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Failure to improve the inequitable geographic distribution of physicians in Japan: a specialty-specific longitudinal study

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1 Failure to improve the inequitable geographic distribution of
2 physicians in Japan: a specialty-specific longitudinal study

3
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6 23 Failure to improve the inequitable geographic distribution of
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9 24 physicians in Japan: a specialty-specific longitudinal study
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14
15 26 **Abstract**

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17 27 **Objectives**

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20 28 In this longitudinal study, we examine changes in the geographic distribution of physicians by
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23 29 clinical specialty in Japan with adjustments for healthcare demand based on population structure.
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26 30 **Methods**

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29 31 The Japanese population was adjusted for healthcare demand using health expenditure per capita
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32 32 stratified by age and sex. The numbers of physicians per 100 000 demand-adjusted population in
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35 33 2000 and 2014 were calculated for sub-prefectural regions known as secondary medical areas.
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37 34 Disparities in the geographic distribution of physicians for each specialty were assessed using the
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40 35 Gini coefficient. A subgroup analysis was conducted by dividing the regions into four groups
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43 36 according to urban-rural classification and initial physician supply.
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46 37 **Results**

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49 38 Over the study period, the number of physicians per 100 000 demand-adjusted population decreased
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52 39 in all clinical specialties (e.g., surgery: 26·0% decrease) excluding pediatrics (33·3% increase) and
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55 40 anesthesiology (21·1% increase). No improvements in geographic disparity were observed in any of
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6 41 the clinical specialties. In particular, geographic disparity worsened in internal medicine, surgery,
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8
9 42 and obstetrics and gynecology. Rural areas with lower initial physician supply had the lowest
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11 43 increase (or highest decrease) in physicians per 100 000 demand-adjusted population in all clinical
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14 44 specialties except pediatrics and anesthesiology. In contrast, urban areas with lower initial physician
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17 45 supply had the highest increase (or lowest decrease) in all clinical specialties.

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20 46 **Conclusion**

21
22 47 The geographic distribution of physicians has failed to improve in any of the clinical specialties.
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25 48 There is also a growing disparity in physician supply between the urban and rural regions. Urgent
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28 49 measures are needed to reduce the geographic disparities in physician supply and regulate the
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31 50 uneven distribution among clinical specialties.

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6 **52 Article Summary**

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9 **53 Strengths and limitations of this study**

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

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

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

84 Although the number of physicians per 100 000 population is generally used as an
85 indicator when examining geographic disparities in physician supply, this measure involves a simple
86 head count that does not account for the inherent variations in healthcare demand among the

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6 87 different age strata and sex.⁴ Furthermore, Japan's population is aging at an unprecedented rate and
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9 88 has transformed into the world's first "super-aged" society (where more than 21% of a country's
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12 89 population is aged 65 years and older). As a consequence, the population structure in Japan is
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15 90 undergoing dramatic changes, which has invariably resulted in changes to healthcare demand. We
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18 91 have previously reported that Japan's healthcare demand increased by 22% from 2000 to 2014 amid
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21 92 worsening geographic disparity in physician supply.¹³ However, studies have yet to be conducted on
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24 93 the disparity in Japan's physician supply according to the different clinical specialties while
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27 94 accounting for the differences in healthcare demand.

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29 95 This study aimed to longitudinally examine changes in the geographic distribution of
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32 96 physicians by clinical specialty in Japan with adjustments for healthcare demand according to
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35 97 population structure.

36 37 38 39 99 **Methods**

40 41 42 100 Data source

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45 101 Data on the number of physicians were obtained from Surveys of Physicians, Dentists, and
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48 102 Pharmacists conducted every two years by the Ministry of Health, Labour and Welfare (MHLW).
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51 103 Population data (age, sex, and location of residence) were extracted from the Annual Report of the
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54 104 National Basic Resident Registration System published by the Ministry of Internal Affairs and

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6 105 Communications, and the number of births were obtained from the Annual Report of Vital Statistics
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9 106 published by the MHLW. We also acquired data on national health expenditure per capita according
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11 107 to patient age in 2013 from the MHLW. The total area of habitable land was ascertained from
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14 108 statistical reports on land areas of prefectures and municipalities by the Geospatial Information
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17 109 Authority of Japan.
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23 111 Physicians and population

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25 112 We targeted physicians working in medical facilities (hospitals and clinics), and excluded physicians
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28 113 working in non-clinical facilities (e.g., research centers and government offices). The following
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31 114 clinical specialties were included in analysis: internal medicine, surgery, orthopedics, OB/GYN,
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34 115 pediatrics, and anesthesiology.
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37 116 In addition to the total population, we also analyzed population subgroups including the
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40 117 female population, pediatric population (<15 years of age), and the number of births. With the
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43 118 exception of the number of births, all study populations were adjusted for healthcare demand. We
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46 119 calculated the number of OB/GYN specialists per 100 000 female population and per 100 000 births,
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49 120 the number of pediatricians per 100 000 pediatric population, and the number of physicians per 100
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51 121 000 population for each of the other clinical specialties.
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6 123 Geographic unit
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9 124 The geographic unit of analysis was the secondary medical area (SMA). There are three regional
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11 125 levels of healthcare provision designated in Japan. Primary medical areas are geographic units where
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14 126 primary care is provided, and are demarcated by municipal borders. Tertiary medical areas are
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17 127 geographic units that provide advanced medical care, and are demarcated by prefectural borders.
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20 128 SMAs are set between primary and tertiary medical areas, and are regions where general medical
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23 129 care (such as inpatient care) is provided; these areas are composed of multiple municipalities. Each
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26 130 prefectural government stipulates the geographic and demographic range of the SMAs within their
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29 131 prefecture. As a result, the boundaries of each SMA can be altered in response to changes in
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32 132 healthcare demand. SMAs have been previously used to examine the inequity in physician supply in
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34 133 Japan.^{6 14} Because the number of SMAs varies slightly over time, our analyses were conducted using
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37 134 the 349 SMAs designated in 2012.
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42 136 Analytical methods
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45 137 This retrospective study longitudinally examined the changes in the geographic distribution of the
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48 138 number of physicians by clinical specialty among Japan's SMAs from 2000 to 2014. The population
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51 139 was first adjusted using adjustment coefficients of healthcare demand, which were calculated based
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54 140 on the health expenditure per capita stratified by age and sex through a previously described
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6 141 method.¹³ Health expenditure per capita is indicative of the general workload of healthcare
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8 142 providers.¹⁵ These expenditures include those for both inpatient and outpatient services, and account
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11 143 for variations in patient health status.¹³ The demand-adjusted population was generated by
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14 144 multiplying the raw population with the adjustment coefficients.

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17 145 Next, geographic disparity was assessed using the Gini coefficient, which is an indicator
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20 146 widely used to examine disparity in the field of economics and has also been applied to analyze
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23 147 geographic disparity in physician supply.^{15 16-18} The coefficients, which take a value from 0
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26 148 (indicating complete equality) to 1 (indicating complete inequality), measure departure from a
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29 149 uniform distribution by drawing Lorenz curves.¹⁷ If the curves of two time points intersect,
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32 150 conclusions cannot be made as to whether or not the inequity of distribution is increasing.¹⁸ Thus, we
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35 151 plotted two Lorenz curves (one each for 2000 and 2014) for each clinical specialty.

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37 152 Finally, a subgroup analysis was conducted by dividing SMAs into groups according to
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40 153 two regional characteristics. Using the method described in Sasaki et al.,¹⁹ we classified each SMA
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43 154 into one of four groups based on whether the SMA was an urban or rural area, and whether the SMA
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46 155 had a higher or lower initial physician supply in 2000. An SMA was designated an urban area (or a
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49 156 rural area) if its population density was higher (or lower) than the median value in all SMAs. The
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52 157 population density of each SMA was calculated using the total area of habitable land and the
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55 158 population in 2000. Next, an SMA was designated as having a higher (or lower) initial physician

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6 159 supply if the number of physicians per 100 000 population was higher (or lower) than the median
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9 160 number of physicians per 100 000 population in all SMAs. The following four groups were
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11 161 analyzed: Group 1, comprising urban areas with higher initial physician supply; Group 2, comprising
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14 162 rural areas with higher initial physician supply; Group 3, comprising rural areas with lower initial
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17 163 physician supply; and Group 4, comprising urban areas with lower initial physician supply. Data
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20 164 from 2000 were used for both the population and physicians. In this subanalysis, we compared the
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23 165 inter-group changes in the number of physicians per 100 000 population between 2000 and 2014.

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25 166 All analyses were performed using R statistical software (V.3.2.2).

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30 31 168 **Results**

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34 169 Figure 1 shows the adjustment coefficients of healthcare demand for the different age strata and sex.
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37 170 These coefficients varied widely among the different categories. In male residents, healthcare
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40 171 demand was lowest (0·2) in those aged in their early twenties and highest (3·83) in those aged 80
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43 172 years and older; this was more than a 19-fold difference between the two groups. In female residents,
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46 173 healthcare demand was lowest (0·2) in those aged in their late teens and highest (3·23) in those aged
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49 174 80 years and older; this was more than a 16-fold difference between the two groups. The adjustment
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52 175 coefficients were applied to the raw population to produce the demand-adjusted population.

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54 176 Table 1 shows the population sizes of the total population, female population, and pediatric

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6 177 population before and after applying the adjustment coefficients in 2000 and 2014. Before
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9 178 adjustment, the population did not substantially change throughout the study period. In contrast, the
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11 179 demand-adjusted total population increased by 23·7% between 2000 and 2014. The number of births,
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14 180 which was not adjusted for healthcare demand, decreased by 15·7%. The pediatric population
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17 181 declined by 11·1% over the study period before and after adjusting for healthcare demand.
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20 182 Table 2 shows the overall numbers of physicians and the numbers of physicians per 100
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22 183 000 population in 2000 and 2014. The overall number of all physicians increased by 22·1% over the
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25 184 study period. Similarly, the number of all physicians per 100 000 population increased by 21·7%.
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28 185 However, the number of all physicians per 100 000 demand-adjusted population decreased by 1·3%.
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31 186 Furthermore, the overall numbers of internists, orthopedists and OB/GYN specialists also increased,
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34 187 but the numbers of these specialists per 100 000 demand-adjusted population declined. The number
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37 188 of OB/GYN specialists per 100 000 births increased by 23·1%. The overall number of surgeons
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40 189 decreased by 8·7%, and the number of surgeons per 100 000 demand-adjusted population decreased
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43 190 by 26·6%. The overall number of anesthesiologists showed a large increase of 50·0%, and the
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46 191 number of anesthesiologists per 100 000 demand-adjusted population increased by 21·1%. The
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49 192 overall number of pediatricians increased by 18·4%, and the number of pediatricians per 100 000
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51 193 demand-adjusted pediatric population increased by 33·3%.
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53 194 Table 3 shows the trends in Gini coefficients for the number of physicians per 100 000
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6 195 population in the SMAs by clinical specialty. There were no substantial changes in the Gini
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9 196 coefficients for the numbers of orthopedists, pediatricians, and anesthesiologists per 100 000
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11 197 demand-adjusted population. However, inequity had worsened in the geographic distribution of
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14 198 internists, surgeons, and OB/GYN specialists (for both the female population and the number of
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17 199 births). In these three specialties, the Lorenz curves in 2014 also demonstrated a tendency to
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20 200 deteriorate more than the curves in 2000 without intersection between the two curves (figures not
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23 201 shown). When comparing the Gini coefficients before and after adjusting for healthcare demand, the
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26 202 trends in the coefficients were similar for each clinical specialty. However, the post-adjustment Gini
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29 203 coefficients of all clinical specialties (except for pediatrics) were higher than their pre-adjustment
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31 204 values.

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34 205 Table 4 summarizes the numbers of physicians per 100 000 population in the four groups
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37 206 of SMAs in the subanalysis. Detailed descriptive statistics of the four groups are provided in the
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40 207 Appendix. Figure 2 shows the temporal increases (2000 to 2014) in the number of physicians by
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43 208 clinical specialty in each group. The temporal increases in the number of internists and orthopedists
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46 209 were similar to those for all physicians. The overall number of surgeons decreased in all groups
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49 210 except for Group 4, and the number of surgeons per 100 000 demand-adjusted population decreased
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51 211 by 20% to 30% in all groups. As shown in Table 4, the number of surgeons per 100 000
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54 212 demand-adjusted population in Group 3 (11·9) was approximately half of the number in Group 1

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6 213 (23·2) in 2014. In all groups, the number of OB/GYN specialists per 100 000 demand-adjusted
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9 214 female population decreased, but the number of OB/GYN specialists per 100 000 births increased.
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11 215 The number of pediatricians per 100 000 demand-adjusted pediatric population increased more in
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14 216 the rural SMAs than in the urban SMAs. The number of anesthesiologists per 100 000
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17 217 demand-adjusted population increased in all groups; in particular, the number in Group 4 increased
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20 218 by more than twice that of the other groups. In all clinical specialties except pediatrics, Group 3 had
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23 219 the lowest increase (or the highest decrease) in the number of physicians per 100 000
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26 220 demand-adjusted population. The 2014-2000 difference and ratio of the number of physicians per
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29 221 100 000 demand-adjusted population between Groups 3 and 4 increased in all clinical specialties
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31 222 except pediatrics.

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35 36 37 224 **Discussion**

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39 225 The four major findings of this study are as follows: First, the demand-adjusted total population had
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42 226 increased by 23·7% between 2000 and 2014, whereas the demand-adjusted pediatric population had
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45 227 decreased by 11·1%. Second, the number of physicians per 100 000 demand-adjusted population
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48 228 decreased in all clinical specialties except pediatrics and anesthesiology. The largest increase
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51 229 (33·3%) was observed in pediatrics. Third, the geographic disparity in the number of physicians per
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54 230 100 000 demand-adjusted population had not improved in all clinical specialties, and had in fact

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6 231 deteriorated in internal medicine, surgery, and OB/GYN. Fourth, the rural areas with lower initial
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9 232 physician supply had the lowest increase (or highest decrease) in the number of physicians per 100
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11 233 000 demand-adjusted population compared with other areas in all clinical specialties except
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14 234 pediatrics and anesthesiology. In contrast, the urban areas with lower initial physician supply had the
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17 235 highest increase (or lowest decrease) in all clinical specialties.

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20 236 The population used in this study was adjusted for healthcare demand among the different
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23 237 age strata and sex using a previously described method.¹³ As seen in Figure 1, there were
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26 238 considerable variations in healthcare demand among the different age strata and sex. Although
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29 239 several papers have examined the demand-adjusted geographic disparity in physician supply,^{15 20}
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31 240 there is currently no gold standard for the adjustment method.²⁰ The method used in this study had
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34 241 been previously verified,¹³ and enables adjustment for healthcare demand according to the age strata.
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37 242 In addition, the inclusion of sex in the calculation of the coefficients may increase the accuracy of
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40 243 adjustments.

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42 244 The number of physicians per 100 000 demand-adjusted population had decreased in
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45 245 internal medicine, surgery, orthopedics, and OB/GYN (per female population). The decline in
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48 246 physician supply was especially notable in surgery and OB/GYN, which corroborates previously
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51 247 reported downward trends in the numbers of physicians in these specialties.¹² The distribution
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54 248 among these specialties is affected by physician preference, experience, and environment. For

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6 249 example, the shortage of surgeons may be influenced by the long working hours, high risk of
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8 250 medical litigation, and low reward for surgical skill.²¹ Previous research has also shown that an
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11 251 increase in female physicians has changed the distribution of specialties because they are more likely
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14 252 to choose OB/GYN and pediatrics instead of surgery.^{22,23} In order to retain a high number of both
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17 253 female and male physicians, improvements must be made to the working environment, such as a
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20 254 reduction of physician working hours by assigning more duties and responsibilities to other
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23 255 non-physician health professionals.²¹

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25 256 Our findings detected a decrease in the numbers of internists and orthopedists despite an
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28 257 increase in healthcare demand. On the other hand, the number of pediatricians per 100 000
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31 258 demand-adjusted pediatric population and OB/GYN specialists per 100 000 births had greatly
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34 259 increased due to a decrease in the pediatrics population and the number of births. The rate of
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37 260 pediatric population decline is expected to eventually exceed the rate of total population decline.²⁴ It
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40 261 may therefore be more useful to properly allocate physicians instead of simply increasing their
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43 262 overall numbers.

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45 263 Based on the temporal trends in Gini coefficients, there were no improvements to the
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48 264 geographic disparity in the number of physicians per 100 000 demand-adjusted population in all
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51 265 clinical specialties between 2000 and 2014. In particular, the inequity in physician supply had
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54 266 worsened in internal medicine, surgery, and OB/GYN. The inequity in surgery and OB/GYN may

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6 267 have been influenced by the decrease or lack of increase in the overall number of physicians in these
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9 268 specialties. These findings suggest that the uneven distribution of physicians among the clinical
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11 269 specialties may exacerbate geographic disparities in physician supply. On the other hand, the number
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14 270 of internists had increased at a rate that was comparable to the overall growth rate. The deterioration
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17 271 in geographic disparity may therefore be related to an increasing tendency toward physician
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20 272 specialization in Japan.²⁵ In fact, although the overall number of general internists had decreased
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23 273 from 74 539 to 61 317 over the study period, there was actually an increase from 21 006 to 48 780
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26 274 physicians in internal subspecialties such as pulmonary, cardiovascular, and gastrointestinal
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29 275 medicine (data not shown). The geographic disparity in physician supply in these subspecialties is
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31 276 greater than the disparity in general internists.⁹

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34 277 The rate of increase in the number of physicians per 100 000 demand-adjusted population
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37 278 in the urban areas was generally higher (or the rate of decrease was lower) than in the rural areas. In
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40 279 all clinical specialties except pediatrics, both the difference and ratio in the number of physicians per
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43 280 100 000 demand-adjusted population between Group 3 and Group 4 in 2014 were larger than the
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46 281 corresponding values in 2000. This indicates that the disparity in physician supply between urban
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49 282 and rural areas had widened over the study period. Group 3 had the lowest initial physician supply,
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52 283 and these regions may be facing a serious physician shortage. This issue should be explored further,
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54 284 and there may be a need for major reforms to ensure adequate physician supply to rural areas. It may
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6 285 also be important to take the initiative in rural areas to improve physician productivity, reduce

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9 286 non-essential workload, and implement technology-based measures such as telemedicine.

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11 287 Prior to 2004, the vast majority of medical graduates joined a medical specialty department

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14 288 (known as an *Ikyoku*) at their university that secures employment for the new graduates. *Ikyoku*

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17 289 generally dispatch physicians to other affiliated hospitals that are often located in rural areas. In this

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20 290 way, the *Ikyoku* were partly responsible for preventing a shortage of physicians in rural areas. After

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23 291 the implementation of a new post-graduate medical education program in 2004, fewer physicians

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26 292 joined an *Ikyoku*. As a consequence, the graduates, now able to choose their training hospital after

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29 293 graduation, were less likely to select a university hospital for training. Due to the decreasing number

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32 294 of member physicians, it became more difficult for the *Ikyoku* to dispatch physicians to affiliate

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34 295 hospitals.¹⁴ Previous studies have also reported that the new program may have exacerbated the

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37 296 inequity in the geographic distribution of physicians.^{14 26} Similarly, this new program may also have

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40 297 contributed to the lack of improvement in geographic disparity observed in this study.

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42 298 The Japanese government has implemented several measures at the prefectural level aimed

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45 299 at improving the geographic disparities in physician supply. In 2006, a "Council for Regional

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48 300 Medicine" was established in each prefecture, and these councils include representatives of the

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51 301 prefectural and local governments, hospitals, medical associations, universities, and residents. The

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54 302 councils discuss detailed measures for securing medical staff with a variety of hospitals, including

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6 303 university hospitals and public hospitals. Furthermore, a "Support Center for Community Medicine"
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9 304 was established in each prefecture in 2011 to secure and retain physicians. These centers adopt the
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11 305 role of "control towers" to address the uneven distribution of physicians within each prefecture.
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14 306 Specifically, the centers are responsible for supporting career advancement for physicians working in
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17 307 rural areas, acting as general liaisons for engaging new physicians, and providing general work
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20 308 information. In addition, the government has raised the regional quota of medical school admissions
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23 309 from 64 students in 2005 to 1 617 students in 2016. The students are obligated to work in a rural area
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26 310 or a designated specialty (such as OB/GYN) for nine years after graduating in return for financial
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28 311 assistance for their studies.²⁷ As the program is relatively new, it remains unclear as to whether the
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31 312 increase in quotas will lead to improvements in the geographic disparity of physicians.

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34 313 There are several limitations in this research. Firstly, the adjustment coefficients may
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37 314 continue to change in the future. However, the coefficients did not change considerably during the
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40 315 study period. In addition, it may be difficult to generalize our adjustment coefficients to other
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43 316 countries as they were calculated using Japanese health expenditure. On the other hand, the
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46 317 adjustment method itself may have applications in other countries. Secondly, there was a lack of
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48 318 information on the physicians' working conditions, such as whether a physician worked full-time or
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51 319 part-time. It may be beneficial for future studies to incorporate mean physician working hours.
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54 320 Finally, there may be other ways to divide the SMAs for the subgroup analysis. However, our

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6 321 subgroup analysis was based on the categorization used in a previous study,¹⁹ and provided an

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9 322 intuitive understanding of the differences in group characteristics.

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14 324 **Conclusion**

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17 325 The geographic distribution of physicians in Japan has failed to improve in any of the clinical

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20 326 specialties. There is also a growing disparity in physician supply between the urban and rural areas.

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23 327 In consideration of the rapidly aging population and the resulting changes in population structure,

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26 328 urgent measures are needed to reduce the geographic disparities in physician supply and regulate the

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29 329 uneven distribution among clinical specialties.

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34 331 **List of abbreviations**

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37 332 OB/GYN, obstetrics and gynecology

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40 333 MHLW, Ministry of Health, Labour and Welfare

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43 334 SMA, secondary medical area

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54 338 Not applicable.

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42 352 interpretation, and drafting the manuscript. SK and NS contributed to the data
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45 353 collection and data management. YI contributed to the study design, data acquisition,
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48 354 and interpretation. All authors critically revised the manuscript, and approved the final
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6 357 **Ethics approval**

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8 358 Ethics committee approval was waived for this study because all of the data are publicly
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11 359 available online and comprise only aggregate values without any personally identifiable
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14 360 information.

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22 363 The funder of the study had no role in study design; collection, analysis, and interpretation of the
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26 365 author had full access to all the data in the study and had final responsibility for the decision to
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28 366 submit for publication.

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34 368 **Data Sharing Statement**

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36 369 No additional data available.

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42 371 **Consent for publication**

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44 372 Not applicable.

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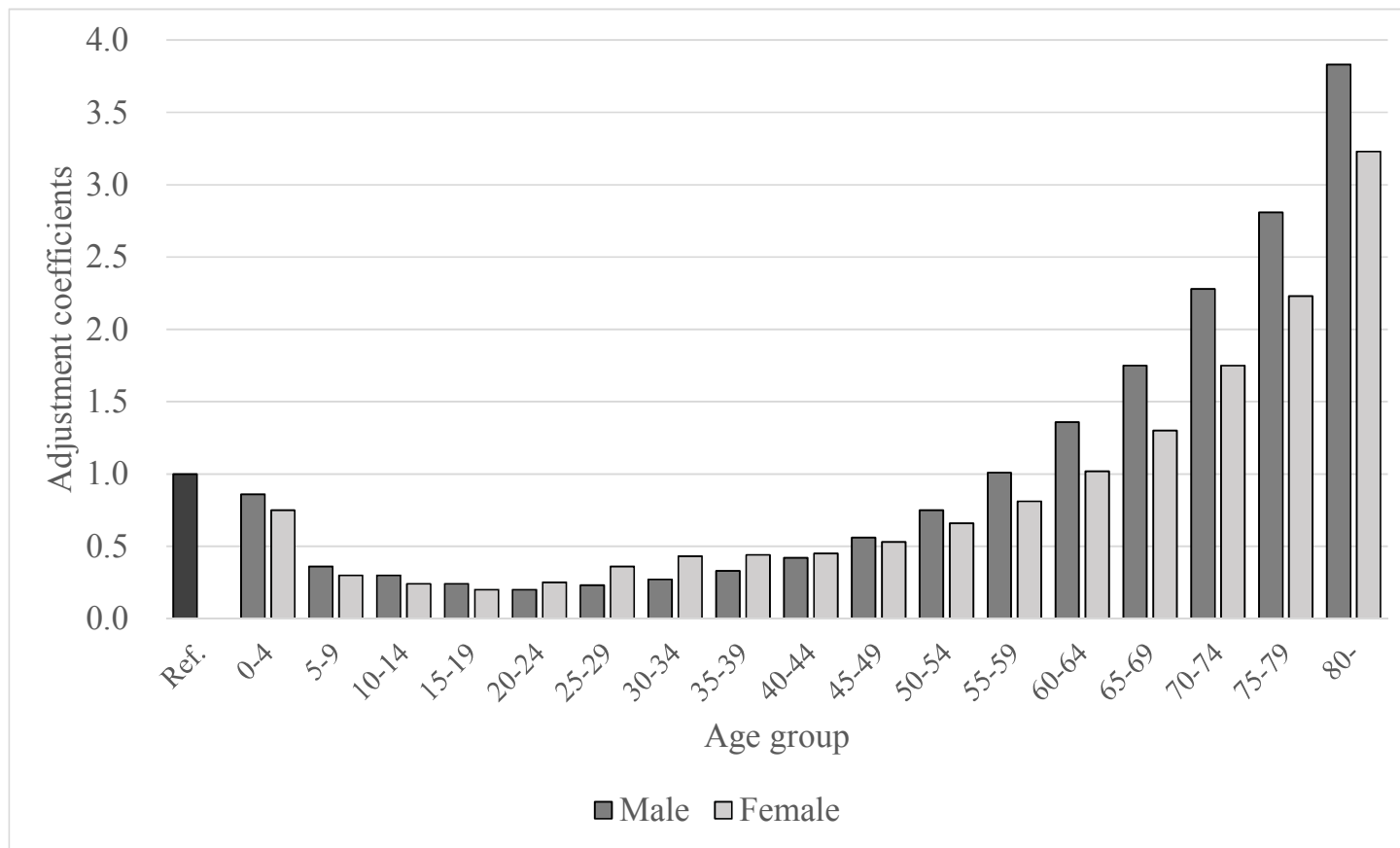
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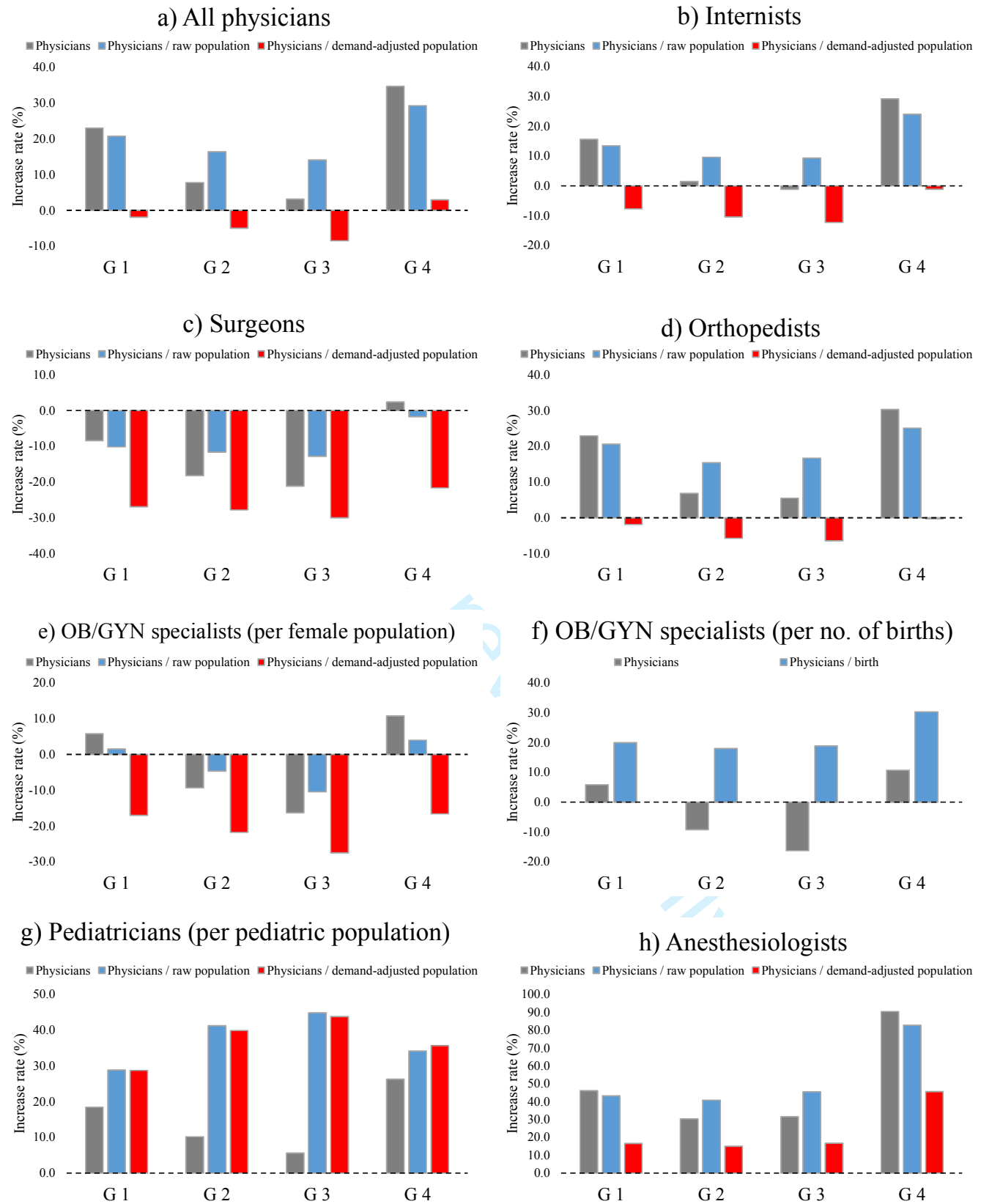
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Figure 1 Adjustment coefficients of healthcare demand by age strata and sex



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

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

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

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

| Year | Before adjustment | | | | After adjustment | | |
|------------------------|-------------------|-------------------|-------------------------------------|---------------------------------|--------------------|--------------------|-------------------------------------|
| | Total population | Female population | Pediatric population * ¹ | Number of births * ² | Total population | Female population | Pediatric population * ¹ |
| 2000 | 126 071 305 | 55 196 259 | 18 553 275 | 1 190 164 | 101 697 295 | 48 349 047 | 8 546 612 |
| 2014 | 126 434 634 | 56 670 449 | 16 489 385 | 1 003 474 | 125 837 379 | 60 902 189 | 7 594 643 |
| Increase in number (%) | 363 329 (0.3%) | 1 474 190 (2.7%) | -2 063 890 (-11.1%) | -186 690(-15.7%) | 24 140 085 (23.7%) | 12 553 142 (26.0%) | -951 969 (-11.1%) |

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

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

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

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

| Year | Specialty | | | | | | | |
|--|----------------|----------------|----------------|---------------|--------------------|--------------------------------|-------------------------|-------------|
| | All physicians | Internists | Surgeons | Orthopedists | OB/GYN specialists | Pediatricians | Anesthesiologists | |
| Overall number of physicians | | | | | | | | |
| 2000 | 243 201 | 95 545 | 25 424 | 19 225 | 12 420 | 14 156 | 5 751 | |
| 2014 | 296 845 | 110 097 | 23 223 | 23 297 | 12 888 | 16 758 | 8 625 | |
| Increase in number (%) | 53 644 (22.1%) | 14 552 (15.2%) | -2 201 (-8.7%) | 4 072 (21.2%) | 468 (3.8%) | 2 602 (18.4%) | 2 874 (50.0%) | |
| Number of physicians per 100 000 population | | | | | | | | |
| Population type | Total | Total | Total | Total | Female | Number of births ^{*1} | Pediatric ^{*2} | Total |
| 2000 | 192.9 | 75.8 | 20.2 | 15.2 | 22.5 | 1 043.6 | 76.3 | 4.6 |
| 2014 | 234.8 | 87.1 | 18.4 | 18.4 | 22.7 | 1 284.3 | 101.6 | 6.8 |
| Increase in number (%) | 41.9 (21.7%) | 11.3 (14.9%) | -1.8 (-8.9%) | 3.2 (21.1%) | 0.2 (0.9%) | 240.7 (23.1%) | 25.3 (33.2%) | 2.2 (47.8%) |
| Number of physicians per 100 000 demand-adjusted population | | | | | | | | |
| Population type | Total | Total | Total | Total | Female | Number of births ^{*1} | Pediatric ^{*2} | Total |
| 2000 | 239.1 | 94.0 | 25.0 | 18.9 | 25.7 | N/A | 165.6 | 5.7 |
| 2014 | 235.9 | 87.5 | 18.5 | 18.5 | 21.2 | N/A | 220.7 | 6.9 |
| Increase in number (%) | -3.2 (-1.3%) | -6.5 (-6.9%) | -6.5 (-26.0%) | -0.4 (-2.1%) | -4.5 (-17.5%) | N/A | 55.1 (33.3%) | 1.2 (21.1%) |

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

^{*2} Pediatric population: all residents aged below 15 years.

OB/GYN: obstetrics/gynecology

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

| Year | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2000-2014 changes |
|---|-------|-------|-------|-------|-------|-------|-------|-------|----------------------|
| Number of physicians per 100 000 population | | | | | | | | | |
| All physicians | 0.195 | 0.193 | 0.194 | 0.194 | 0.199 | 0.202 | 0.205 | 0.206 | 0.011 |
| Internists | 0.183 | 0.179 | 0.177 | 0.175 | 0.177 | 0.179 | 0.183 | 0.181 | -0.002 |
| Surgeons | 0.204 | 0.202 | 0.197 | 0.190 | 0.194 | 0.206 | 0.210 | 0.209 | 0.005 |
| Orthopedists | 0.202 | 0.201 | 0.196 | 0.191 | 0.195 | 0.193 | 0.192 | 0.196 | -0.006 |
| OB/GYN specialists (per female population) | 0.226 | 0.218 | 0.226 | 0.240 | 0.260 | 0.263 | 0.266 | 0.270 | 0.043 |
| OB/GYN specialists (per number of births) * | 0.231 | 0.220 | 0.227 | 0.225 | 0.243 | 0.243 | 0.248 | 0.250 | 0.019 |
| Pediatricians (per pediatric population) | 0.248 | 0.244 | 0.239 | 0.243 | 0.246 | 0.244 | 0.247 | 0.246 | -0.003 |
| Anesthesiologists | 0.445 | 0.435 | 0.438 | 0.433 | 0.434 | 0.428 | 0.432 | 0.429 | -0.016 |
| Number of physicians per 100 000 demand-adjusted population | | | | | | | | | |
| All physicians | 0.212 | 0.210 | 0.214 | 0.219 | 0.227 | 0.231 | 0.234 | 0.237 | 0.025 |
| Internists | 0.186 | 0.182 | 0.185 | 0.184 | 0.191 | 0.194 | 0.199 | 0.199 | 0.013 |
| Surgeons | 0.204 | 0.202 | 0.198 | 0.189 | 0.199 | 0.213 | 0.218 | 0.219 | 0.015 |
| Orthopedists | 0.215 | 0.212 | 0.208 | 0.204 | 0.211 | 0.211 | 0.210 | 0.213 | -0.002 |
| OB/GYN specialists (per female population) | 0.254 | 0.247 | 0.255 | 0.272 | 0.292 | 0.296 | 0.299 | 0.303 | 0.049 |
| Pediatricians (per pediatric population) | 0.244 | 0.240 | 0.235 | 0.240 | 0.243 | 0.240 | 0.243 | 0.242 | -0.002 |
| Anesthesiologists | 0.456 | 0.447 | 0.451 | 0.448 | 0.449 | 0.445 | 0.450 | 0.447 | -0.009 |

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

OB/GYN: obstetrics/gynecology

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

| | Before adjustment | | After adjustment | |
|--|-------------------|--------|------------------|-------|
| | 2000 | 2014 | 2000 | 2014 |
| Total number of physicians per 100 000 population | | | | |
| Group 1 | 247.0 | 297.9 | 311.6 | 305.7 |
| Group 2 | 194.8 | 226.6 | 213.9 | 203.3 |
| Group 3 | 124.6 | 142.1 | 138.9 | 127.0 |
| Group 4 | 126.3 | 163.1 | 166.9 | 171.9 |
| Number of internists per 100 000 population | | | | |
| Group 1 | 95.2 | 108.0 | 120.1 | 110.8 |
| Group 2 | 79.8 | 87.5 | 87.6 | 78.5 |
| Group 3 | 54.0 | 59.1 | 60.2 | 52.8 |
| Group 4 | 49.6 | 61.4 | 65.5 | 64.7 |
| Number of surgeons per 100 000 population | | | | |
| Group 1 | 25.2 | 22.6 | 31.8 | 23.2 |
| Group 2 | 21.8 | 19.3 | 24.0 | 17.3 |
| Group 3 | 15.3 | 13.3 | 17.1 | 11.9 |
| Group 4 | 12.9 | 12.7 | 17.0 | 13.3 |
| Number of orthopedists per 100 000 population | | | | |
| Group 1 | 18.6 | 22.4 | 23.5 | 23.0 |
| Group 2 | 16.6 | 19.2 | 18.2 | 17.2 |
| Group 3 | 10.8 | 12.6 | 12.0 | 11.2 |
| Group 4 | 10.7 | 13.4 | 14.2 | 14.2 |
| Number of OB/GYN specialists per 100 000 female population | | | | |
| Group 1 | 28.4 | 28.9 | 33.2 | 27.5 |
| Group 2 | 20.2 | 19.3 | 20.3 | 15.8 |
| Group 3 | 13.9 | 12.4 | 14.1 | 10.2 |
| Group 4 | 16.3 | 17.0 | 20.0 | 16.7 |
| Number of OB/GYN specialists per 100 000 births * | | | | |
| Group 1 | 1316.5 | 1578.9 | N/A | N/A |
| Group 2 | 1051.3 | 1240.3 | N/A | N/A |
| Group 3 | 714.9 | 849.8 | N/A | N/A |
| Group 4 | 702.1 | 914.7 | N/A | N/A |
| Number of pediatricians per 100 000 pediatric population | | | | |

| | | | | | |
|---|---------|------|------|-------|-------|
| 1 | | | | | |
| 2 | Group 1 | 49·0 | 63·1 | 211·5 | 272·3 |
| 3 | Group 2 | 35·5 | 50·2 | 158·0 | 221·0 |
| 4 | Group 3 | 22·6 | 32·7 | 100·7 | 144·8 |
| 5 | Group 4 | 27·3 | 36·7 | 117·6 | 159·4 |

8 Number of anesthesiologists per 100 000 population

| | | | | | |
|----|---------|-----|-----|-----|-----|
| 9 | | | | | |
| 10 | Group 1 | 6·6 | 9·4 | 8·3 | 9·7 |
| 11 | Group 2 | 4·4 | 6·1 | 4·8 | 5·5 |
| 12 | Group 3 | 1·9 | 2·8 | 2·1 | 2·5 |
| 13 | Group 4 | 2·2 | 4·1 | 2·9 | 4·3 |

16 Group 1: urban areas with higher initial physician supply; Group 2: rural areas with higher initial physician
 17 supply; Group 3: rural areas with lower initial physician supply; Group 4: urban areas with lower initial
 18 physician supply.
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20 * As the number of births was not adjusted for healthcare demand, the numbers of OB/GYN specialists per
 21 100 000 demand-adjusted births are not shown.
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23 N/A: not applicable; OB/GYN: obstetrics/gynecology
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Appendix table. 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 | | | | |
| Total physicians | 1 536·0(1 409·7) | 619·2(433·5) | 352·0(295·3) | 175·5(127·2) |
| Internists | 592·0(566·4) | 242·9(165·3) | 144·3(105·2) | 76·1(52·0) |
| Surgeons | 156·5(142·1) | 63·1(42·2) | 39·5(28·4) | 21·6(14·2) |
| Orthopedists | 115·8(94·4) | 52·6(36·4) | 30·0(25·9) | 15·2(12·2) |
| OB/GYN specialists | 78·1(71·8) | 34·1(26·3) | 16·4(15·6) | 8·6(6·5) |
| Pediatricians | 88·0(71·9) | 40·3(31) | 19·1(19·8) | 9·6(7·8) |
| Anesthesiologists | 40·9(40·1) | 10·9(9·8) | 7·9(9·8) | 2·7(3·2) |
| Raw population | | | | |
| Total population | 621 865·5(458 098·5) | 490 244·5(341 301·8) | 180 718·5(125 140·5) | 140 925·7(100 156·8) |
| Female population | 274 615·3(203 154·4) | 209 062·4(144 107·6) | 81 044·7(54 965·4) | 62 047·6(43 331·9) |
| Pediatric population | 89 778·6(62 866·3) | 73 620·8(48 171·0) | 26 837·6(19 441·3) | 21 202·8(15 429·6) |
| Number of births * | 41 599·4(29 459·0) | 34 246·1(22 935·5) | 12 070·9(8 837·2) | 9 497·2(6 971·3) |
| Demand-adjusted population | | | | |
| Total population | 492 971·0(349 667·3) | 370 991·2(242 817·0) | 164 585·9(103 001·3) | 126 410·8(84 059·2) |
| Female population | 235 594·4(166 553·3) | 170 624·5(109 441·9) | 80 861·9(49 177·2) | 61 184·3(39 965·6) |
| Pediatric population | 41 599·4(29 459·0) | 34 246·1(22 935·5) | 12 070·9(8 837·2) | 9 497·2(6 971·3) |

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

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

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

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

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

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1 Examining changes in the equity of physician distribution in
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3
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6 22 Examining changes in the equity of physician distribution in
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9 23 Japan: a specialty-specific longitudinal study
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14
15 25 **Abstract**

16
17 26 **Objectives**

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20 27 In this longitudinal study, we examined changes in the geographic distribution of physicians in Japan
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23 28 from 2000 to 2014 by clinical specialty with adjustments for healthcare demand based on population
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26 29 structure.

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29 30 **Methods**

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31 31 The Japanese population was adjusted for healthcare demand using health expenditure per capita
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33
34 32 stratified by age and sex. The numbers of physicians per 100 000 demand-adjusted population in
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37 33 2000 and 2014 were calculated for sub-prefectural regions known as secondary medical areas.
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40 34 Disparities in the geographic distribution of physicians for each specialty were assessed using Gini
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43 35 coefficients. A subgroup analysis was conducted by dividing the regions into four groups according
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46 36 to urban-rural classification and initial physician supply.

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49 37 **Results**

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51 38 Over the study period, the number of physicians per 100 000 demand-adjusted population decreased
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54 39 in all clinical specialties (e.g., surgery: 26·0% decrease) except pediatrics (33·3% increase) and

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6 40 anesthesiology (21.1% increase). No reductions in geographic disparity were observed in any of the
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9 41 clinical specialties. Geographic disparity increased substantially in internal medicine, surgery, and
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11 42 obstetrics and gynecology. Rural areas with lower initial physician supply experienced the highest
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14 43 decreases in physicians per 100 000 demand-adjusted population for all clinical specialties except
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16
17 44 pediatrics and anesthesiology. In contrast, urban areas with lower initial physician supply
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20 45 experienced the lowest decreases in physicians per 100 000 demand-adjusted population in internal
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23 46 medicine, surgery, orthopedics, and obstetrics and gynecology, but the highest increase in
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26 47 anesthesiology.

28 **Conclusion**

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31 49 Between 2000 and 2014, the number of physicians per 100 000 demand-adjusted population in Japan
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34 50 decreased in all specialties except pediatrics and anesthesiology. There is also a growing urban-rural
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37 51 disparity in physician supply in all specialties except pediatrics. Additional measures may be needed
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40 52 to resolve these issues and improve physician distribution in Japan.

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6 54 **Article Summary**

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9 55 Strengths and limitations of this study

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11 56 • This study longitudinally examined specialty-specific changes in the geographic distribution of
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14 57 Japanese physicians with adjustments for healthcare demand according to population structure.
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17 58 • The adjustment method used in this study was previously verified, and enables adjustment for
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20 59 healthcare demand according to age strata using health expenditure per capita.
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22
23 60 • Both age and sex were included in the calculation of the adjustment coefficients to increase the
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26 61 accuracy of adjustments.
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29 62 • There was a lack of information on the physicians' working conditions, such as whether a
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32 63 physician worked full-time or part-time.
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35 64 • It may be difficult to generalize our adjustment coefficients to other countries as they were
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38 65 calculated using Japanese health expenditure, but the adjustment method itself may have
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41 66 applications in other countries.
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6 **70 Introduction**

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9 71 The presence of inequities in the geographic distribution of physicians is a major social problem in
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11 72 many countries.¹⁻⁴ In Japan, the geographic disparity in physician supply has long been recognized
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14 73 as a serious flaw in the healthcare provision system.^{5,6} The lack of regulations that dictate where
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17 74 individual physicians work in Japan has led to the concentration of physicians in urban regions and a
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20 75 shortfall in rural areas, thereby resulting in uneven access to health care throughout the country.^{5,6}
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23 76 On the other hand, Japan has entered a period of population decline,⁷ and an oversupply of
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26 77 physicians is imminent if their numbers continue to rise at current rates. Attempts to control the total
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29 78 number of physicians have been met with resistance from various interest groups.⁸

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31 79 In addition to the geographic disparity in physician supply, Japan also faces issues
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34 80 stemming from an uneven distribution of physicians among the clinical specialties.⁹ Previous studies
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37 81 from the US have reported that the geographic distribution of physicians varies according to clinical
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40 82 specialty.^{10,11} Similarly, geographic disparities in the number of physicians in pediatrics, obstetrics
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43 83 and gynecology (OB/GYN), and anesthesiology have been documented in Japan.¹² However, few
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46 84 studies have longitudinally examined the geographic distribution of physicians according to clinical
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49 85 specialty.

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51 86 Although the number of physicians per 100 000 population is generally used as an
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54 87 indicator when examining geographic disparities in physician supply, this measure involves a simple

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6 88 head count that does not account for the inherent variations in healthcare demand among the
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9 89 different age strata and sex.⁴ Furthermore, Japan's population is aging at an unprecedented rate,
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11 90 which has resulted in its transformation into the world's first "super-aged" society (where more than
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14 91 21% of a country's population is aged 65 years and older). As a consequence, the population
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17 92 structure in Japan is undergoing dramatic changes, which has invariably led to changes to healthcare
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20 93 demand. We previously reported that Japan's healthcare demand increased by 22% from 2000 to
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23 94 2014 amid worsening geographic disparity in physician supply.¹³ However, studies have yet to be
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26 95 conducted on the disparity in Japan's physician supply for different clinical specialties while
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29 96 accounting for the differences in healthcare demand.

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31 97 This study aimed to longitudinally examine specialty-specific changes in the geographic
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34 98 distribution of physicians in Japan from 2000 to 2014 with adjustments for healthcare demand based
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37 99 on population structure.

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41 42 101 **Methods**

43 44 45 102 Data source

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48 103 Data on the number of physicians were obtained from the Survey of Physicians, Dentists, and

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51 104 Pharmacists conducted every two years by the Ministry of Health, Labour and Welfare (MHLW).

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54 105 Physicians in Japan are required to participate in this survey, which includes information on each

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6 106 physician's specialty and the type and location (municipality) of their workplace. Population data
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9 107 (age, sex, and location of residence) were extracted from the Annual Report of the National Basic
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11 108 Resident Registration System published by the Ministry of Internal Affairs and Communications,
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14 109 and data on the number of births were obtained from the Annual Report of Vital Statistics published
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17 110 by the MHLW. We also acquired data on national health expenditure per capita according to patient
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20 111 age in 2013 from the MHLW. The total area of habitable land was ascertained from statistical reports
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23 112 on land areas of prefectures and municipalities by the Geospatial Information Authority of Japan.
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28 114 Physicians and population
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31 115 We targeted physicians working in clinical facilities (hospitals and clinics), and excluded physicians
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34 116 working in non-clinical facilities (e.g., research centers and government offices). The following
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37 117 clinical specialties were included in analysis: internal medicine, surgery, orthopedics, OB/GYN,
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40 118 pediatrics, and anesthesiology. Internal medicine, surgery, and orthopedics were selected because
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43 119 these departments generally have more physicians than other departments. The remaining three
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46 120 specialties were selected because of their previously reported geographic disparities in physician
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48 121 supply throughout Japan.¹²
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51 122 In addition to the total population, we also analyzed the female population, pediatric
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54 123 population (<15 years of age), and the number of births. With the exception of the number of births,
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6 124 all study populations were adjusted for healthcare demand. We calculated the number of OB/GYN
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9 125 specialists per 100 000 female population and per 100 000 births, the number of pediatricians per
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11 126 100 000 pediatric population, and the number of physicians per 100 000 population for each of the
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14 127 other clinical specialties.
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17 128
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20 129 Geographic unit
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23 130 The geographic unit of analysis was the secondary medical area (SMA). The Japanese government
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25 131 has designated three regional levels of healthcare provision. Primary medical areas are geographic
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28 132 units where primary care is provided, and are demarcated by municipal borders. Tertiary medical
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31 133 areas are geographic units that provide advanced medical care, and are demarcated by prefectural
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34 134 borders. SMAs are set between primary and tertiary medical areas, and are regions where general
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37 135 medical care (such as inpatient care) is provided; these areas are composed of multiple
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40 136 municipalities. Each prefectural government stipulates the geographic and demographic range of the
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43 137 SMAs within their prefecture. As a result, the boundaries of each SMA can be altered in response to
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46 138 changes in healthcare demand. SMAs have been previously used to examine the inequities in
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48 139 physician supply in Japan.^{6 14} Because the number of SMAs varies slightly over time, this study was
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51 140 conducted using the 349 SMAs designated in 2012.
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6 142 Analytical methods
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9 143 This retrospective study longitudinally examined the changes in the geographic distribution of the
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11 144 number of physicians by clinical specialty among Japan's SMAs from 2000 to 2014. The primary
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14 145 outcomes were the overall number of physicians per 100,000 population and the trends in Gini
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17 146 coefficients (indicating geographic disparity) for each specialty during the study period. The
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20 147 secondary outcomes were the changes in physician numbers during the same period for subgroups
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23 148 that were categorized according to regional characteristics (urban-rural classification and initial
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26 149 physician supply).

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28 150 The population was first adjusted using adjustment coefficients of healthcare demand,
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31 151 which were calculated based on the health expenditure per capita stratified by age and sex through a
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34 152 previously described method.¹³ Health expenditure per capita is likely indicative of the general
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37 153 workload of healthcare providers.¹⁵ These expenditures include those for both inpatient and
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40 154 outpatient services, and account for variations in patient health status.¹³ The demand-adjusted
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43 155 population was generated by multiplying the raw population with the adjustment coefficients.

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45 156 Next, geographic disparity was assessed using the Gini coefficient. This indicator, which is
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48 157 widely used to examine disparity in the field of economics, has been applied to analyze geographic
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51 158 disparity in physician supply.^{15 16-18} We calculated the Gini coefficients for each specialty every two
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54 159 years from 2000 to 2014. The coefficients, which take a value from 0 (indicating complete equality)

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6 160 to 1 (indicating complete inequality), measure departure from a uniform distribution by drawing
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9 161 Lorenz curves.¹⁷ If the curves of two time points intersect, conclusions cannot be made as to whether
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11 162 or not the inequity of distribution is increasing.¹⁸ Thus, we plotted two Lorenz curves (one each for
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14 163 2000 and 2014) for each clinical specialty.

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16
17 164 Finally, a subgroup analysis was conducted by dividing SMAs into groups according to
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20 165 two regional characteristics. Using the method described in Sasaki et al.,¹⁹ we classified each SMA
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23 166 into one of four groups based on whether the SMA was an urban or rural area, and whether the SMA
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26 167 had a higher or lower initial physician supply in 2000. An SMA was designated an urban area (or a
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29 168 rural area) if its population density was higher (or lower) than the median value in all SMAs. The
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31 169 population density of each SMA was calculated using the total area of habitable land and the
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34 170 population in 2000. Next, an SMA was designated as having a higher (or lower) initial physician
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37 171 supply if the number of physicians per 100 000 population was higher (or lower) than the median
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40 172 number of physicians per 100 000 population in all SMAs. The following four groups were
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43 173 analyzed: Group 1, which comprised urban areas with higher initial physician supply; Group 2,
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45
46 174 which comprised rural areas with higher initial physician supply; Group 3, which comprised rural
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49 175 areas with lower initial physician supply; and Group 4, which comprised urban areas with lower
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51 176 initial physician supply. Data from 2000 were used for both the population and physicians. In this
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54 177 subgroup analysis, we compared the inter-group changes in the number of physicians per 100 000

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6 178 population between 2000 and 2014.
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9 179 All analyses were performed using R statistical software (V.3.2.2).
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14 181 **Results**
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17 182 Table 1 shows the population sizes of the total population, female population, and pediatric
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19 183 population before and after applying the adjustment coefficients in 2000 and 2014. The adjustment
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21 184 coefficients for the different age strata and sex are provided Appendix Figure. Before adjustment, the
22
23 185 total population did not substantially change throughout the study period. In contrast, the
24
25 186 demand-adjusted total population increased by 23.7% between 2000 and 2014. The number of births,
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27 187 which was not adjusted for healthcare demand, decreased by 15.7%. The pediatric population
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29 188 declined by 11.1% over the study period both before and after adjusting for healthcare demand.
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36 189 Table 2 shows the overall number of physicians and the number of physicians per 100 000
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38 190 population in 2000 and 2014. The overall number of all physicians increased by 22.1% over the
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40 191 study period. Similarly, the number of all physicians per 100 000 population increased by 21.7%.
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45 192 However, the number of all physicians per 100 000 demand-adjusted population decreased by 1.3%.
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48 193 The number of physicians per 100,000 demand-adjusted population in surgery and OB/GYN
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50 194 declined by 26.0% and 17.5%, respectively. In contrast, the number of OB/GYN specialists per
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52 195 100,000 births increased by 23.1% due to the declining number of births. The number of physicians
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6 196 per 100,000 demand-adjusted population in pediatrics and anesthesiology increased by 33.3% and
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8
9 197 21.1%, respectively.

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11 198 Table 3 shows the trends in Gini coefficients for the number of physicians per 100 000
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14 199 population in the SMAs by clinical specialty. There were no substantial changes in the Gini
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17 200 coefficients for the numbers of orthopedists, pediatricians, and anesthesiologists per 100 000
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20 201 demand-adjusted population. However, inequity increased in the geographic distribution of internists,
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23 202 surgeons, and OB/GYN specialists (for both the female population and the number of births). In
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26 203 each of these three specialties, the Lorenz curve in 2014 tended to deteriorate more than the curve in
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29 204 2000 without intersection between the two curves (figures not shown). When comparing the Gini
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32 205 coefficients before and after adjusting for healthcare demand, the trends in the coefficients were
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35 206 similar for each clinical specialty. However, the post-adjustment Gini coefficients for all clinical
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38 207 specialties (except for pediatrics) were higher than their pre-adjustment values.

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40 208 Table 4 summarizes the changes in the numbers of physicians per 100 000 population in
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43 209 the four groups of SMAs. Detailed descriptive statistics of the four groups are provided in the
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46 210 Appendix table. Figure 1 shows the temporal increases (2000 to 2014) in the number of physicians
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49 211 by clinical specialty in each group of SMAs. The temporal increases in the number of internists and
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52 212 orthopedists were similar to those for all physicians. The overall number of surgeons decreased in all
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55 213 groups except for Group 4, and the number of surgeons per 100 000 demand-adjusted population

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6 214 decreased by 20% to 30% in all groups. As shown in Table 4, the number of surgeons per 100 000
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9 215 demand-adjusted population in Group 3 (11·9) was approximately half of the corresponding number
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12 216 in Group 1 (23·2) in 2014. In all groups, the number of OB/GYN specialists per 100 000
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15 217 demand-adjusted female population decreased, but the number of OB/GYN specialists per 100 000
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18 218 births increased. The number of pediatricians per 100 000 demand-adjusted pediatric population
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21 219 increased more in the rural SMAs than in the urban SMAs. The number of anesthesiologists per 100
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23 220 000 demand-adjusted population increased in all groups; in particular, the number in Group 4
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26 221 increased by more than twice that of the other groups. In all clinical specialties except pediatrics and
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29 222 anesthesiology, Group 3 had the highest decrease in the number of physicians per 100 000
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32 223 demand-adjusted population. The 2014-2000 difference and ratio of the number of physicians per
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35 224 100 000 demand-adjusted population between Groups 3 and 4 increased in all clinical specialties
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38 225 except pediatrics.
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227 **Discussion**

228 The four major findings of this study are as follows: First, the demand-adjusted population increased
229 by 23·7% between 2000 and 2014, whereas the demand-adjusted pediatric population decreased by
230 11·1%. Second, the number of physicians per 100 000 demand-adjusted population decreased in all
231 clinical specialties except pediatrics and anesthesiology. The largest increase (33·3%) was observed

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6 232 in pediatrics. Third, the geographic disparity in the number of physicians per 100 000
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9 233 demand-adjusted population did not decline in all clinical specialties, and had in fact increased in
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11 234 internal medicine, surgery, and OB/GYN. Fourth, rural areas with lower initial physician supply had
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14 235 the highest decrease in the number of physicians per 100 000 demand-adjusted population compared
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17 236 with other areas in all clinical specialties except pediatrics and anesthesiology. In contrast, urban
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20 237 areas with lower initial physician supply had the lowest decrease in internal medicine, surgery,
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23 238 orthopedics and OBG/GYN, but the highest increase in anesthesiology.

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25 239 The population used in this study was adjusted for healthcare demand among the different
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28 240 age strata and sex using a previously described method.¹³ Although several studies have examined
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31 241 the demand-adjusted geographic disparity in physician supply,^{15 20} there is currently no gold standard
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34 242 method for adjustment.²⁰ The method used in this study was previously verified,¹³ and enables
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37 243 adjustment for healthcare demand according to age strata. In addition, the inclusion of sex in the
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40 244 calculation of the coefficients may increase the accuracy of adjustments.

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42 245 The number of physicians per 100 000 demand-adjusted population decreased in internal
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45 246 medicine, surgery, orthopedics, and OB/GYN (per female population). The decline in physician
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48 247 supply was particularly large in surgery and OB/GYN, which corroborates previously reported
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51 248 downward trends in the numbers of physicians in these specialties.¹² The distribution among
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54 249 specialties is affected by physician preference, experience, and environment. For example, the

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6 250 shortage of surgeons may be influenced by the long working hours, high risk of medical litigation,
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9 251 and low reward for surgical skill.²¹ Previous research has also shown that an increase in female
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12 252 physicians has affected the distribution of specialties because they are more likely to choose
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15 253 OB/GYN and pediatrics instead of surgery.^{22 23} In order to ensure a high number of both female and
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18 254 male physicians, we believe that improvements should be made to the working environment, such as
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21 255 a reduction in physician working hours by assigning more duties and responsibilities to
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24 256 non-physician health professionals.²¹ On the other hand, there was a large increase in the number of
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27 257 anesthesiologists during the study period. Japan is experiencing an increasing need for
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30 258 anesthesiologists due to the rising number of surgeries conducted, the increasing complexity of
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33 259 surgery owing to advances in surgical techniques and the overall aging of patients, as well as the
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36 260 growing social expectations for safety in anesthesia.²⁴ Due to the initial shortage of anesthesiologists,
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39 261 the offering of higher salaries may have contributed to attracting more specialists. In addition, the
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42 262 increase in anesthesiologists may have been influenced by the growing number of female physicians.
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45 263 Because anesthesiologists generally do not have their own patients or on-call duties, this specialty
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48 264 may be more compatible with raising families. The increase in female anesthesiologists from 26.7%
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51 265 to 37.6% during the study period is consistent with this possibility.

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54 266 Our findings detected a decrease in the numbers of internists and orthopedists despite an
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57 267 increase in healthcare demand. On the other hand, the number of pediatricians per 100 000

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6 268 demand-adjusted pediatric population and OB/GYN specialists per 100 000 births greatly increased
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9 269 due to a decline in the pediatrics population and the number of births. The rate of pediatric
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11 270 population decline is expected to eventually exceed the rate of total population decline.²⁵ It may
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14 271 therefore be more useful to ensure the optimal allocation of physicians instead of simply increasing
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17 272 their overall numbers.

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20 273 Based on the analysis of Gini coefficients, there were no reductions in geographic disparity
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23 274 in the number of physicians per 100 000 demand-adjusted population in all clinical specialties
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26 275 between 2000 and 2014. In particular, the inequity in physician supply increased in internal medicine,
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28 276 surgery, and OB/GYN. The inequity in surgery and OB/GYN may have been influenced by the
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31 277 decrease or lack of increase in the overall number of physicians in these specialties. These findings
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34 278 suggest that the uneven distribution of physicians among the clinical specialties may exacerbate
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37 279 geographic disparities in physician supply. On the other hand, the number of internists increased at a
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40 280 rate that was comparable to the overall growth rate. The increase in geographic disparity may
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43 281 therefore be related to an increasing tendency toward physician specialization in Japan.²⁶ Although
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46 282 the overall number of general internists decreased from 74 539 to 61 317 over the study period, there
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48
49 283 was actually an increase from 21 006 to 48 780 physicians in internal subspecialties such as
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52 284 pulmonary, cardiovascular, and gastrointestinal medicine (data not shown). The geographic disparity
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54 285 in physician supply in these subspecialties is greater than the disparity in general internists.⁹

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6 286 The rate of increase in the number of physicians per 100 000 demand-adjusted population
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9 287 in the urban areas was generally higher than in the rural areas. In all clinical specialties except
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11 288 pediatrics, both the difference and ratio in the number of physicians per 100 000 demand-adjusted
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14 289 population between Group 3 and Group 4 in 2014 were larger than the corresponding values in 2000.
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17 290 This indicates that the urban-rural disparity in physician supply widened over the study period.
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20 291 Group 3 had the lowest initial physician supply, and these regions may be facing a serious physician
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23 292 shortage. This issue should be explored further, and there may be a need for major reforms to ensure
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26 293 adequate physician supply to rural areas. It may also be important to implement measures in rural
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29 294 areas to improve physician productivity, reduce non-essential workload, and implement
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31 295 technology-based systems such as telemedicine.
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34 296 Prior to 2004, the vast majority of medical graduates joined a clinical specialty department
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37 297 (known as an *Ikyoku*) at their university that secures employment for the new graduates. *Ikyoku*
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40 298 generally dispatch physicians to other affiliated hospitals that are often located in rural areas. In this
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43 299 way, the *Ikyoku* were partly responsible for preventing a shortage of physicians in rural areas. On the
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46 300 other hand, medical graduates did not receive mandatory clinical training under this system. As a
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49 301 result, few graduates were able to acquire a wide range of medical skills through comprehensive and
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51 302 systematic training.²⁷ In addition, training assessments were not adequately performed under the
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54 303 *Ikyoku* system.²⁷ In order to improve the overall quality of clinical training throughout Japan, the
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6 304 MHLW mandated a standardized 2-year training program in 2004. Furthermore, there was a large
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9 305 increase in the number of non-university hospitals that medical graduates could attend as part of this
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11 306 training program after 2004. As a consequence, the graduates, now able to choose their training
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14 307 hospital after graduation, were less likely to select a university hospital for training. Due to the
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17 308 decreasing number of member physicians, it became more difficult for the *Ikyoku* to dispatch
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20 309 physicians to affiliate hospitals.¹⁴ Previous studies have also reported that the new program may
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23 310 have increased the inequity in the geographic distribution of physicians^{14 28}. Similarly, this new
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26 311 program may also have contributed to the lack of reduction in geographic disparity in this study.

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28 312 The Japanese government has implemented several measures at the prefectural level aimed
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31 313 at reducing the geographic disparity in physician supply. In 2006, a "Council for Regional Medicine"
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34 314 was established in each prefecture, and these councils include representatives of the prefectural and
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37 315 local governments, hospitals, medical associations, universities, and residents. The councils discuss
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40 316 detailed measures for securing medical staff with a variety of hospitals, including university
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43 317 hospitals and public hospitals. Furthermore, a "Support Center for Community Medicine" was
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46 318 established in each prefecture in 2011 to secure and retain physicians. These centers adopt the role of
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49 319 "control towers" to address the uneven distribution of physicians within each prefecture. Specifically,
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52 320 the centers are responsible for supporting career advancement for physicians working in rural areas,
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54 321 acting as general liaisons for engaging new physicians, and providing general work information. In

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6 322 addition, the government has raised the regional quota of medical school admissions from 64
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9 323 students in 2005 to 1 617 students in 2016. The students are obligated to work in a rural area or a
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11 324 designated specialty (such as OB/GYN) for nine years after graduating in return for financial
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14 325 assistance for their studies.²⁹ As the program is relatively new, it remains unclear as to whether the
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17 326 increase in quotas will lead to reductions in the geographic disparity of physicians.

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20 327 There are several limitations in this research. First, the adjustment coefficients may
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23 328 continue to change in the future. However, the coefficients did not fluctuate considerably during the
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26 329 study period. In addition, it may be difficult to generalize our adjustment coefficients to other
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29 330 countries as they were calculated using Japanese health expenditure. Nevertheless, the adjustment
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32 331 method itself may have applications in other countries. Second, there was a lack of information on
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35 332 the physicians' working conditions, such as whether a physician worked full-time or part-time. It
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38 333 may be beneficial for future studies to incorporate mean physician working hours. Finally, there may
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41 334 be other ways to divide the SMAs for the subgroup analysis. However, our subgroup analysis was
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44 335 based on the categorization used in a previous study,¹⁹ and provided an intuitive understanding of the
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47 336 differences in group characteristics.

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51 338 **Conclusion**

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54 339 Between 2000 and 2014, the number of physicians per 100 000 demand-adjusted population in Japan

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6 340 decreased in all specialties except pediatrics and anesthesiology. There is also a growing urban-rural
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9 341 disparity in physician supply in all specialties except pediatrics. In consideration of the rapidly aging
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12 342 population and the resulting changes in population structure, additional measures may be needed to
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15 343 resolve these issues and improve physician distribution in Japan.
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20 345 **List of abbreviations**

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22 346 OB/GYN, obstetrics and gynecology

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25 347 MHLW, Ministry of Health, Labour and Welfare

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28 348 SMA, secondary medical area

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34 350 **Footnotes**

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40 352 Not applicable.

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45 354 **Competing interests**

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48 355 The authors declare that they have no competing interests.

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13
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20 363 **Contributors**

21
22 364 KH contributed to the study conception and design, data collection, analysis, interpretation, and
23
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25 365 drafting of the manuscript. SK and NS contributed to the data collection and data management. YI
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28 366 contributed to the study design, data acquisition, and interpretation. All authors critically revised the
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31 367 manuscript, and approved the final version.
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37 369 **Ethics approval**

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40 370 Ethics committee approval was waived for this study because all of the data are publicly available
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43 371 online and comprise only aggregate values without any personally identifiable information.
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48 373 **Role of the funding source**

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51 374 The funder of the study had no role in study design; collection, analysis, and interpretation of the
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54 375 data; writing of the report; or the decision to submit the paper for publication. The corresponding
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6 376 author had full access to all the data in the study and had final responsibility for the decision to

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9 377 submit for publication.

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14 379 **Data sharing statement**

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17 380 No additional data available.

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22 382 **Consent for publication**

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25 383 Not applicable.

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11 468 **Figure titles**
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14 469 **Figure 1** Temporal increases in physician numbers from 2000 to 2014 for the four
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17 470 groups of secondary medical areas
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20 471 **Appendix Figure** Adjustment coefficients of healthcare demand by age strata and sex
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25 473 **Figure legend**
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28 474 **Figure1**
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31 475 Group 1 (G1): urban areas with higher initial physician supply; Group 2 (G2): rural
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34 476 areas with higher initial physician supply; Group 3 (G3): rural areas with lower initial
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37 477 physician supply; Group 4 (G4): urban areas with lower initial physician supply. * As
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40 478 the number of births was not adjusted for healthcare demand, the numbers of OB/GYN
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43 479 specialists per 100 000 demand-adjusted births are not shown. OB/GYN:
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45 480 obstetrics/gynecology
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48 481 **Appendix Figure**
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51 482 Ref.: reference value, which is the mean health expenditure per capita of all patients.
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Table 1 Population sizes in 2000 and 2014 before and after adjustment for healthcare demand

| Year | Before adjustment | | | | After adjustment | | |
|------------------------|-------------------|-------------------|-------------------------|---------------------|--------------------|--------------------|-------------------------|
| | Total population | Female population | Pediatric population *1 | Number of births *2 | Total population | Female population | Pediatric population *1 |
| 2000 | 126 071 305 | 55 196 259 | 18 553 275 | 1 190 164 | 101 697 295 | 48 349 047 | 8 546 612 |
| 2014 | 126 434 634 | 56 670 449 | 16 489 385 | 1 003 474 | 125 837 379 | 60 902 189 | 7 594 643 |
| Increase in number (%) | 363 329 (0.3%) | 1 474 190 (2.7%) | -2 063 890 (-11.1%) | -186 690(-15.7%) | 24 140 085 (23.7%) | 12 553 142 (26.0%) | -951 969 (-11.1%) |

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

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

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

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

| Year | Specialty | | | | | | | |
|--|----------------|----------------|----------------|---------------|--------------------|--------------------------------|-------------------------|-------------|
| | All physicians | Internists | Surgeons | Orthopedists | OB/GYN specialists | Pediatricians | Anesthesiologists | |
| Overall number of physicians | | | | | | | | |
| 2000 | 243 201 | 95 545 | 25 424 | 19 225 | 12 420 | 14 156 | 5 751 | |
| 2014 | 296 845 | 110 097 | 23 223 | 23 297 | 12 888 | 16 758 | 8 625 | |
| Increase in number (%) | 53 644 (22.1%) | 14 552 (15.2%) | -2 201 (-8.7%) | 4 072 (21.2%) | 468 (3.8%) | 2 602 (18.4%) | 2 874 (50.0%) | |
| Number of physicians per 100 000 population | | | | | | | | |
| Population type | Total | Total | Total | Total | Female | Number of births ^{*1} | Pediatric ^{*2} | Total |
| 2000 | 192.9 | 75.8 | 20.2 | 15.2 | 22.5 | 1 043.6 | 76.3 | 4.6 |
| 2014 | 234.8 | 87.1 | 18.4 | 18.4 | 22.7 | 1 284.3 | 101.6 | 6.8 |
| Increase in number (%) | 41.9 (21.7%) | 11.3 (14.9%) | -1.8 (-8.9%) | 3.2 (21.1%) | 0.2 (0.9%) | 240.7 (23.1%) | 25.3 (33.2%) | 2.2 (47.8%) |
| Number of physicians per 100 000 demand-adjusted population | | | | | | | | |
| Population type | Total | Total | Total | Total | Female | Number of births ^{*1} | Pediatric ^{*2} | Total |
| 2000 | 239.1 | 94.0 | 25.0 | 18.9 | 25.7 | N/A | 165.6 | 5.7 |
| 2014 | 235.9 | 87.5 | 18.5 | 18.5 | 21.2 | N/A | 220.7 | 6.9 |
| Increase in number (%) | -3.2 (-1.3%) | -6.5 (-6.9%) | -6.5 (-26.0%) | -0.4 (-2.1%) | -4.5 (-17.5%) | N/A | 55.1 (33.3%) | 1.2 (21.1%) |

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

^{*2} Pediatric population: all residents aged below 15 years.

OB/GYN: obstetrics/gynecology

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

| Year | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2000-2014 changes |
|---|-------|-------|-------|-------|-------|-------|-------|-------|----------------------|
| Number of physicians per 100 000 population | | | | | | | | | |
| All physicians | 0.195 | 0.193 | 0.194 | 0.194 | 0.199 | 0.202 | 0.205 | 0.206 | 0.011 |
| Internists | 0.183 | 0.179 | 0.177 | 0.175 | 0.177 | 0.179 | 0.183 | 0.181 | -0.002 |
| Surgeons | 0.204 | 0.202 | 0.197 | 0.190 | 0.194 | 0.206 | 0.210 | 0.209 | 0.005 |
| Orthopedists | 0.202 | 0.201 | 0.196 | 0.191 | 0.195 | 0.193 | 0.192 | 0.196 | -0.006 |
| OB/GYN specialists (per female population) | 0.226 | 0.218 | 0.226 | 0.240 | 0.260 | 0.263 | 0.266 | 0.270 | 0.043 |
| OB/GYN specialists (per number of births) * | 0.231 | 0.220 | 0.227 | 0.225 | 0.243 | 0.243 | 0.248 | 0.250 | 0.019 |
| Pediatricians (per pediatric population) | 0.248 | 0.244 | 0.239 | 0.243 | 0.246 | 0.244 | 0.247 | 0.246 | -0.003 |
| Anesthesiologists | 0.445 | 0.435 | 0.438 | 0.433 | 0.434 | 0.428 | 0.432 | 0.429 | -0.016 |
| Number of physicians per 100 000 demand-adjusted population | | | | | | | | | |
| All physicians | 0.212 | 0.210 | 0.214 | 0.219 | 0.227 | 0.231 | 0.234 | 0.237 | 0.025 |
| Internists | 0.186 | 0.182 | 0.185 | 0.184 | 0.191 | 0.194 | 0.199 | 0.199 | 0.013 |
| Surgeons | 0.204 | 0.202 | 0.198 | 0.189 | 0.199 | 0.213 | 0.218 | 0.219 | 0.015 |
| Orthopedists | 0.215 | 0.212 | 0.208 | 0.204 | 0.211 | 0.211 | 0.210 | 0.213 | -0.002 |
| OB/GYN specialists (per female population) | 0.254 | 0.247 | 0.255 | 0.272 | 0.292 | 0.296 | 0.299 | 0.303 | 0.049 |
| Pediatricians (per pediatric population) | 0.244 | 0.240 | 0.235 | 0.240 | 0.243 | 0.240 | 0.243 | 0.242 | -0.002 |
| Anesthesiologists | 0.456 | 0.447 | 0.451 | 0.448 | 0.449 | 0.445 | 0.450 | 0.447 | -0.009 |

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

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For peer review only

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

| | Before adjustment | | After adjustment | |
|--|-------------------|----------------|------------------|---------------|
| | 2000 | 2014 | 2000 | 2014 |
| Total number of physicians per 100 000 population | | | | |
| Group 1 | 247.0 | 297.9 (20.6%) | 311.6 | 305.7 (-1.9%) |
| Group 2 | 194.8 | 226.6 (16.3%) | 213.9 | 203.3 (-5.0%) |
| Group 3 | 124.6 | 142.1 (14.0%) | 138.9 | 127.0 (-8.6%) |
| Group 4 | 126.3 | 163.1 (29.1%) | 166.9 | 171.9 (3.0%) |
| Number of internists per 100 000 population | | | | |
| Group 1 | 95.2 | 108.0 (13.4%) | 120.1 | 110.8 (-7.7%) |
| Group 2 | 79.8 | 87.5 (9.6%) | 87.6 | 78.5 (-10.4%) |
| Group 3 | 54.0 | 59.1 (9.4%) | 60.2 | 52.8 (-12.3%) |
| Group 4 | 49.6 | 61.4 (23.8%) | 65.5 | 64.7 (-1.2%) |
| Number of surgeons per 100 000 population | | | | |
| Group 1 | 25.2 | 22.6 (-10.3%) | 31.8 | 23.2 (-27.0%) |
| Group 2 | 21.8 | 19.3 (-11.5%) | 24.0 | 17.3 (-27.9%) |
| Group 3 | 15.3 | 13.3 (-13.1%) | 17.1 | 11.9 (-30.4%) |
| Group 4 | 12.9 | 12.7 (-1.6%) | 17.0 | 13.3 (-21.8%) |
| Number of orthopedists per 100 000 population | | | | |
| Group 1 | 18.6 | 22.4 (20.4%) | 23.5 | 23.0 (-2.1%) |
| Group 2 | 16.6 | 19.2 (15.7%) | 18.2 | 17.2 (-5.5%) |
| Group 3 | 10.8 | 12.6 (16.7%) | 12.0 | 11.2 (-6.7%) |
| Group 4 | 10.7 | 13.4 (25.2%) | 14.2 | 14.2 (0.0%) |
| Number of OB/GYN specialists per 100 000 female population | | | | |
| Group 1 | 28.4 | 28.9 (1.8%) | 33.2 | 27.5 (-17.2%) |
| Group 2 | 20.2 | 19.3 (-4.5%) | 20.3 | 15.8 (-22.2%) |
| Group 3 | 13.9 | 12.4 (-10.8%) | 14.1 | 10.2 (-27.7%) |
| Group 4 | 16.3 | 17.0 (4.3%) | 20.0 | 16.7 (-16.5%) |
| Number of OB/GYN specialists per 100 000 births * | | | | |
| Group 1 | 1316.5 | 1578.9 (19.9%) | N/A | N/A |
| Group 2 | 1051.3 | 1240.3 (18.0%) | N/A | N/A |
| Group 3 | 714.9 | 849.8 (18.9%) | N/A | N/A |
| Group 4 | 702.1 | 914.7 (30.3%) | N/A | N/A |
| Number of pediatricians per 100 000 pediatric population | | | | |

| | | | | |
|--|------|--------------|-------|---------------|
| Group 1 | 49.0 | 63.1 (28.8%) | 211.5 | 272.3 (28.7%) |
| Group 2 | 35.5 | 50.2 (41.4%) | 158.0 | 221.0 (39.9%) |
| Group 3 | 22.6 | 32.7 (44.7%) | 100.7 | 144.8 (43.8%) |
| Group 4 | 27.3 | 36.7 (34.4%) | 117.6 | 159.4 (35.5%) |
| Number of anesthesiologists per 100 000 population | | | | |
| Group 1 | 6.6 | 9.4 (42.4%) | 8.3 | 9.7 (16.9%) |
| Group 2 | 4.4 | 6.1 (38.6%) | 4.8 | 5.5 (14.6%) |
| Group 3 | 1.9 | 2.8 (47.4%) | 2.1 | 2.5 (19.0%) |
| Group 4 | 2.2 | 4.1 (86.4%) | 2.9 | 4.3 (48.3%) |

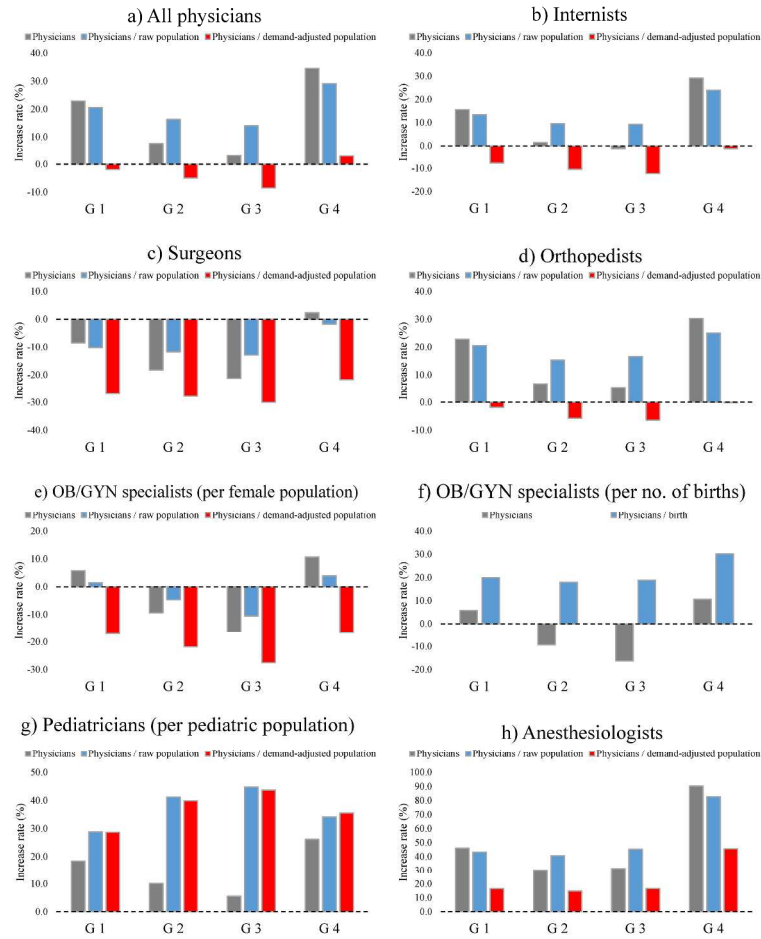
Group 1: urban areas with higher initial physician supply; Group 2: rural areas with higher initial physician supply; Group 3: rural areas with lower initial physician supply; Group 4: urban areas with lower initial physician supply.

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

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

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

Figure 1



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

297x420mm (300 x 300 DPI)

Appendix table. 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 | | | | |
| Total physicians | 1 536.0(1 409.7) | 619.2(433.5) | 352.0(295.3) | 175.5(127.2) |
| Internists | 592.0(566.4) | 242.9(165.3) | 144.3(105.2) | 76.1(52.0) |
| Surgeons | 156.5(142.1) | 63.1(42.2) | 39.5(28.4) | 21.6(14.2) |
| Orthopedists | 115.8(94.4) | 52.6(36.4) | 30.0(25.9) | 15.2(12.2) |
| OB/GYN specialists | 78.1(71.8) | 34.1(26.3) | 16.4(15.6) | 8.6(6.5) |
| Pediatricians | 88.0(71.9) | 40.3(31) | 19.1(19.8) | 9.6(7.8) |
| Anesthesiologists | 40.9(40.1) | 10.9(9.8) | 7.9(9.8) | 2.7(3.2) |
| Raw population | | | | |
| Total population | 621 865.5(458 098.5) | 490 244.5(341 301.8) | 180 718.5(125 140.5) | 140 925.7(100 156.8) |
| Female population | 274 615.3(203 154.4) | 209 062.4(144 107.6) | 81 044.7(54 965.4) | 62 047.6(43 331.9) |
| Pediatric population | 89 778.6(62 866.3) | 73 620.8(48 171.0) | 26 837.6(19 441.3) | 21 202.8(15 429.6) |
| Number of births * | 41 599.4(29 459.0) | 34 246.1(22 935.5) | 12 070.9(8 837.2) | 9 497.2(6 971.3) |
| Demand-adjusted population | | | | |
| Total population | 492 971.0(349 667.3) | 370 991.2(242 817.0) | 164 585.9(103 001.3) | 126 410.8(84 059.2) |
| Female population | 235 594.4(166 553.3) | 170 624.5(109 441.9) | 80 861.9(49 177.2) | 61 184.3(39 965.6) |
| Pediatric population | 41 599.4(29 459.0) | 34 246.1(22 935.5) | 12 070.9(8 837.2) | 9 497.2(6 971.3) |

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|---|------------------|------------------|--------------|--------------|
| Area (km ²) | 311.5(221.5) | 242.8(141.4) | 360.9(238.5) | 458.6(485.8) |
| Population density (per km ²) | 3 023.7(3 403.4) | 2 591.6(2 510.6) | 514.5(140.9) | 393.5(186.9) |

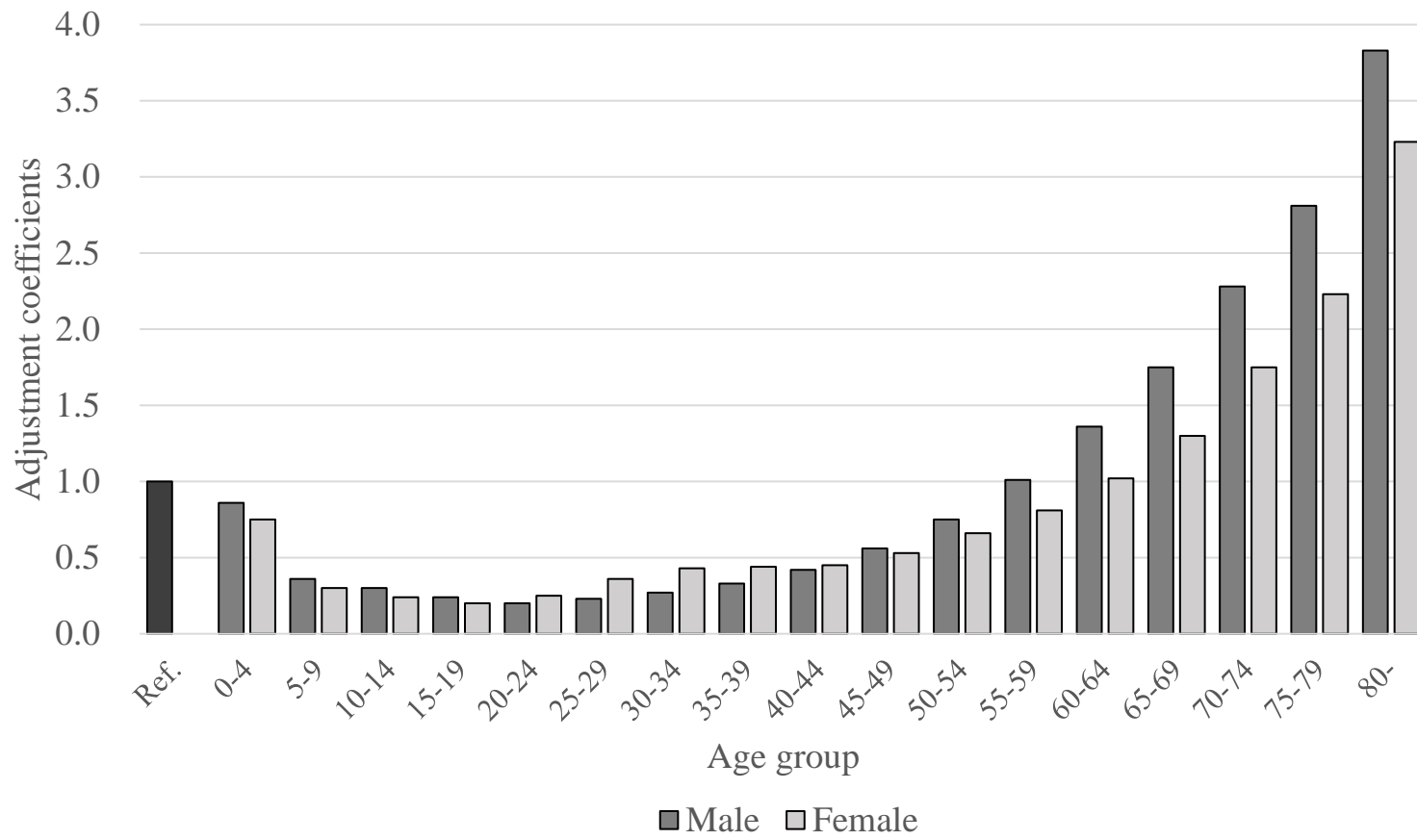
Group 1 and Group 2: Higher initial physician supply, Group 3 and Group 4: Lower initial physician supply.

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

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

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Appendix Figure.



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

| | Item No | Recommendation |
|------------------------------|---------|---|
| Title and abstract | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract -p3 (b) Provide in the abstract an informative and balanced summary of what was done and what was found – p3-4 |
| Introduction | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported -p6-7 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses – p7 |
| Methods | | |
| Study design | 4 | Present key elements of study design early in the paper – p10-12 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection –p8-9 |
| Participants | 6 | (a) <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 – p8-9 (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 – p10 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group –p7-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias –p7-8 |
| Study size | 10 | Explain how the study size was arrived at – p7-9 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – p11 |
| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding –p10-12 (b) Describe any methods used to examine subgroups and interactions –p11-12 (c) Explain how missing data were addressed –p7-8 (d) <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 –p20 |

Continued on next page

Results

| | | |
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| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed—Table 1, Table 2, and Table 4 (b) Give reasons for non-participation at each stage—7-8 (c) Consider use of a flow diagram – no use |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders—p8-9 (b) Indicate number of participants with missing data for each variable of interest—p7-8 (c) <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—p12-14 |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included –not applicable (b) Report category boundaries when continuous variables were categorized—p11 (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – not applicable |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses—p13-14 |

Discussion

| | | |
|------------------|----|---|
| Key results | 18 | Summarise key results with reference to study objectives—p14-15 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias—p20 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence—p15-20 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results—p20 |

Other information

| | | |
|---------|----|--|
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based—p22-23 |
|---------|----|--|

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

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

BMJ Open

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

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

3
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6 19 **Word count:**
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6 22 Examining changes in the equity of physician distribution in
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9 23 Japan: a specialty-specific longitudinal study
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14
15 25 **Abstract**

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17 26 **Objectives**

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20 27 In this longitudinal study, we examined changes in the geographic distribution of physicians in Japan
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23 28 from 2000 to 2014 by clinical specialty with adjustments for healthcare demand based on population
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26 29 structure.

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29 30 **Methods**

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31 31 The Japanese population was adjusted for healthcare demand using health expenditure per capita
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33
34 32 stratified by age and sex. The numbers of physicians per 100 000 demand-adjusted population
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37 33 (DAP) in 2000 and 2014 were calculated for sub-prefectural regions known as secondary medical
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39
40 34 areas. Disparities in the geographic distribution of physicians for each specialty were assessed using
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43 35 Gini coefficients. A subgroup analysis was conducted by dividing the regions into four groups
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46 36 according to urban-rural classification and initial physician supply.
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49 37 **Results**

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51 38 Over the study period, the number of physicians per 100 000 DAP decreased in all specialties
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54 39 assessed (internal medicine: -6·9%, surgery: -26·0%, orthopedics: -2·1%, obstetrics/gynecology [per
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6 40 female population]: -17.5%) except pediatrics (+33.3%) and anesthesiology (+21.1%). No
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9 41 reductions in geographic disparity were observed in any of the specialties assessed. Geographic
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11 42 disparity increased substantially in internal medicine, surgery, and obstetrics and gynecology. Rural
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14 43 areas with lower initial physician supply experienced the highest decreases in physicians per 100 000
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17 44 DAP for all specialties assessed except pediatrics and anesthesiology. In contrast, urban areas with
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20 45 lower initial physician supply experienced the lowest decreases in physicians per 100 000 DAP in
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23 46 internal medicine, surgery, orthopedics, and obstetrics and gynecology, but the highest increase in
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26 47 anesthesiology.

28 **Conclusion**

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31 49 Between 2000 and 2014, the number of physicians per 100 000 DAP in Japan decreased in all
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34 50 specialties assessed except pediatrics and anesthesiology. There is also a growing urban-rural
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37 51 disparity in physician supply in all specialties assessed except pediatrics. Additional measures may
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40 52 be needed to resolve these issues and improve physician distribution in Japan.
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6 54 **Article Summary**
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9 55 Strengths and limitations of this study
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- 11 56 • This study longitudinally examined specialty-specific changes in the geographic distribution of
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14 57 Japanese physicians with adjustments for healthcare demand according to population structure.
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17 58 • The adjustment method used in this study was previously verified, and enables adjustment for
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20 59 healthcare demand according to age strata using health expenditure per capita.
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23 60 • Both age and sex were included in the calculation of the adjustment coefficients to increase the
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26 61 accuracy of adjustments.
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29 62 • There was a lack of information on the physicians' working conditions, such as whether a
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32 63 physician worked full-time or part-time.
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35 64 • It is difficult to generalize our adjustment coefficients to other countries as they were calculated
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37 65 using Japanese health expenditure, but the adjustment method itself may have applications in
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40 66 other countries.
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68 **Introduction**

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

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

84 Although the number of physicians per 100 000 population is generally used as an
85 indicator when examining geographic disparities in physician supply, this measure involves a simple

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6 86 head count that does not account for the inherent variations in healthcare demand among the
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9 87 different age strata and sex.⁴ Furthermore, Japan's population is aging at an unprecedented rate,
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11 88 which has resulted in its transformation into the world's first "super-aged" society (where more than
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14 89 21% of a country's population is aged 65 years and older). As a consequence, the population
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17 90 structure in Japan is undergoing dramatic changes, which has invariably led to changes to healthcare
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20 91 demand. We previously reported that Japan's healthcare demand increased by 22% from 2000 to
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23 92 2014 amid worsening geographic disparity in physician supply.¹³ However, studies have yet to be
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26 93 conducted on the disparity in Japan's physician supply for different clinical specialties while
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29 94 accounting for the differences in healthcare demand.

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31 95 This study aimed to longitudinally examine specialty-specific changes in the geographic
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34 96 distribution of physicians in Japan from 2000 to 2014 with adjustments for healthcare demand based
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37 97 on population structure.

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41 42 99 **Methods**

43 44 45 100 **Data source**

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48 101 Data on the number of physicians were obtained from the Survey of Physicians, Dentists, and

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51 102 Pharmacists conducted every two years by the Ministry of Health, Labour and Welfare (MHLW).

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54 103 Physicians in Japan are required to participate in this survey, which includes information on each

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6 104 physician's specialty and the type and location (municipality) of their workplace. Population data
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9 105 (age, sex, and location of residence) were extracted from the Annual Report of the National Basic
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11 106 Resident Registration System published by the Ministry of Internal Affairs and Communications,
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14 107 and data on the number of births were obtained from the Annual Report of Vital Statistics published
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17 108 by the MHLW. We also acquired data on national health expenditure per capita according to patient
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20 109 age in 2013 from the MHLW. The total area of habitable land was ascertained from statistical reports
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23 110 on land areas of prefectures and municipalities by the Geospatial Information Authority of Japan.
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28 112 Physicians and population
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31 113 We targeted physicians working in clinical facilities (hospitals and clinics), and excluded physicians
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34 114 working in non-clinical facilities (e.g., research centers and government offices). The following
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37 115 clinical specialties were included in analysis: internal medicine, surgery, orthopedics, OB/GYN,
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40 116 pediatrics, and anesthesiology. Internal medicine, surgery, and orthopedics were selected because
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43 117 these departments generally have more physicians than other departments. The remaining three
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46 118 specialties were selected because of their previously reported geographic disparities in physician
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48 119 supply throughout Japan.¹²
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51 120 In addition to the total population, we also analyzed the female population, pediatric
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54 121 population (<15 years of age), and the number of births. With the exception of the number of births,
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6 122 all study populations were adjusted for healthcare demand. We calculated the number of OB/GYN
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9 123 specialists per 100 000 female population and per 100 000 births, the number of pediatricians per
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12 124 100 000 pediatric population, and the number of physicians per 100 000 population for each of the
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14 125 other clinical specialties.

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20 127 Geographic unit

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23 128 The geographic unit of analysis was the secondary medical area (SMA). The Japanese government
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26 129 has designated three regional levels of healthcare provision. Primary medical areas are geographic
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29 130 units where primary care is provided, and are demarcated by municipal borders. Tertiary medical
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32 131 areas are geographic units that provide advanced medical care, and are demarcated by prefectural
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35 132 borders. SMAs are set between primary and tertiary medical areas, and are regions where general
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38 133 medical care (such as inpatient care) is provided; these areas are composed of multiple
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41 134 municipalities. Each prefectural government stipulates the geographic and demographic range of the
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44 135 SMAs within their prefecture. As a result, the boundaries of each SMA can be altered in response to
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47 136 changes in healthcare demand. SMAs have been previously used to examine the inequities in
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50 137 physician supply in Japan.^{6 14} Because the number of SMAs varies slightly over time, this study was
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53 138 conducted using the 349 SMAs designated in 2012.

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6 140 Analytical methods
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9 141 This retrospective study longitudinally examined the changes in the geographic distribution of the
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11 142 number of physicians by clinical specialty among Japan's SMAs from 2000 to 2014. The primary
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14 143 outcomes were the overall number of physicians per 100,000 population and the trends in Gini
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17 144 coefficients (indicating geographic disparity) for each specialty during the study period. The
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20 145 secondary outcomes were the changes in physician numbers during the same period for subgroups
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23 146 that were categorized according to regional characteristics (urban-rural classification and initial
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26 147 physician supply).

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28 148 The population was first adjusted using adjustment coefficients of healthcare demand,
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31 149 which were calculated based on the health expenditure per capita stratified by age and sex through a
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34 150 previously described method.¹³ Health expenditure per capita is likely indicative of the general
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37 151 workload of healthcare providers.¹⁵ These expenditures include those for both inpatient and
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40 152 outpatient services, and account for variations in patient health status.¹³ The demand-adjusted
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43 153 population was generated by multiplying the raw population with the adjustment coefficients.

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45 154 Next, geographic disparity was assessed using the Gini coefficient. This indicator, which is
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48 155 widely used to examine disparity in the field of economics, has been applied to analyze geographic
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51 156 disparity in physician supply.^{15 16-18} We calculated the Gini coefficients for each specialty every two
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54 157 years from 2000 to 2014. The coefficients, which take a value from 0 (indicating complete equality)

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6 158 to 1 (indicating complete inequality), measure departure from a uniform distribution by drawing
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9 159 Lorenz curves.¹⁷ If the curves of two time points intersect, conclusions cannot be made as to whether
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11 160 or not the inequity of distribution is increasing.¹⁸ Thus, we plotted two Lorenz curves (one each for
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14 161 2000 and 2014) for each clinical specialty.

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17 162 Finally, a subgroup analysis was conducted by dividing SMAs into groups according to
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20 163 two regional characteristics. Using the method described in Sasaki et al.,¹⁹ we classified each SMA
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23 164 into one of four groups based on whether the SMA was an urban or rural area, and whether the SMA
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26 165 had a higher or lower initial physician supply in 2000. An SMA was designated an urban area (or a
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29 166 rural area) if its population density was higher (or lower) than the median value in all SMAs. The
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31 167 population density of each SMA was calculated using the total area of habitable land and the
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34 168 population in 2000. Next, an SMA was designated as having a higher (or lower) initial physician
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37 169 supply if the number of physicians per 100 000 population was higher (or lower) than the median
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40 170 number of physicians per 100 000 population in all SMAs. The following four groups were
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43 171 analyzed: Group 1, which comprised urban areas with higher initial physician supply; Group 2,
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46 172 which comprised rural areas with higher initial physician supply; Group 3, which comprised rural
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49 173 areas with lower initial physician supply; and Group 4, which comprised urban areas with lower
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51 174 initial physician supply. Data from 2000 were used for both the population and physicians. In this
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54 175 subgroup analysis, we compared the inter-group changes in the number of physicians per 100 000
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6 176 population between 2000 and 2014.
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9 177 All analyses were performed using R statistical software (V.3.2.2).
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14 179 **Results**
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17 180 Table 1 shows the population sizes of the total population, female population, and pediatric
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19 181 population before and after applying the adjustment coefficients in 2000 and 2014. The adjustment
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21 182 coefficients for the different age strata and sex are provided Appendix Figure. Before adjustment, the
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23 183 total population did not substantially change throughout the study period. In contrast, the
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25 184 demand-adjusted total population increased by 23·7% between 2000 and 2014. The number of births,
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27 185 which was not adjusted for healthcare demand, decreased by 15·7%. The pediatric population
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29 186 declined by 11·1% over the study period both before and after adjusting for healthcare demand.
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36 187 Table 2 shows the overall number of physicians and the number of physicians per 100 000
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39 188 population in 2000 and 2014. The overall number of all physicians increased by 22·1% over the
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41 189 study period. Similarly, the number of all physicians per 100 000 population increased by 21·7%.

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44 190 However, the number of all physicians per 100 000 demand-adjusted population decreased by 1·3%.

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47 191 The number of physicians per 100,000 demand-adjusted population in surgery and OB/GYN

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49 192 declined by 26·0% and 17·5%, respectively. In contrast, the number of OB/GYN specialists per

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51 193 100,000 births increased by 23·1% due to the declining number of births. The number of physicians
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6 194 per 100,000 demand-adjusted population in pediatrics and anesthesiology increased by 33·3% and
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9 195 21·1%, respectively.

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11 196 Table 3 shows the trends in Gini coefficients for the number of physicians per 100 000
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14 197 population in the SMAs by clinical specialty. There were no substantial changes in the Gini
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17 198 coefficients for the numbers of orthopedists, pediatricians, and anesthesiologists per 100 000
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20 199 demand-adjusted population. However, inequity increased in the geographic distribution of internists,
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23 200 surgeons, and OB/GYN specialists (for both the female population and the number of births). In
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26 201 each of these three specialties, the Lorenz curve in 2014 tended to deteriorate more than the curve in
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29 202 2000 without intersection between the two curves (figures not shown). When comparing the Gini
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31 203 coefficients before and after adjusting for healthcare demand, the trends in the coefficients were
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34 204 similar for each clinical specialty. However, the post-adjustment Gini coefficients for all clinical
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37 205 specialties (except for pediatrics) were higher than their pre-adjustment values.

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40 206 Table 4 summarizes the changes in the numbers of physicians per 100 000 population in
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43 207 the four groups of SMAs. Detailed descriptive statistics of the four groups are provided in the
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46 208 Appendix table. Figure 1 shows the temporal increases (2000 to 2014) in the number of physicians
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49 209 by clinical specialty in each group of SMAs. The temporal increases in the number of internists and
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52 210 orthopedists were similar to those for all physicians. The overall number of surgeons decreased in all
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54 211 groups except for Group 4, and the number of surgeons per 100 000 demand-adjusted population
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6 212 decreased by 20% to 30% in all groups. As shown in Table 4, the number of surgeons per 100 000
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9 213 demand-adjusted population in Group 3 (11·9) was approximately half of the corresponding number
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12 214 in Group 1 (23·2) in 2014. In all groups, the number of OB/GYN specialists per 100 000
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15 215 demand-adjusted female population decreased, but the number of OB/GYN specialists per 100 000
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18 216 births increased. The number of pediatricians per 100 000 demand-adjusted pediatric population
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21 217 increased more in the rural SMAs than in the urban SMAs. The number of anesthesiologists per 100
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23 218 000 demand-adjusted population increased in all groups; in particular, the number in Group 4
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26 219 increased by more than twice that of the other groups. In all clinical specialties except pediatrics and
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29 220 anesthesiology, Group 3 had the highest decrease in the number of physicians per 100 000
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32 221 demand-adjusted population. The 2014-2000 difference and ratio of the number of physicians per
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35 222 100 000 demand-adjusted population between Groups 3 and 4 increased in all clinical specialties
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38 223 except pediatrics.

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41 42 225 **Discussion**

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45 226 The four major findings of this study are as follows: First, the demand-adjusted population increased
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48 227 by 23·7% between 2000 and 2014, whereas the demand-adjusted pediatric population decreased by
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51 228 11·1%. Second, the number of physicians per 100 000 demand-adjusted population decreased in all
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54 229 clinical specialties except pediatrics and anesthesiology. The largest increase (33·3%) was observed

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6 230 in pediatrics. Third, the geographic disparity in the number of physicians per 100 000
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9 231 demand-adjusted population did not decline in all clinical specialties, and had in fact increased in
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11 232 internal medicine, surgery, and OB/GYN. Fourth, rural areas with lower initial physician supply had
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14 233 the highest decrease in the number of physicians per 100 000 demand-adjusted population compared
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17 234 with other areas in all clinical specialties except pediatrics and anesthesiology. In contrast, urban
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20 235 areas with lower initial physician supply had the lowest decrease in internal medicine, surgery,
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23 236 orthopedics and OBG/GYN, but the highest increase in anesthesiology.

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25 237 The population used in this study was adjusted for healthcare demand among the different
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28 238 age strata and sex using a previously described method.¹³ Although several studies have examined
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31 239 the demand-adjusted geographic disparity in physician supply,^{15,20} there is currently no gold standard
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34 240 method for adjustment.²⁰ The method used in this study was previously verified,¹³ and enables
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37 241 adjustment for healthcare demand according to age strata. In addition, the inclusion of sex in the
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40 242 calculation of the coefficients may increase the accuracy of adjustments.

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42 243 The number of physicians per 100 000 demand-adjusted population decreased in internal
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45 244 medicine, surgery, orthopedics, and OB/GYN (per female population). The decline in physician
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48 245 supply was particularly large in surgery and OB/GYN, which corroborates previously reported
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51 246 downward trends in the numbers of physicians in these specialties.¹² The distribution among
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54 247 specialties is affected by physician preference, experience, and environment. For example, the

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6 248 shortage of surgeons may be influenced by the long working hours, high risk of medical litigation,
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9 249 and low reward for surgical skill.²¹ Previous research has also shown that an increase in female
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12 250 physicians has affected the distribution of specialties because they are more likely to choose
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15 251 OB/GYN and pediatrics instead of surgery.^{22 23} In order to ensure a high number of both female and
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18 252 male physicians, we believe that improvements should be made to the working environment, such as
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21 253 a reduction in physician working hours by assigning more duties and responsibilities to
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24 254 non-physician health professionals.²¹ On the other hand, there was a large increase in the number of
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27 255 anesthesiologists during the study period. Japan is experiencing an increasing need for
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30 256 anesthesiologists due to the rising number of surgeries conducted, the increasing complexity of
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33 257 surgery owing to advances in surgical techniques and the overall aging of patients, as well as the
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36 258 growing social expectations for safety in anesthesia.²⁴ The increase in anesthesiologists may have
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39 259 been influenced by the growing number of female physicians. The increase in female
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42 260 anesthesiologists from 26.7% to 37.6% during the study period is consistent with this possibility.
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45 261 On the other hand, the number of pediatricians per 100 000 demand-adjusted pediatric
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48 262 population and OB/GYN specialists per 100 000 births increased substantially due to a decline in the
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51 263 pediatrics population and the number of births. The rate of pediatric population decline is expected
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54 264 to eventually exceed the rate of total population decline.²⁵ It may therefore be more useful to ensure
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57 265 the optimal allocation of physicians instead of simply increasing their overall numbers.

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6 266 Based on the analysis of Gini coefficients, there were no reductions in geographic disparity
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9 267 in the number of physicians per 100 000 demand-adjusted population in all clinical specialties
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11 268 between 2000 and 2014. In particular, the inequity in physician supply increased in internal medicine,
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14 269 surgery, and OB/GYN. The inequity in surgery and OB/GYN may have been influenced by the
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17 270 decrease or lack of increase in the overall number of physicians in these specialties. These findings
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20 271 suggest that the uneven distribution of physicians among the clinical specialties may exacerbate
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23 272 geographic disparities in physician supply. On the other hand, the number of internists increased at a
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26 273 rate that was comparable to the overall growth rate. The increase in geographic disparity may
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28 274 therefore be related to an increasing tendency toward physician specialization in Japan.²⁶ Although
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31 275 the overall number of general internists decreased from 74 539 to 61 317 over the study period, there
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34 276 was actually an increase from 21 006 to 48 780 physicians in internal medicine subspecialties such
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37 277 as pulmonary, cardiovascular, and gastrointestinal medicine (data not shown). The geographic
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40 278 disparity in physician supply in these subspecialties is greater than the disparity in general
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43 279 internists.⁹ As a supplementary analysis, we calculated the Gini coefficients for general internal
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46 280 medicine and its subspecialties from 2000 to 2014. The results confirmed that the coefficient in the
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49 281 internal medicine subspecialties was consistently more than twice that of general internal medicine
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51 282 (General internal medicine: 0.173 in 2000 to 0.149 in 2014, Internal subspecialties: 0.386 in 2000 to
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54 283 0.390 in 2014).

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6 284 The rate of increase in the number of physicians per 100 000 demand-adjusted population
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9 285 in the urban areas was generally higher than in the rural areas. In all clinical specialties except
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11 286 pediatrics, both the difference and ratio in the number of physicians per 100 000 demand-adjusted
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14 287 population between Group 3 and Group 4 in 2014 were larger than the corresponding values in 2000.
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17 288 This indicates that the urban-rural disparity in physician supply widened over the study period.
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20 289 Group 3 had the lowest initial physician supply, and these regions may be facing a serious physician
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23 290 shortage. This issue should be explored further, and there may be a need for major reforms to ensure
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26 291 adequate physician supply to rural areas. It may also be important to implement measures in rural
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29 292 areas to improve physician productivity, reduce non-essential workload, and implement
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32 293 technology-based systems such as telemedicine.
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34 294 Prior to 2004, the vast majority of medical graduates joined a clinical specialty department
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37 295 (known as an *Ikyoku*) at their university that secures employment for the new graduates. *Ikyoku*
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40 296 generally dispatch physicians to other affiliated hospitals that are often located in rural areas. In this
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43 297 way, the *Ikyoku* were partly responsible for preventing a shortage of physicians in rural areas. On the
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46 298 other hand, medical graduates did not receive mandatory clinical training under this system. As a
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49 299 result, few graduates were able to acquire a wide range of medical skills through comprehensive and
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52 300 systematic training.²⁷ In addition, training assessments were not adequately performed under the
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54 301 *Ikyoku* system.²⁷ In order to improve the overall quality of clinical training throughout Japan, the
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6 302 MHLW mandated a standardized 2-year training program in 2004. Furthermore, there was a large
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9 303 increase in the number of non-university hospitals that medical graduates could attend as part of this
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11 304 training program after 2004. As a consequence, the graduates, now able to choose their training
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14 305 hospital after graduation, were less likely to select a university hospital for training. Due to the
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17 306 decreasing number of member physicians, it became more difficult for the *Ikyoku* to dispatch
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20 307 physicians to affiliate hospitals.¹⁴ Previous studies have also reported that the new program may
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23 308 have increased the inequity in the geographic distribution of physicians^{14,28}. Similarly, this new
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26 309 program may also have contributed to the lack of reduction in geographic disparity in this study.

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29 310 The Japanese government has implemented several measures at the prefectural level aimed
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31 311 at reducing the geographic disparity in physician supply. In 2006, a "Council for Regional Medicine"
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34 312 was established in each prefecture, and these councils include representatives of the prefectural and
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37 313 local governments, hospitals, medical associations, universities, and residents. The councils discuss
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40 314 detailed measures for securing medical staff with a variety of hospitals, including university
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43 315 hospitals and public hospitals. Furthermore, a "Support Center for Community Medicine" was
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46 316 established in each prefecture in 2011 to secure and retain physicians. These centers adopt the role of
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49 317 "control towers" to address the uneven distribution of physicians within each prefecture. Specifically,
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52 318 the centers are responsible for supporting career advancement for physicians working in rural areas,
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54 319 acting as general liaisons for engaging new physicians, and providing general work information. In
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6 320 addition, the government has raised the regional quota of medical school admissions from 64
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9 321 students in 2005 to 1 617 students in 2016. The students are obligated to work in a rural area or a
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11 322 designated specialty (such as OB/GYN) for nine years after graduating in return for financial
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14 323 assistance for their studies.²⁹ As the program is relatively new, it remains unclear as to whether the
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17 324 increase in quotas will lead to reductions in the geographic disparity of physicians.

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20 325 There are several limitations in this research. First, the adjustment coefficients may
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22 326 continue to change in the future. However, the coefficients did not fluctuate considerably during the
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24 327 study period. In addition, it may be difficult to generalize our adjustment coefficients to other
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26 328 countries as they were calculated using Japanese health expenditure. Nevertheless, the adjustment
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28 329 method itself may have applications in other countries. Second, there was a lack of information on
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30 330 the physicians' working conditions, such as whether a physician worked full-time or part-time. It
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32 331 may be beneficial for future studies to incorporate mean physician working hours. Third, our
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34 332 analysis had focused on specialties with a large number of physicians and previously reported
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36 333 geographic disparities. This may have introduced selection bias as other specialties may not have
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38 334 experienced the same geographic disparities described in this study. Finally, there may be other ways
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40 335 to divide the SMAs for the subgroup analysis. However, our subgroup analysis was based on the
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42 336 categorization used in a previous study,¹⁹ and provided an intuitive understanding of the differences
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44 337 in group characteristics.
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9 339 **Conclusion**

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11 340 Between 2000 and 2014, the number of physicians per 100 000 demand-adjusted population in Japan
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14 341 decreased in all specialties assessed except pediatrics and anesthesiology. There is also a growing
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17 342 urban-rural disparity in physician supply in all specialties assessed except pediatrics. In
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20 343 consideration of the rapidly aging population and the resulting changes in population structure,
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23 344 additional measures may be needed to resolve these issues and improve physician distribution in
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31 347 **List of abbreviations**

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34 348 DAP, demand-adjusted population
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37 349 OB/GYN, obstetrics and gynecology
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40 350 MHLW, Ministry of Health, Labour and Welfare
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43 351 SMA, secondary medical area

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48 353 **Footnotes**

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51 354 **Acknowledgements**

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54 355 Not applicable.
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9 357 **Competing interests**

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11 358 The authors declare that they have no competing interests.
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34 366 **Contributors**

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37 367 KH contributed to the study conception and design, data collection, analysis, interpretation, and
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39 368 drafting of the manuscript. SK and NS contributed to the data collection and data management. YI
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41 369 contributed to the study design, data acquisition, and interpretation. All authors critically revised the
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43 370 manuscript, and approved the final version.
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51 372 **Ethics approval**

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53 373 Ethics committee approval was waived for this study because all of the data are publicly available
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6 374 online and comprise only aggregate values without any personally identifiable information.
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11 376 **Role of the funding source**
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14 377 The funder of the study had no role in study design; collection, analysis, and interpretation of the
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17 378 data; writing of the report; or the decision to submit the paper for publication. The corresponding
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20 379 author had full access to all the data in the study and had final responsibility for the decision to
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23 380 submit for publication.
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28 382 **Data sharing statement**
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31 383 No additional data available.
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37 385 **Consent for publication**
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40 386 Not applicable.
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25 471 **Figure titles**

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28 472 **Figure 1** Temporal increases in physician numbers from 2000 to 2014 for the four groups of

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31 473 secondary medical areas

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34 474 **Appendix Figure** Adjustment coefficients of healthcare demand by age strata and sex

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40 476 **Figure legends**

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43 477 **Figure 1**

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45 478 Group 1 (G1): urban areas with higher initial physician supply; Group 2 (G2): rural areas with higher

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48 479 initial physician supply; Group 3 (G3): rural areas with lower initial physician supply; Group 4 (G4):

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51 480 urban areas with lower initial physician supply. * As the number of births was not adjusted for

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54 481 healthcare demand, the numbers of OB/GYN specialists per 100 000 demand-adjusted births are not

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482 shown. OB/GYN: obstetrics/gynecology.

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484 **Appendix Figure**

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

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

| Year | Before adjustment | | | | After adjustment | | |
|------------------------|-------------------|-------------------|-------------------------------------|---------------------------------|--------------------|--------------------|-------------------------------------|
| | Total population | Female population | Pediatric population * ¹ | Number of births * ² | Total population | Female population | Pediatric population * ¹ |
| 2000 | 126 071 305 | 55 196 259 | 18 553 275 | 1 190 164 | 101 697 295 | 48 349 047 | 8 546 612 |
| 2014 | 126 434 634 | 56 670 449 | 16 489 385 | 1 003 474 | 125 837 379 | 60 902 189 | 7 594 643 |
| Increase in number (%) | 363 329 (0.3%) | 1 474 190 (2.7%) | -2 063 890 (-11.1%) | -186 690(-15.7%) | 24 140 085 (23.7%) | 12 553 142 (26.0%) | -951 969 (-11.1%) |

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

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

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

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

| Year | Specialty | | | | | | | |
|--|----------------|----------------|----------------|---------------|--------------------|--------------------------------|-------------------------|-------------|
| | All physicians | Internists | Surgeons | Orthopedists | OB/GYN specialists | Pediatricians | Anesthesiologists | |
| Overall number of physicians | | | | | | | | |
| 2000 | 243 201 | 95 545 | 25 424 | 19 225 | 12 420 | 14 156 | 5 751 | |
| 2014 | 296 845 | 110 097 | 23 223 | 23 297 | 12 888 | 16 758 | 8 625 | |
| Increase in number (%) | 53 644 (22.1%) | 14 552 (15.2%) | -2 201 (-8.7%) | 4 072 (21.2%) | 468 (3.8%) | 2 602 (18.4%) | 2 874 (50.0%) | |
| Number of physicians per 100 000 population | | | | | | | | |
| Population type | Total | Total | Total | Total | Female | Number of births ^{*1} | Pediatric ^{*2} | Total |
| 2000 | 192.9 | 75.8 | 20.2 | 15.2 | 22.5 | 1 043.6 | 76.3 | 4.6 |
| 2014 | 234.8 | 87.1 | 18.4 | 18.4 | 22.7 | 1 284.3 | 101.6 | 6.8 |
| Increase in number (%) | 41.9 (21.7%) | 11.3 (14.9%) | -1.8 (-8.9%) | 3.2 (21.1%) | 0.2 (0.9%) | 240.7 (23.1%) | 25.3 (33.2%) | 2.2 (47.8%) |
| Number of physicians per 100 000 demand-adjusted population | | | | | | | | |
| Population type | Total | Total | Total | Total | Female | Number of births ^{*1} | Pediatric ^{*2} | Total |
| 2000 | 239.1 | 94.0 | 25.0 | 18.9 | 25.7 | N/A | 165.6 | 5.7 |
| 2014 | 235.9 | 87.5 | 18.5 | 18.5 | 21.2 | N/A | 220.7 | 6.9 |
| Increase in number (%) | -3.2 (-1.3%) | -6.5 (-6.9%) | -6.5 (-26.0%) | -0.4 (-2.1%) | -4.5 (-17.5%) | N/A | 55.1 (33.3%) | 1.2 (21.1%) |

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

^{*2} Pediatric population: all residents aged below 15 years.

OB/GYN: obstetrics/gynecology

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

| Year | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2000-2014 changes |
|---|-------|-------|-------|-------|-------|-------|-------|-------|----------------------|
| Number of physicians per 100 000 population | | | | | | | | | |
| All physicians | 0.195 | 0.193 | 0.194 | 0.194 | 0.199 | 0.202 | 0.205 | 0.206 | 0.011 |
| Internists | 0.183 | 0.179 | 0.177 | 0.175 | 0.177 | 0.179 | 0.183 | 0.181 | -0.002 |
| Surgeons | 0.204 | 0.202 | 0.197 | 0.190 | 0.194 | 0.206 | 0.210 | 0.209 | 0.005 |
| Orthopedists | 0.202 | 0.201 | 0.196 | 0.191 | 0.195 | 0.193 | 0.192 | 0.196 | -0.006 |
| OB/GYN specialists (per female population) | 0.226 | 0.218 | 0.226 | 0.240 | 0.260 | 0.263 | 0.266 | 0.270 | 0.043 |
| OB/GYN specialists (per number of births) * | 0.231 | 0.220 | 0.227 | 0.225 | 0.243 | 0.243 | 0.248 | 0.250 | 0.019 |
| Pediatricians (per pediatric population) | 0.248 | 0.244 | 0.239 | 0.243 | 0.246 | 0.244 | 0.247 | 0.246 | -0.003 |
| Anesthesiologists | 0.445 | 0.435 | 0.438 | 0.433 | 0.434 | 0.428 | 0.432 | 0.429 | -0.016 |
| Number of physicians per 100 000 demand-adjusted population | | | | | | | | | |
| All physicians | 0.212 | 0.210 | 0.214 | 0.219 | 0.227 | 0.231 | 0.234 | 0.237 | 0.025 |
| Internists | 0.186 | 0.182 | 0.185 | 0.184 | 0.191 | 0.194 | 0.199 | 0.199 | 0.013 |
| Surgeons | 0.204 | 0.202 | 0.198 | 0.189 | 0.199 | 0.213 | 0.218 | 0.219 | 0.015 |
| Orthopedists | 0.215 | 0.212 | 0.208 | 0.204 | 0.211 | 0.211 | 0.210 | 0.213 | -0.002 |
| OB/GYN specialists (per female population) | 0.254 | 0.247 | 0.255 | 0.272 | 0.292 | 0.296 | 0.299 | 0.303 | 0.049 |
| Pediatricians (per pediatric population) | 0.244 | 0.240 | 0.235 | 0.240 | 0.243 | 0.240 | 0.243 | 0.242 | -0.002 |
| Anesthesiologists | 0.456 | 0.447 | 0.451 | 0.448 | 0.449 | 0.445 | 0.450 | 0.447 | -0.009 |

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

OB/GYN: obstetrics/gynecology

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

| | Before adjustment | | After adjustment | |
|--|-------------------|----------------|------------------|---------------|
| | 2000 | 2014 | 2000 | 2014 |
| Total number of physicians per 100 000 population | | | | |
| Group 1 | 247.0 | 297.9 (20.6%) | 311.6 | 305.7 (-1.9%) |
| Group 2 | 194.8 | 226.6 (16.3%) | 213.9 | 203.3 (-5.0%) |
| Group 3 | 124.6 | 142.1 (14.0%) | 138.9 | 127.0 (-8.6%) |
| Group 4 | 126.3 | 163.1 (29.1%) | 166.9 | 171.9 (3.0%) |
| Number of internists per 100 000 population | | | | |
| Group 1 | 95.2 | 108.0 (13.4%) | 120.1 | 110.8 (-7.7%) |
| Group 2 | 79.8 | 87.5 (9.6%) | 87.6 | 78.5 (-10.4%) |
| Group 3 | 54.0 | 59.1 (9.4%) | 60.2 | 52.8 (-12.3%) |
| Group 4 | 49.6 | 61.4 (23.8%) | 65.5 | 64.7 (-1.2%) |
| Number of surgeons per 100 000 population | | | | |
| Group 1 | 25.2 | 22.6 (-10.3%) | 31.8 | 23.2 (-27.0%) |
| Group 2 | 21.8 | 19.3 (-11.5%) | 24.0 | 17.3 (-27.9%) |
| Group 3 | 15.3 | 13.3 (-13.1%) | 17.1 | 11.9 (-30.4%) |
| Group 4 | 12.9 | 12.7 (-1.6%) | 17.0 | 13.3 (-21.8%) |
| Number of orthopedists per 100 000 population | | | | |
| Group 1 | 18.6 | 22.4 (20.4%) | 23.5 | 23.0 (-2.1%) |
| Group 2 | 16.6 | 19.2 (15.7%) | 18.2 | 17.2 (-5.5%) |
| Group 3 | 10.8 | 12.6 (16.7%) | 12.0 | 11.2 (-6.7%) |
| Group 4 | 10.7 | 13.4 (25.2%) | 14.2 | 14.2 (0.0%) |
| Number of OB/GYN specialists per 100 000 female population | | | | |
| Group 1 | 28.4 | 28.9 (1.8%) | 33.2 | 27.5 (-17.2%) |
| Group 2 | 20.2 | 19.3 (-4.5%) | 20.3 | 15.8 (-22.2%) |
| Group 3 | 13.9 | 12.4 (-10.8%) | 14.1 | 10.2 (-27.7%) |
| Group 4 | 16.3 | 17.0 (4.3%) | 20.0 | 16.7 (-16.5%) |
| Number of OB/GYN specialists per 100 000 births * | | | | |
| Group 1 | 1316.5 | 1578.9 (19.9%) | N/A | N/A |
| Group 2 | 1051.3 | 1240.3 (18.0%) | N/A | N/A |
| Group 3 | 714.9 | 849.8 (18.9%) | N/A | N/A |
| Group 4 | 702.1 | 914.7 (30.3%) | N/A | N/A |
| Number of pediatricians per 100 000 pediatric population | | | | |

| | | | | |
|--|------|--------------|-------|---------------|
| Group 1 | 49.0 | 63.1 (28.8%) | 211.5 | 272.3 (28.7%) |
| Group 2 | 35.5 | 50.2 (41.4%) | 158.0 | 221.0 (39.9%) |
| Group 3 | 22.6 | 32.7 (44.7%) | 100.7 | 144.8 (43.8%) |
| Group 4 | 27.3 | 36.7 (34.4%) | 117.6 | 159.4 (35.5%) |
| Number of anesthesiologists per 100 000 population | | | | |
| Group 1 | 6.6 | 9.4 (42.4%) | 8.3 | 9.7 (16.9%) |
| Group 2 | 4.4 | 6.1 (38.6%) | 4.8 | 5.5 (14.6%) |
| Group 3 | 1.9 | 2.8 (47.4%) | 2.1 | 2.5 (19.0%) |
| Group 4 | 2.2 | 4.1 (86.4%) | 2.9 | 4.3 (48.3%) |

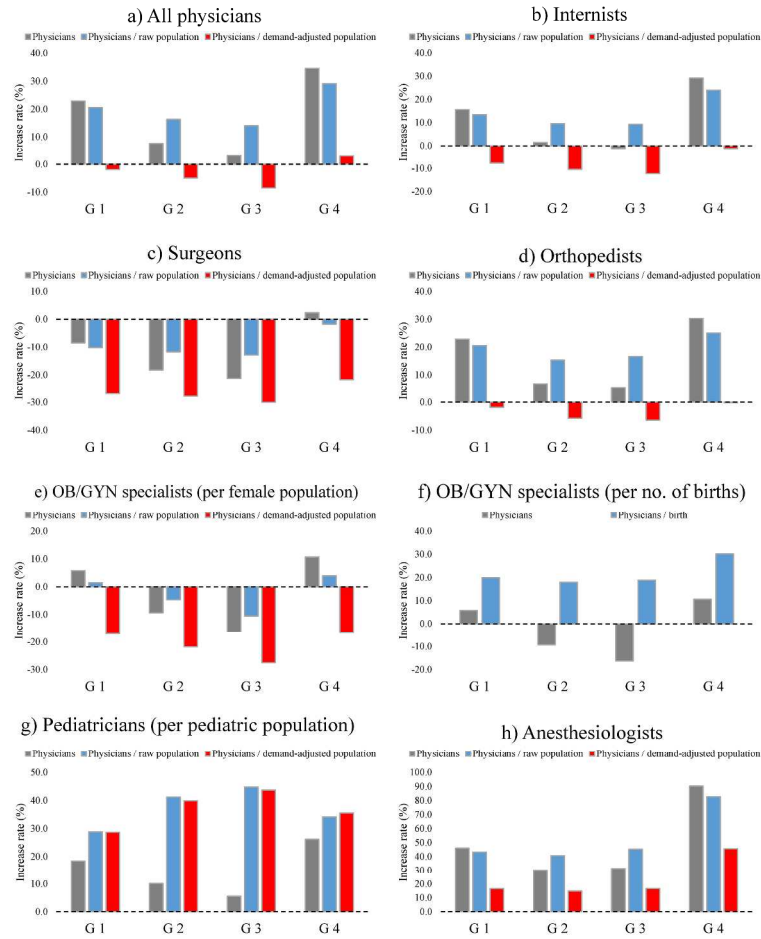
Group 1: urban areas with higher initial physician supply; Group 2: rural areas with higher initial physician supply; Group 3: rural areas with lower initial physician supply; Group 4: urban areas with lower initial physician supply.

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

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

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

Figure 1



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

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Appendix table. Descriptive statistics of the four groups of secondary medical areas in 2000

| Urban / Rural Group | Urban | | Rural | |
|----------------------------|----------------------|----------------------|----------------------|----------------------|
| | Group 1 | Group 4 | Group 2 | Group 3 |
| | Mean(SD) | Mean(SD) | Mean(SD) | Mean(SD) |
| Number of physicians | | | | |
| Total physicians | 1 536.0(1 409.7) | 619.2(433.5) | 352.0(295.3) | 175.5(127.2) |
| Internists | 592.0(566.4) | 242.9(165.3) | 144.3(105.2) | 76.1(52.0) |
| Surgeons | 156.5(142.1) | 63.1(42.2) | 39.5(28.4) | 21.6(14.2) |
| Orthopedists | 115.8(94.4) | 52.6(36.4) | 30.0(25.9) | 15.2(12.2) |
| OB/GYN specialists | 78.1(71.8) | 34.1(26.3) | 16.4(15.6) | 8.6(6.5) |
| Pediatricians | 88.0(71.9) | 40.3(31) | 19.1(19.8) | 9.6(7.8) |
| Anesthesiologists | 40.9(40.1) | 10.9(9.8) | 7.9(9.8) | 2.7(3.2) |
| Raw population | | | | |
| Total population | 621 865.5(458 098.5) | 490 244.5(341 301.8) | 180 718.5(125 140.5) | 140 925.7(100 156.8) |
| Female population | 274 615.3(203 154.4) | 209 062.4(144 107.6) | 81 044.7(54 965.4) | 62 047.6(43 331.9) |
| Pediatric population | 89 778.6(62 866.3) | 73 620.8(48 171.0) | 26 837.6(19 441.3) | 21 202.8(15 429.6) |
| Number of births * | 41 599.4(29 459.0) | 34 246.1(22 935.5) | 12 070.9(8 837.2) | 9 497.2(6 971.3) |
| Demand-adjusted population | | | | |
| Total population | 492 971.0(349 667.3) | 370 991.2(242 817.0) | 164 585.9(103 001.3) | 126 410.8(84 059.2) |
| Female population | 235 594.4(166 553.3) | 170 624.5(109 441.9) | 80 861.9(49 177.2) | 61 184.3(39 965.6) |
| Pediatric population | 41 599.4(29 459.0) | 34 246.1(22 935.5) | 12 070.9(8 837.2) | 9 497.2(6 971.3) |

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|---|------------------|------------------|--------------|--------------|
| Area (km ²) | 311.5(221.5) | 242.8(141.4) | 360.9(238.5) | 458.6(485.8) |
| Population density (per km ²) | 3 023.7(3 403.4) | 2 591.6(2 510.6) | 514.5(140.9) | 393.5(186.9) |

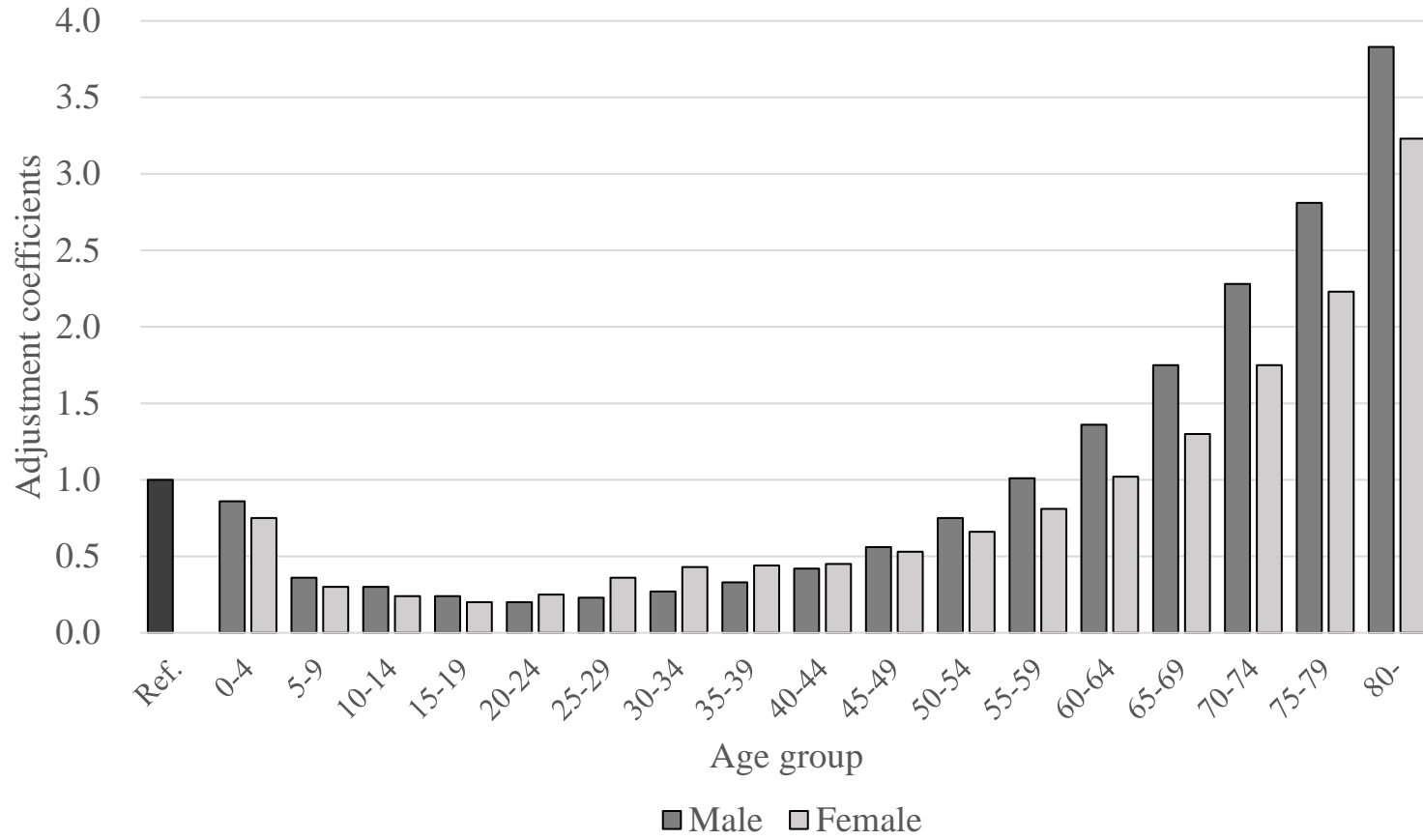
Group 1 and Group 2: Higher initial physician supply, Group 3 and Group 4: Lower initial physician supply.

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

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

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Appendix Figure.



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

| | Item No | Recommendation |
|------------------------------|---------|---|
| Title and abstract | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract -p3 (b) Provide in the abstract an informative and balanced summary of what was done and what was found – p3-4 |
| Introduction | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported -p6-7 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses – p7 |
| Methods | | |
| Study design | 4 | Present key elements of study design early in the paper – p10-12 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection –p8-9 |
| Participants | 6 | (a) <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 – p8-9 (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 – p10 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group –p7-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias –p7-8 |
| Study size | 10 | Explain how the study size was arrived at – p7-9 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why – p11 |
| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding –p10-12 (b) Describe any methods used to examine subgroups and interactions –p11-12 (c) Explain how missing data were addressed –p7-8 (d) <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 –p20 |

Continued on next page

Results

| | | |
|------------------|-----|--|
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed—Table 1, Table 2, and Table 4 (b) Give reasons for non-participation at each stage—7-8 (c) Consider use of a flow diagram – no use |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders—p8-9 (b) Indicate number of participants with missing data for each variable of interest—p7-8 (c) <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—p12-14 |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included –not applicable (b) Report category boundaries when continuous variables were categorized—p11 (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – not applicable |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses—p13-14 |

Discussion

| | | |
|------------------|----|---|
| Key results | 18 | Summarise key results with reference to study objectives—p14-15 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias—p20 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence—p15-20 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results—p20 |

Other information

| | | |
|---------|----|--|
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based—p22-23 |
|---------|----|--|

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

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