Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Beyond Salary: Habitable-Area Population Density and Postgraduate Residency Match Outcomes at Japanese University Hospitals—A Nationwide Hospital-Level Study

Takehiko Hanaki

hanaki-ttr@umin.ac.jp

Tottori University Faculty of Medicine

Maho Fujita

Tottori University Faculty of Medicine

Hiroshi Sunada

Tottori University Hospital

Rumiko Omatsu

Tottori University Faculty of Medicine

Saki Shinzato

Tottori University Faculty of Medicine

Yoshiyuki Fujiwara

Tottori University Faculty of Medicine

Masaru Ueki

Tottori University Faculty of Medicine

Research Article

Keywords: postgraduate clinical training, residency match, university hospitals, match fill rate, habitable-area population density

Posted Date: November 3rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11558136/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

University hospitals play a central role in postgraduate clinical training in Japan, yet filling residency positions remains challenging. Geographic conditions may be associated with recruitment outcomes independently of institutional characteristics and financial incentives. This study examined the association between habitable-area population density and residency position filling at Japanese university hospitals.

Methods

This preregistered nationwide hospital-level cross-sectional study included all 81 main university hospitals in Japan. Official results from the 2026 Japan Residency Matching Program were analyzed using quasi-binomial logistic regression. The primary adjusted model included habitable-area population density, hospital bed count, and university ownership. An additional model incorporated estimated annual resident remuneration for 79 hospitals. Matching outcomes from 2025 were examined in a historical analysis.

Results

In 2026, 2,473 of 3,310 residency positions were filled (74.7%). Each doubling of habitable-area population density was associated with higher odds of position filling after adjustment for hospital bed count and university ownership (odds ratio [OR], 1.56; 95% confidence interval [CI], 1.24–1.95). This association remained similar after additional adjustment for remuneration (OR, 1.54; 95% CI, 1.21–1.96). Estimated remuneration was not statistically associated with position filling (OR per 1 million JPY, 0.86; 95% CI, 0.54–1.39). The 2025 analysis showed an association in the same direction (adjusted OR per doubling, 1.73; 95% CI, 1.39–2.16).

Conclusions

Higher habitable-area population density was associated with greater residency position filling at Japanese university hospitals. This association was not materially attenuated by adjustment for measured institutional characteristics, including remuneration. Geographic context should be considered when interpreting residency recruitment outcomes and planning postgraduate clinical training. These hospital-level findings do not establish causality or identify the factors underlying individual graduates' residency choices.

Trial registration

Not applicable

1. Introduction

The transition from undergraduate medical education to postgraduate clinical training marks an important shift in professional responsibilities, as medical graduates assume greater responsibility for patient care under supervision [1]. In Japan, physicians intending to engage in clinical practice are required to undergo at least two years of postgraduate clinical training after obtaining a medical license [2]. University hospitals have traditionally served as important training sites for both undergraduate medical education and postgraduate clinical training in Japan. With the introduction of a nationwide residency matching system in 2003 and mandatory postgraduate clinical training in 2004, university hospitals faced increased competition from non-university teaching hospitals for junior residents. The proportion of junior residents training at university hospitals declined substantially following the reform [3]. Recruiting junior residents has remained a challenge for many university hospitals [4].

Previous studies in Japan have examined associations between institutional and regional characteristics and residency program popularity or application patterns. Using nationwide interim matching data from 2019, Nishizaki et al. defined program popularity as the ratio of first-choice registrations to recruitment capacity. They found higher popularity among non-university hospitals, hospitals with greater ambulance caseloads, and hospitals located in more populous prefectures, whereas monthly salary and bonus availability were not significantly associated with popularity [4]. A study of all 81 main university hospitals found that implementation of the Tasukigake training model, which alternates training between university and cooperating hospitals, was not significantly associated with program popularity in multivariable analysis [5]. More recently, Hamatsu et al. found that urban location and a higher proportion of alumni professors were associated with lower application-to-capacity ratios among graduates applying to their alma mater for postgraduate clinical training [6].

Resident remuneration has also been examined in relation to residency program popularity. Using interim matching data from 2006 and 2009, Enari and Hashimoto found a positive association between resident salary and the applicant-to-quota ratio among non-university teaching hospitals in a hospital fixed-effects analysis [7]. Meanwhile, Ikki et al. found that non-university teaching hospitals in the most populous cities had lower basic monthly resident wages but higher first-choice applicant-to-quota ratios [8]. Although these studies used different samples and analytical approaches, their findings suggest that both resident remuneration and geographic context may be relevant to residency application patterns.

Studies in the United States have also examined associations between geographic and program characteristics and residency and fellowship match outcomes. Studies of rural family medicine residency programs in the United States have reported varying associations between geographic characteristics and match rates, while emphasizing that match rates should not be equated with program quality [9, 10]. A study of radiology fellowship programs in the United States also found that

program size and perceived reputation were associated with whether programs filled their recruitment quotas [11].

However, the Japanese studies reviewed above primarily examined application-based measures of residency recruitment rather than the proportion of positions filled in the official residency matching results. First-choice registrations reflect applicants' expressed preferences, whereas position filling reflects the outcome of matching applicants and hospitals within available recruitment quotas, before subsequent recruitment. Whether regional characteristics and resident remuneration are associated with position filling at Japanese university hospitals remains unclear.

Previous Japanese studies have used prefectural or municipal population to characterize the geographic context of residency programs [4, 5]. However, population counts alone do not account for the amount of land available for habitation. Population density based on total municipal area is also influenced by the extent of forestland and major lakes, which are excluded when calculating habitable land area. Habitable-area population density, defined as population divided by habitable land area, provides a continuous indicator of population concentration.

We therefore conducted a nationwide hospital-level study of all 81 main university hospitals in Japan to examine whether habitable-area population density was associated with residency position filling in the official 2026 Japan Residency Matching Program results. We hypothesized that hospitals located in areas with lower habitable-area population density would have lower residency position fill rates. We examined this association after adjusting for hospital bed count and university ownership, and assessed whether it persisted after additional adjustment for estimated annual resident remuneration.

2. Methods

2.1 Study design and preregistration

We conducted a nationwide, hospital-level cross-sectional study to examine the association between habitable-area population density and residency position filling as reported in the official Japan Residency Matching Program (JRMP) results. The prespecified analytic sample consisted of 81 main university hospitals.

The study protocol and statistical analysis plan were preregistered on the Open Science Framework (OSF) on September 1, 2026, and the predictor dataset was finalized before the release of the 2026 JRMP matching results (OSF registration: https://osf.io/kg8bz/overview?view_only=85154d11a2ed4c388011198afc5b0cde) [12, 13]. The 2026 JRMP cycle constituted the primary analysis. Matching outcomes from the 2025 JRMP cycle were examined separately as a secondary historical analysis. The reporting of this study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies [14].

2.2 Study population and setting

Applicants and participating hospitals submit rank-order lists through the JRMP, which announces matching results annually [12].

The unit of analysis was the main university hospital. Branch hospitals, affiliated hospitals, and other separately operated facilities were excluded, and their recruitment quotas and matched resident counts were not aggregated with those of the main university hospital. National Defense Medical College Hospital was excluded a priori because it did not participate in the 2026 JRMP and operates a separate postgraduate clinical training system for medical officers under the Ministry of Defense. The prespecified hospital sample remained unchanged after the release of the 2026 matching results. The 2026 JRMP cycle corresponded to postgraduate clinical training commencing in April 2027.

2.3 Matching outcomes

The matching results were manually extracted from the official JRMP program-level results as of October 22, 2026 [13]. These results represented positions filled through the JRMP matching process before any subsequent recruitment and did not reflect the total number of residents ultimately recruited by each hospital. For each main university hospital, recruitment quotas and numbers of matched residents were summed across all residency programs listed under that hospital. Programs listed separately under branch, affiliated, or other hospitals were not included. Data were independently verified by two investigators, and discrepancies were resolved by consensus.

The hospital-level fill rate was calculated as the number of matched residents divided by the recruitment quota and was used for descriptive purposes. The number of unfilled positions was calculated as the recruitment quota minus the number of matched residents. For regression analyses, the numbers of matched and unfilled positions were analyzed as grouped binomial data rather than treating the fill rate as a continuous outcome.

2.4 Primary exposure and geographic linkage

The primary exposure was habitable-area population density. Municipal population was obtained from the 2026 Surveys of Population, Population Change and the Number of Households based on the Basic Resident Registration, using total municipal population as of January 1, 2026 [15]. Habitable land area was obtained from the Statistical Observations of Municipalities 2026 within the System of Social and Demographic Statistics [16].

Each university hospital was linked to the municipality containing the street address of its main hospital. For hospitals located in government-designated cities, city-level population and habitable land area were used. For hospitals located in Tokyo's 23 special wards, ward-specific population and habitable land area were used.

Habitable-area population density was calculated as municipal population divided by habitable land area in square kilometers. Because of its right-skewed distribution, the natural logarithm of habitable-area population density was used in regression analyses. The population data, habitable land area data,

geographic linkage, and derived density values were finalized before the release of the 2026 matching results.

2.5 Hospital characteristics

Three additional hospital-level characteristics were prespecified: hospital bed count, university ownership, and estimated annual resident remuneration.

Hospital bed count was obtained from the “Hospital (facility information)” open dataset of the Medical Information Net published by the Ministry of Health, Labour and Welfare, using data as of June 1, 2026, and was used as an indicator of hospital scale [17]. University ownership was categorized as national, public, or private [18].

Estimated annual resident remuneration was derived from official university hospital sources available in 2026 for the 2027 recruitment cycle, according to prespecified rules (Supplementary Table S1). Hospital-level estimates are provided in Supplementary Table S2. Remuneration values were finalized before the release of the 2026 JRMP matching results. Remuneration could not be determined according to the prespecified approach for two eligible hospitals.

2.6 Statistical analysis

Continuous variables were summarized using medians and interquartile ranges, and categorical variables using counts and percentages. Hospital-level fill rates were summarized descriptively. The overall fill rate was calculated as the total number of matched residents divided by the total recruitment quota across all included hospitals.

The primary analysis modeled the probability that an available residency position was filled using grouped binomial regression, with the numbers of matched and unfilled positions specified as the outcome. A logit link was used, with quasi-binomial logistic regression prespecified as the primary implementation to account for extra-binomial variation.

Three regression models were prespecified. Model 1 included the natural logarithm of habitable-area population density. Model 2, the primary adjusted model, additionally included hospital bed count and university ownership. Model 3 further included estimated annual resident remuneration.

University ownership was modeled as a categorical variable, with national universities as the reference category. Hospital bed count was expressed per 100 beds and estimated annual remuneration per 1 million JPY for ease of interpretation. For habitable-area population density, effect estimates were expressed as the OR corresponding to a doubling of density, calculated as $\exp(\beta \times \ln 2)$. To facilitate interpretation, we additionally expressed the Model 2 estimate as an adjusted OR comparing the 75th (Q3) with the 25th percentile (Q1) of observed habitable-area population density, calculated as $\exp[\beta \times \ln(Q3/Q1)]$. The corresponding 95% CI was derived from the same fitted model.

Model 3 was used to assess whether the association persisted after additional adjustment for resident remuneration. No missing predictor values were imputed. Because remuneration data were unavailable for two hospitals, Model 3 included 79 hospitals, whereas Models 1 and 2 included all 81 hospitals. Differences in the estimated association between Models 2 and 3 were interpreted cautiously and not as evidence that remuneration explained, mediated, or causally accounted for the association.

For the prespecified secondary historical analysis, the same three quasi-binomial regression specifications were applied to the 2025 JRMP matching outcomes using the same hospital-level predictor data as in the 2026 analysis. Because the 2025 matching outcomes were already publicly available when the protocol was finalized, this analysis was considered historical and was not interpreted as a temporally aligned validation analysis.

Effect estimates were reported as odds ratios (ORs) with 95% confidence intervals (CIs). For quasi-binomial models, confidence intervals were calculated using model-based standard errors and critical values from the t distribution with the corresponding residual degrees of freedom. Statistical inference was based primarily on effect estimates and their confidence intervals. Statistical tests were two-sided where applicable, with a nominal significance level of 0.05. No formal adjustment for multiple testing was applied across the three prespecified models because they represented complementary specifications of the same primary association rather than independent primary hypotheses.

Model diagnostics included assessment of overdispersion, multicollinearity, nonlinearity of the association with habitable-area population density, and influential observations. Overdispersion was assessed using the Pearson dispersion parameter. Multicollinearity was assessed using generalized variance inflation factors (GVIFs), with degree-of-freedom-adjusted GVIFs used for terms with more than 1 degree of freedom [19]. Departure from linearity on the log-density scale was assessed by comparing Model 2 with an otherwise equivalent model incorporating a natural spline with 3 degrees of freedom for log-transformed habitable-area population density, using an F test. Influential observations in Model 2 were examined using Cook’s distance, leverage, and DFBETAs.

Sensitivity analyses included conventional binomial logistic regression fitted using glm() and beta-binomial regression fitted using the glmmTMB package [20], retaining the same grouped outcome structure and covariate specification as the corresponding primary models. Additional sensitivity analyses included an equal-hospital-weight analysis, geographic-unit clustered robust standard errors calculated using the sandwich package [21], restriction of Model 2 to the 79 hospitals with available remuneration data, and leave-one-hospital-out analyses

In the equal-hospital-weight analysis, hospital-level fill rates were modeled using unweighted quasi-binomial fractional-response regression, without weighting hospitals according to their recruitment quotas. For the geographically clustered analysis, the geographic unit used to assign population data to each hospital was used as the clustering variable. Cluster-robust standard errors were calculated using an HC1 correction, with confidence intervals based on the t distribution with degrees of freedom equal to the number of clusters minus one.

No interactions or subgroup analyses were prespecified. No stepwise regression, automated variable selection, or predictor selection based on univariable P values was performed. No eligible hospital was excluded because of an extreme predictor or outcome value. Data inconsistencies identified during data collection were resolved by review of the original source rather than by automatic exclusion. Because the study included all prespecified eligible main university hospitals in Japan, no formal sample size calculation was performed. All statistical analyses were performed using R version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria). Package versions used for the final analyses were documented.

Additional post hoc exploratory analyses were conducted to examine relationships involving remuneration. The association between estimated annual remuneration and log-transformed habitable-area population density was assessed using Pearson's correlation coefficient, with Spearman's rank correlation coefficient calculated as a supplementary measure. The unadjusted association between remuneration and residency position filling was examined using univariable quasi-binomial logistic regression, with remuneration expressed per 1 million JPY. These analyses were restricted to the 79 hospitals with available remuneration data. These exploratory analyses did not alter the prespecified regression models.

2.7 Missing data

No numerical imputation of missing predictor values was performed. Models 1 and 2 included all 81 eligible hospitals. Estimated annual resident remuneration was unavailable for two eligible hospitals; therefore, Model 3 was based on 79 complete cases for remuneration.

2.8 Secondary historical analysis

Hospital-level matching outcomes from the 2025 JRMP cycle were examined as a secondary historical analysis to assess the consistency of the association between habitable-area population density and residency position filling across the two cycles [22]. The same hospital eligibility criteria and program-aggregation rules used for the 2026 outcome were applied to the 2025 data.

The same predictor set and three-model structure used for the 2026 analysis were applied to the 2025 matching outcome. Because the 2025 matching outcomes were already publicly available when the protocol was finalized and the predictor measurements were fixed using 2026 data, these analyses were treated as historical secondary analyses rather than temporally aligned validation analyses.

2.9 Ethical considerations

This study used exclusively publicly available, institution-level aggregate data and did not involve individual-level or personally identifiable information. Under Section 3(1)(c)(ii) of the Japanese Ethical Guidelines for Medical and Biological Research Involving Human Subjects, research using only existing information that does not constitute information relating to individuals falls outside the scope of the guidelines [23]. Therefore, institutional ethics review and individual informed consent were not required.

The study was conducted in accordance with the relevant ethical principles of the Declaration of Helsinki, as applicable to research using publicly available, institution-level aggregate data.

3. Results

3.1 Study sample and 2026 matching outcomes

A total of 81 main university hospitals were included in the analysis, comprising 42 hospitals affiliated with national universities, 8 with public universities, and 31 with private universities. The median number of hospital beds was 813 (interquartile range [IQR], 653–965), and the median habitable-area population density was 2,875 persons/km² (IQR, 1,131–6,963). Estimated annual remuneration was available for 79 hospitals, with a median of 4.08 million JPY (IQR, 3.60–4.74).

In the 2026 matching cycle, the 81 hospitals offered 3,310 residency positions, of which 2,473 were filled and 837 remained unfilled, corresponding to an overall weighted fill rate of 74.7%. The median recruitment quota per hospital was 38 (IQR, 31–48), and the median number of matched residents was 30 (IQR, 19–42). The median hospital-level fill rate was 80.6% (IQR, 55.2%–96.9%), and 18 hospitals (22.2%) filled all available positions. Characteristics of the included hospitals and their 2026 matching outcomes are summarized in Table 1.

3.2 Association between habitable-area population density and 2026 matching outcomes

The unadjusted association between habitable-area population density and hospital-level residency position fill rate is shown in Fig. 1, with estimated annual resident remuneration additionally represented by point color in Fig. 1B for the 79 hospitals with available remuneration data. In Model 1, a doubling of habitable-area population density was associated with higher odds of filling an available residency position (OR, 1.63; 95% CI, 1.32–2.00; $P < 0.001$).

(A) Association between habitable-area population density and hospital-level residency position fill rate. Point size represents the recruitment quota. The solid line represents the fitted relationship from the unadjusted quasi-binomial model (Model 1), and the shaded band indicates the 95% confidence interval. (B) Association between habitable-area population density and hospital-level residency position fill rate, with point color indicating estimated annual resident remuneration. Remuneration data were available for 79 of 81 hospitals. The x-axis is displayed on a logarithmic scale in both panels.

In the prespecified primary adjusted model (Model 2), which included hospital bed count and university ownership, a doubling of habitable-area population density remained associated with higher odds of residency position filling (OR, 1.56; 95% CI, 1.24–1.95; $P < 0.001$). Expressed as a comparison between the 75th percentile (6,963 persons/km²) and the 25th percentile (1,131 persons/km²) of observed

habitable-area population density, the corresponding adjusted OR was 3.19 (95% CI, 1.76–5.80). Full model estimates are presented in Table 2.

3.3 Remuneration-adjusted analysis

Estimated annual remuneration data were unavailable for two hospitals; therefore, Model 3 included 79 hospitals. After additional adjustment for estimated annual remuneration, a doubling of habitable-area population density was associated with higher odds of residency position filling (OR, 1.54; 95% CI, 1.21–1.96; P < 0.001). The association between estimated annual remuneration and residency position filling was not statistically significant (OR per 1 million JPY increase, 0.86; 95% CI, 0.54–1.39; P = 0.545). Full estimates from Model 3 are shown in Table 2.

3.4 Exploratory analyses of remuneration

In post hoc exploratory analyses, estimated annual resident remuneration was negatively correlated with log-transformed habitable-area population density (Pearson's r = − 0.43; 95% CI, − 0.60 to − 0.23; P < 0.001). A similar association was observed using Spearman's rank correlation (ρ = −0.45; P < 0.001; Fig. 2A).

In the univariable quasi-binomial model, higher estimated annual remuneration was associated with lower odds of residency position filling (OR per 1 million JPY increase, 0.60; 95% CI, 0.38–0.94; P = 0.025; Fig. 2B). The corresponding OR was closer to 1 in the prespecified multivariable Model 3 (Table 2).

1. (A) Association between estimated annual resident remuneration and log-transformed habitable-area population density. The solid line represents the fitted linear regression line, and the shaded band indicates the 95% confidence interval. Estimated remuneration was inversely correlated with log-transformed habitable-area population density (Pearson r = − 0.43; 95% CI, − 0.60 to − 0.23; P < 0.001).
2. (B) Association between estimated annual resident remuneration and hospital-level residency position fill rate. Point size represents the recruitment quota. The solid line represents the fitted relationship from the post hoc univariable quasi-binomial model, and the shaded band indicates the 95% confidence interval. Higher remuneration was associated with lower odds of position filling (OR per 1 million JPY, 0.60; 95% CI, 0.38–0.94; P = 0.025). Remuneration data were available for 79 of 81 hospitals.

3.5 Historical analysis of the 2025 matching cycle

In the prespecified historical secondary analysis of the 2025 matching cycle, a doubling of habitable-area population density was associated with higher odds of residency position filling in Model 2 (OR, 1.73; 95% CI, 1.39–2.16; P < 0.001). After additional adjustment for estimated annual remuneration in Model 3, the corresponding OR was 1.67 (95% CI, 1.32–2.11; P < 0.001). The association between estimated annual remuneration and residency position filling was not statistically significant in Model 3 (OR per

1 million JPY increase, 0.74; 95% CI, 0.47–1.14; P = 0.171). Full results of the 2025 historical analysis are shown in Supplementary Table S3.

3.6 Sensitivity analyses and model diagnostics

Additional sensitivity analyses yielded estimates similar to those of the primary analysis. Conventional binomial regression produced identical point estimates to the quasi-binomial models (OR per doubling, 1.56 in Model 2 and 1.54 in Model 3), but narrower confidence intervals (95% CI, 1.45–1.67 and 1.43–1.66, respectively), consistent with the absence of an overdispersion adjustment. In the equal-hospital-weight analysis, the OR for residency position filling per doubling of habitable-area population density was 1.55 (95% CI, 1.23–1.96) in Model 2. The corresponding OR was 1.60 (95% CI, 1.31–1.95) using beta-binomial regression and 1.56 (95% CI, 1.29–1.89) when geographic-unit clustered robust standard errors were applied. Restricting Model 2 to the 79 hospitals with available remuneration data yielded an OR of 1.58 (95% CI, 1.26–1.98). In leave-one-hospital-out analyses, the OR per doubling of habitable-area population density ranged from 1.47 to 1.73, with the direction of the association unchanged across all analyses. Detailed results are presented in Supplementary Table S4.

The dispersion parameter for the primary Model 2 was 10.44. Comparison with a model incorporating a natural spline for log-transformed habitable-area population density did not indicate a statistically significant departure from the linear specification (P = 0.213). Adjusted generalized variance inflation factors were 1.31 or lower across Models 2 and 3. Influence diagnostics and other model diagnostics are summarized in Supplementary Table S5.

4. Discussion

In this nationwide hospital-level study of all 81 main university hospitals in Japan, higher habitable-area population density was consistently associated with greater residency position filling at the time of the JRMP results. In the prespecified primary adjusted analysis for the 2026 matching cycle, a doubling of habitable-area population density was associated with 1.56-fold higher odds of an available residency position being filled after adjustment for hospital bed count and university ownership. The corresponding OR was 1.54 after additional adjustment for estimated annual resident remuneration in the 79 hospitals with available remuneration data. Although a post hoc univariable analysis showed an inverse association between remuneration and position filling, the association was not statistically significant in the prespecified remuneration-adjusted Model 3. A similar association between habitable-area population density and position filling was observed in the prespecified historical analysis of the 2025 matching cycle. Sensitivity analyses yielded estimates of broadly similar magnitude. Taken together, these findings suggest that geographic context should be considered alongside measured institutional characteristics when interpreting residency matching outcomes, although causal relationships cannot be established.

Previous Japanese studies have examined associations between geographic and institutional characteristics and postgraduate residency recruitment, but have largely focused on application-based

measures rather than position filling at the official matching results. Nishizaki et al. reported higher program popularity in more populous prefectures based on first-choice registrations relative to recruitment capacity [4], while Watanabe et al. examined university-hospital program popularity in relation to institutional characteristics and local population size [5]. In contrast, Hamatsu et al. reported that urban location was associated with lower application-to-capacity ratios among graduates applying to their alma mater for postgraduate clinical training [6]. These findings suggest that associations with geographic characteristics may differ depending on the study population and the recruitment outcome examined. To our knowledge, the present study is the first nationwide investigation of the association between habitable-area population density and residency position filling across all main university hospitals in Japan. By examining position filling at the official matching results, which reflects the matching of applicants and hospitals within available recruitment quotas rather than expressed applicant preferences alone, this study provides a complementary perspective on the relationship between geographic context and postgraduate residency recruitment.

Habitable-area population density provides a geographic measure that differs from both absolute population size and conventional population density calculated using total municipal land area. Municipalities with similar populations may differ substantially in the amount of habitable land, a distinction that population counts alone do not capture. Conversely, conventional population density may be substantially influenced by mountainous, forested, and other non-habitable areas. Using habitable land as the denominator may therefore provide a more relevant measure of population concentration in settings where non-habitable land occupies a substantial share of municipal area, although it does not directly describe how residents are distributed within that area. Importantly, however, this measure is not itself an indicator of urban attractiveness or quality of life. Rather, it should be interpreted as a geographic proxy that may correlate with transportation connectivity, access to services and amenities, employment opportunities for household members, and other features of the regional environment. Because these characteristics were not measured directly, the present analysis cannot identify which of them, if any, contribute to the observed association or establish a causal effect of population concentration on residency position filling.

The findings regarding remuneration warrant particular consideration. In a panel analysis of non-university teaching hospitals, Enari and Hashimoto found a positive association between salary and the applicant-to-quota ratio after accounting for time-invariant hospital characteristics, suggesting that financial incentives may be relevant to residency program selection [7]. In a separate cross-sectional study of non-university teaching hospitals, Ikki et al. reported lower average resident wages but higher first-choice applicant-to-quota ratios in the most populous cities [8]. Although these studies differed in their study populations and analytical approaches, they suggest that the relationships among remuneration, geographic context, and residency recruitment are not straightforward. In the present study, estimated annual remuneration was negatively correlated with log-transformed habitable-area population density, indicating that hospitals in less densely populated areas tended to offer higher estimated remuneration. Higher remuneration was also associated with lower odds of position filling in a post hoc univariable analysis. However, this inverse association was attenuated after adjustment for

habitable-area population density and other hospital characteristics. In the prespecified remuneration-adjusted Model 3, the OR for remuneration was 0.86 per 1 million JPY increase (95% CI, 0.54–1.39), with the confidence interval compatible with both lower and higher odds of position filling. Furthermore, our remuneration measure represented estimated nominal annual amounts derived from publicly available institutional sources, rather than actual earnings or remuneration adjusted for regional differences in living costs. Variable payments, housing support, other benefits, and differences in purchasing power may affect the financial attractiveness of residency programs but were not fully captured. Hospitals facing geographic or competitive disadvantages may also offer higher remuneration as a recruitment strategy, although our cross-sectional data cannot establish such a mechanism. Accordingly, the present findings should not be interpreted as indicating that higher remuneration reduces residency recruitment or that financial incentives are ineffective. Rather, the association between habitable-area population density and position filling remained evident after adjustment for the available measure of remuneration.

The association between habitable-area population density and position filling was also observed in the prespecified historical analysis of the 2025 matching cycle, with an OR in the same direction and of broadly comparable magnitude to that observed in 2026. However, both analyses involved the same 81 hospitals, and the 2025 analysis used the predictor values assembled for the primary 2026 analysis rather than measurements specific to 2025. Furthermore, the 2025 matching outcomes were already publicly available when the study protocol was finalized, and matching patterns within hospitals may be correlated across adjacent years. These findings therefore should not be interpreted as independent temporal validation or evidence of reproducibility in a separate population. Rather, they indicate that the observed geographic association was present in both matching cycles within the same hospital population.

The primary 2026 association was also robust to several analytical choices. Equal-hospital-weight analysis, beta-binomial regression, and restriction to hospitals with complete remuneration data yielded ORs of broadly comparable magnitude. Applying geographic-unit clustered robust standard errors retained the Model 2 point estimate, with a 95% confidence interval that continued to exclude 1. The direction of the association also remained unchanged in leave-one-hospital-out analyses. Collectively, these findings support the stability of the estimated association across the analytical approaches examined, while not excluding residual confounding or establishing causality.

These findings have implications for the interpretation of residency recruitment outcomes. The fill rate at the time of the official JRMP results represents the proportion of available residency positions filled through the matching process and does not reflect subsequent recruitment or final staffing levels. Moreover, the fill rate depends on both the number of matched residents and the recruitment quota. Hospitals may recruit substantial numbers of residents yet have relatively low fill rates when their recruitment quotas are large relative to the number of matched residents, particularly when multiple programs, including those with collaborative training arrangements, are aggregated at the hospital level. Although the grouped binomial models incorporated recruitment quotas as the number of trials, they did not explicitly model how recruitment quotas were determined or how residency programs were

structured. Consequently, differences in position filling should not be interpreted solely as differences in institutional recruitment capability or educational quality. This interpretation is consistent with previous caution against using residency matching outcomes as direct indicators of program quality [10]. Accordingly, comparisons of match-result fill rates across university hospitals should take into account both geographic context and institutional program structures.

The broader implications extend to policies intended to address regional disparities in postgraduate clinical training. University hospitals operate within regional environments that may facilitate or constrain recruitment in ways that are not readily modifiable by individual institutions. A recent simulation study using 2022 Japanese residency matching data found that substantial adjustments to the geographic allocation of residency positions produced only limited reductions in regional disparities in the distribution of matched residents under the scenarios examined [24]. Although that study addressed a different research question, it suggests that changing recruitment quota allocations alone may have limited effects on the geographic distribution of residents. The present findings likewise suggest that recruitment outcomes should be interpreted within a broader regional context rather than attributed exclusively to institutional recruitment efforts or financial conditions. For hospitals in lower-density areas, these findings do not imply that lower fill rates are inevitable or that increasing remuneration would be ineffective. Future research should examine how geographic accessibility, training opportunities, regional graduate supply, competition among teaching hospitals, and financial and nonfinancial incentives jointly relate to residency selection and position filling.

Several limitations should be considered. First, the primary analysis was cross-sectional and conducted at the hospital level, precluding causal inference or conclusions about individual applicants' preferences. Second, the outcome was measured at the time of the official JRMP matching results and did not capture residents recruited through subsequent recruitment processes. Although recruitment quotas were incorporated as the number of trials in the grouped binomial models, their determinants and differences in program composition were not separately modeled. Third, potentially important regional factors were not measured, including the supply of medical graduates, recruitment capacity at competing non-university teaching hospitals, and graduates' tendency to remain at their alma mater. These unmeasured factors may contribute to residual confounding of the association between habitable-area population density and position filling. Fourth, habitable-area population density was assigned according to the municipality of each main university hospital and may not fully reflect residents' actual living or training environments, particularly when rotations occur at affiliated institutions. The choice of administrative boundaries may also affect geographic measurement. Fifth, outcomes were aggregated across programs within each main university hospital, potentially obscuring within-institution differences in recruitment. Sixth, estimated remuneration was unavailable for two hospitals and did not fully capture actual earnings, variable compensation, nonmonetary benefits, or regional differences in purchasing power. The post hoc exploratory analyses involving remuneration were not prespecified and should therefore be interpreted as hypothesis-generating. Finally, the study was restricted to main university hospitals in Japan, and the findings may not be directly generalizable to non-university teaching hospitals or other residency systems.

5. Conclusion

In conclusion, among all 81 main university hospitals in Japan, higher habitable-area population density was associated with greater residency position filling at the time of the official JRMP matching results. The association was observed after adjustment for hospital bed count and university ownership, remained of similar magnitude in the remuneration-adjusted analysis of 79 hospitals, and was broadly consistent across sensitivity analyses. The nonsignificant association for estimated remuneration does not establish that financial incentives are unimportant in residency selection. These findings highlight the importance of considering geographic context alongside institutional and financial factors when interpreting residency matching outcomes and planning efforts to support postgraduate clinical training in lower-density areas.

Abbreviations

CI
Confidence interval
GVIF
Generalized variance inflation factor
IQR
Interquartile range
JRMP
Japan Residency Matching Program
OR
Odds ratio
OSF
Open Science Framework
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology

Declarations

Ethics approval and consent to participate

This study used exclusively publicly available, institution-level aggregate data and did not involve individual-level or personally identifiable information. Under Section 3(1)(C)(ii) of the Japanese Ethical Guidelines for Medical and Biological Research Involving Human Subjects, research using only existing information that does not relate to individuals falls outside the scope of the guidelines [23]. Therefore, institutional ethics review and informed consent to participate were not required.

Consent to Publish declaration

Not applicable

Availability of data and materials

The data used in this study were derived exclusively from publicly available sources. The study protocol, statistical analysis plan, and prespecified predictor dataset were preregistered on the Open Science Framework (OSF) before the release of the 2026 residency matching outcomes. The hospital-level dataset and R code supporting the findings of this study are available to editors and peer reviewers through a private Figshare link (https://figshare.com/s/2394a17803939a3b427f). These materials will be made publicly available through Figshare upon publication of the article. No individual-level or personally identifiable data were used.

Competing interests

The authors declare no competing interests related to this study.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' contributions

T.H. conceptualized the study. T.H., M.F., H.S., and M.U. contributed to the methodology. T.H., M.F., R.O., and S.S. performed data curation. T.H., M.F., and H.S. conducted the formal analyses. H.S. contributed to validation. T.H. and M.F. prepared the visualizations and managed the project. Y.F. and M.U. provided supervision. T.H. and M.F. wrote the original draft of the manuscript. All authors reviewed and edited the manuscript.

Trial registration

Not applicable

References

1. Chaou C-H, Yu S-R, Chang Y-C, Ma S-D, Tseng H-M, Hsieh M-J, et al. The evolution of medical students' preparedness for clinical practice during the transition of graduation: a longitudinal study from the undergraduate to postgraduate periods. BMC Med Educ. 2021;21:260.
2. Nishigori H. Medical education in Japan. Med Teach. 2024;46(Suppl 1):S4–10.
3. Nomura K, Yano E, Mizushima S, Endo H, Aoki M, Shinozaki H, et al. The shift of residents from university to non-university hospitals in Japan: a survey study. J Gen Intern Med. 2008;23(7):1105–9.
4. Nishizaki Y, Ueda R, Shinozaki T, Tokuda Y. Hospital characteristics preferred by medical students for their residency programs: a nationwide matching data analysis. J Gen Fam Med. 2020;21(6):242–7.

5. Watanabe S, Kataoka K, Sekine M, Aune D, Shikino K, Nishizaki Y. Characteristics of university hospitals implementing the postgraduate clinical training Tasukigake Method and their correlation with program popularity: a cross-sectional study. Adv Med Educ Pract. 2023;14:323–32.
6. Hamatsu K, Sekine M, Kataoka K, Kiyama Y, Aune D, Nishizaki Y. Factors influencing medical students' decisions to remain at their alma mater for postgraduate clinical training: a cross-sectional study in Japan. PLoS ONE. 2025;20(7):e0327502.
7. Enari T, Hashimoto H. Does salary affect the choice of residency in non-university teaching hospitals? A panel analysis of Japan Residency Matching Programme data. Hum Resour Health. 2013;11:12.
8. Ikki Y, Yamada M, Sekine M. Regional disparity of certified teaching hospitals on physicians' workload and wages, and popularity among medical students in Japan. Environ Health Prev Med. 2021;26:75.
9. Malaty W, Pathman DE. Factors affecting the match rate of rural training tracks in family practice. Fam Med. 2002;34(4):258–61.
10. Longenecker R, Oster NV, Peterson LE, Andrilla CHA, Schmitz DF, Evans DV, et al. A match made in rural: interpreting match rates and exploring best practices. Fam Med. 2023;55(7):426–32.
11. Shah AS, Tulk AH, Shrestha R, Buckner-Petty SA, Fox MG. Analysis of National Resident Matching Program for radiology fellowships: factors affecting program fill rates. J Am Coll Radiol. 2024;21(10):1697–705.
12. Japan Residency Matching Program. Japan Residency Matching Program. https://www.jrmp.jp/. Accessed 22 Oct 2026.
13. Japan Residency Matching Program. 2026 matching results by residency program, as of October 22. 2026. 2026. https://www.jrmp2.jp/koho/2026/2026all-program-kekka.pdf. Accessed 22 Oct 2026.
14. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. PLoS Med. 2007;4(10):e296. 10.1371/journal.pmed.0040296.
15. Ministry of Internal Affairs and Communications, Population J. Population Change and Number of Households Based on the Basic Resident Registration, 2026: Table 26 – 03, Total Population, Population Change and Number of Households by Municipality. 2026. https://www.e-stat.go.jp/stat-search/files?stat_infid=000040479049. Accessed 22 Oct 2026.
16. Statistics, Bureau. Ministry of Internal Affairs and Communications, Japan. Statistical Observations of Municipalities 2026: Basic Data B, Natural Environment. 2026. https://www.e-stat.go.jp/stat-search/files?stat_infid=000040463585. Accessed 22 Oct 2026.
17. Ministry of Health, Labour and Welfare, Japan. Medical Information Net Open Data: Hospital (Facility Information), data as of June 1, 2026. 2026.

https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryou/iryou/newpage_43373.html. Accessed 22 Oct 2026.

18. Ministry of Education, Culture, Sports, Science and Technology, Japan. Nationwide List of Universities, FY2025. 2025. https://www.mext.go.jp/a_menu/koutou/ichiran/mext_00050.html. Accessed 22 Oct 2026.
19. Fox J, Monette G. Generalized collinearity diagnostics. J Am Stat Assoc. 1992;87(417):178–83.
20. Brooks ME, Kristensen K, van Benthem KJ, Magnusson A, Berg CW, Nielsen A, et al. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. R J. 2017;9(2):378–400. 10.32614/RJ-2017-066.
21. Zeileis A, Köll S, Graham N. Various versatile variances: an object-oriented implementation of clustered covariances in R. J Stat Softw. 2020;95(1):1–36. 10.18637/jss.v095.i01.
22. Japan Residency Matching Program. 2025 matching results by residency program. 2025. https://www.jrmp2.jp/oubosya/2025kekka.pdf. Accessed 22 Oct 2026.
23. Ministry of Education, Culture, Sports, Science and Technology, Japan; Ministry of Health, Labour and Welfare, Japan; Ministry of Economy, Trade and Industry, Japan. Ethical Guidelines for Medical and Biological Research Involving Human Subjects. 2023. https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/hokabunya/kenkyujigyou/i-kenkyu/index.html. Accessed 28 Oct 2026.
24. Ide H, Hiramatsu Y, Furui Y, Koike S. Effects of residency matching policies on regional distribution of residents: a simulation study using a stable matching algorithm. BMC Med Educ. 2026. 10.1186/s12909-026-10245-3.

Tables

Tables 1 and 2 are available in the Supplementary Files section.

Figures

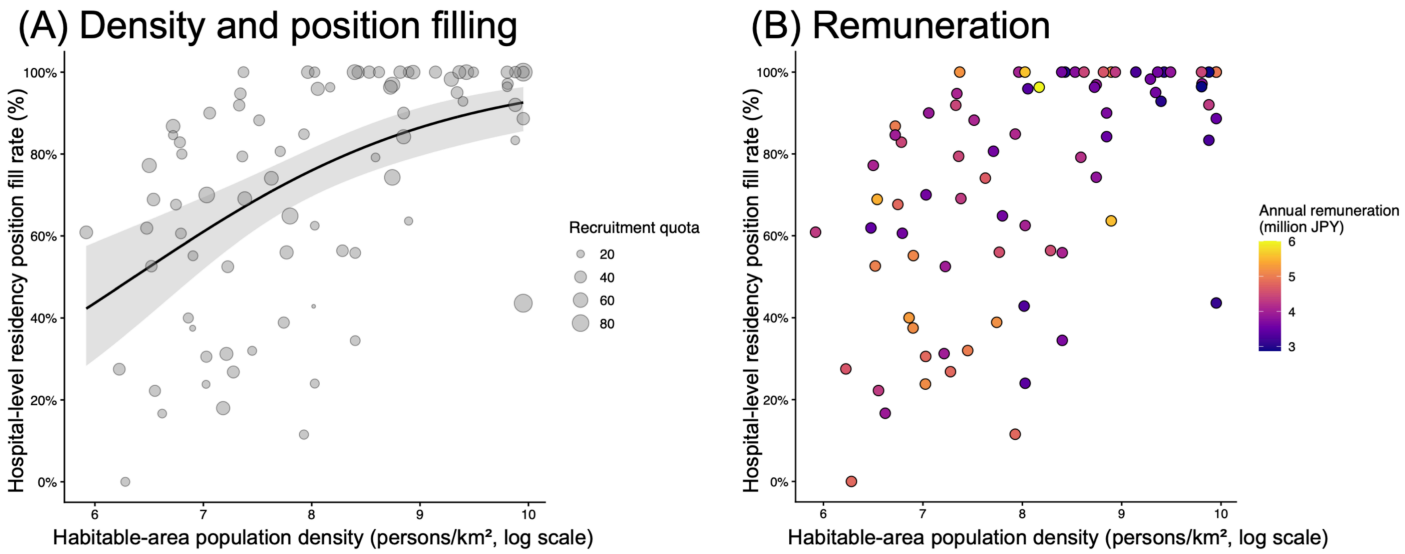


Figure 1

Habitable-area population density, residency position filling, and estimated annual resident remuneration in 2026.

(A) Association between habitable-area population density and hospital-level residency position fill rate. Point size represents the recruitment quota. The solid line represents the fitted relationship from the unadjusted quasi-binomial model (Model 1), and the shaded band indicates the 95% confidence interval. (B) Association between habitable-area population density and hospital-level residency position fill rate, with point color indicating estimated annual resident remuneration. Remuneration data were available for 79 of 81 hospitals. The x-axis is displayed on a logarithmic scale in both panels.

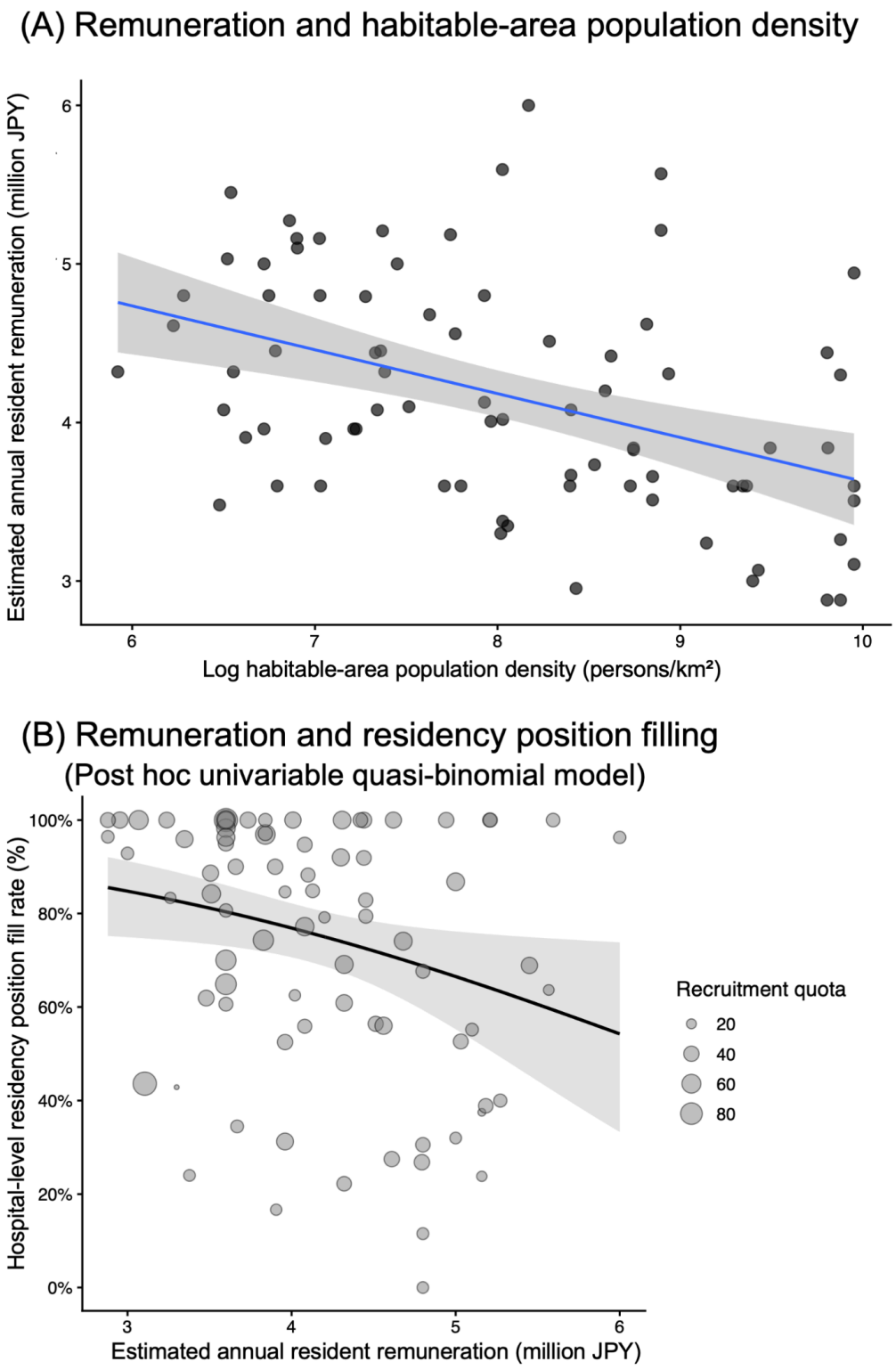


Figure 2

Exploratory associations of estimated annual resident remuneration with habitable-area population density and residency position filling in 2026.

(A) Association between estimated annual resident remuneration and log-transformed habitable-area population density. The solid line represents the fitted linear regression line, and the shaded band

indicates the 95% confidence interval. Estimated remuneration was inversely correlated with log-transformed habitable-area population density (Pearson r = −0.43; 95% CI, −0.60 to −0.23; P < 0.001).

(B) Association between estimated annual resident remuneration and hospital-level residency position fill rate. Point size represents the recruitment quota. The solid line represents the fitted relationship from the post hoc univariable quasi-binomial model, and the shaded band indicates the 95% confidence interval. Higher remuneration was associated with lower odds of position filling (OR per 1 million JPY, 0.60; 95% CI, 0.38–0.94; P = 0.025). Remuneration data were available for 79 of 81 hospitals.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTableS15.pdf
- floatimage1.png
- floatimage3.png