increase in number (%)	363 329 (0·3%)	1 474 190 (2·7%)	-2 063 890 (-11·1%)	-186 690(-15·7%)	24 140 085 (23·7%)	12 553 142 (26·0%)	-951 969 (-11·1%)

Healthcare demand was adjusted by multiplying the raw population with adjustment coefficients that were calculated using health expenditure per capita stratified by age and sex.

[*1] Pediatric population: all residents aged below 15 years.

[*2] The number of births was not adjusted for healthcare demand.

Table 2 Overall numbers of physicians and numbers of physicians per 100 000 population in 2000 and 2014

	Specialty							
Year	All physicians	Internists	Surgeons	Orthopedists	OB/GYN specialists		Pediatricians	Anesthesiologists
Overall number of physicians								
2000	243 201	95 545	25 424	19 225	12 420		14 156	5 751
2014	296 845	110 097	23 223	23 297	12 888		16 758	8 625
Increase in number (%)	53 644 (22·1%)	14 552 (15·2%)	-2 201 (-8·7%)	4 072 (21·2%)	468 (3·8%)		2 602 (18·4%)	2 874 (50·0%)
Number of physicians per 100 000 population								
Population type	Total	Total	Total	Total	Female	Number of births [*1]	Pediatric [*2]	Total
2000	192·9	75·8	20·2	15·2	22·5	1 043·6	76·3	4·6
2014	234·8	87·1	18·4	18·4	22·7	1 284·3	101·6	6·8
Increase in number (%)	41·9 (21·7%)	11·3 (14·9%)	-1·8 (-8·9%)	3·2 (21·1%)	0·2 (0·9%)	240·7 (23·1%)	25·3 (33·2%)	2·2 (47·8%)
Number of physicians per 100 000 demand-adjusted population								
Population type	Total	Total	Total	Total	Female	Number of births [*1]	Pediatric [*2]	Total
2000	239·1	94·0	25·0	18·9	25·7	N/A	165·6	5·7
2014	235·9	87·5	18·5	18·5	21·2	N/A	220·7	6·9
Increase in number (%)	-3·2 (-1·3%)	-6·5 (-6·9%)	-6·5 (-26·0%)	-0·4 (-2·1%)	-4·5 (-17·5%)	N/A	55·1 (33·3%)	1·2 (21·1%)

[*1] As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

[*2] Pediatric population: all residents aged below 15 years.

OB/GYN: obstetrics/gynecology

Table 3 Trends in Gini coefficients for the number of physicians per 100 000 population in secondary medical areas by clinical specialty

Year	2000	2002	2004	2006	2008	2010	2012	2014	2000-2014 changes
Number of physicians per 100 000 population									
All physicians	0·195	0·193	0·194	0·194	0·199	0·202	0·205	0·206	0·011
Internists	0·183	0·179	0·177	0·175	0·177	0·179	0·183	0·181	-0·002
Surgeons	0·204	0·202	0·197	0·190	0·194	0·206	0·210	0·209	0·005
Orthopedists	0·202	0·201	0·196	0·191	0·195	0·193	0·192	0·196	-0·006
OB/GYN specialists (per female population)	0·226	0·218	0·226	0·240	0·260	0·263	0·266	0·270	0·043
OB/GYN specialists (per number of births) *	0·231	0·220	0·227	0·225	0·243	0·243	0·248	0·250	0·019
Pediatricians (per pediatric population)	0·248	0·244	0·239	0·243	0·246	0·244	0·247	0·246	-0·003
Anesthesiologists	0·445	0·435	0·438	0·433	0·434	0·428	0·432	0·429	-0·016
Number of physicians per 100 000 demand-adjusted population									
All physicians	0·212	0·210	0·214	0·219	0·227	0·231	0·234	0·237	0·025
Internists	0·186	0·182	0·185	0·184	0·191	0·194	0·199	0·199	0·013
Surgeons	0·204	0·202	0·198	0·189	0·199	0·213	0·218	0·219	0·015
Orthopedists	0·215	0·212	0·208	0·204	0·211	0·211	0·210	0·213	-0·002
OB/GYN specialists (per female population)	0·254	0·247	0·255	0·272	0·292	0·296	0·299	0·303	0·049
Pediatricians (per pediatric population)	0·244	0·240	0·235	0·240	0·243	0·240	0·243	0·242	-0·002
Anesthesiologists	0·456	0·447	0·451	0·448	0·449	0·445	0·450	0·447	-0·009

* As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

OB/GYN: obstetrics/gynecology

Table 4 Descriptive statistics of the number of physicians per 100 000 population in the four groups of secondary medical areas in 2000 and 2014

	Before adjustment		After adjustment	
	2000	2014	2000	2014
Total number of physicians per 100 000 population				
Group 1	247·0	297·9 (20·6%)	311·6	305·7 (-1·9%)
Group 2	194·8	226·6 (16·3%)	213·9	203·3 (-5·0%)
Group 3	124·6	142·1 (14·0%)	138·9	127·0 (-8·6%)
Group 4	126·3	163·1 (29·1%)	166·9	171·9 (3·0%)
Number of internists per 100 000 population				
Group 1	95·2	108·0 (13·4%)	120·1	110·8 (-7·7%)
Group 2	79·8	87·5 (9·6%)	87·6	78·5 (-10·4%)
Group 3	54·0	59·1 (9·4%)	60·2	52·8 (-12·3%)
Group 4	49·6	61·4 (23·8%)	65·5	64·7 (-1·2%)
Number of surgeons per 100 000 population				
Group 1	25·2	22·6 (-10·3%)	31·8	23·2 (-27·0%)
Group 2	21·8	19·3 (-11·5%)	24·0	17·3 (-27·9%)
Group 3	15·3	13·3 (-13·1%)	17·1	11·9 (-30·4%)
Group 4	12·9	12·7 (-1·6%)	17·0	13·3 (-21·8%)
Number of orthopedists per 100 000 population				
Group 1	18·6	22·4 (20·4%)	23·5	23·0 (-2·1%)
Group 2	16·6	19·2 (15·7%)	18·2	17·2 (-5·5%)
Group 3	10·8	12·6 (16·7%)	12·0	11·2 (-6·7%)
Group 4	10·7	13·4 (25·2%)	14·2	14·2 (0·0%)
Number of OB/GYN specialists per 100 000 female population				
Group 1	28·4	28·9 (1·8%)	33·2	27·5 (-17·2%)
Group 2	20·2	19·3 (-4·5%)	20·3	15·8 (-22·2%)
Group 3	13·9	12·4 (-10·8%)	14·1	10·2 (-27·7%)
Group 4	16·3	17·0 (4·3%)	20·0	16·7 (-16·5%)
Number of OB/GYN specialists per 100 000 births *				
Group 1	1316·5	1578·9 (19·9%)	N/A	N/A
Group 2	1051·3	1240·3 (18·0%)	N/A	N/A
Group 3	714·9	849·8 (18·9%)	N/A	N/A
Group 4	702·1	914·7 (30·3%)	N/A	N/A
Number of pediatricians per 100 000 pediatric population				

Group 1	49·0	63·1 (28·8%)	211·5	272·3 (28·7%)
Group 2	35·5	50·2 (41·4%)	158·0	221·0 (39·9%)
Group 3	22·6	32·7 (44·7%)	100·7	144·8 (43·8%)
Group 4	27·3	36·7 (34·4%)	117·6	159·4 (35·5%)
Number of anesthesiologists per 100 000 population				
Group 1	6·6	9·4 (42·4%)	8·3	9·7 (16·9%)
Group 2	4·4	6·1 (38·6%)	4·8	5·5 (14·6%)
Group 3	1·9	2·8 (47·4%)	2·1	2·5 (19·0%)
Group 4	2·2	4·1 (86·4%)	2·9	4·3 (48·3%)

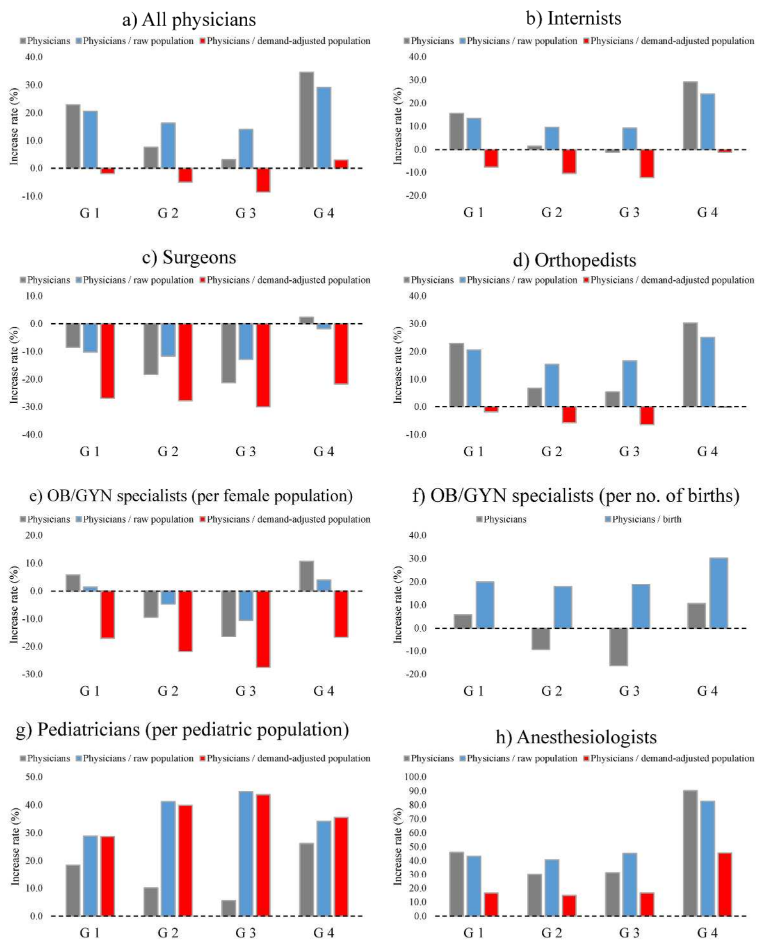
Group 1: urban areas with higher initial physician supply; Group 2: rural areas with higher initial physician supply; Group 3: rural areas with lower initial physician supply; Group 4: urban areas with lower initial physician supply.

[*] As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown.

N/A: not applicable; OB/GYN: obstetrics/gynecology

The parenthesis represents the percentage of increase/decrease between 2000 and 2014.

Figure 1



Group 1 (G1): urban areas with higher initial physician supply; Group 2 (G2): rural areas with higher initial physician supply; Group 3 (G3): rural areas with lower initial physician supply; Group 4 (G4): urban areas with lower initial physician supply. * As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not shown. OB/GYN: obstetrics/gynecology

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Appendix table. 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				
Total physicians	1 536·0(1 409·7)	619·2(433·5)	352·0(295·3)	175·5(127·2)
Internists	592·0(566·4)	242·9(165·3)	144·3(105·2)	76·1(52·0)
Surgeons	156·5(142·1)	63·1(42·2)	39·5(28·4)	21·6(14·2)
Orthopedists	115·8(94·4)	52·6(36·4)	30·0(25·9)	15·2(12·2)
OB/GYN specialists	78·1(71·8)	34·1(26·3)	16·4(15·6)	8·6(6·5)
Pediatricians	88·0(71·9)	40·3(31)	19·1(19·8)	9·6(7·8)
Anesthesiologists	40·9(40·1)	10·9(9·8)	7·9(9·8)	2·7(3·2)
Raw population				
Total population	621 865·5(458 098·5)	490 244·5(341 301·8)	180 718·5(125 140·5)	140 925·7(100 156·8)
Female population	274 615·3(203 154·4)	209 062·4(144 107·6)	81 044·7(54 965·4)	62 047·6(43 331·9)
Pediatric population	89 778·6(62 866·3)	73 620·8(48 171·0)	26 837·6(19 441·3)	21 202·8(15 429·6)
Number of births *	41 599·4(29 459·0)	34 246·1(22 935·5)	12 070·9(8 837·2)	9 497·2(6 971·3)
Demand-adjusted population				
Total population	492 971·0(349 667·3)	370 991·2(242 817·0)	164 585·9(103 001·3)	126 410·8(84 059·2)
Female population	235 594·4(166 553·3)	170 624·5(109 441·9)	80 861·9(49 177·2)	61 184·3(39 965·6)
Pediatric population	41 599·4(29 459·0)	34 246·1(22 935·5)	12 070·9(8 837·2)	9 497·2(6 971·3)

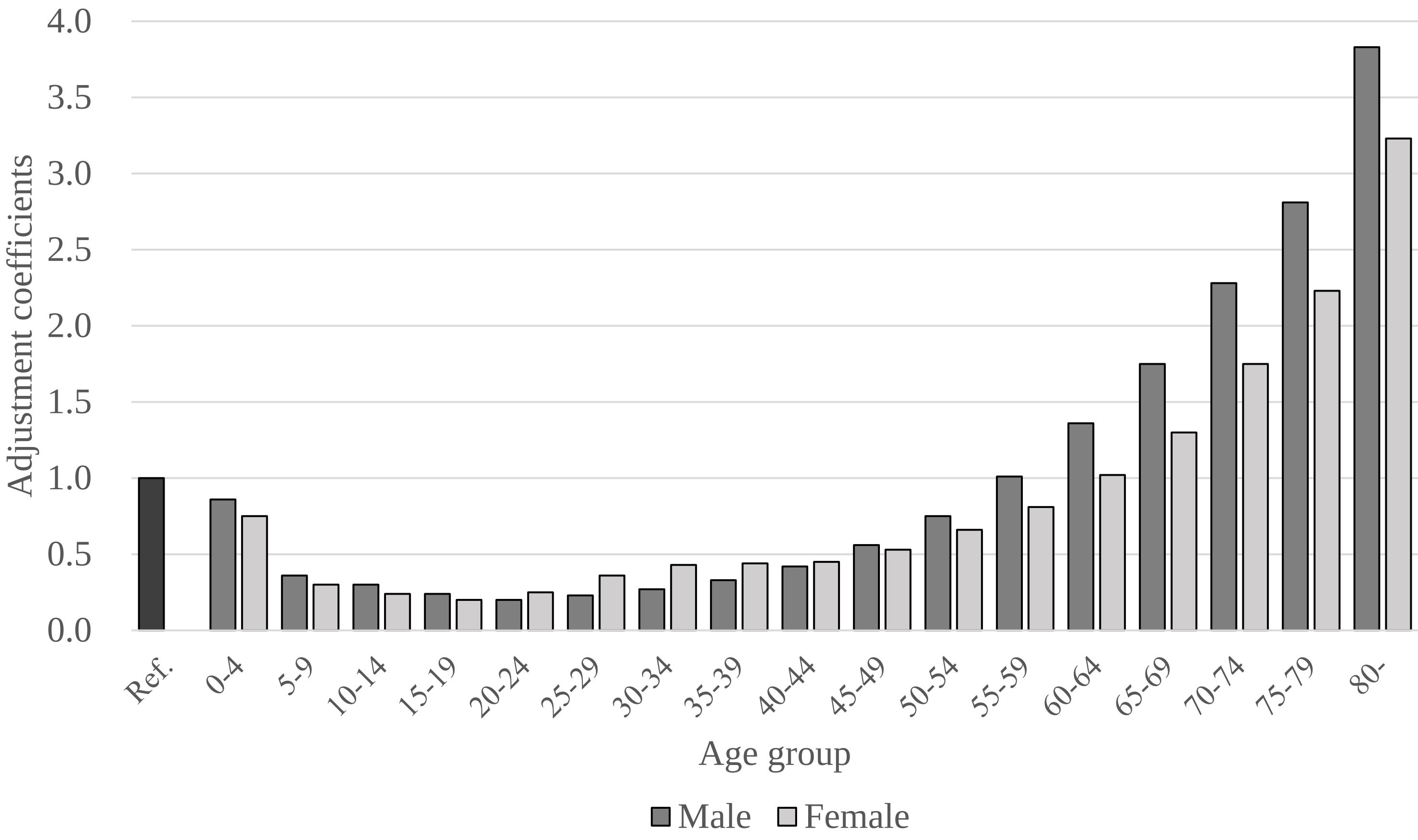
Area (km^2)	311·5(221·5)	242·8(141·4)	360·9(238·5)	458·6(485·8)
Population density (per km^2)	3 023·7(3 403·4)	2 591·6(2 510·6)	514·5(140·9)	393·5(186·9)

Group 1 and Group 2: Higher initial physician supply, Group 3 and Group 4: Lower initial physician supply.

* The number of births was not adjusted for healthcare demand.

OB/GYN: obstetrics/gynecology; SD: standard deviation

Appendix Figure.



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 -p3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found – p3-4
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported -p6-7
Objectives	3	State specific objectives, including any prespecified hypotheses – p7
Methods		
Study design	4	Present key elements of study design early in the paper – p10-12
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection –p8-9
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 – p8-9
		(*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 – p10
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 –p7-8
Bias	9	Describe any efforts to address potential sources of bias –p7-8
Study size	10	Explain how the study size was arrived at – p7-9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – p11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding –p10-12
		(*b*) Describe any methods used to examine subgroups and interactions –p11-12
		(*c*) Explain how missing data were addressed –p7-8
		(*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 –p20

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 –Table 1, Table 2, and Table 4
		(b) Give reasons for non-participation at each stage –7-8
		(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 –p8-9
		(b) Indicate number of participants with missing data for each variable of interest –p7-8
		(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 –p12-14
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 –p11
		(*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 –p13-14

Discussion

Key results	18	Summarise key results with reference to study objectives – p14-15
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 –p20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence –p15-20
Generalisability	21	Discuss the generalisability (external validity) of the study results –p20

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 –p22-23

*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.