

# BMJ Open Future projection of the physician workforce and its geographical equity in Japan: a cohort-component model

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## ABSTRACT

**Introduction** The geographical inequity of physicians is a serious problem in Japan. However, there is little evidence of inequity in the future geographical distribution of physicians, even though the future physician supply at the national level has been estimated. In addition, possible changes in the age and sex distribution of future physicians are unclear. Thus, the purpose of this study is to project the future geographical distribution of physicians and their demographics.

**Methods** We used a cohort-component model with the following assumptions: basic population, future mortality rate, future new registration rate, and future in-migration and out-migration rates. We examined changes in the number of physicians from 2005 to 2035 in secondary medical areas (SMAs) in Japan. To clarify the trends by regional characteristics, SMAs were divided into four groups based on urban or rural status and initial physician supply (lower/higher). The number of physicians was calculated separately by sex and age strata.

**Results** From 2005 to 2035, the absolute number of physicians aged 25–64 will decline by 6.1% in rural areas with an initially lower physician supply, but it will increase by 37.0% in urban areas with an initially lower supply. The proportion of aged physicians will increase in all areas, especially in rural ones with an initially lower supply, where it will change from 14.4% to 31.3%. The inequity in the geographical distribution of physicians will expand despite an increase in the number of physicians in rural areas.

**Conclusions** We found that the geographical disparity of physicians will worsen from 2005 to 2035. Furthermore, physicians aged 25–64 will be more concentrated in urban areas, and physicians will age more rapidly in rural places than urban ones. The regional disparity in the physician supply will worsen in the future if new and drastic measures are not taken.

## INTRODUCTION

Inequity in the geographical distribution of physicians is a major issue in many countries.<sup>1–6</sup> In Japan, concern over this problem has grown in recent years because of a discussion on whether to maintain or reduce the number of enrolments in medical schools.<sup>7</sup> Although Japan's total population is expected to decrease from 128.06 million in 2010 to 116.62 million in 2030,<sup>8</sup> the number of

## Strengths and limitations of this study

- We projected the geographical distribution of physicians in Japan in the future.
- A cohort-component model is widely used for making population projections, and provides a flexible and powerful approach.
- In order to increase the accuracy of the future projection and make it easier to understand, we divided 342 areas into 4 area groups based on urban/rural status and lower/higher physician supply, based on earlier studies.
- We could not calculate an accurate full-time equivalent of physician, because the database used in the study did not include their work hours.
- There is the possibility that the trends used in our future projection will change significantly due to developments in policy and environment.

physicians has consistently increased because the current number of enrolments in medical schools has been maintained. Thus, this situation may lead to an oversupply of physicians in the future. In fact, according to the Ministry of Health, Labour and Welfare (MHLW), healthcare demand and physician supply will become balanced in 2024.<sup>9</sup> On the other hand, the inequitable geographical distribution of physicians has remained and worsened.<sup>2 10 11</sup> Only certain areas may receive the benefits of the increasing number of physicians. Consequently, in order to judge the future supply–demand balance of physicians, it is important to produce a clear future projection of the number of physicians by region.

In addition, physicians' sex–age structure has been changing because of an increase in the number of female physicians and physicians aged 65 and over. After the rate of female enrolment in medical schools gradually raised from 18% in 1982 to 30% in 1993, it then stayed at about 30% until 2016.<sup>12</sup> The percentage of female physicians increased from 12.7% in 1994 to 20.4% in 2014. Researchers have reported differences

in workplace and specialty preferences between male and female physicians.<sup>13 14</sup>

Similarly, the number of physicians aged 65 and over is expected to increase in the future. The Japanese government implemented a plan intended to ensure 'at least one medical school for each prefecture' in 1973, which established new medical faculties in prefectures that lacked them, to resolve a physician shortage. As a result, the number of enrolments in medical programmes increased quickly from 4000 in 1969 to 8280 in 1981. Since then, the number gradually increased to 9262 by 2015. Physicians who graduated in 1981 will reach the age of 65 in around 2030. According to The Japan Institute for Labour Policy and Training,<sup>15</sup> physicians over 60 tend to work three-quarters as long as those in their 30s. In addition, older physicians are more likely to retire from practice and go on to have a central role in education and management. In Japan, it has reported that the age of hospital physicians in rural areas is higher than in urban, and the difference in average age has been increasing between 1994 and 2014.<sup>16</sup> Thus, when discussing the physician supply, the number of physicians should be separated into younger physicians and older physicians.

Some studies have predicted the number of physicians at the national level and reported that the total number is expected to increase.<sup>17–19</sup> However, in discussing the future physician supply, it is also important to estimate different trends in the geographical distribution of physicians. Consequently, the purpose of this study is to project the future geographical distribution of physicians and their demographics.

## METHODS

### Data source

This study obtained data on physicians for every year between 2005 and 2015 from the Medical Database supplied by Nihon Ultmarc (Tokyo). It was constructed and operated under the system of 'shared use and joint maintenance' by companies and organisations that were limited to the medical, welfare and health field. It was compiled by the companies and organisation using institutions' websites, direct inquiries and interviews with physicians. Personal information listed in the database was handled appropriately according to the personal information protection law (specified at Ultmarc's website in Japanese: [https://www.ultmarc.co.jp/privacy/shared\\_use/](https://www.ultmarc.co.jp/privacy/shared_use/)). We were offered the database excluding personal information such as names or addresses. The use of this database in medical science studies is permitted. Recently, several studies were conducted using the database.<sup>20 21</sup> The database lists each physician's sex, birth year, graduation year and the municipality where they practise. Although some physicians had missing values for birth year, we estimated their age using their graduation year. We excluded physicians who had missing values for both birth year and year of medical school graduation, who accounted for about 2%–3% of the total number of physicians each year.

Population data were collected from the National Basic Resident Register, which is published annually by the Ministry of Internal Affairs and Communications. Population density was calculated by dividing the number of people residing in each secondary medical area (SMA) by area (km<sup>2</sup>). The area (km<sup>2</sup>) of each SMA was obtained from statistical reports on land areas of prefectures and municipalities by the Geospatial Information Authority of Japan. Estimated populations for 2020–2035 were obtained from the Population Projections for Japan (January 2012) by the National Institute of Population and Social Security Research.

### Physicians

The Medical Database includes physicians who work at hospitals and clinics, and those who work at research institutions, educational institutions and welfare facilities, and physicians whose workplace is not registered. In this study, physicians whose workplace was not registered are defined as physicians not working. Physicians not working includes both temporary leave and retirement. However, it is unnecessary to identify these statuses in the model. In the future projection, we used all physicians in the database. In the results, however, we showed only the results for physicians working in hospitals or clinics.

There were physicians who had more than two workplaces registered but did not include information on working hours for each workplace in the database. Thus, we assumed that they worked the same hours at each workplace. For example, when a physician worked at two places, he/she was counted as 0.5 people in each area in which the workplaces were cited. Note that if a physician worked at an uneven number of places, we would round the number so that the total number would not be an integer.

In addition, our model assumed that all physicians retire at least by the age of 80, based on previous research,<sup>22</sup> although there is no compulsory retirement age for physicians in Japan. In the subanalysis, the number of physicians under 65 years old was also calculated. In the Medical Database, a person's record is removed if they die. Thus, if a physician was removed from the database before reaching 80 years old, we defined them as death.

### The geographical unit

The geographical unit for this analysis was SMAs. In Japan, there are three levels of medical area: primary, secondary and tertiary. A primary medical area is set by the municipal boundary and generally provides basic primary care. A tertiary medical area is set by the prefectural boundary and provides the most advanced and specialised medical treatment. An SMA falls between primary and tertiary and is established by each prefectural government. An SMA is set according to medical resources and geographical factors, and mainly covers general inpatient medical care. All SMAs expect to offer sufficient healthcare, but the inequity in the physician supply has not yet been resolved.<sup>10 11 23</sup> We analysed the 342 designated SMAs

from 2012 in our study. Note that we excluded seven SMAs in Fukushima prefecture in our analysis because the estimated population data in these areas were lacking due to the large earthquake in 2011.

In order to increase the accuracy of the future projection and make it easier to understand, we divided the 342 SMAs into 4 area groups based on urban/rural status and lower/higher physician supply, based on earlier studies.<sup>11 21 23</sup> Therefore, each group cuts across multiple SMAs and prefectures. The degree of urbanisation was defined as the median value of population density in 2005 as a proxy variable, and the degree of the initial physician supply was defined as the median value of number of physicians per 100 000 population in 2005. Through the combination of these two criteria, SMAs were divided into four groups: group 1 was composed of urban SMAs with a higher initial physician supply, group 2 of rural SMAs with a higher supply, group 3 of rural SMAs with a lower supply and group 4 of urban SMAs with a lower supply. In this study, these four groups were used to resemble four areas. Thus, a migrant physician was defined as a physician who changed their workplace from one group to another during the study period.

As previously mentioned, some physicians work for research, education and welfare organisations, and they were categorised into the 'other' group. In addition, some physicians were not registered with any institutions, and they were classified as the 'non-working' group. Therefore, in our calculation, there were six groups—group 1, group 2, group 3, group 4, other and non-working—but the results for the other and non-working groups are not shown.

### The model

We projected the future supply of physicians using a cohort-component model, which is widely used for making population projections.<sup>17 24–28</sup> This model provides a flexible and powerful approach.<sup>29</sup>

Our model treated each component of change in the physician workforce: mortality, new registrations, out-migration and in-migration. The physician workforce was divided into cohorts by age and sex. There were 11 5-year age cohorts, including one for 25–29 years old and continuing on to 30–34, 35–39 and so on up to 75–79. After separating males and females, there were 22 cohorts.

This model required the following assumptions to be set for each sex and age group: (1) basic physician workforce, (2) future mortality rate, (3) future new registrations rate, (4) future in-migration rate and (5) future out-migration rate. For the basic physician workforce, which served as the starting point for the projections, we used data on the physician workforce by age and sex as in the year 2015. About 16% of physicians from 25 to 29 years old are unknown in any workplace, because they are residents and often move around various medical institutions and departments. Therefore, it was difficult to capture their workplaces. In order to avoid underestimation, for physicians aged 25–29, we allocated physicians whose

workplaces were unknown according to the percentage composition of physicians aged 25–29 in their workplaces that were known.

We calculated the mortality rate, new registrations rate, in-migration rate and out-migration rate of each group using the Medical Database during the 5 years from 2011 to 2015 and assumed that the rate would remain constant until 2035. As shown in figure 1, for the migration rate, we adopted a two-region model that was developed by focusing on two regions, one representing the area group to be projected and the other representing the rest of the area groups.<sup>29</sup> The two-region model is more accurate than the net migration model, which is widely used, while the former model has more computational complexity than the latter.<sup>29</sup> The difference between the two methods is that when calculating the migration rate, the former distinguishes between in-migration and out-migration, while the latter calculates them collectively. Then, when calculating the out-migration rate, the denominator is the number of physicians in the group to be projected, whereas when calculating the in-migration rate, the denominator is the number of physicians in the group to be projected subtracted from the number of physicians in all groups (eg, all groups—group 1). All analyses were performed using R statistical software (V.3.4.3).

### Patient and public involvement

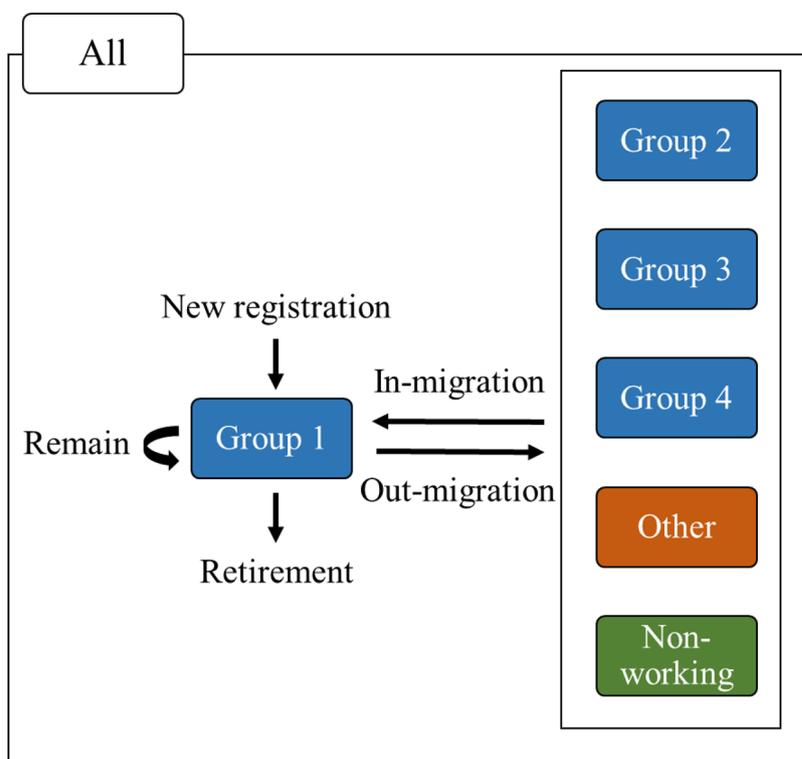
Patients and public were not involved.

### RESULTS

Table 1 summarises the descriptive statistics for the four area groups composed of SMAs in 2015. There were 102 SMAs in group 1, 69 in group 2, 102 in group 3 and 69 in group 4.

Table 2 presents the changes in population, the absolute number of physicians and female physicians, and physicians aged 25–64 in groups 1–4 between 2005 and 2035. The total populations of the rural groups (groups 2 and 3) will decrease 3–5 times compared with those of the urban groups (groups 1 and 4). On the other hand, the number of physicians will increase in all groups, especially in group 4, which will increase by 25.7%. The number of female physicians will increase by more than 50% in all groups, with group 4 seeing a particularly large increase of 74.8%. Note that the number of physicians aged 25–64 will increase only in urban groups, and the number will decrease in rural groups.

Figure 2 shows the physician workforce pyramid for each group between 2005 and 2035. From the pyramid for 2015, male physicians in their 50s accounted for the largest proportion in all groups. In the case of female physicians, there was a peak in their 30s to early 40s. In 2035, in group 1, the age-specific distribution of male physicians will be close to flat, and the proportion of female physicians will increase. In group 3, the peak for male physicians will come from the late 60s to the early 70s, and the proportion of female physicians will not



Groups 1, 2, 3, and 4 consist of practicing physicians at clinics and hospitals. The other group consists of physicians working in non-medical institutions (e.g., research, education, and welfare organizations). These groups were divided based on urban/rural status and lower/higher physician supply. The non-working group consists of physicians who have not been registered by any institutions.

In a two-region gross model, when calculating the in-migration and out-migration rates, each denominator is different. Below is how we calculated in-migration and out-migration for Group 1:

In-migration rate = the number of in-migrations/(all – group 1)

Out-migration rate = the number of out-migrations/group 1

**Figure 1** The concept of the two-region gross migration model for group 1.

increase as much. Remarkably, the ageing rate of physicians will increase year by year in all groups. From 2005 to 2035, the proportion of aged physicians will change from 13.1% to 24.9% in all groups, 12.5% to 23.2% in group

1, 12.3% to 25.1% in group 2, 14.4% to 31.1% in group 3 and 15.2% to 27.0% in group 4. The ageing rates of physicians will accelerate more rapidly in group 3 than in other groups.

**Table 1** Descriptive statistics for the four groups of SMA

Year	2015			
	Group 1	Group 2	Group 3	Group 4
Group	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
No of SMAs	102	69	102	69
Population	642 597.2 (482 508.7)	151 509.4 (111 306.4)	128 375.4 (94 651.9)	508 911.4 (379 888.0)
Density of population (km <sup>2</sup> )	3275.9 (3721.8)	471.2 (154.9)	352.3 (167.2)	2613.1 (2774.7)
Physicians	1587.3 (1499.7)	306.3 (263.5)	174.8 (130.6)	757.5 (606.9)
Physicians per 100 000 population	233.6 (93.4)	193.1 (35.2)	134.5 (23.5)	145.5 (19.7)

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

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

We excluded seven SMAs in Fukushima prefecture from our analysis because the estimated population data for those areas were lacking due to the large earthquake in 2011.

SMAs, secondary medical areas.

**Table 2** Temporal estimate changes in population and physician number for the four groups of SMAs

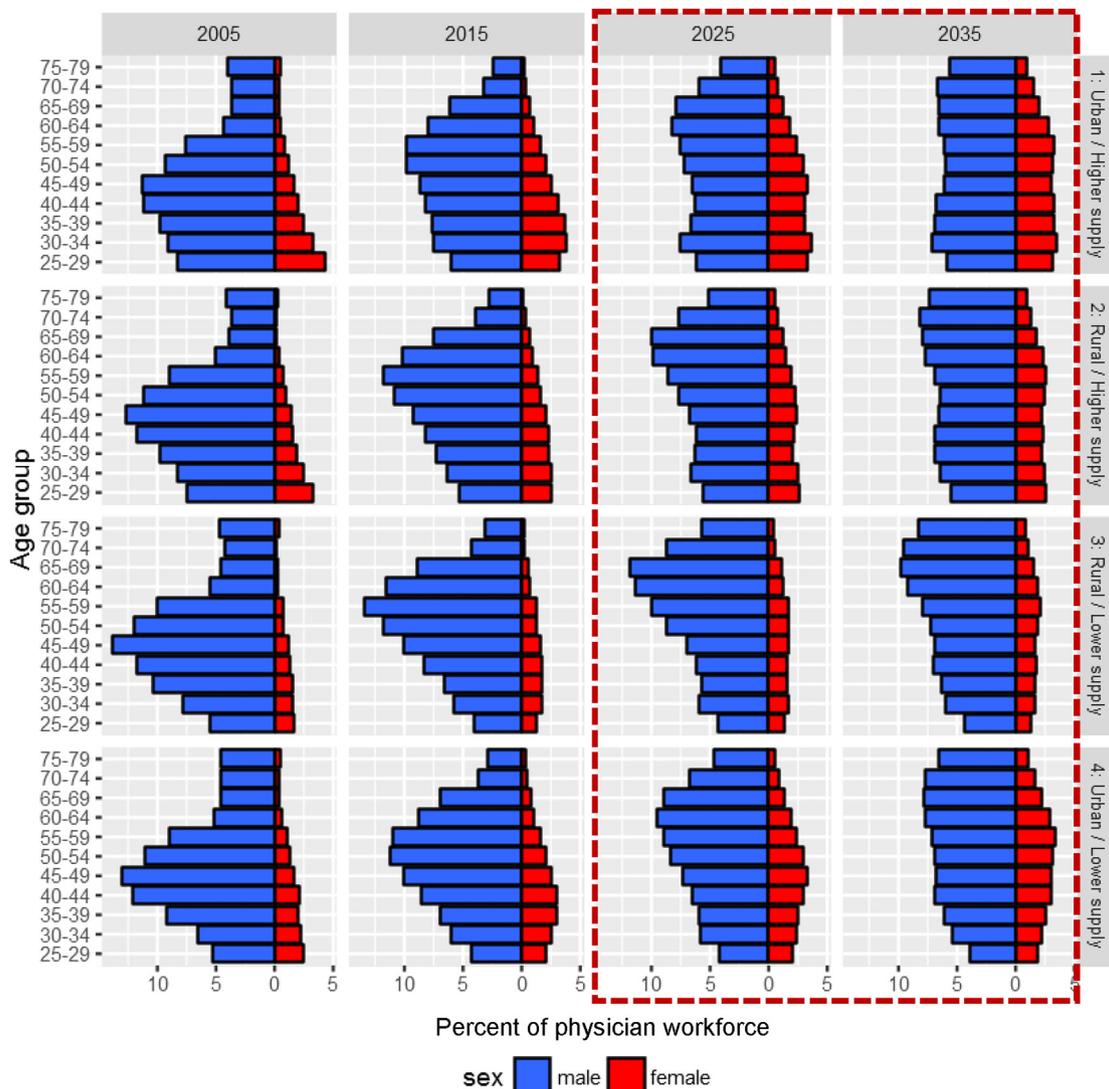
Year	2005	2015	2025	2035	Change ratio (2005–2035) (%)	Change ratio (2015–2035) (%)
<b>Population</b>						
Overall	124 761 597	124 208 237	118 878 650	110 536 987	–11.4	–11.0
Group 1	65 019 656	65 544 912	63 737 034	59 685 250	–8.2	–8.9
Group 2	11 172 787	10 454 148	9 318 048	8 309 718	–25.6	–20.5
Group 3	14 252 074	13 094 288	11 486 338	10 114 557	–29.0	–22.8
Group 4	34 317 080	35 114 889	34 337 230	32 427 462	–5.5	–7.7
<b>Physicians</b>						
Overall	243 264.6	275 932.2	312 642.1	326 989.4	34.4	18.5
Group 1	159 884.7	178 362.4	201 170.1	210 641.5	31.7	18.1
Group 2	21 740.4	22 932.6	25 331.7	25 728.1	18.3	12.2
Group 3	17 535.2	18 828.4	20 511.4	20 470.7	16.7	8.7
Group 4	44 104.3	55 808.8	65 628.9	70 149.0	59.1	25.7
<b>Female physicians</b>						
Overall	39 172.4	56 814.8	75 510.4	91 057.8	132.5	60.3
Group 1	28 096.3	39 924.8	52 430.5	62 689.8	123.1	57.0
Group 2	2862.4	3796.4	4993.5	5958.1	108.2	56.9
Group 3	1695.8	2301.4	2967.4	3549.6	109.3	54.2
Group 4	6517.9	10 792.2	15 119.0	18 860.3	189.4	74.8
<b>Physicians aged 25–64</b>						
Overall	211 309.7	237 355.2	244 287.9	245 610.6	16.2	3.5
Group 1	139 846.6	155 006.8	160 099.3	161 672.5	15.6	4.3
Group 2	19 058.3	19 422.9	18 968.8	18 625.8	–2.3	–4.1
Group 3	15 012.9	15 562.9	14 705.2	14 096.3	–6.1	–9.4
Group 4	37 391.9	47 362.6	50 514.6	51 216.0	37.0	8.1

SMAs, secondary medical areas.

Figure 3 presents the changes in the number of physicians of all ages, physicians aged 25–64, physicians aged 65 and over, and female physicians of all ages in each group from 2005 to 2035, when the number of physicians as of 2005 is set to 100 (online supplementary appendix figure 1A–D present the results in the case of physicians aged 25–34, 35–44, 45–54 and 55–64). As shown in figure 3A, in group 4, there will be a significant increase in the number of physicians of all ages. In groups 2 and 3, the number will be on an upward trend until 2025, but there will be little increase after that. As shown in figure 3B, in groups 2 and 3, the number of physicians aged 25–64 will show a rather decreasing trend; it is expected to be lower in 2035 than in 2005. Figure 3C shows that the number of physicians aged 65 years and older will increase by 250% at the national level and at almost the same speed in all groups. On the other hand, as shown in figure 3D, the number of female physicians will increase more in group 4 than in the other groups.

Figure 4 presents the changes in the number of physicians of all ages, physicians aged 25–64, physicians aged 65 and over, and female physicians of all

ages per 100 000 population in each group from 2005 to 2035 (online supplementary appendix figure 2A–D present the results in the case of physicians aged 25–34, 35–44, 45–54 and 55–64). In all groups, the number of physicians of all ages per 100 000 population will increase. However, the gap between the group with the most physicians (group 1) and that with the least (group 3) will not be filled regardless of the large population decline in group 3. The absolute disparity in the number of physicians of all ages per 100 000 population will increase from 122.9 to 150.5 between 2005 and 2035 (group 1: 245.9 vs group 3: 123.0 in 2005; group 1: 352.9 vs group 3: 202.4 in 2035). Similarly, the absolute disparity in the number of physicians aged 25–64 per 100 000 population will increase from 109.8 to 131.5 between 2005 and 2035 (group 1: 215.1 vs group 3: 105.3 in 2005; group 1: 270.9 vs group 3: 139.9 in 2035). Furthermore, the absolute disparity in the number of female physicians of all ages per 100 000 population will increase from 31.3 to 69.9 between 2005 and 2035 (group 1: 43.2 vs group 3: 11.9 in 2005; group 1: 105.0 vs group 3: 35.1 in 2035).



The physician workforce pyramid surrounded by the red dotted line shows the future projection.

**Figure 2** Physician workforce pyramids for the four area groups in 2005, 2015, 2025 and 2035.

## DISCUSSION

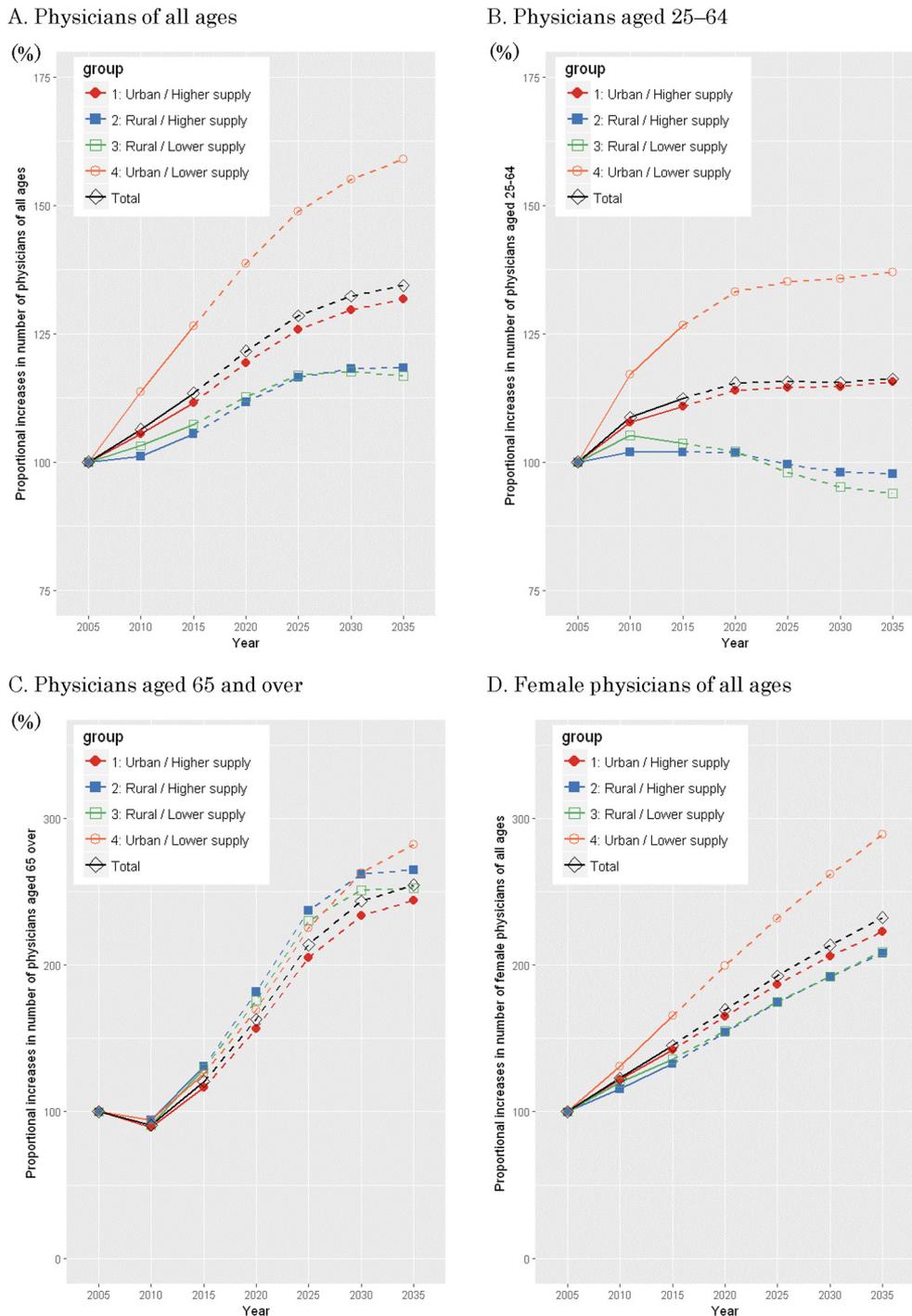
### Main findings

Our study revealed that the inequity of the geographical distribution of physicians will increase from 2005 to 2035. Notably, our future projection found that the number of physicians aged 25–64 will decline by 6.1% in the rural group with an initially lower physician supply (group 3), although it will increase by 37.0% in the urban group with an initially lower supply (group 4). The proportion of aged physicians will increase in all groups, especially in group 3, where it will change from 17.3% to 31.3%. The number of female physicians will increase more in group 4 than in the other groups. The gap in the physician supply between groups 1 and 3 will continue to expand for physicians of all ages, those aged 25–64 and female physicians.

### The inequity of the physician supply

Our results showed that the regional disparity in the physician supply will not be resolved even if the number

of physicians continues to increase at the same pace as at present. Similarly, a previous study, which used a physician survey by the MHLW, reported that the geographical disparity in the physician supply at the prefecture level will continue until 2035 in Japan.<sup>17</sup> The disparity in the physician supply will expand if new and drastic measures are not adopted. Currently, the number of enrolments in medical schools is at an all-time high, although a reduction in the number has been discussed in relation to Japan's shrinking population.<sup>7,30</sup> On the other hand, there is concern that reducing the number of enrolments may cause the inequity in the geographical distribution of physicians to become more serious. In fact, our results showed that in 2035, the number of physicians per 100 000 population in group 3 will be less than 60% of group 1, and will be below the OECD average number in 2015.<sup>31</sup> Thus, reducing the number of enrolments while maintaining the current physician supply system may result in



**Figure 3** Estimated trends in the number of physicians from 2005 to 2035.

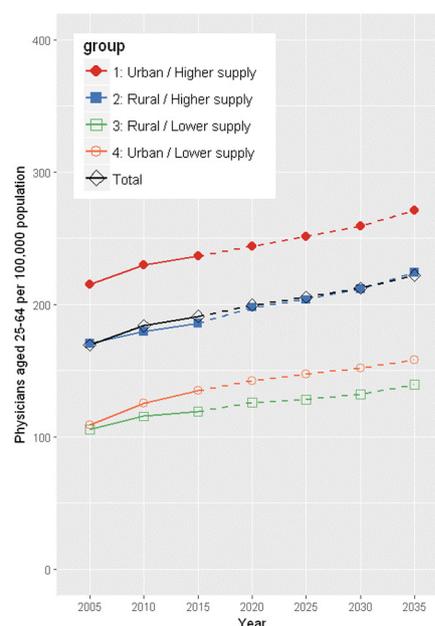
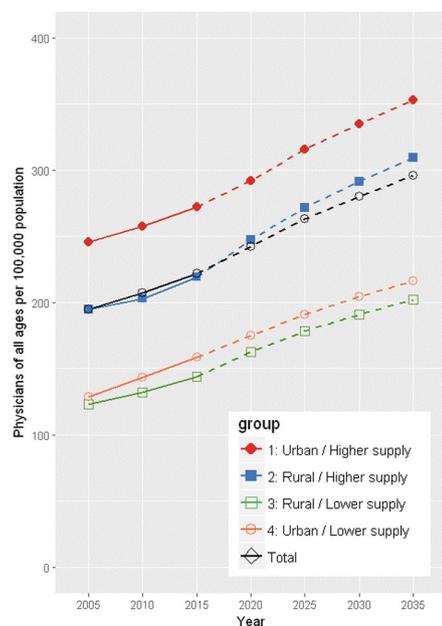
a serious physician shortage in rural areas, especially for those in group 3.

### Female physicians

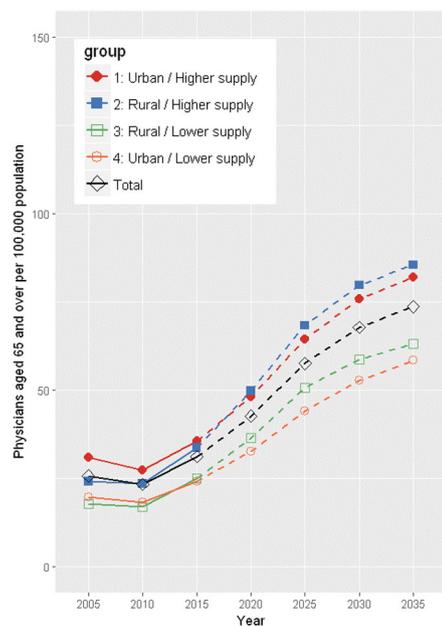
Internationally, more women are becoming involved in medicine.<sup>32 33</sup> Some studies reported that female physicians are less likely to work in rural areas than in urban ones.<sup>13 14</sup> In fact, our results indicated that female physicians will increase more in group 4 and the gap in the female physician supply between groups 1 and 3 will expand greatly. Female physicians are often prevented from working in rural, remote areas by cultural and

social factors.<sup>34</sup> In particular, the gender gap in Japan, which is composed of gender gaps in economic, political, educational and health criteria, was ranked 101 out of 145 countries.<sup>35</sup> Kaneto *et al*<sup>13</sup> reported that the pattern of workforce participation by female physicians was the same as that of women working in other industries in Japan. That is, they were affected by family issues, particularly with their children. In addition, although the number of female physicians has increased in Japan, the proportion of female physicians is the lowest (20%) among the OECD countries (OECD average: 45%).<sup>36</sup>

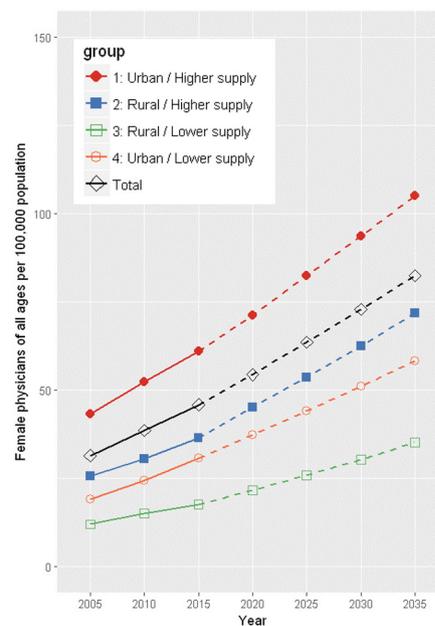
A. Physicians of all ages per 100,000 population B. Physicians aged 25–64 per 100,000 population



C. Physicians aged 65 and over per 100,000 population



D. Female physicians of all ages per 100,000 population



**Figure 4** Estimated trends in the number of physicians per 100 000 population from 2005 to 2035.

Thus, the government and workforce planners should continue to take measures to overcome the obstacles to work in rural areas for female physicians and change the male-dominated workforce.

### Younger and older physicians

Physician ageing has been of concern in developed countries. [Figure 3C](#) shows that the number of physicians aged 65 and over will increase rapidly in all groups. The correlation between physician ageing and clinical performance is controversial.<sup>37</sup> Further, regarding the supply of physicians, it is possible that physician ageing exacerbates

physician shortage because older physicians are likely to retire and have shorter working hours than young physicians. Hence, in order to secure the physician supply, it is important to increase the number of younger physicians. However, [figure 3B](#) shows that physicians aged 25–64 in groups 2 and 3 which are the rural groups, will not increase but rather decrease.

This trend may be affected by the fact that young physicians are not gathering at university hospitals because of the new clinical training system for residents established in 2004. Before that, the university hospitals took

responsibility for dispatching physicians to rural areas. Many residents belonged to university hospitals and received training. However, since the new system was started, residents have had many options for training hospitals, and the number of residents choosing university hospitals has decreased. As a result, the number of physicians at university hospitals became insufficient, making it difficult to dispatch physicians to rural areas. Some researchers have reported that the new system exacerbated the regional disparity in the physician supply.<sup>2 38</sup> In addition, this may also be related to changes in physicians' specialist orientations in Japan.<sup>23 39 40</sup> This may lead to a concentration of physicians in urban areas because physicians with high expertise (or physicians trying to become such physicians) are likely to be concentrated in urban areas due to the facilities, environment and number of cases.

Note that the number of physicians aged 65 and over decreased a little from 2005 to 2010, but only temporarily. The main reason for this decrease was that the number of physicians aged 75–79 was higher than that of other older physicians as of 2005. They became physicians around the end of the Second World War; therefore, there is the possibility that the number of physicians temporarily increased at that time. As of 2010, they became 80 years old and older and were left out of the study. Thus, our results showed a temporary decrease from 2005 to 2010. We also confirmed the same trend in a different physician database in 2004: the physician survey by the MHLW.

### Physician supply policies

WHO published guidelines for securing healthcare providers in remote and rural areas, and it strongly encouraged students from rural backgrounds to enrol in medical departments.<sup>41</sup> This solution was clarified in previous studies,<sup>42 43</sup> and such a policy has recently been strengthened in Japan. A regional quota admission system for medical schools has been introduced: it is called the *chiikiwaku* system.<sup>44</sup> This system has been implemented by each university by combining the following elements: (1) scholarship, (2) time of selection (prior to or after enrolment), (3) obligation to work in a rural area or a specific department for a certain period after graduation (approximately 9 years) and (4) designation of home town. Because the regional quota started to increase in around 2008, it will be necessary to verify the effect in the future. The effect of this system is barely reflected in our future projection using data up to 2015.

On the other hand, WHO guidelines also recommended regulation, financial incentives, and personal and professional support. In terms of financial incentive, scholarships are being offered from local governments to medical students other than regional quota students, subject to working in rural areas or in a specific clinical department. Besides this, rural physicians tend to have higher salaries than urban physicians because of a lack of physicians in rural areas and financial support to regional hospitals from the public sector. In terms of professional

support, telemedicine in image diagnosis, as well as advice and education using video conference, are widespread. Moreover, the national and prefecture governments support rural physicians by dispatching locums from rural health-supporting hospitals (*hekichi-iryokyoten-byouin*) and providing educational opportunities based on regional health plans (*chiiki-iryokeikaku*). Although these efforts have been made, the inequity in geographical distribution of numbers of physicians has been expanding.

For physicians working in rural areas, it is becoming a big concern as to whether or not they can acquire expertise. To eliminate such anxiety, it is important to concretely prepare career paths for such physicians to gain expertise. One possibility is to create opportunities to acquire expertise at a hospital that can provide good training. Furthermore, further strengthening of remote support for diagnosis, planning, treatment and professional education is also considered necessary. With this support, it may be better to develop the system collectively at the national level, rather than within each local government. In addition, based on the hub-and-spoke model taken from logistics, it may be better to establish and strengthen hub hospitals in rural areas, which can be responsible for the educational and training functions that are likely to be lacking in rural areas.

### Limitations

This study had several limitations. First of all, the database did not include work hours. Thus, we could not calculate an accurate full-time equivalent. Second, the physician database that we used was collected by medical representatives of pharmaceutical companies. Thus, some physicians may not have been registered because they did not come into contact with a medical representative. In addition, we excluded physicians who were missing data for both birth year and graduation year. This may have caused some bias. However, when compared with the database and the physician survey conducted by the MHLW, there was almost no difference in the number of physicians per age group (data not shown). Because the database we used updates the data on a daily basis, it may be more accurate than the physician survey, which is conducted every 2 years. Third, our future projection was based on trends from 2011 to 2015, and there is the possibility that these trends will change significantly due to developments in policy and environment.

### CONCLUSIONS

Using the cohort-component method, our study revealed that the geographical distribution of physicians will worsen, although the number of physicians per 100 000 population in rural areas will increase. Furthermore, physicians aged 25–64 will be concentrated in urban areas, and the ageing rate of physicians will accelerate more rapidly in rural areas than urban ones. The regional

disparity in the physician supply will worsen in the future if new and drastic measures are not put in place.

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## REFERENCES

- Shinjo D, Aramaki T. Geographic distribution of healthcare resources, healthcare service provision, and patient flow in Japan: a cross sectional study. *Soc Sci Med* 2012;75:1954–63.
- Toyabe S. Trend in geographic distribution of physicians in Japan. *Int J Equity Health* 2009;8:5.
- Anand S, Fan VY, Zhang J, et al. China's human resources for health: quantity, quality, and distribution. *Lancet* 2008;372:1774–81.
- Morris S, Sutton M, Gravelle H. Inequity and inequality in the use of health care in England: an empirical investigation. *Soc Sci Med* 2005;60:1251–66.
- Isabel C, Paula V. Geographic distribution of physicians in Portugal. *Eur J Health Econ* 2010;11:383–93.
- Pitblado JR, Pong RW. *Geographic distribution of physicians in Canada*. Sudbury, Ontario, Canada: Centre for Rural and Northern Health Research, Laurentian University, 1999.
- Asano N, Kobayashi Y, Kano K. Issues of intervention aimed at preventing prospective surplus of physicians in Japan. *Med Educ* 2001;35:488–94.
- National Institute of Population and Social Security Research, 2012. Population projection for Japan:2011–2060. <http://www.ipss.go.jp/syoushika/tohkei/newest04/gh2401.pdf> (accessed 29 Feb 2016).
- the Ministry of Health, Labour and Welfare, 2016. Interim Summary of the meeting about the balance between physician supply and healthcare demand. <http://www.mhlw.go.jp/stf/shingi2/0000126444.html> (accessed 7 Nov 2016).
- Tanihara S, Kobayashi Y, Une H, et al. Urbanization and physician maldistribution: a longitudinal study in Japan. *BMC Health Serv Res* 2011;11:260.
- 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:e013922.
- Ministry of Education C, Sports, Science and Technology, 2016. gakkokihonchosa (School Basic Survey). [http://www.mext.go.jp/b\\_menu/toukei/chousa01/kihon/1267995.htm](http://www.mext.go.jp/b_menu/toukei/chousa01/kihon/1267995.htm) (accessed Oct 25 2016).
- Kaneto C, Toyokawa S, Inoue K, et al. Gender difference in physician workforce participation in Japan. *Health Policy* 2009;89:115–23.
- Doescher MP, Ellsbury KE, Hart LG. The distribution of rural female generalist physicians in the United States. *J Rural Health* 2000;16:111–8.
- The Japan Institute for Labour Policy and Training. The survey of the hospital physician's working condition and attitude 2012. <http://www.jil.go.jp/institute/research/2012/documents/0102.pdf> (accessed 7 Nov 2016).
- Matsumoto M, Kimura K, Inoue K, et al. Aging of hospital physicians in rural Japan: a longitudinal study based on national census data. *PLoS One* 2018;13:e0198317.
- Yuji K, Imoto S, Yamaguchi R, et al. Forecasting Japan's physician shortage in 2035 as the first full-fledged aged society. *PLoS One* 2012;7:e50410.
- Koike S, Yasunaga H, Matsumoto S, et al. A future estimate of physician distribution in hospitals and clinics in Japan. *Health Policy* 2009;92:244–9.
- Ishikawa T, Ohba H, Yokooka Y, et al. Forecasting the absolute and relative shortage of physicians in Japan using a system dynamics model approach. *Hum Resour Health* 2013;11:41.
- Kamitani S, Nakamura F, Itoh M, et al. Differences in medical schools' regional retention of physicians by school type and year of establishment: effect of new schools built under government policy. *BMC Health Serv Res* 2015;15:581.
- Sasaki H, Otsubo T, Imanaka Y. Widening disparity in the geographic distribution of pediatricians in Japan. *Hum Resour Health* 2013;11:59.
- Ricketts TC, Adamson WT, Fraher EP, et al. Future supply of pediatric surgeons: analytical study of the current and projected supply of pediatric surgeons in the context of a rapidly changing process for specialty and subspecialty training. *Ann Surg* 2017;265:609–15.
- Hara K, Kunisawa S, Sasaki N, et al. Examining changes in the equity of physician distribution in Japan: a specialty-specific longitudinal study. *BMJ Open* 2018;8:e018538.
- By L, Zhang JT, He H. Resident population prediction based on cohort-component method. In: Wu DD, ed. *Modeling risk management in sustainable construction*. Berlin: Springer-Verlag Berlin, 2011:343–50.
- U.S. Census Bureau. Population Projections - Methodology 2014. Updated 6 Jul 2012. <https://www.census.gov/population/projections/methodology/> (accessed 10 Nov 2016).
- Office for National Statistics, 2016. Subnational population projections QMI - Office for National Statistics U.K <https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/qmis/subnationalpopulationprojectionsqmi> (accessed 10 Nov 2016).
- National Institute of Population and Social Security Research. Population projection for Japan 2016. [http://www.ipss.go.jp/site-ad/index\\_english/esuikai/gh2401e.asp](http://www.ipss.go.jp/site-ad/index_english/esuikai/gh2401e.asp) (accessed 10 Nov 2016).
- United Nations, Department of Economic and Social Affairs, 2015. World population prospects: the 2015 revision, methodology of the united nations population estimates and projections. [https://esa.un.org/unpd/wpp/Publications/Files/WPP2015\\_Methodology.pdf](https://esa.un.org/unpd/wpp/Publications/Files/WPP2015_Methodology.pdf) (accessed 10 Nov 2016).
- Stanley K, Jeff S, David T, et al. *State and local population projections*. New York: Kluwer Academic, 2006.
- Study group on the supply and demand of physicians of MHLW, 2006. The study group report on the supply and demand of physicians. <http://www.mhlw.go.jp/shingi/2006/07/dl/s0728-9c.pdf> (accessed 16 Apr 2017).
- OECD. *Health at a Glance 2017 - OECD Indicators*. Paris: OECD Publishing, 2017.
- Kilminster S, Downes J, Gough B, et al. Women in medicine—is there a problem? A literature review of the changing gender composition, structures and occupational cultures in medicine. *Med Educ* 2007;41:39–49.
- Levinson W, Lurie N. When most doctors are women: what lies ahead? *Ann Intern Med* 2004;141:471–4.
- Dussault G, Franceschini MC. Not enough there, too many here: understanding geographical imbalances in the distribution of the health workforce. *Hum Resour Health* 2006;4:12.
- World Economic Forum, 2016. Global Gender Gap Report 2016. <http://reports.weforum.org/global-gender-gap-report-2016/> (accessed Nov 23 2016).
- OECD. *Health at a glance 2015: OECD indicators*. Paris: OECD publishing, 2015.
- Kupfer JM. The Graying of US Physicians: Implications for Quality and the Future Supply of Physicians. *JAMA* 2016;315:341–2.
- 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.
- 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.
- 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;96:239–44.



41. WHO. *Increasing access to health workers in remote and rural areas through improved retention Global policy recommendations*. Switzerland: WHO Press, 2010.
42. Magnus JH, Tollan A. Rural doctor recruitment: does medical education in rural districts recruit doctors to rural areas? *Med Educ* 1993;27:250–3.
43. Grobler L, Marais BJ, Mabunda S. Interventions for increasing the proportion of health professionals practising in rural and other underserved areas. *Cochrane Database Syst Rev* 2015;6:Cd005314.
44. 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:e011165.