

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-013922
Article Type:	Research
Date Submitted by the Author:	18-Aug-2016
Complete List of Authors:	Hara, Koji; Kyoto University Graduate School of Medicine, Department of Healthcare Economics and Quality Management Otsubo, Tetsuya; Kyoto University Graduate School of Medicine, Department of Healthcare Economics and Quality Management Kunisawa, Susumu; Kyoto University Graduate School of Medicine, Department of Healthcare Economics and Quality Management Imanaka, Yuichi; Kyoto University Graduate School of Medicine, Department of Healthcare Economics and Quality Management
Primary Subject Heading:	Health policy
Secondary Subject Heading:	Public health
Keywords:	Japan, Physicians, geographic distribution, sufficiency, healthcare demand, equity

SCHOLARONE™
Manuscripts

1
2
3 1 Worsening Sufficiency and Equity in the Geographic Distribution of
4
5
6 2 Physicians in Japan
7
8
9 3

10 4 **Authors:**

11
12 5 Koji Hara, Tetsuya Otsubo, PhD, Susumu Kunisawa, MD, PhD, and Yuichi Imanaka,
13
14 6 MD, PhD

15
16
17 7 Department of Healthcare Economics and Quality Management, Graduate School of
18
19 8 Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku, Kyoto City, Kyoto, Japan
20
21 9 606-8501
22
23

24 10
25
26 11 **Corresponding author:**

27
28 12 Yuichi Imanaka, Professor

29
30 13 Mailing address: Department of Healthcare Economics and Quality Management,
31
32 14 Graduate School of Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku,
33
34 15 Kyoto City, Kyoto, Japan 606-8501

35
36 16 Tel: +81 75 753 4454

37
38 17 Fax: +81 75 753 4455

39
40 18 Email: imanaka-y@umin.net
41
42
43

44 19

45 20 **Word count:**

46
47 21 3,137 words
48
49
50
51
52
53
54
55
56
57
58
59
60

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

Abstract

Objectives

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

Methods

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

Results

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

Conclusions

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

Strengths and limitations of this study

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

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
- The trends in sufficiency and equity in Japan's physician supply changed after adjusting healthcare demand, indicating that healthcare demand should be considered when examining the geographic distribution of physicians. This adjustment will become increasingly important as the age structure of the Japanese population continues to change.
 - The primary limitation of this study is that it was a retrospective study and, as such, does not provide estimates on future physician supply and healthcare demand.

Keywords

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

Introduction

The inequitable geographic distribution of physicians is a pressing issue in many countries¹⁻⁴. There are at least two reasons why this issue attracts social and political attention. The reason comes from the issue of equity and social justice, that is, a citizen's right to access healthcare equally. The other is rooted in the belief in linkages between physician availability and health status⁵.

Studies that address this topic frequently use the number of physicians per population as an indicator of physician supply. However, this simple calculations may present an oversimplification of findings due to its reliance on simple head counts that ignore differences within a population⁵. In particular, healthcare demand is likely to differ substantially among the age strata as elderly people tend to require more health care. As many parts of the world are experiencing accelerated population ageing, it is becoming increasingly important to consider the differences in age-dependent healthcare demand when examining physician supply.

Population ageing has become a key policy issue throughout the world⁶. Japan currently has the highest proportion of people aged 65 years or older, and became one of the first "super-aged" societies when this proportion exceeded 21% in 2007⁷. In addition, Japan's rate of population ageing is unprecedented: the rise in the proportion of people aged 65 years or older from 10% to 20% occurred within 20 years. In contrast, the UK had almost 79 years and the US had almost 59 years to adapt to this shift in population age structure. Furthermore, Japan's proportion of elderly people is predicted to rise to 33.4% in 2035 and 39.9% in 2060⁸, indicating that its population is still undergoing rapid changes.

1
2
3 83
4 84 In Japan, the issue of the number of physicians has been changing from a shortage to a surplus. Japan
5
6 85 faced a shortage of physicians in the 1960s and 1970s⁹. During that period, the country experienced a
7
8 86 massive increase in population from 94 million to 117 million people. The government at that time aimed
9
10 87 to ensure a minimum of 150 physicians for every 100 000 people, and doubled medical school
11
12 88 enrolments in the 1970s to increase physician supply. The target number of physicians was achieved in
13
14 89 1984, and has since continued to increase. Due to the ageing and projected decrease of the Japanese
15
16 90 population, the possible surplus of physicians is an issue that needs to be addressed. Although the
17
18 91 government-sanctioned reduction of enrolments in medical schools has been proposed as a possible
19
20 92 measure to control physician numbers, this measure is controversial and has been met with resistance
21
22 93 from several interest groups¹⁰. Detailed and accurate information on physician supply that accounts for
23
24 94 age-dependent healthcare demand is needed to support this decision-making process.
25
26 95

27 96 Although previous studies have examined trends in physician geographic distribution using healthcare
28
29 97 demand-adjusted populations^{11 12}, there is currently no standardized method for adjusting healthcare
30
31 98 demand. Furthermore, the trends in physician supply in a super-aged society such as Japan have yet to be
32
33 99 investigated. In this study, we conducted a longitudinal examination of the geographic distribution of
34
35 100 physicians with adjustment for healthcare demand according to the changing age structure of the
36
37 101 Japanese population.
38
39 102

103 **Methods**

104 **Data sources**

105 The number of physicians was obtained from the National Physician Census, which is conducted
106
107 biennially by the Ministry of Health, Labour and Welfare. The census data included the type and location
108
109 (municipality) of workplace for each physician. Population data were collected from the National Basic
110
111 Resident Register, which is published annually by the Ministry of Internal Affairs and Communications.
112
113 We collected national health expenditure data from the Ministry of Health, Labour and Welfare, and
114
115 calculated the expenditure per capita for each age group in 2014. Although national health expenditure
116
117 includes various types of health care, we only used general treatment medical fees for our analysis
118
119 because the other types of care were deemed to have little direct relevance to the number of physicians.
120
121
122

1
2
3 113 Medical consultation rates were collected from the 2014 Patient Survey conducted by the Ministry of
4
5 114 Health, Labour and Welfare. Population density was calculated by dividing the number of people
6
7 115 residing in each secondary medical area (SMA, described below) by the area (km²). The area of each
8
9 116 region was obtained from statistical reports on land areas of prefectures and municipalities by the
10
11 117 Geospatial Information Authority of Japan.
12

13 14 119 **Physicians and population**

15
16 120 Practicing physicians at all Japanese clinics and hospitals were included in analysis, whereas registered
17
18 121 physicians working in non-clinician roles (e.g., basic researchers or government officials) were excluded.
19
20 122 Physician numbers were calculated for both the raw (unadjusted) population and the healthcare
21
22 123 demand-adjusted population; the former included all Japanese citizens and the latter included all
23
24 124 Japanese citizens adjusted for age-dependent healthcare demand. The population was stratified into
25
26 125 5-year age groups, with the initial group comprising persons aged 0 to 4 years and the final group
27
28 126 comprising persons aged 80 years or older.
29

30 31 128 **Secondary medical areas**

32
33 129 The SMA was used as the geographic unit of analysis. The Japanese government has designated medical
34
35 130 service administration areas throughout the country, and these areas are categorized into primary,
36
37 131 secondary, and tertiary medical areas. Primary medical areas are set at the municipal level, and generally
38
39 132 represent areas that are capable of providing basic primary care to residents. Tertiary medical areas are
40
41 133 generally set at the prefectural level, and generally represent areas that are capable of providing the most
42
43 134 advanced and specialized medical treatments. SMAs, which are between these two levels, generally
44
45 135 supply and manage the majority of primary care and emergency medical services to regional
46
47 136 communities. Therefore, SMAs are arguably the most important of the three geographic units with regard
48
49 137 to implementing health policies. The geographic boundaries of the primary and tertiary medical areas are
50
51 138 based on existing regional borders, whereas SMAs are demarcated by the prefectural governments based
52
53 139 on healthcare provision capabilities. As a result, SMAs are directly relevant to the functional aspects of
54
55 140 healthcare administration. Previous studies on physician geographic distribution in Japan have been
56
57 141 conducted at the municipal level^{9 13}, although recent studies have also focused on SMAs^{4 14 15}. SMA
58
59 142 boundaries can be modified by prefectural governments in response to changing healthcare requirements.
60

1
2
3 143 In this study, we analysed the 349 designated SMAs in 2012.
4
5 144

6
7 145 **Analysis of physician distribution**

8 146 First, we calculated the healthcare demand-adjusted population using adjustment coefficients that were
9
10 147 derived according to the health expenditure per capita for each age group. The health expenditure for
11
12 148 each age group was divided by the overall mean health expenditure of the population, and the obtained
13
14 149 quotients were used as age group-specific adjustment coefficients. We applied the adjustment
15
16 150 coefficients to the raw population to obtain the healthcare demand-adjusted population. The numbers of
17
18 151 physicians per 100 000 population in the SMAs were calculated for both the raw and demand-adjusted
19
20 152 populations, and these values were used in the following analyses. In addition, we assessed the
21
22 153 robustness of the adjustment coefficients by comparing them with alternative coefficients based on
23
24 154 medical consultation rates instead of health expenditure, and also examined the annual changes in the
25
26 155 adjustment coefficients by age group during the study period.
27

28
29 157 Next, we assessed the equity of the geographic distribution of physicians. The Gini coefficient was used
30
31 158 as the indicator of equity, and has been widely used in similar analyses^{2 4 16-18}. This coefficient measures
32
33 159 the degree of departure from a uniform distribution known as the Lorenz curve, and takes a value
34
35 160 between 0 (indicating perfect equality) and 1 (indicating perfect inequality). The Lorenz curve for the
36
37 161 SMAs was plotted based on the number of physicians per 100 000 population.
38

39
40 163 We then examined the time-based trends in the number of SMAs with a low physician supply. SMAs
41
42 164 were categorized into quartiles according to the number of physicians per 100 000 raw population in
43
44 165 2000, and the SMAs in the first quartile were specified as having a low physician supply. We examined
45
46 166 the changes in the proportions of SMAs that fulfilled this criterion throughout the study period.
47

48
49 168 Finally, we divided SMAs into four groups according to two criteria: whether they were rural or urban,
50
51 169 and whether they had a lower or higher initial physician supply at the start of the study period. Using an
52
53 170 approach described previously in¹⁴ the degree of urbanization was determined using the population
54
55 171 density in 2000 as a proxy variable, and the initial physician supply was indicated using the number of
56
57 172 physicians per 100 000 population in 2000. We divided the SMAs according to the median values of each
58
59
60

1
2
3 173 variable to obtain four groups: Group 1 comprised urban SMAs with a higher initial physician supply,
4
5 174 Group 2 comprised rural SMAs with a higher initial physician supply, Group 3 comprised rural areas
6
7 175 with a lower initial physician supply, and Group 4 comprised urban areas with a lower initial physician
8
9 176 supply. The changes in physician numbers were compared among these groups. All analyses were
10
11 177 performed using R statistical software (version 3.2.2).
12
13 178

14 179 **Results**

15
16 180 As shown in Table 1, the adjustment coefficients for the age groups ranged from 0.22 (15–24 years) to
17
18 181 3.33 (80 years or older). The adjustment coefficient of the elderly population (65 years or older) was
19
20 182 approximately four times that of the younger population (10–39 years). The results of robustness testing
21
22 183 indicated that our adjustment coefficient was consistent with the results of the alternative coefficient
23
24 184 based on medical consultation rates, with a high level of correlation (correlation coefficient: 0.99)
25
26 185 between the primary adjustment coefficients and medical consultations rates by age group. Furthermore,
27
28 186 our coefficient also appeared robust to time-based changes from 2000 to 2014 (data not shown).
29
30 187

31 188 Table 2 shows the temporal trends in the number of physicians and population from 2000 to 2014 at
32
33 189 2-year intervals. The number of physicians consistently increased by approximately 6000 to 8000 every
34
35 190 two years, and was 1.22 times higher in 2014 than in 2000. The raw population generally remained
36
37 191 unchanged throughout the study period. In contrast, the healthcare demand-adjusted population was 1.23
38
39 192 times higher in 2014 than it was in 2000. Hence, the increase rate of the demand-adjusted population
40
41 193 slightly exceeded the increase rate of physicians.
42
43 194

44 195 Table 3 summarizes the descriptive statistics for the 349 SMAs. The mean number of physicians and
45
46 196 demand-adjusted population had increased between 2000 and 2014. Figure 1 illustrates the temporal
47
48 197 changes in Gini coefficient for the number of physicians per 100 000 population (both raw and
49
50 198 demand-adjusted) at the SMA level, and indicates that the equity in physician numbers had worsened in
51
52 199 both populations. In particular, equity had deteriorated more (higher Gini coefficient) in the healthcare
53
54 200 demand-adjusted population.
55
56 201

57 202 Figure 2 shows the changes in the proportion of SMAs with a low physician supply across the study
58
59
60

1
2
3 203 period. In the raw population, the proportion consistently decreased from 24.9% to 13.2% (with a brief
4 204 increase between 2006 and 2008). In contrast, the same proportion in the healthcare demand-adjusted
5 205 population consistently increased from 24.9% to 35.0% (with a brief decrease between 2000 and 2002);
6 206 notably, there was a relatively large increase of 4.5% between 2006 and 2008 in the demand-adjusted
7 207 population.
8
9

10
11
12 208
13
14 209 Table 4 presents the changes in the absolute numbers of physicians and physicians per 100 000
15 210 population in Groups 1 to 4 between 2000 and 2014. There were 100 SMAs in Group 1, 75 SMAs in
16 211 Group 2, 99 SMAs in Group 3, and 75 SMAs in Group 4. The absolute numbers of physicians showed
17 212 considerable increases in Groups 1 and 4, whereas the increases were smaller in the other two groups. In
18 213 the raw population, all groups (including the rural areas) exhibited increases in the number of physicians
19 214 per 100 000 population. In contrast, the number of physicians per 100 000 healthcare demand-adjusted
20 215 population was observed to decrease in all groups except Group 4.
21
22
23
24
25
26
27

28 29 217 **Discussion**

30 218 We conducted a longitudinal examination of the geographic distribution of physicians in Japan that
31 219 accounted for changes in age-dependent healthcare demand in accordance with the changing age
32 220 structure of the Japanese population. Our study produced two major findings: First, the equity in
33 221 physician geographic distribution for the demand-adjusted population had worsened throughout the
34 222 study period when analysing the time-based trends of both Gini coefficient and the number of SMAs
35 223 with a low physician supply. Second, the number of physicians per 100 000 healthcare demand-adjusted
36 224 population decreased in all types of areas except for urban areas with a lower initial physician supply.
37
38
39
40
41
42
43
44

45 226 Although the number of physicians per population has been widely used as an indicator of physician
46 227 supply, it does not account for intra-population variations in healthcare demand. Healthcare demand
47 228 differs among the age strata because elderly people tend to utilize more health care. As Japan is
48 229 undergoing unprecedented population ageing, changes in age structure and healthcare demand should
49 230 be considered when examining the geographic distribution of physicians.
50
51
52
53
54

55 231
56 232 In fact, the changes in the number of physicians per raw population in each group were markedly
57
58
59
60

1
2
3 233 different from the changes in the demand-adjusted population. The number of physicians per 100 000
4 234 raw population had seemingly increased in all types of areas, especially in the urban groups: there was an
5 235 increase of 22.9% in Group 1 and 34.5% in Group 4. However, after adjusting healthcare demand, the
6 236 number decreased by 1.3% in Group 1, and increased by 3.5% in Group 4; the number of physicians also
7 237 decreased in the rural groups. The disparity in results indicates that it is necessary to adjust healthcare
8 238 demand when analysing physician supply. Furthermore, this adjustment will become increasingly
9 239 important in the future as the age structure of the Japanese population continues to change.
10
11
12
13
14
15
16
17

18 241 Despite the consistent nationwide increase in the absolute number of physicians, this increase was not
19 242 accompanied by improved equity in physician distribution. It has been previously proposed that
20 243 increasing the overall number of physicians may resolve uneven physician distribution as competitive
21 244 forces play a major role in determining distribution patterns^{19,20}. However, studies in Japan have reported
22 245 that increases in overall physician numbers have not been able to improve the regional disparity in
23 246 physician supply^{4,9,21}. Similarly, our results indicate that this disparity has not been resolved in recent
24 247 years. In fact, the problem appears to have worsened when physician supply was analysed in the
25 248 healthcare demand-adjusted population. We surmise that equity in physician supply will continue to
26 249 worsen without the prompt development and implementation of appropriate measures.
27
28
29
30
31
32
33
34

35 250
36 251 The number of SMAs with a low physician supply had appeared to decrease throughout the study period
37 252 in the raw population, but adjusting for age-dependent healthcare demand revealed that these SMAs had
38 253 actually increased. We posit that these conflicting results may be attributed to the higher increase rate of
39 254 the demand-adjusted population relative to the increase rate of physicians. An earlier study found that
40 255 physician supply had increased in SMAs with small populations due to the larger effects of reductions in
41 256 population size⁴. However, our study was able to detect reductions in the number of physicians in SMAs
42 257 with similarly small populations when healthcare demand was adjusted. Although population numbers
43 258 have been decreasing in rural areas, their demand for health care is increasing due to the rising proportion
44 259 of elderly persons.
45
46
47
48
49
50
51
52

53 260
54 261 Although physician supply had appeared to increase in Group 1 (urban SMAs with a higher initial
55 262 physician supply), our study showed that the supply had actually decreased after healthcare demand was
56
57
58
59
60

1
2
3 263 adjusted. This discovery is interesting in that it contradicts the convention that physician supply tends to
4 264 increase in urban areas, and indicates that healthcare demand has rapidly increased in these regions.
5
6 265 Many countries are experiencing population ageing; the OECD has reported an increase of 23.8% in
7
8 266 elderly populations in urban areas from 2001 to 2011, whereas the increase was lower in rural areas at
9
10 267 18.2%²². It is therefore evident that physician shortages are not limited to rural areas, and should also be
11
12 268 actively addressed as an urban issue. On the other hand, our study also found that physician supply had
13
14 269 increased in Group 4 (urban SMAs with lower initial physician supply) after adjusting healthcare
15
16 270 demand. Many SMAs in Group 4 are composed of suburban areas with large populations and relatively
17
18 271 small numbers of physicians. Despite the increase in physician supply in Group 4, the number of
19
20 272 physicians per 100 000 demand-adjusted population was almost half that of Group 1 in 2014.
21
22 273
23 274 Our findings are also important in the context of the study setting: Japan has gained worldwide attention
24
25 275 as it addresses the challenges of a super-aged society²³. Due to the lengthy training periods and declining
26
27 276 birth rate in Japan, it will be difficult to quickly increase the number of physicians if needed. We
28
29 277 therefore propose that there is a need for major reform of the healthcare delivery system that does not rely
30
31 278 on increasing physician numbers. For example, possible measures include establishing and enhancing
32
33 279 the roles of medical teams to improve physician productivity or promoting the utilization of information
34
35 280 and communications technology, such as telemedicine.
36
37 281
38 282 Several studies have previously attempted to account for healthcare demand through the use of variables
39
40 283 such as patient age, sex, and health status^{11 12 24}. In this study, we elected to use health expenditure per
41
42 284 capita as the adjustment coefficient to represent healthcare demand. This indicator was chosen based on
43
44 285 the assumption that expenditure per capita is reflective of the general workload of healthcare providers
45
46 286 across regions and provider types¹². Japan's healthcare system is characterized by universal health
47
48 287 coverage, and hospital reimbursements for medical services are uniform throughout the nation²⁵. Hence,
49
50 288 health expenditure provides a standardized indicator that reflects the vast majority of healthcare services
51
52 289 provided (with the exception of cosmetic, advanced, or experimental care not covered under insurance),
53
54 290 and generally indicates the same workload regardless of where patients receive healthcare services.
55
56 291 Furthermore, we consider that medical health expenditure per capita more accurately reflects the degree
57
58 292 of workload than medical consultation rates because the former accounts for variations in patient health
59
60

1
2
3 293 status.
4
5 294
6
7 295 These findings should be interpreted in the context of several limitations. First, this was a retrospective
8
9 296 study and, as such, does not provide estimates on future physician supply and healthcare demand. Next,
10
11 297 the long-term generalizability of our adjustment coefficient may be susceptible to changes in population
12
13 298 structure. However, our study showed that the coefficient remained essentially unchanged from 2000 to
14
15 299 2014, and it is not likely to undergo major changes in the near future. In addition, the coefficient itself
16
17 300 cannot be applied to other countries, but the adjustment method may have applications outside of Japan.
18
19 301

302 **Conclusions**

303 The number of physicians per 100 000 raw population had seemingly increased in both urban and rural
304
305 areas in Japan. After healthcare demand was adjusted, however, physician supply was observed to
306
307 decrease in all types of areas except for urban areas with lower initial physician supply. In addition,
308
309 physician distribution had consistently become less equitable in recent years. These results indicate the
310
311 need for major reform of Japan's healthcare system.

312 **List of abbreviations**

313 SMA, secondary medical area

314 **Footnotes**

315 **Acknowledgements**

316 Not applicable.

317 **Competing interests**

318 The authors declare that they have no competing interests.

319 **Funding**

320 This work was supported in part by Health Sciences Research Grants from the Ministry of Health,
321
322 Labour grant number H27-iryō-ippān-001 and Welfare of Japan and a Grant-in-Aid for Scientific
323
324 Research from the Japan Society for the Promotion of Science grant number [A]16H02634.

323

324 **Contributors**

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

329

330 **Ethics approval and consent to participate**

331 Not applicable

332

333 **Consent for publication**

334 Not applicable

335

336 **Reference**

- 337 1. Horev T, Pesis-Katz I, Mukamel DB. Trends in geographic disparities in allocation of health care
338 resources in the US. *Health Policy* 2004;**68**:223-32. doi: 10.1016/j.healthpol.2003.09.011
- 339 2. Isabel C, Paula V. Geographic distribution of physicians in Portugal. *European Journal of Health*
340 *Economics* 2010;**11**:383-93. doi: 10.1007/s10198-009-0208-8
- 341 3. Anand S, Fan VY, Zhang J, et al. China's human resources for health: quantity, quality, and
342 distribution. *Lancet* 2008;**372**:1774-81. doi: 10.1016/s0140-6736(08)61363-x
- 343 4. Tanihara S, Kobayashi Y, Une H, et al. Urbanization and physician maldistribution: a
344 longitudinal study in Japan. *BMC Health Serv Res* 2011;**11**:260. doi:
345 10.1186/1472-6963-11-260
- 346 5. Pitblado JR, and Raymond W. Pong. Geographic distribution of physicians in Canada. Sudbury,
347 Ontario, Canada: Centre for Rural and Northern Health Research, Laurentian University
348 1999.
- 349 6. WHO. World report on ageing and health 2015.
350 http://apps.who.int/iris/bitstream/10665/186463/1/9789240694811_eng.pdf
351 [accessed 12 Jul 2016].
- 352 7. National Institute of Population and Social Security Research. Population statistics book 2015.

- 1
2
3 353 http://www.ipss.go.jp/syoushika/tohkei/Popular/P_Detail2015.asp?fname=T02-18.htm
4
5 354 (accessed 12 Jul 2016).
6
7 355 8. National Institute of Population and Social Security Research. population projection for
8
9 356 Japan:2011-2060 2012. <http://www.ipss.go.jp/syoushika/tohkei/newest04/gh2401.pdf>
10 357 (accessed 29 Jul 2016).
11
12 358 9. Kobayashi Y, Takaki H. Geographic distribution of physicians in Japan. *Lancet* 1992;**340**:1391-3.
13
14 359 10. Asano N, Kobayashi Y, Kano K. Issues of intervention aimed at preventing prospective surplus
15
16 360 of physicians in Japan. *Med Educ* 2001;**35**:488-94.
17
18 361 11. Gravelle H, Sutton M. Inequality in the geographical distribution of general practitioners in
19
20 362 England and Wales 1974-1995. *J Health Serv Res Policy* 2001;**6**:6-13.
21
22 363 12. Hann M, Gravelle H. The maldistribution of general practitioners in England and Wales:
23
24 364 1974-2003. *Br J Gen Pract* 2004;**54**:894-8.
25
26 365 13. Toyabe S. Trend in geographic distribution of physicians in Japan. *Int J Equity Health* 2009;**8**:5.
27
28 366 doi: 10.1186/1475-9276-8-5
29
30 367 14. Sasaki H, Otsubo T, Imanaka Y. Widening disparity in the geographic distribution of
31
32 368 pediatricians in Japan. *Hum Resour Health* 2013;**11**:59. doi: 10.1186/1478-4491-11-59
33
34 369 15. Shinjo D, Aramaki T. Geographic distribution of healthcare resources, healthcare service
35
36 370 provision, and patient flow in Japan: a cross sectional study. *Soc Sci Med*
37
38 371 2012;**75**:1954-63. doi: 10.1016/j.socscimed.2012.07.032
39
40 372 16. Munga MA, Maestad O. Measuring inequalities in the distribution of health workers: the case
41
42 373 of Tanzania. *Human Resources for Health* 2009;**7**:12. doi: 10.1186/1478-4491-7-4
43
44 374 17. Theodorakis PN, Mantzavinis GD. Inequalities in the distribution of rural primary care
45
46 375 physicians in two remote neighboring prefectures of Greece and Albania. *Rural Remote*
47
48 376 *Health* 2005;**5**:457.
49
50 377 18. Kanchanachitra C, Lindelow M, Johnston T, et al. Human resources for health in southeast
51
52 378 Asia: shortages, distributional challenges, and international trade in health services.
53
54 379 *Lancet* 2011;**377**:769-81. doi: 10.1016/s0140-6736(10)62035-1
55
56 380 19. Newhouse JP, Williams AP, Bennett BW, et al. Where have all the doctors gone? *Jama*
57
58 381 1982;**247**:2392-6.
59
60 382 20. Schwartz WB, Newhouse JP, Bennett BW, et al. The changing geographic distribution of

- 1
2
3 383 board-certified physicians. *N Engl J Med* 1980;**303**:1032-8. doi:
4 10.1056/nejm198010303031803
5 384
6
7 385 21. Matsumoto M, Inoue K, Bowman R, et al. Geographical distributions of physicians in Japan and
8 US: Impact of healthcare system on physician dispersal pattern. *Health Policy*
9 386 2010;**96**:255-61. doi: 10.1016/j.healthpol.2010.02.012
10 387
11
12 388 22. OECD. Ageing in Cities. Paris: OECD Publishing 2015.
13
14 389 23. McCurry J. Japan will be model for future super-ageing societies. *Lancet* 2015;**386**:1523-23.
15
16 390 24. Kephart G, Asada Y. Need-based resource allocation: different need indicators, different
17 results? *BMC Health Serv Res* 2009;**9**:122. doi: 10.1186/1472-6963-9-122
18 391
19
20 392 25. Ikegami N, Yoo BK, Hashimoto H, et al. Japanese universal health coverage: evolution,
21 achievements, and challenges. *Lancet* 2011;**378**:1106-15. doi:
22 10.1016/s0140-6736(11)60828-3
23 394
24
25
26
27

28 **Figure titles**

29 **Figure 1:** Temporal changes in Gini coefficients of the number of physicians per 100 000 population in
30 secondary medical areas
31 398

32 **Figure 2:** Temporal changes in the proportion of secondary medical areas with a low physician supply
33 399
34

35 400

36 **Figure legend**

37 **Figure2:** SMA, Secondary medical area
38 402

39 SMAs with a low physician supply were defined as those in the first quartile according to the number of
40 403
41 404 physicians per 100 000 population in 2000; the y-axis shows the proportion of SMAs defined according
42 405 to this criterion to all 349 SMAs.
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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

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

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

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

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

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

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

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

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

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

SD, standard deviation

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

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

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

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

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

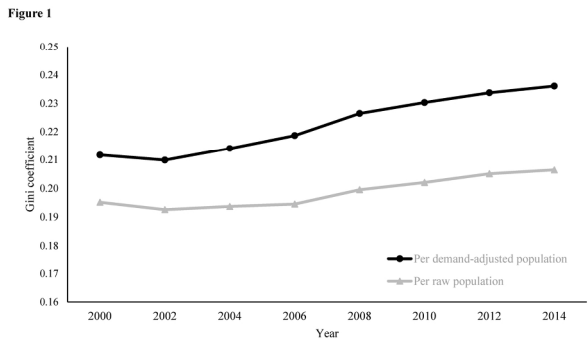


Figure 1: Temporal changes in Gini coefficients of the number of physicians per 100 000 population in secondary medical areas

209x148mm (300 x 300 DPI)

Figure 2

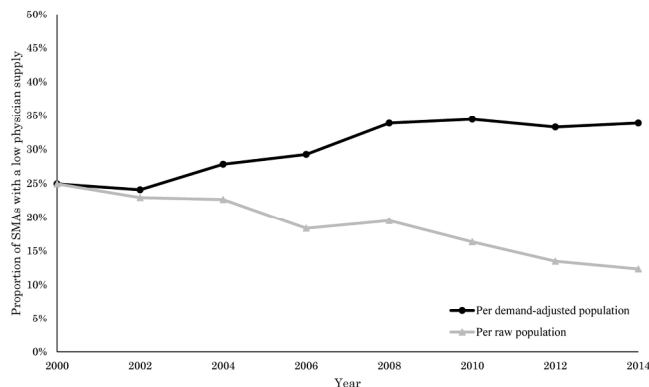


Figure 2: Temporal changes in the proportion of secondary medical areas with a low physician supply
 Figure2: SMA, Secondary medical area
 SMAs with a low physician supply were defined as those in the first quartile according to the number of physicians per 100 000 population in 2000; the y-axis shows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

209x148mm (300 x 300 DPI)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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

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

Continued on next page

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed –p7 (b) Give reasons for non-participation at each stage –not applicable (c) Consider use of a flow diagram – no use
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders –not applicable (b) Indicate number of participants with missing data for each variable of interest –not applicable (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures –p7-8
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included –not applicable (b) Report category boundaries when continuous variables were categorized –not applicable (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses –p8

Discussion

Key results	18	Summarise key results with reference to study objectives – p8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias –p11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence –p8-11
Generalisability	21	Discuss the generalisability (external validity) of the study results –p10

Other information

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based –p12
---------	----	--

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

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

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-013922.R1
Article Type:	Research
Date Submitted by the Author:	04-Nov-2016
Complete List of Authors:	Hara, Koji; Kyoto University Graduate School of Medicine, Department of Healthcare Economics and Quality Management Otsubo, Tetsuya; Kyoto University Graduate School of Medicine, Department of Healthcare Economics and Quality Management Kunisawa, Susumu; Kyoto University Graduate School of Medicine, Department of Healthcare Economics and Quality Management Imanaka, Yuichi; Kyoto University Graduate School of Medicine, Department of Healthcare Economics and Quality Management
Primary Subject Heading:	Health policy
Secondary Subject Heading:	Public health
Keywords:	Japan, Physicians, geographic distribution, sufficiency, healthcare demand, equity

SCHOLARONE™
Manuscripts

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

3
4
5
6
7
8
9
10
11 **Authors:**

12 Koji Hara, MA, Tetsuya Otsubo, PhD, Susumu Kunisawa, MD, PhD, and Yuichi

13 Imanaka, MD, PhD

14 Department of Healthcare Economics and Quality Management, Graduate School of

15 Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku, Kyoto City, Kyoto, Japan

16 606-8501

17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Corresponding author:

12 Yuichi Imanaka, Professor

13 Mailing address: Department of Healthcare Economics and Quality Management,

14 Graduate School of Medicine, Kyoto University; Yoshida Konoe-cho, Sakyo-ku,

15 Kyoto City, Kyoto, Japan 606-8501

16 Tel: +81 75 753 4454

17 Fax: +81 75 753 4455

18 Email: imanaka-y@umin.net

19
20
21
22
Word count:

21 3,614words

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

Abstract

Objectives

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

Methods

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

Results

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

Conclusions

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

51 **Strengths and limitations of this study**

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

62 **Keywords**

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

65 **Introduction**

66 The inequitable geographic distribution of physicians is a pressing issue in many countries¹⁻⁴. There are
67 at least two reasons why this issue attracts social and political attention. The first reason comes from the
68 issue of equity and social justice, that is, a citizen's right to access healthcare equally. The other is rooted
69 in the belief in linkages between physician availability and health status⁵.

70
71 Studies that address this topic frequently use the number of physicians per population as an indicator of
72 physician supply. However, this simple calculation may present an oversimplification of findings due to
73 its reliance on simple head counts that ignore differences within a population⁵. In particular, healthcare
74 demand is likely to differ substantially among the age strata as elderly people tend to require more health
75 care. As many parts of the world are experiencing accelerated population ageing, it is becoming
76 increasingly important to consider the differences in age-dependent healthcare demand when examining
77 physician supply.

78
79 Population ageing has become a key policy issue throughout the world⁶. Japan currently has the highest
80 proportion of people aged 65 years or older, and became one of the first "super-aged" societies when this
81 proportion exceeded 21% in 2007⁷. In addition, Japan's rate of population ageing is unprecedented: the

1
2
3 82 proportion of people aged 65 years or older rose from 10% to 20% within 20 years. In contrast, the UK
4
5 83 had almost 79 years and the US almost 59 years to adapt to this shift in population age structure.
6
7 84 Furthermore, Japan's proportion of elderly people is predicted to rise to 33.4% in 2035 and 39.9% in
8
9 85 2060⁸, indicating that its population is still undergoing rapid changes.
10

11
12 86
13 87 In Japan, the issue concerning the number of physicians has shifted from a shortage to a surplus. Japan
14
15 88 faced a shortage of physicians in the 1960s and 1970s⁹. During that period, the country experienced a
16
17 89 massive increase in population from 94 million to 117 million people. The government at that time aimed
18
19 90 to ensure a minimum of 150 physicians for every 100 000 people, and doubled medical school
20
21 91 enrolments in the 1970s to bolster physician supply. The target number of physicians was achieved in
22
23 92 1984, but has since continued to increase. Due to the ageing and projected decrease of the Japanese
24
25 93 population, the possible surplus of physicians is an issue that needs to be addressed. Although the
26
27 94 government-sanctioned reduction of enrolments in medical schools has been proposed as a possible
28
29 95 measure to control physician numbers, this measure is controversial and has been met with resistance
30
31 96 from several interest groups¹⁰. Detailed and accurate information on physician supply that accounts for
32
33 97 age-dependent healthcare demand is needed to support this decision-making process.
34

35
36 98
37 99 Although previous studies have examined trends in physician geographic distribution using healthcare
38
39 100 demand-adjusted populations^{11 12}, there is currently no standardised method for adjusting healthcare
40
41 101 demand. Furthermore, the trends in physician supply in a super-aged society such as Japan have yet to be
42
43 102 investigated. In this study, we conducted a longitudinal examination of the geographic distribution of
44
45 103 physicians with adjustment for healthcare demand according to the changing age structure of the
46
47 104 Japanese population.
48

106 **Methods**

107 **Data sources**

108 The number of physicians was obtained from the National Physician Census, which is conducted
109
110 biennially by Japan's Ministry of Health, Labour and Welfare (MHLW). The census data included the
111
112 type and location (municipality) of workplace for each physician. Population data were collected from
113
114 the National Basic Resident Register, which is published annually by the Ministry of Internal Affairs and
115

1
2
3 112 Communications. We collected data on national health expenditure per capita according to patient age in
4
5 113 2014 from the MHLW. Although national health expenditure includes various types of health care, we
6
7 114 only used general treatment medical fees for our analysis because the other types of care were deemed to
8
9 115 have little direct relevance to the number of physicians. Medical consultation rates were collected from
10
11 116 the 2014 Patient Survey conducted by the MHLW. Population density was calculated by dividing the
12
13 117 number of people residing in each secondary medical area (SMA, described below) by the area (km²).
14
15 118 The area of each region was obtained from statistical reports on land areas of prefectures and
16
17 119 municipalities by the Geospatial Information Authority of Japan.
18
19
20

21 **Physicians and population**

22 Practicing physicians at all Japanese clinics and hospitals were included in analysis, whereas registered
23
24 123 physicians working in non-clinician roles (e.g., basic researchers or government officials) were excluded.
25
26 124 Physician densities were calculated for both the raw (unadjusted) population and the healthcare
27
28 125 demand-adjusted population; the former included all Japanese citizens and the latter included all
29
30 126 Japanese citizens adjusted for age-dependent healthcare demand. The population was stratified into
31
32 127 5-year age groups, with the initial group comprising persons aged 0 to 4 years and the final group
33
34 128 comprising persons aged 80 years or older.
35

36 **Secondary medical areas**

37
38 131 The SMA was used as the geographic unit of analysis. The Japanese government has designated medical
39
40 132 service administration areas throughout the country, and these areas are categorised into primary,
41
42 133 secondary, and tertiary medical areas. Primary medical areas are set at the municipal level, and generally
43
44 134 represent areas that are capable of providing basic primary care to residents. Tertiary medical areas are
45
46 135 generally set at the prefectural level, and generally represent areas that are capable of providing the most
47
48 136 advanced and specialised medical treatments. SMAs, which are between these two levels, supply and
49
50 137 manage the majority of primary care and emergency medical services to regional communities.
51
52 138 Therefore, SMAs are arguably the most important of the three geographic units with regard to
53
54 139 implementing health policies. The geographic boundaries of the primary and tertiary medical areas are
55
56 140 based on existing regional borders, whereas SMAs are demarcated by the prefectural governments based
57
58 141 on healthcare provision capabilities. As a result, SMAs are directly relevant to the functional aspects of
59
60

1
2
3 142 healthcare administration. Previous studies on physician geographic distribution in Japan have been
4 143 conducted at the municipal level^{9 13}, although recent studies have also focused on SMAs^{4 14 15}. SMA
5
6 144 boundaries can be modified by prefectural governments in response to changing healthcare requirements.
7
8 145 In this study, we analysed the 349 designated SMAs in 2012.
9

10 146

11 147 **Analysis of physician distribution**

12
13
14 148 First, we calculated the healthcare demand-adjusted population using adjustment coefficients that were
15 149 derived according to the health expenditure per capita for each age group. The health expenditure for
16 150 each age group was divided by the overall mean health expenditure of the population, and the obtained
17 151 quotients were used as age group-specific adjustment coefficients. We then applied the adjustment
18 152 coefficients to the raw population to obtain the healthcare demand-adjusted population. The numbers of
19 153 physicians per 100 000 population in the SMAs were calculated for both the raw and demand-adjusted
20 154 populations, and these values were used in the following analyses. In addition, we assessed the
21 155 robustness of the adjustment coefficients by comparing them with alternative coefficients based on
22 156 medical consultation rates instead of health expenditure, and also examined the annual changes in the
23 157 adjustment coefficients by age group during the study period.
24
25
26
27
28
29
30
31

32 158

33
34 159 Next, we assessed the equity of the geographic distribution of physicians. The Gini coefficient was used
35 160 as the indicator of equity, and has been widely used in similar analyses^{2 4 16-18}. This coefficient measures
36 161 the degree of departure from a uniform distribution known as the Lorenz curve, and takes a value
37 162 between 0 (indicating perfect equality) and 1 (indicating perfect inequality). The Lorenz curve for the
38 163 SMAs was plotted based on the number of physicians per 100 000 population.
39
40
41
42
43

44 164

45 165 We then examined the time-based trends in the number of SMAs with a low physician supply. SMAs
46 166 were categorised into quartiles according to the number of physicians per 100 000 raw population or 100
47 167 000 healthcare demand-adjusted population in 2000, and the SMAs in the first quartiles were specified as
48 168 having a low physician supply. We examined the changes in the proportions of SMAs that fulfilled this
49 169 criterion throughout the study period.
50
51
52
53
54

55 170

56 171 Finally, we divided SMAs into four groups according to two criteria: whether they were rural or urban,
57
58
59
60

1
2
3 172 and whether they had a lower or higher initial physician supply at the start of the study period. Using an
4 173 approach described in an earlier study¹⁴, the degree of urbanization was determined using the population
5 174 density in 2000 as a proxy variable. We divided the SMAs according to the median value of the
6 175 population density in 2000 to obtain two groups: SMAs with population densities above the median
7 176 value were designated urban areas, whereas SMAs with population densities below the median value
8 177 were designated rural areas. Similarly, the initial physician supply was calculated using the number of
9 178 physicians per 100 000 population in 2000. We divided the SMAs according to the median values of the
10 179 initial physician supply to obtain two groups: SMAs with initial physician densities above the median
11 180 value were designated as having higher initial physician supply, whereas SMAs with initial physician
12 181 densities below the median value were designated as having lower initial physician supply. Based on a
13 182 combination of these two criteria, the SMAs were divided into four groups: Group 1 comprised urban
14 183 SMAs with a higher initial physician supply, Group 2 comprised rural SMAs with a higher initial
15 184 physician supply, Group 3 comprised rural areas with a lower initial physician supply, and Group 4
16 185 comprised urban areas with a lower initial physician supply. The changes in physician numbers were
17 186 compared among these groups. All analyses were performed using R statistical software (version 3.2.2).

187

188 **Results**

189 As shown in Table 1, the adjustment coefficients for the age groups ranged from 0.22 (15–24 years) to
190 3.33 (80 years or older). The adjustment coefficient of the elderly population (65 years or older) was
191 approximately four times that of the younger population (10–39 years). The results of robustness testing
192 indicated that our adjustment coefficient was consistent with the results of the alternative coefficient
193 based on medical consultation rates, with a high level of correlation (correlation coefficient: 0.99)
194 between the primary adjustment coefficients and medical consultations rates by age group. Furthermore,
195 our coefficient also appeared robust to time-based changes from 2000 to 2014 (data not shown).

196

197 Table 2 shows the temporal trends in the number of physicians and population from 2000 to 2014 at
198 2-year intervals. The number of physicians consistently increased by approximately 6000 to 8000 every
199 two years, and was 1.22 times higher in 2014 than in 2000. The raw population generally remained
200 unchanged throughout the study period. In contrast, the healthcare demand-adjusted population was 1.23
201 times higher in 2014 than it was in 2000. Hence, the increase rate of the demand-adjusted population

1
2
3 202 slightly exceeded the increase rate of physicians.
4
5 203

6 204 Table 3 and Table 4 summarize the descriptive statistics for the 349 SMAs and the four groups,
7
8 205 respectively. Table 3 shows that the mean number of physicians and demand-adjusted population had
9
10 206 increased between 2000 and 2014. Figure 1 illustrates the temporal changes in Gini coefficient for the
11
12 207 number of physicians per 100 000 population (both raw and demand-adjusted) at the SMA level, and
13
14 208 indicates that the equity in physician numbers had worsened in both populations. In particular, equity had
15
16 209 deteriorated more (higher Gini coefficient) in the healthcare demand-adjusted population.
17

18 210
19 211 Figure 2 shows the changes in the proportion of SMAs with a low physician supply across the study
20
21 212 period. In the raw population, the proportion consistently decreased from 24.9% to 13.2% (with a brief
22
23 213 increase between 2006 and 2008). In contrast, the same proportion in the healthcare demand-adjusted
24
25 214 population consistently increased from 24.9% to 35.0% (with a brief decrease between 2000 and 2002);
26
27 215 notably, there was a relatively large increase of 4.5% between 2006 and 2008 in the demand-adjusted
28
29 216 population.
30

31 217
32 218 Table 5 presents the changes in the absolute numbers of physicians and physicians per 100 000
33
34 219 population in Groups 1 to 4 between 2000 and 2014. There were 100 SMAs in Group 1, 75 SMAs in
35
36 220 Group 2, 99 SMAs in Group 3, and 75 SMAs in Group 4. The absolute numbers of physicians showed
37
38 221 considerable increases in Groups 1 and 4, whereas the increases were smaller in the other two groups. In
39
40 222 the raw population, all groups (including the rural areas) exhibited increases in the number of physicians
41
42 223 per 100 000 population. In contrast, the number of physicians per 100 000 healthcare demand-adjusted
43
44 224 population was observed to decrease in all groups except Group 4.
45

46 225 47 226 **Discussion**

48 227 We conducted a longitudinal examination of the geographic distribution of physicians in Japan that
49
50 228 accounted for changes in age-dependent healthcare demand in accordance with the changing age
51
52 229 structure of the Japanese population. Our study produced two major findings: First, the equity in
53
54 230 physician geographic distribution for the demand-adjusted population had worsened throughout the
55
56 231 study period when analysing the time-based trends of both Gini coefficient and the number of SMAs
57
58
59
60

1
2
3 232 with a low physician supply. Second, the number of physicians per 100 000 healthcare demand-adjusted
4 233 population decreased in all types of areas except for urban areas with a lower initial physician supply.
5
6 234

7
8 235 Although the number of physicians per population has been widely used as an indicator of physician
9 236 supply, it does not account for intra-population variations in healthcare demand. Healthcare demand
10 237 differs among the age strata because elderly people tend to utilize more health care. As Japan is
11 238 undergoing unprecedented population ageing, changes in age structure and healthcare demand should be
12 239 considered when examining the geographic distribution of physicians.
13
14
15
16
17

18 240
19 241 Notably, the changes in the number of physicians per raw population in each group were markedly
20 242 different from the changes in the demand-adjusted population. The number of physicians per 100 000
21 243 raw population had seemingly increased in all types of areas, especially in the urban groups: there was an
22 244 increase of 22.9% in Group 1 and 34.5% in Group 4. However, after adjusting healthcare demand, the
23 245 number decreased by 1.3% in Group 1, and increased by 3.5% in Group 4. Furthermore, decreases were
24 246 also observed in the rural groups, where the number decreased by 4.4% in Group 2 and by 7.6% in Group
25 247 3. The disparity in results indicates that it is necessary to adjust healthcare demand when analysing
26 248 physician supply. Furthermore, this adjustment will become increasingly important in the future as the
27 249 age structure of the Japanese population continues to change.
28
29
30
31
32
33
34
35

36 250
37 251 Despite the consistent nationwide increase in the absolute number of physicians, this was not
38 252 accompanied by improved equity in physician distribution. It has been previously proposed that
39 253 increasing the overall number of physicians may resolve uneven physician distribution as competitive
40 254 forces play a major role in determining distribution patterns^{19,20}. However, studies in Japan have reported
41 255 that increases in overall physician numbers have not been able to improve the regional disparity in
42 256 physician supply^{4,9,21}. Similarly, our results indicate that this disparity has not been resolved in recent
43 257 years. In fact, the problem appears to have worsened when physician supply was analysed in the
44 258 healthcare demand-adjusted population. We surmise that equity in physician supply will continue to
45 259 worsen without the prompt development and implementation of appropriate measures.
46
47
48
49
50
51
52
53
54
55

56 261 The number of SMAs with a low physician supply had appeared to decrease throughout the study period
57
58
59
60

1
2
3 262 in the raw population, but adjusting for age-dependent healthcare demand revealed that these SMAs had
4 263 actually increased. We posit that these conflicting results may be attributed to the higher increase rate of
5 264 the demand-adjusted population relative to the increase rate of physicians. An earlier study found that
6 265 physician supply had increased in SMAs with small populations due to the larger effects of reductions in
7 266 population size⁴. However, our study was able to detect reductions in the number of physicians in SMAs
8 267 with similarly small populations when healthcare demand was adjusted. Although population numbers
9 268 have been decreasing in rural areas, their demand for health care is growing due to the rising proportion
10 269 of elderly persons.
11
12

13
14
15
16
17
18
19 271 Although physician supply had appeared to increase in Group 1 (urban SMAs with a higher initial
20 272 physician supply), our study showed that the supply had actually decreased after healthcare demand was
21 273 adjusted. This discovery is interesting in that it contradicts the convention that physician supply tends to
22 274 increase in urban areas, and indicates that healthcare demand has rapidly increased in these regions.
23 275 Many countries are experiencing population ageing; the OECD has reported an increase of 23.8% in
24 276 elderly populations in urban areas from 2001 to 2011, whereas the increase was lower in rural areas at
25 277 18.2%²². It is therefore evident that physician shortages are not limited to rural areas, and should also be
26 278 actively addressed as an urban issue. On the other hand, our study also found that physician supply had
27 279 increased in Group 4 (urban SMAs with lower initial physician supply) after adjusting healthcare
28 280 demand. Many SMAs in Group 4 are composed of suburban areas with large populations and relatively
29 281 small numbers of physicians. Despite the increase in physician supply in Group 4, the number of
30 282 physicians per 100 000 demand-adjusted population was almost half that of Group 1 in 2014.
31
32

33
34
35
36
37
38
39
40
41
42
43
44 284 Our findings are also important in the context of the study setting: Japan has gained worldwide attention
45 285 as it addresses the challenges of a super-aged society²³. Although the adjustment methodology itself may
46 286 have international applications, our results are not generalisable to other countries in their current form.
47 287 Nevertheless, these results have substantial implications on the importance of demand adjustment on
48 288 physician supply. Due to the lengthy physician training periods and declining birth rate in Japan, it will
49 289 be difficult to quickly increase the number of physicians if needed. We therefore propose that there is a
50 290 need for major reform of the healthcare delivery system that does not rely on increasing physician
51 291 numbers. Possible measures include establishing and enhancing the roles of medical teams to improve
52
53
54
55
56
57
58
59
60

1
2
3 292 physician productivity or promoting the utilization of information and communications technology, such
4
5 293 as telemedicine.

6 294
7
8 295 Since 2007, the Japanese government has implemented several measures aimed at improving the
9
10 296 geographic distribution and availability of physicians in rural areas. For example, all prefectures in Japan
11
12 297 have established a regional medical support center tasked with resolving the inequities in physician
13
14 298 geographic distribution and incentivizing the move of physicians to less urban areas. These centers
15
16 299 usually provide banking services and career development support for young physicians working in areas
17
18 300 with an insufficient physician supply. In addition, the government has expanded the “*Chiikiwaku*”
19
20 301 system, which sets regional quotas for medical school students and grants scholarships with stipulations
21
22 302 on future rural practice. These efforts are fairly recent, and their effects on physician supply remain
23
24 303 unclear²⁴.

25 304
26
27 305 Several studies have previously attempted to account for healthcare demand through the use of variables
28
29 306 such as patient age, sex, and health status^{11 12 25}. In this study, we elected to use health expenditure per
30
31 307 capita as the adjustment coefficient to represent healthcare demand. This indicator was chosen based on
32
33 308 the assumption that expenditure per capita is reflective of the general workload of healthcare providers
34
35 309 across regions and provider types¹¹. The Nuffield Trust—a charitable trust in the UK that also predicts
36
37 310 future health expenditure—has reported a relationship between healthcare demand and health
38
39 311 expenditure²⁶. In addition, Japan’s healthcare system is characterised by universal health coverage, and
40
41 312 hospital reimbursements for medical services are uniform throughout the nation²⁷. Hence, health
42
43 313 expenditure provides a standardised indicator that reflects the vast majority of healthcare services (with
44
45 314 the exception of cosmetic, advanced, or experimental care not covered under insurance), and generally
46
47 315 indicates the same workload regardless of where patients receive healthcare services. Furthermore, we
48
49 316 consider that medical health expenditure per capita more accurately reflects the degree of workload than
50
51 317 medical consultation rates because the former accounts for variations in patient health status.

52 318
53 319 These findings should be interpreted in the context of several limitations. First, this was a retrospective
54
55 320 study and, as such, does not provide estimates on future physician supply and healthcare demand.

56 321 Although future physician supply estimates are beyond the scope of this study, they should be addressed
57
58
59
60

1
2
3 322 in future research. Second, it is possible that a small number of physicians who work in Japanese clinics
4 323 and hospitals do not participate in the National Physician Census, which may introduce a degree of
5
6 324 sampling bias. However, because all physicians in Japan are legally required to participate in the census,
7
8 325 the number of non-participating physicians is likely to be too small to have a discernible effect on our
9
10 326 results. Third, it is possible that individual health expenditure may not reflect the degree of physician
11
12 327 workload. On the other hand, at a macro level, using health expenditure is better than medical
13
14 328 consultation rates because the latter are unadjusted and therefore completely unweighted for physician
15
16 329 workload. Fourth, SMAs may be divided into groups using various other criteria. In this study, we
17
18 330 adopted a simple approach based on an earlier study¹⁴, and were able to obtain distinctly different results
19
20 331 among the groups. Fifth, the long-term generalizability of our adjustment coefficient may be susceptible
21
22 332 to changes in population structure. However, our study showed that the coefficient remained essentially
23
24 333 unchanged from 2000 to 2014, and it is not likely to undergo major changes in the near future. Finally,
25
26 334 the adjustment coefficient in its current form cannot be applied to studies in other countries, but the
27
28 335 adjustment method may have applications outside of Japan.

336

337 **Conclusions**

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

344

345 **List of abbreviations**

346 MHLW, Ministry of Health, Labour and Welfare

347 SMA, secondary medical area

348

349 **Footnotes**

350 **Acknowledgements**

351 Not applicable.

1
2
3 3524 353 **Competing interests**5 354 The authors declare that they have no competing interests.
6
7
8 3559
10 356 **Funding**11 357 This work was supported in part by a Health Sciences Research Grant from the Ministry of Health,
12 358 Labour and Welfare of Japan (Grant number: H27-iryō-ippān-001) and a Grant-in-Aid for Scientific
13 359 Research from the Japan Society for the Promotion of Science (Grant number: [A]16H02634).
14
15
16 36017
18
19 361 **Contributors**20 362 KH contributed to the study conception and design, data collection, analysis, interpretation, and drafting
21 363 the manuscript. TO and SK contributed to the data collection and data management. YI contributed to the
22 364 study design, data acquisition, and interpretation. All authors critically revised the manuscript, and
23 365 approved the final version.
24
25
26 36627
28
29 367 **Ethics approval**30 368 Ethics committee approval was waived for this study because all of the data are publicly available online
31 369 and comprise only aggregate values without any personally identifiable information.
32
33
34 37035
36
37 371 **Consent for publication**38 372 Not applicable
39
40
41 37342
43 374 **Data sharing**44 375 No additional data
45
46
47 376 **Reference**

- 48
-
- 49 377 1. Horev T, Pesis-Katz I, Mukamel DB. Trends in geographic disparities in allocation of health care
-
- 50 378 resources in the US.
- Health Policy*
- 2004;68(2):223-32. doi:
-
- 51 379 10.1016/j.healthpol.2003.09.011
-
- 52
-
- 53 380 2. Isabel C, Paula V. Geographic distribution of physicians in Portugal.
- European Journal of Health*
-
- 54 381
- Economics*
- 2010;11(4):383-93. doi: 10.1007/s10198-009-0208-8
-
- 55
-
- 56
-
- 57
-
- 58
-
- 59
-
- 60

- 1
2
3 382 3. Anand S, Fan VY, Zhang J, et al. China's human resources for health: quantity, quality, and
4
5 383 distribution. *Lancet* 2008;372(9651):1774-81. doi: 10.1016/s0140-6736(08)61363-x
6
7 384 4. Tanihara S, Kobayashi Y, Une H, et al. Urbanization and physician maldistribution: a
8
9 385 longitudinal study in Japan. *BMC Health Serv Res* 2011;11:260. doi:
10 386 10.1186/1472-6963-11-260
11
12 387 5. Pitblado JR, and Raymond W. Pong. Geographic distribution of physicians in Canada. Sudbury,
13 388 Ontario, Canada: Centre for Rural and Northern Health Research, Laurentian University
14 389 1999.
15
16 390 6. WHO. World report on ageing and health 2015 [Available from:
17 391 http://apps.who.int/iris/bitstream/10665/186463/1/9789240694811_eng.pdf
18 392 accessed 12 Feb 2016.
19
20 393 7. National Institute of Population and Social Security Research. Population statistics book 2015
21 394 [Available from:
22 395 http://www.ipss.go.jp/syoushika/tohkei/Popular/P_Detail2015.asp?fname=T02-18.htm
23 396 accessed 12 Feb 2016.
24
25 397 8. National Institute of Population and Social Security Research. population projection for
26 398 Japan:2011-2060 2012 [Available from:
27 399 <http://www.ipss.go.jp/syoushika/tohkei/newest04/gh2401.pdf> accessed 29 Feb 2016.
28
29 400 9. Kobayashi Y, Takaki H. Geographic distribution of physicians in Japan. *Lancet*
30 401 1992;340(8832):1391-3.
31
32 402 10. Asano N, Kobayashi Y, Kano K. Issues of intervention aimed at preventing prospective surplus
33 403 of physicians in Japan. *Med Educ* 2001;35(5):488-94.
34
35 404 11. Gravelle H, Sutton M. Inequality in the geographical distribution of general practitioners in
36 405 England and Wales 1974-1995. *J Health Serv Res Policy* 2001;6(1):6-13.
37
38 406 12. Hann M, Gravelle H. The maldistribution of general practitioners in England and Wales:
39 407 1974-2003. *Br J Gen Pract* 2004;54(509):894-8.
40
41 408 13. Toyabe S. Trend in geographic distribution of physicians in Japan. *Int J Equity Health* 2009;8:5.
42 409 doi: 10.1186/1475-9276-8-5
43
44 410 14. Sasaki H, Otsubo T, Imanaka Y. Widening disparity in the geographic distribution of
45 411 pediatricians in Japan. *Hum Resour Health* 2013;11:59. doi: 10.1186/1478-4491-11-59
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

- 1
2
3 412 15. Shinjo D, Aramaki T. Geographic distribution of healthcare resources, healthcare service
4 413 provision, and patient flow in Japan: a cross sectional study. *Soc Sci Med*
5 414 2012;75(11):1954-63. doi: 10.1016/j.socscimed.2012.07.032
6
7
8 415 16. Munga MA, Maestad O. Measuring inequalities in the distribution of health workers: the case
9 416 of Tanzania. *Human Resources for Health* 2009;7:12. doi: 10.1186/1478-4491-7-4
10
11 417 17. Theodorakis PN, Mantzavinis GD. Inequalities in the distribution of rural primary care
12 418 physicians in two remote neighboring prefectures of Greece and Albania. *Rural Remote*
13 419 *Health* 2005;5(3):457.
14
15 420 18. Kanchanachitra C, Lindelow M, Johnston T, et al. Human resources for health in southeast
16 421 Asia: shortages, distributional challenges, and international trade in health services.
17 422 *Lancet* 2011;377(9767):769-81. doi: 10.1016/s0140-6736(10)62035-1
18
19 423 19. Newhouse JP, Williams AP, Bennett BW, et al. Where have all the doctors gone? *Jama*
20 424 1982;247(17):2392-6.
21
22 425 20. Schwartz WB, Newhouse JP, Bennett BW, et al. The changing geographic distribution of
23 426 board-certified physicians. *N Engl J Med* 1980;303(18):1032-8. doi:
24 427 10.1056/nejm198010303031803
25
26 428 21. Matsumoto M, Inoue K, Bowman R, et al. Geographical distributions of physicians in Japan and
27 429 US: Impact of healthcare system on physician dispersal pattern. *Health Policy*
28 430 2010;96(3):255-61. doi: 10.1016/j.healthpol.2010.02.012
29
30 431 22. OECD. Ageing in Cities. Paris: OECD Publishing 2015.
31
32 432 23. McCurry J. Japan will be model for future super-ageing societies. *Lancet*
33 433 2015;386(10003):1523-23.
34
35 434 24. Matsumoto M, Takeuchi K, Tanaka J, et al. Follow-up study of the regional quota system of
36 435 Japanese medical schools and prefecture scholarship programmes: a study protocol. *BMJ*
37 436 *Open* 2016;6(4):e011165. doi: 10.1136/bmjopen-2016-011165
38
39 437 25. Kephart G, Asada Y. Need-based resource allocation: different need indicators, different
40 438 results? *BMC Health Serv Res* 2009;9:122. doi: 10.1186/1472-6963-9-122
41
42 439 26. Nuffield Trust. Person Based Resource Allocation - Predictive Risk 2016 [Available from:
43 440 [http://www.nuffieldtrust.org.uk/our-work/projects/person-based-resource-allocation-](http://www.nuffieldtrust.org.uk/our-work/projects/person-based-resource-allocation-pbra)
44 441 [pbra](http://www.nuffieldtrust.org.uk/our-work/projects/person-based-resource-allocation-pbra) accessed 20 Oct 2016.

1
2
3 442 27. Ikegami N, Yoo BK, Hashimoto H, et al. Japanese universal health coverage: evolution,
4 443 achievements, and challenges. *Lancet* 2011;378(9796):1106-15. doi:
5 444 10.1016/s0140-6736(11)60828-3
6
7
8
9 445

10 446 **Figure titles**

11 447 **Figure 1** Temporal changes in Gini coefficients of the number of physicians per 100 000 population in
12 448 secondary medical areas

13 449 **Figure 2** Temporal changes in the proportion of secondary medical areas with a low physician supply

14 450

15 451 **Figure legend**

16 452 **Figure2**

17 453 Secondary medical areas (SMAs) with a low physician supply were defined as those in the first quartile
18 454 according to the number of physicians per 100 000 population in 2000; the y-axis shows the proportion
19 455 of SMAs defined according to this criterion to all 349 SMAs.
20
21
22
23
24
25
26
27
28

29 456

30 457
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

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

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

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

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

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

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

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

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

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

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

SD, standard deviation

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

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

Group 1 and Group 2: Higher initial physician supply,

Group 3 and Group 4: Lower initial physician supply

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

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

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

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

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

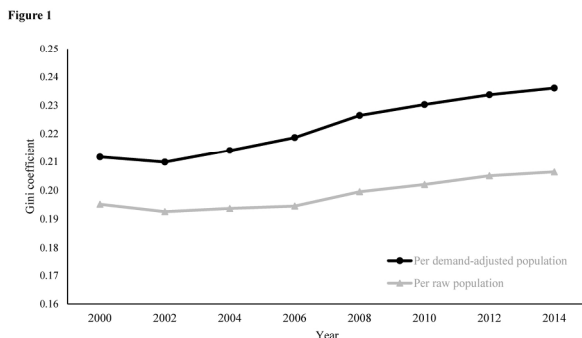


Figure 1 Temporal changes in Gini coefficients of the number of physicians per 100 000 population in secondary medical areas

209x148mm (300 x 300 DPI)

ew only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 2

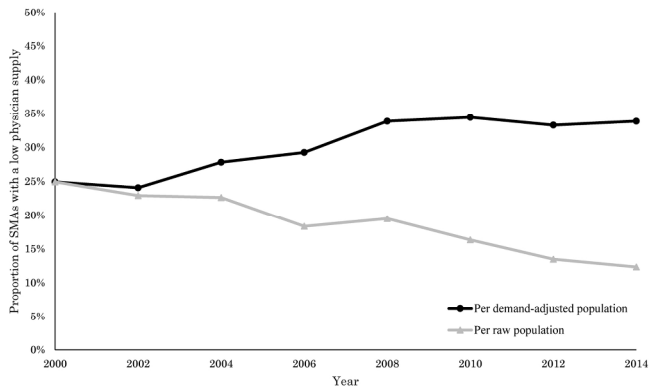


Figure 2 Temporal changes in the proportion of secondary medical areas with a low physician supply

209x148mm (300 x 300 DPI)

Review only

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

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

Continued on next page

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed –p7, Table 2,4 (b) Give reasons for non-participation at each stage –not applicable (c) Consider use of a flow diagram – no use
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders –Table 3 (b) Indicate number of participants with missing data for each variable of interest –not applicable (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures –p7-8
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included –not applicable (b) Report category boundaries when continuous variables were categorized –not applicable (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses –p8

Discussion

Key results	18	Summarise key results with reference to study objectives – p8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias –p11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence –p8-11
Generalisability	21	Discuss the generalisability (external validity) of the study results –p10

Other information

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based –p13
---------	----	--

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

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