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Provider-side inequality and spatial clustering of inpatient specialized rehabilitation across acute and post-acute care in South Korea: A nationwide claims study

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Abstract

Background

Geographic variation in inpatient specialized rehabilitation may reflect different patterns of recorded service provision across care stages. We compared provider-side distributional inequality and spatial clustering between acute-care and post-acute stages in South Korea.

Methods

Using nationwide Health Insurance Review and Assessment Service claims from January 2022 through November 2024, we studied patients with at least one tertiary- or general-hospital admission; 2023 was the primary analysis year. Provider-side service density was defined as claims-derived specialized rehabilitation minutes per 100 inpatient days across 250 reference subregions and pathway-defined care stages. We assessed inpatient-day-weighted Gini and Theil T indices, Theil decomposition across three broad regional categories, and global and local spatial clustering. Secondary ecological analyses examined estimated-residence-based rehabilitation use across 17 regions.

Results

Density was estimable in 167 acute-care and 237 post-acute areas. Gini (0.350 versus 0.336) and Theil T (0.218 versus 0.205) indices were numerically similar across stages. Most Theil T inequality arose within broad regional categories (96.9% and 93.2%, respectively). Median post-acute density among estimable subregions was markedly lower in non-capital provinces (1.0) than in the capital region (159.9) or non-capital major cities (150.1). Positive global spatial autocorrelation was detected in post-acute care (Moran's $I = 0.244$, $p < 0.001$) but not acute care ($I = 0.017$, $p = 0.232$); local Getis–Ord Gi* analyses identified 3 hotspots and 11 coldspots versus 0 and 1, respectively (FDR-adjusted $q < 0.05$). Across 17 regions, post-acute density correlated with rehabilitation receipt among eligible transfer blocks ($\rho = 0.723$, $p = 0.001$) and outside-estimated-residence minute share ($\rho = -0.699$, $p = 0.002$); several non-capital provinces had relatively high nonlocal shares.

Conclusions

Distributional inequality and spatial clustering provide complementary descriptions of recorded rehabilitation provision across care stages. Health-services monitoring should assess both provider-side service density and estimated-residence-based use without equating low provision with unmet rehabilitation need.

Background

For patients with rehabilitation needs during or after acute hospitalization, rehabilitation can support functional recovery and return to everyday life. Its timing, setting, and continuity should reflect patients' clinical needs and recovery trajectories [1, 2]. Yet financial coverage and the geographic organization of services are distinct dimensions of healthcare provision [3]. Studies in publicly financed systems have documented regional variation in post-acute service availability, institutional arrangements, and use [4, 5]. Understanding service geography therefore requires examining where and how much care is delivered alongside formal coverage.

Inpatient specialized rehabilitation offers a useful basis for comparing the geographic distribution of a defined service across inpatient care stages. During acute hospitalization, rehabilitation may accompany medical or surgical treatment; subsequent inpatient care may involve rehabilitation facilities, long-term care hospitals, and other institutions with different clinical functions [2, 6]. Because the settings involved perform different healthcare functions and may have different geographic distributions, specialized rehabilitation need not follow the same spatial pattern across acute-care and post-acute stages [7].

Facility locations and bed counts alone do not reveal where and how much specialized rehabilitation is delivered [8]. Post-acute service use may reflect not only clinical needs but also patient and family circumstances, preferences, and the availability and organization of local services [4, 5]. These considerations make it important to distinguish the geographic presence of healthcare providers from the services they actually deliver. Healthcare access research distinguishes potential access—the opportunity to obtain care—from observed use [9, 10]. Claims-derived rehabilitation volumes offer a complementary provider-side perspective on recorded service delivery [8]. In this study, we express this activity relative to inpatient care as specialized rehabilitation minutes per 100 inpatient days.

Distributional inequality describes variation in service density across subregions regardless of their locations, whereas spatial clustering assesses whether areas with similarly high or low density are geographically proximate. Two care stages can therefore show comparable inequality but different spatial arrangements of rehabilitation delivery. The choice of geographic units can also influence observed variation [11]. Assessing within- and between-category inequality alongside spatial clustering distinguishes distributional differences from the geographic grouping of high- and low-density areas.

South Korea combines nationwide health insurance and Medical Aid with substantial regional variation in healthcare provision [12, 13]. Previous research on selected central nervous system rehabilitation treatments documented concentration in the capital region and other large urban areas in 2007, 2012, and 2017, alongside lower treatment rates in more socioeconomically deprived districts [14]. A recent nationwide Japanese study quantified age- and sex-standardized geographic variation in inpatient rehabilitation provision across secondary medical service areas and examined associations with regional workforce and socioeconomic characteristics using spatial models [15].

However, broad regional contrasts may conceal substantial differences among smaller areas within the same regional category. Research on essential primary care, although addressing a different type of service, illustrates how geographic disparities may become more visible at finer spatial scales [16]. As

population ageing heightens the importance of rehabilitation and continuing care [1], understanding service geography requires examining not only how unevenly care is delivered but also how that variation is distributed and spatially arranged. Despite evidence of regional variation, it remains unclear in South Korea whether inequality in inpatient specialized rehabilitation occurs predominantly within or between broad regional categories, or whether its spatial clustering differs between acute-care and post-acute stages. South Korea therefore provides a case for examining how nationally organized healthcare financing can coexist with different geographic patterns of recorded service delivery—a question relevant to other health systems facing similar challenges.

Using nationwide Health Insurance Review and Assessment Service (HIRA) claims from 2022–2024, with 2023 as the primary analysis year, we compared the provider-side geography of inpatient specialized rehabilitation across analytically defined acute-care and post-acute stages. We characterized distributional inequality and spatial clustering in rehabilitation service density, assessed variation within and between broad regional categories, and examined temporal stability. A secondary ecological analysis examined how regional post-acute service density corresponded to estimated-residence-based rehabilitation receipt and the share of rehabilitation minutes delivered outside estimated residence. This approach distinguishes the geography of recorded service provision from estimated-residence-based use.

Methods

Data and research design

Study design and data source

This retrospective observational study used nationwide HIRA reimbursement claims. HIRA reviews claims under South Korea's National Health Insurance (covering approximately 97% of the population) and Medical Aid (covering most others). We identified patients with at least one tertiary- or general-hospital admission between January 1, 2022, and November 30, 2024, and retrieved all their reimbursed inpatient and outpatient claims from every type of healthcare provider during that period. Thus, the study captures reimbursed healthcare use in this admission-defined cohort, not utilization by the entire Korean population (Fig. 1; Table S1).

The primary year, 2023, was the most recent fully observable calendar year whose post-acute entrants could complete a 180-day observation window before data availability ended. Provider-side analyses covered care delivered January 1–December 31, 2023. Secondary estimated-residence analyses included pathways entering post-acute inpatient care during 2023 with administratively complete observation of the 180-day post-entry window.

Annual supplementary analyses used common January–November windows in 2022–2024 because 2024 data ended November 30. Claims included de-identified patient and provider identifiers, admission

and discharge dates, provider locations, diagnosis codes, and billed service-item codes. Individual inpatient claims were reconstructed into inpatient episodes. Where required for the analysis, temporally contiguous inpatient episodes occurring at different healthcare institutions were linked into a continuous care pathway, termed a transfer block.

Supplementary Tables S1–S15 and Figures S1–S5 are provided in Additional file 1.

Inpatient episodes and analytic care stages

An inpatient episode was defined as a continuous inpatient stay by the same patient at the same institution. To account for administratively split billing records (e.g., monthly claims), consecutive inpatient claims for that patient and institution were combined when the next claim's recorded admission date fell on the same day as, or the day after, the preceding claim's discharge date (gap ≤ 1 day). The episode began at the earliest admission date and ended at the final discharge date.

For this analysis, tertiary and general hospitals were classified as acute-care providers. The non-acute provider group included hospitals other than tertiary and general hospitals, designated rehabilitation medical institutions, long-term care hospitals, Korean medicine institutions, clinics, and other providers with inpatient activity. Designated rehabilitation medical institutions are government-designated facilities providing intensive recovery-phase rehabilitation; long-term care hospitals provide inpatient medical care rather than residential nursing-home care. Provider classification did not depend on whether specialized rehabilitation was billed. Acute-care and post-acute stages were analytic inpatient stages defined by provider type and care pathway, not directly observed phases of clinical recovery.

Within each transfer block, post-acute entry was the first admission to a non-acute provider after an acute-care episode. Provider-side inpatient time was divided at this index admission. The acute-care segment ended the day before post-acute entry; subsequent inpatient time within the block remained in the post-acute segment, including returns to acute-care providers. The post-acute observation window comprised 180 calendar days, counting the index admission date as day 1 and ending 179 days later, on day 180, inclusive. Inpatient time after this window was excluded. Acute admissions without post-acute entry also contributed to acute-care analyses. The stages thus are not mutually exclusive patient cohorts: comparisons describe system-level delivery in different inpatient stages, not within-patient before-and-after changes.

Transfer blocks were constructed by linking temporally contiguous inpatient episodes at different institutions with a discharge-to-admission gap of ≤ 1 day for acute-to-acute transitions and ≤ 7 days for transitions involving a non-acute provider, including acute-to-non-acute, non-acute-to-non-acute, and non-acute-to-acute transitions. Transfer blocks were used to define post-acute entry and the unit of observation for the secondary estimated-residence-based analysis.

Definition and measurement of inpatient specialized rehabilitation

Specialized rehabilitation was defined as inpatient rehabilitation procedures billed under specialized rehabilitation fee codes in the National Health Insurance fee schedule. Identification was based on billed procedures, not designation as a rehabilitation medical institution. Recovery-phase rehabilitation items billed at designated rehabilitation medical institutions and specialized rehabilitation items billed at other eligible institutions were combined into a single measure. Thus, qualifying specialized rehabilitation provided outside designated institutions was retained. Care not represented by the selected fee codes, including non-covered rehabilitation, was outside this measure; absence of a selected claim did not establish absence of all rehabilitation-related care.

For each qualifying rehabilitation fee item, billed service counts were multiplied by its standard treatment duration in the reimbursement schedule, converted to minutes, and summed within each inpatient episode. Episodes with more than zero total specialized rehabilitation minutes were classified as receiving specialized rehabilitation. Outpatient, home-based, and community-based rehabilitation were excluded.

When an inpatient episode crossed the beginning or end of the primary analysis period or the boundary of the 180-day post-acute observation window, total specialized rehabilitation minutes were allocated proportionally according to the fraction of the episode's calendar days that overlapped the relevant analysis period, while inpatient days included only the actual dates falling within that period. This allocation assumes that rehabilitation minutes were distributed uniformly across the episode's calendar days. The numerator and denominator of service density therefore referred to the same calendar period.

Geographic framework

The primary provider-side analysis used a national reference geography comprising 250 subregions, broadly corresponding to cities (si), counties (gun), and districts (gu). Provider-location codes and boundaries were harmonized to this common geographic framework across study years. These subregions represent the locations of healthcare providers and were not newly derived functional healthcare regions based on observed patient flows.

We used Korea's 17 first-level administrative regions for regional descriptions and secondary analyses. For descriptive comparisons and Theil decomposition, we grouped them into the capital region (Seoul, Incheon, Gyeonggi), non-capital major cities (Busan, Daegu, Gwangju, Daejeon, Ulsan, Sejong), and eight non-capital provinces. Sejong, a special self-governing city, was included among major cities for descriptive purposes. These categories distinguish the capital region from other major-city jurisdictions and provinces encompassing both urban and rural areas; they do not represent socioeconomic deprivation or a uniform urban–rural classification.

The primary geographic anchor was the location of the healthcare institution where the service was delivered. Estimated residence constituted a separate geographic anchor and was used only in the

secondary analysis examining ecological correspondence between post-acute provider-side rehabilitation service density and observed regional rehabilitation use.

Analytic Methods

National service profile and provider-area rehabilitation service density

For 2023, the national profile of inpatient specialized rehabilitation was summarized separately for the acute-care and post-acute stages using the number of patients and inpatient episodes, the number and proportion of patients receiving any specialized rehabilitation, the number and proportion of inpatient episodes with specialized rehabilitation, total specialized rehabilitation minutes, and specialized rehabilitation minutes per 100 inpatient days. Because the same patient could contribute multiple inpatient episodes within a care stage, patients were counted uniquely within each stage.

In the primary 2023 provider-side analysis, rehabilitation service density for subregion a and inpatient care stage s was defined as

$$SD_{as} = 100 \times \frac{\sum_{e} M_{eas}}{\sum_{e} D_{eas}}$$

where M_{eas} denotes specialized rehabilitation minutes allocated to inpatient episode e at providers located in subregion a and care stage s between January 1 and December 31, 2023, and D_{eas} denotes the corresponding inpatient days.

The unit, specialized rehabilitation minutes per 100 inpatient days, is a scaling convention, not 100 days of follow-up. All inpatient days, including those without specialized rehabilitation, contributed to the denominator. Service density describes specialized rehabilitation relative to total inpatient activity at area providers. It does not measure intensity per treated patient, physical capacity, population-based availability, potential spatial accessibility, or fulfillment of local residents' rehabilitation needs.

First-level regional density used the same ratio of summed rehabilitation minutes to summed inpatient days across providers, rather than the mean of subregional densities. Primary analyses included only subregion–care-stage cells with estimable minutes and positive inpatient days under disclosure rules. Cells excluded under the study-specific minimum-count criterion described below were treated as non-estimable rather than as true zeros.

Distributional inequality and geographic-scale decomposition

The distribution of rehabilitation service density across estimable provider areas was summarized using the unweighted median and interquartile range. Distributional inequality across subregions was

assessed using Gini coefficients and Theil T indices, both calculated from untransformed service-density values and weighted by inpatient days. Higher values indicate greater inequality in rehabilitation service density across areas. True zero-density areas were retained; their contribution to the Theil T index was defined as zero.

We ranked estimable areas by service density, selected the highest-density 10% of areas (rounding the area count upward), and calculated their share of all retained specialized rehabilitation minutes. The top decile was therefore selected by density, not total volume.

The inpatient-day-weighted Theil T index was decomposed into between-category and within-category components for the three broad regional categories. The within-category component weighted each category-specific Theil index by that category's share of retained rehabilitation minutes; the between-category component reflected differences in category-level mean service density. The two components sum to the total index.

Spatial clustering

Distributional inequality and spatial clustering were prespecified as distinct: Gini and Theil indices describe the distribution of density values, whereas spatial autocorrelation assesses their arrangement across neighboring areas.

For spatial analyses, boundaries were transformed to KGD2002 / Unified CS (EPSG:5179), and a representative point on the surface of each subregional polygon was generated. Spatial-weight matrices were constructed separately for the acute-care and post-acute stages using only provider areas with estimable service density in the corresponding stage.

The primary neighborhood structure was a symmetric eight-nearest-neighbor graph (KNN8), constructed by connecting each representative point to its eight nearest neighbors using projected-coordinate distances and symmetrizing the neighbor relationships. For Global Moran's I, spatial weights were row-standardized. Because the service-density distribution was right-skewed, we applied a log(1 + SD) transformation to reduce the influence of extreme high values in the primary spatial autocorrelation analyses.

Global spatial autocorrelation was assessed using Global Moran's I [17]. Statistical significance was evaluated using 9,999 Monte Carlo permutations with a one-sided alternative for positive spatial autocorrelation.

Local spatial clustering was assessed using the standardized Getis–Ord G_i^* statistic [18]. A binary spatial-weight structure based on KNN8 neighbors plus the focal area itself was used. Under total randomization, the transformed density values were permuted across all areas while the spatial-weight structure was held fixed. Two-sided p values were calculated from 9,999 permutations by comparing absolute permuted and observed statistics, with one added to both the exceedance count and the

number of permutations. The Benjamini–Hochberg false-discovery-rate (FDR) procedure was applied across the local tests within each care stage and analytic specification [19, 20]. Areas with an FDR-adjusted q < 0.05 and a positive z score were classified as hotspots, whereas those with an FDR-adjusted q < 0.05 and a negative z score were classified as coldspots.

Because the numbers of estimable areas differed between stages, a common-support sensitivity analysis used the same geographic support and spatial-weight structure for both stages. Neither comparison was interpreted as a formal statistical test of the difference between the two Moran's I statistics.

Secondary ecological correspondence with estimated-residence-based rehabilitation use

The secondary ecological analysis comprised valid transfer blocks entering post-acute care in 2023 with administratively complete observation through day 180, as defined above. This requirement concerns the available calendar observation period, not survival or uninterrupted hospitalization for 180 days. Transfer blocks, rather than patients, were the observation unit because patients could contribute temporally distinct blocks.

Registered or actual addresses were unavailable. Residence was estimated across the 17 first-level regions from full-period utilization: the modal region of clinic or dental-clinic outpatient visits, then hospital-level or higher outpatient visits if the first source was unavailable, and finally the region with greatest cumulative inpatient stay if outpatient data were insufficient. Low modal-region dominance triggered a separate ambiguity flag. Estimated residence is thus a utilization-derived proxy, not registered or actual residence.

For region r, inpatient rehabilitation receipt was defined as

$$\mathrm{Receipt}_r = 100 \times \frac{N_{r,\mathrm{rehab}>0}}{N_{r,\mathrm{complete180}}}$$

where $N_{r,\mathrm{complete180}}$ is the number of transfer blocks assigned to estimated resident region r with complete 180-day calendar observation after post-acute entry, and $N_{r,\mathrm{rehab}>0}$ is the number of those blocks with any inpatient specialized rehabilitation during the 180-day period. This measure represents the proportion of observed post-acute inpatient entrants receiving any inpatient specialized rehabilitation, not the rehabilitation utilization rate of the entire regional population or access among all acute-care discharges.

The share of rehabilitation minutes delivered outside estimated residence was defined as

$$\mathrm{Nonlocal}_r = 100 \times \frac{\sum_b M_{br}^{\mathrm{outside}}}{\sum_b M_{br}^{\mathrm{total}}}$$

where $M_{br}^{outside}$ denotes rehabilitation minutes delivered outside the estimated resident region for transfer block b assigned to region r, and M_{br}^{total} denotes all inpatient specialized rehabilitation minutes delivered during the corresponding 180-day observation period. This measure was calculated after aggregating rehabilitation minutes across transfer blocks within each estimated resident region; it was not the mean of block-level nonlocal-use proportions.

Spearman correlations across 17 regions assessed post-acute service density against rehabilitation receipt and outside-estimated-residence minute share. Each region contributed one observation, and two-sided p values used an asymptotic approximation rather than an exact test. Density was anchored to provider location; use measures had estimated-residence anchors and different denominators. Associations were interpreted descriptively and ecologically, not as individual causal effects on receipt or nonlocal use.

Sensitivity analyses

Sensitivity analyses evaluated the robustness of the main findings across temporal windows, spatial specifications, analytic samples, disclosure handling, residence definitions, and regional associations.

Temporal stability was assessed over common January–November windows in 2022–2024 using the primary national-profile and inpatient-day-based service-density definitions. Separate annual spatial analyses used monthly mean specialized rehabilitation minutes per 100,000 population; this population-normalized measure was used to assess annual local-cluster persistence and did not replace primary service density. Areas classified as both hotspots and coldspots across years were labeled mixed/variable. Otherwise, same-direction clusters identified in at least two years were classified as persistent, and those identified in only one year as intermittent.

Spatial robustness analyses tested KNN6, KNN10, and queen contiguity alongside primary KNN8, with log1p, rank, and raw-value transformations (9,999 permutations for the primary specification; 1,999 for alternatives). Common-support analyses used the same 165 estimable subregions and one symmetric KNN8 graph for both stages. Disclosure sensitivity assessed the shares of national rehabilitation minutes and episodes retained in exported data. Supplementary population-normalized analyses compared lower-bound zero assignment for non-exported areas with estimates restricted to exported cells.

We repeated density and clustering analyses among transfer blocks involving acute-care surgery or intensive care unit admission. This restriction assessed acute-care medical-use intensity, not clinical rehabilitation need or eligibility. Residence-definition analyses, separate from the 2023 ecological analysis, used the pooled validated 2022–2024 complete-180-day transfer-block set, either excluding ambiguous residence assignments or restricting residence estimation to clinic/dental-clinic outpatient modes with dominance ≥ 0.40. The 2023 pathway-scope analysis compared all valid post-acute pathways with forward acute-to-post-acute pathways only.

Robustness of regional associations was assessed using age-adjusted partial rank correlations and leave-one-region-out analyses. Regional proportions of residents aged ≥ 65 and ≥ 75 years were calculated from 2023 resident-registration population data for the 17 first-level administrative regions. For the association between post-acute service density and outside-estimated-residence rehabilitation minute share, partial rank correlations controlled separately for regional proportions aged ≥ 65 and ≥ 75 years. All three variables were ranked using average ranks for ties; residuals from separate regressions of ranked density and ranked outside-residence share on ranked age proportion were then correlated. Two-sided p values used a t approximation with n − 3 degrees of freedom. Leave-one-region-out analyses sequentially excluded each of the 17 regions and recalculated both secondary Spearman correlations.

Disclosure control, statistical software, and ethics

Data preparation, episode and transfer-block reconstruction, care-stage classification, rehabilitation-minute calculation, and aggregate exports used SAS 9.4 within secure HIRA facilities. Patient and provider identifiers were not exported.

For the exported provider-area data, a conservative minimum-count criterion was applied at the subregion–care-stage level. Cells were retained only when both total patient and inpatient-episode counts were at least five and, where nonzero, the corresponding counts of patients and episodes with specialized rehabilitation were also at least five. Cells not meeting these criteria were excluded from the primary analyses and treated as non-estimable rather than as true zeros.

Spatial-data processing, statistical analyses, and production of tables and figures were performed in R version 4.5.1. The sf package was used for spatial-data processing and spdep for spatial weights and Global Moran's I analyses; weighted inequality measures, Theil decomposition, and the local G_i^* permutation procedure were implemented in custom R functions. Reproducible fixed random seeds were used for permutation analyses. Statistical significance was defined at $p < 0.05$, with BH-adjusted q values used for local cluster classification. Global Moran's I used one-sided tests for positive spatial autocorrelation, whereas local clustering and regional correlation analyses used two-sided tests.

Ethics approval

, waiver of informed consent, and HIRA data-use authorization are reported in the Declarations section.

AI-assisted manuscript preparation

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) for English-language editing and refinement of the manuscript text. After using this tool, the authors reviewed and edited the content as necessary and take full responsibility for the content of the published article.

Results

National inpatient specialized rehabilitation profile

In 2023, the acute-care stage included 4,573,479 patients and 6,679,996 inpatient episodes. Of these, 120,669 patients (2.6%) and 136,176 episodes (2.0%) had any inpatient specialized rehabilitation. The post-acute stage included 380,862 patients and 488,866 inpatient episodes, of which 63,866 patients (16.8%) and 76,884 episodes (15.7%) had specialized rehabilitation. Total claims-derived specialized rehabilitation time was 21.33 million minutes in the acute-care stage and 29.63 million minutes in the post-acute stage. National rehabilitation service density was 49.5 and 157.8 specialized rehabilitation minutes per 100 inpatient days, respectively (Table S2). Patients could contribute to both stages; these counts therefore do not describe mutually exclusive cohorts.

Regional and subregional variation in provider-side rehabilitation service density

In 2023, rehabilitation service density was estimable for 167 subregional provider areas in the acute-care stage and 237 in the post-acute stage. Median subregional service density was 37.4 specialized rehabilitation minutes per 100 inpatient days (interquartile range [IQR], 17.6–60.5) in acute care and 78.8 (IQR, 0.0–176.8) in post-acute care (Table 1). The disclosure-safe subregional data retained 99.992% and 99.999% of national specialized rehabilitation minutes, respectively (Table S3). Rehabilitation service density varied across both first-level regions and subregional provider areas in both care stages (Fig. 2). Variation was also evident among subregions within each of the three broad regional categories (Table S4; Figure S1). In post-acute care, the median subregional service density was 1.0 minute per 100 inpatient days (IQR, 0.0–79.0) in non-capital provinces, compared with 159.9 (97.3–223.8) in the capital region and 150.1 (70.4–209.4) in non-capital major cities (Table S4).

Table 1
Provider-area variation, distributional inequality, and spatial clustering of inpatient specialized rehabilitation, 2023

Measure	Acute-care stage	Post-acute stage
Provider service density		
Provider areas with estimable service density, n	167	237
Specialized rehabilitation minutes / 100 inpatient days, median (IQR)	37.4 (17.6–60.5)	78.8 (0.0–176.8)
Inpatient-day-weighted Gini coefficient	0.350	0.336
Inpatient-day-weighted Theil index	0.218	0.205
Service-volume concentration		
Share of retained rehabilitation minutes delivered in highest-density 10% of provider areas, %	19.9	30.8
Broad regional-category decomposition		
Between-category share of weighted Theil, %	3.1	6.8
Within-category share of weighted Theil, %	96.9	93.2
Spatial organization		
Global Moran's I (permutation p value)	0.017 (0.232)	0.244 (< 0.001)
FDR-significant hotspots, n	0	3
FDR-significant coldspots, n	1	11
Primary provider reference window: January-December 2023.		
The reference geography contains 250 harmonized subregional provider areas; service-density summaries use only cells with estimable provider inpatient activity.		
Service density is specialized rehabilitation minutes per 100 inpatient days. Gini and Theil statistics are weighted by provider inpatient days.		
For the top-decile concentration measure, provider areas are ranked by service density before the share of retained rehabilitation minutes is calculated.		
Abbreviations: FDR, false discovery rate; IQR, interquartile range.		

Distributional inequality and spatial clustering

The inpatient-day-weighted Gini coefficient for subregional service density was 0.350 in the acute-care stage and 0.336 in the post-acute stage, while the corresponding weighted Theil T indices were 0.218

and 0.205. Thus, distributional inequality was numerically similar in magnitude across the two care stages. The share of retained specialized rehabilitation minutes delivered in the highest-density 10% of provider areas was nevertheless higher in post-acute care: 30.8%, compared with 19.9% in acute care (Table 1).

Between-category differences across the capital region, non-capital major cities, and non-capital provinces accounted for 3.1% of total Theil T inequality in the acute-care stage and 6.8% in the post-acute stage. The remaining 96.9% and 93.2%, respectively, were attributable to differences among subregions within the same broad regional category (Table 1; Table S5).

Positive global spatial autocorrelation was detected for post-acute service density (Moran's I = 0.244, $p < 0.001$), but not for acute-care density (Moran's I = 0.017, p = 0.232), under the primary specification. In the FDR-adjusted local Getis–Ord G_i^* analysis, no hotspots and one coldspot were identified in the acute-care stage, compared with 3 hotspots and 11 coldspots in the post-acute stage (Table 1; Fig. 3). Numerically similar weighted inequality indices thus coexisted with different observed clustering patterns.

Temporal stability

Annual comparisons for 2022–2024 used the common January-through-November observation window available in all three years. National rehabilitation service density in the acute-care stage was 47.2, 49.3, and 46.8 minutes per 100 inpatient days in 2022, 2023, and 2024, respectively, remaining broadly stable across years. Corresponding post-acute service density was 155.6, 157.5, and 172.9 minutes per 100 inpatient days (Table S6). Annual small-area distributions are shown separately in Figure S2.

Supplementary annual spatial analyses using monthly specialized rehabilitation minutes per 100,000 population under the 250-area lower-bound specification showed higher Global Moran's I values in post-acute than acute care across the examined spatial weights and raw, rank, and log1p transformations (Figure S3). In observed-cell analyses using the population-normalized provider measure, Global Moran's I in acute care was − 0.001 (p = 0.435) in 2022, − 0.016 (p = 0.603) in 2023, and − 0.017 (p = 0.612) in 2024, whereas the corresponding post-acute values were 0.215, 0.219, and 0.220, with $p < 0.001$ in all three years (Table S7). In the population-normalized annual local-cluster analysis, which used the 250-area lower-bound specification, no significant clusters were identified in acute care, whereas 21 post-acute subregions were classified as persistent coldspots and 3 as persistent hotspots (Table S8; Figure S4).

Secondary ecological correspondence with estimated-residence-based rehabilitation use

Substantial regional variation was observed in both post-acute provider-side service density and estimated-residence-based rehabilitation use across the 17 first-level administrative regions (Table 2). Post-acute service density ranged from 2.5 minutes per 100 inpatient days in Sejong to 218.9 in Daejeon.

The proportion of eligible post-acute transfer blocks with any inpatient specialized rehabilitation within the complete 180-day observation window ranged from 8.7% in Gwangju to 18.9% in Daegu. The share of rehabilitation minutes delivered outside estimated residence ranged from 8.4% in Daejeon to 99.5% in Sejong. Despite its low provider-side density, 13.2% of Sejong’s 1,571 eligible post-acute transfer blocks included specialized rehabilitation (Table 2).

Table 2
Regional post-acute rehabilitation service density and estimated-residence-based rehabilitation use, 2023

Estimated resident region	Provider-side service density	Estimated-residence-based use		
	Post-acute specialized rehabilitation min / 100 inpatient days	Complete 180-day blocks, n	Blocks with inpatient specialized rehabilitation within 180 days, %	Rehabilitation minutes outside estimated resident region, %
Capital region				
Seoul	168.5	52,541	17.1	31.1
Incheon	202.5	19,183	15.5	13.0
Gyeonggi	181.5	68,871	16.7	18.6
Non-capital major cities				
Busan	149.9	24,652	15.5	12.3
Daegu	204.0	17,343	18.9	8.6
Gwangju	128.6	17,464	8.7	11.1
Daejeon	218.9	9,238	16.9	8.4
Ulsan	174.7	6,336	14.1	13.9
Sejong	2.5	1,571	13.2	99.5
Non-capital provinces				
Gangwon	180.4	10,408	14.5	32.7
Chungbuk	189.8	10,001	18.2	29.5
Chungnam	109.9	15,309	13.2	50.9
Jeonbuk	113.3	22,403	11.1	24.0
Jeonnam	71.2	21,884	9.7	55.2
Gyeongbuk	109.4	18,658	14.6	46.0
Gyeongnam	136.2	23,633	14.4	26.5
Jeju	116.5	3,409	16.0	21.1

Estimated resident region	Provider-side service density	Estimated-residence-based use		
	Post-acute specialized rehabilitation min / 100 inpatient days	Complete 180-day blocks, n	Blocks with inpatient specialized rehabilitation within 180 days, %	Rehabilitation minutes outside estimated resident region, %
Capital region				
Provider-side service density is anchored to provider location and uses January-December 2023 provider activity.				
Estimated-residence-based measures use post-acute transfer blocks with complete 180-day follow-up.				
The rehabilitation receipt denominator is complete-180-day post-acute inpatient transfer blocks, not the regional population or all acute discharges.				
Outside estimated residence means outside the utilization-derived estimated resident province/metropolitan city and is not interpreted as inappropriate care.				
This table is a secondary ecological correspondence display; provider-side density and resident-side use are distinct constructs.				

At the regional level, post-acute provider-side service density was positively correlated with inpatient rehabilitation receipt (Spearman ρ = 0.723, p = 0.001) and negatively correlated with the share of rehabilitation minutes delivered outside estimated residence (ρ=−0.699, p = 0.002) (Fig. 4). After excluding Sejong, both associations remained in the same direction, with correlations of 0.709 (p = 0.002) and − 0.638 (p = 0.008), respectively. In leave-one-region-out analyses, correlations with rehabilitation receipt ranged from 0.676 to 0.768, whereas correlations with the share of rehabilitation minutes delivered outside estimated residence ranged from − 0.768 to − 0.638; all repeated analyses had p < 0.01 (Table S9).

Sensitivity analyses

The primary stage-specific pattern of global spatial autocorrelation was consistent across all 12 combinations of spatial weights and transformations, with significant positive autocorrelation detected in post-acute care but not acute care (Table S10). Restricting both stages to the same 165 subregions and shared KNN8 weights yielded Moran's I values of 0.011 (p = 0.284) in acute care and 0.134 (p < 0.001) in post-acute care (Table S11). Restriction to pathways involving acute-care surgery or intensive care unit use produced little change in global autocorrelation, but post-acute local-cluster counts increased from 3 to 16 hotspots and from 11 to 17 coldspots, indicating greater sensitivity of local classifications (Table S12; Figure S5).

Regional rehabilitation-use measures remained stable across alternative estimated-residence definitions in a separate pooled 2022–2024 sensitivity analysis (Table S13). Restricting the 2023 analysis to

forward acute-to-post-acute pathways also yielded highly concordant regional rankings for rehabilitation receipt and outside-estimated-residence minute share (Spearman ρ = 0.990 and 0.998, respectively; Table S14). The negative regional association between post-acute service density and outside-estimated-residence minute share persisted after separately accounting for regional proportions aged ≥ 65 and ≥ 75 years (partial rank ρ=−0.663 and − 0.646, respectively; Table S15).

Discussion

Principal findings

Although inpatient specialized rehabilitation varied geographically in both care stages, inpatient-day-weighted Gini and Theil T indices were numerically similar, whereas observed spatial clustering patterns contrasted. Post-acute care showed positive global spatial autocorrelation and multiple local hotspots and coldspots; acute care showed no significant positive global spatial autocorrelation and only one local coldspot under the primary specification. More than 90% of Theil T inequality arose within broad regional categories, while median post-acute service density among estimable subregions was markedly lower in non-capital provinces than in the capital region or non-capital major cities. Across 17 regions, higher post-acute provider-side density was associated with greater rehabilitation receipt and a lower share of rehabilitation minutes delivered outside estimated residence; several non-capital provinces had relatively high outside-residence minute shares. These findings highlight distributional inequality, spatial clustering, and geographic scale as complementary descriptors while distinguishing provider-side service density from estimated-residence-based use.

Distributional inequality, spatial clustering, and geographic scale

Inequality indices summarize density differences without identifying their locations [21]; spatial analyses assess the geographic clustering of similar values. The post-acute findings thus indicate not only an uneven distribution but also evidence of clustering among high- and low-density areas. Conversely, the acute-care findings do not establish spatial uniformity or independence. Similar inequality magnitudes need not imply similar service geographies.

Most inpatient-day-weighted Theil T inequality arose among subregions within the three broad regional categories, indicating substantial geographic heterogeneity that broad regional summaries cannot fully capture. Alongside this within-category variation, marked differences were also evident between regional categories: the unweighted median post-acute service density among estimable subregions was 1.0 minute per 100 inpatient days in non-capital provinces, compared with 159.9 in the capital region and 150.1 in non-capital major cities. These findings highlight two complementary dimensions of geographic variation: inequality within broad regional categories and differences in typical subregional service density between them. Earlier Korean research similarly shows that variation depends on spatial units and that finer scales can reveal discrepancies hidden at broader levels [11, 16]. Our findings extend this

scale-sensitive perspective to delivered inpatient rehabilitation, without implying that the processes generating inequality operate only locally.

Differences between acute and post-acute spatial organization

The higher national rehabilitation service density in post-acute care reflects greater recorded provision per inpatient day, not necessarily greater treatment intensity per recipient. Our pathway-defined post-acute stage spanned multiple inpatient settings, including returns to acute-care providers; the acute-care stage comprised tertiary- and general-hospital care before post-acute entry. Korean research documented rehabilitation hospitalizations across institutions among patients admitted with ischemic stroke in 2017 [6] and metropolitan concentration of selected central nervous system rehabilitation treatments in 2007, 2012, and 2017 [14]. Together with evidence of different spatial organization of specialized services across healthcare settings [22], these studies contextualize but do not explain the observed stage-specific patterns.

US research likewise found that service areas derived from post-acute rehabilitation admissions differed from acute-hospital referral regions [7]. Our study addresses a related question through stage-specific service provision on a fixed administrative geography, rather than constructing new service regions. Provider composition, workforce, beds, and patient mix are plausible contributors to the observed contrast, but their contributions were not decomposed [23]. Future studies should relate small-area specialized-provider presence and composition, beds, and personnel to actual service density.

Annual analyses using common observation windows, including separate population-normalized analyses, provided complementary evidence of recurring stage-specific patterns. Robustness was stronger for global autocorrelation than for individual local classifications: restricting pathways to those involving acute-care surgery or intensive care unit use left global Moran's I nearly unchanged, but increased the number of post-acute hotspots and coldspots. These findings support the overall spatial contrast without implying that individual cluster designations are invariant.

Secondary ecological correspondence with estimated-residence-based use

Regions with higher post-acute provider-side service density had a larger proportion of eligible post-acute transfer blocks with inpatient specialized rehabilitation and a lower share of rehabilitation minutes delivered outside estimated residence. These positive and negative associations persisted when individual regions, including Sejong, were excluded. Higher post-acute service density also remained associated with a lower outside-estimated-residence share of rehabilitation minutes after separately accounting for regional proportions aged ≥ 65 and ≥ 75 years.

These associations coexisted with considerable regional variation. Several non-capital provinces, including Jeonnam, Chungnam, and Gyeongbuk, had relatively high shares of rehabilitation minutes

delivered outside estimated residence, although this pattern was not uniform across regions. Such descriptive differences highlight the importance of examining regional variation without assuming that broad administrative categories represent homogeneous service environments.

Among US Medicare beneficiaries with stroke, combinations of locally available post-acute provider types were associated with receiving care outside the home Hospital Service Area [24]. A national study also documented care outside newly delineated Rehabilitation Service Areas [25]. These studies contextualize, rather than validate, our findings: their patient-level use measures and utilization-based service areas differ from our treatment-minute shares and first-level administrative regions.

Sejong illustrates why the two geographic anchors should be distinguished. Its very low provider-side density coexisted with rehabilitation receipt among eligible transfer blocks assigned to Sejong and the delivery of nearly all their rehabilitation minutes outside the region (Table 2). These findings illustrate that provider-side service density and estimated-residence-based rehabilitation use capture related but distinct dimensions of rehabilitation geography and should not be treated as interchangeable measures.

Implications for spatial planning and health-services monitoring

A single supply measure or broad regional average may inadequately describe specialized-service geography [3, 26]. Claims-derived specialized rehabilitation minutes per 100 inpatient days describe recorded rehabilitation provision relative to local inpatient activity, complementing information on facilities and formal coverage. Within-category inequality underscores spatial-scale selection in analysis and planning, while combined inequality and clustering measures distinguish low values from their spatial grouping among neighboring areas [27, 28].

The low median post-acute service density across non-capital provincial subregions, together with relatively high outside-estimated-residence minute shares in several provinces, identifies a pattern warranting closer regional assessment. Clusters of low-density provider areas can motivate joint service review across neighboring jurisdictions, without implying that every small area requires an independent rehabilitation facility. Planning decisions require additional evidence on clinical need, workforce and beds, travel burden, patient outcomes, and available alternatives to inpatient care [22, 29]. The relevant question is whether observed patterns represent appropriate specialization or problematic disparity, not whether provision is spatially uniform.

For health systems with nationally defined benefits, the transferable implication is to evaluate formal coverage alongside the quantity and spatial organization of services actually recorded. The Korean case illustrates why national benefit arrangements and local service organization should be considered separately when describing the geography of care [1, 22].

Strengths and limitations

A major strength of this study is the comparison of claims-derived inpatient rehabilitation provision across analytic care stages within a common 250-subregion reference framework. We also distinguished conceptually between distributional inequality and spatial clustering and used Theil decomposition to separate variation between broad regional categories from variation within them. Sensitivity analyses assessed how the observed patterns depended on geographic support, spatial specification, observation period, and pathway scope.

Several limitations should also be considered. First, the study cohort was constructed from patients who had at least one admission to a tertiary or general hospital during the study period. Patients without such an admission were outside the source cohort, and outpatient, home-based, and community-based rehabilitation were outside the inpatient service measure. The findings should not be generalized to the geography of all rehabilitation services delivered in South Korea.

Second, estimated residence was derived from healthcare utilization rather than actual addresses, and stability across alternative definitions does not establish its validity. The secondary ecological analysis was restricted to post-acute entrants with administratively complete 180-day observation and was based on only 17 regions. Associations remain susceptible to unmeasured regional factors and spatial dependence, for which correlation p values were not adjusted, and cannot support individual-level or causal inference. Outside-region rehabilitation-minute shares also do not measure travel burden or the proportion of patients who traveled.

Finally, acute-care and post-acute stages were defined by provider type and inpatient pathway rather than directly observed clinical recovery stages. The post-acute segment included subsequent returns to acute-care providers, and comparisons represented system-level service delivery rather than paired within-patient changes.

Conclusions

In South Korea, inpatient specialized rehabilitation showed substantial small-area variation within a common national financing framework. Numerically similar inpatient-day-weighted Gini and Theil T indices across acute-care and post-acute stages coexisted with different observed spatial clustering patterns, while most Theil T inequality occurred within broad regional categories. Within this heterogeneous geography, median post-acute service density among estimable subregions was markedly lower in non-capital provinces than in the capital region or non-capital major cities. At the regional level, provider-side density was associated with estimated-residence-based rehabilitation use, with relatively high shares of rehabilitation minutes delivered outside estimated residence in several provinces. These findings underscore the importance of assessing both between- and within-category geographic variation while distinguishing provider location from estimated residence. Monitoring rehabilitation geography should therefore combine measures of recorded service provision, distributional inequality, and spatial clustering without equating low service density with unmet rehabilitation need.

Abbreviations

BH: Benjamini–Hochberg

CS: coordinate system

EPSG: geodetic coordinate reference system identifier

FDR: false discovery rate

HIRA: Health Insurance Review and Assessment Service

IQR: interquartile range

KGD2002: Korean Geodetic Datum 2002

KNN: k-nearest neighbors (e.g., KNN6, KNN8, and KNN10)

SAS: SAS statistical software

SD: service density (as used in log[1 + SD])

US: United States

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of the National Evidence-based Healthcare Collaborating Agency (NECA; approval number: NECAIRB25-007-6; approval date: 8 April 2025). The requirement for individual informed consent was waived because the study used de-identified administrative claims data. Data access was approved by the Health Insurance Review and Assessment Service (HIRA; approval number: M20250626010).

Consent for publication

Not applicable. The manuscript contains no identifiable individual-level information.

Availability of data and materials

The individual-level claims data used in this study are not publicly available because they were accessed under restrictions imposed by the Health Insurance Review and Assessment Service (HIRA). Researchers may apply to HIRA for access through its established application and review procedures; access is subject to HIRA approval.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

JY: Conceptualization, Methodology, Formal analysis, Writing – original draft. ES: Investigation, Writing – review & editing. JH: Investigation, Writing – review & editing. NL: Methodology, Data curation, Writing – review & editing. SS: Methodology, Data curation, Writing – review & editing. DGS: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration.

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Figures

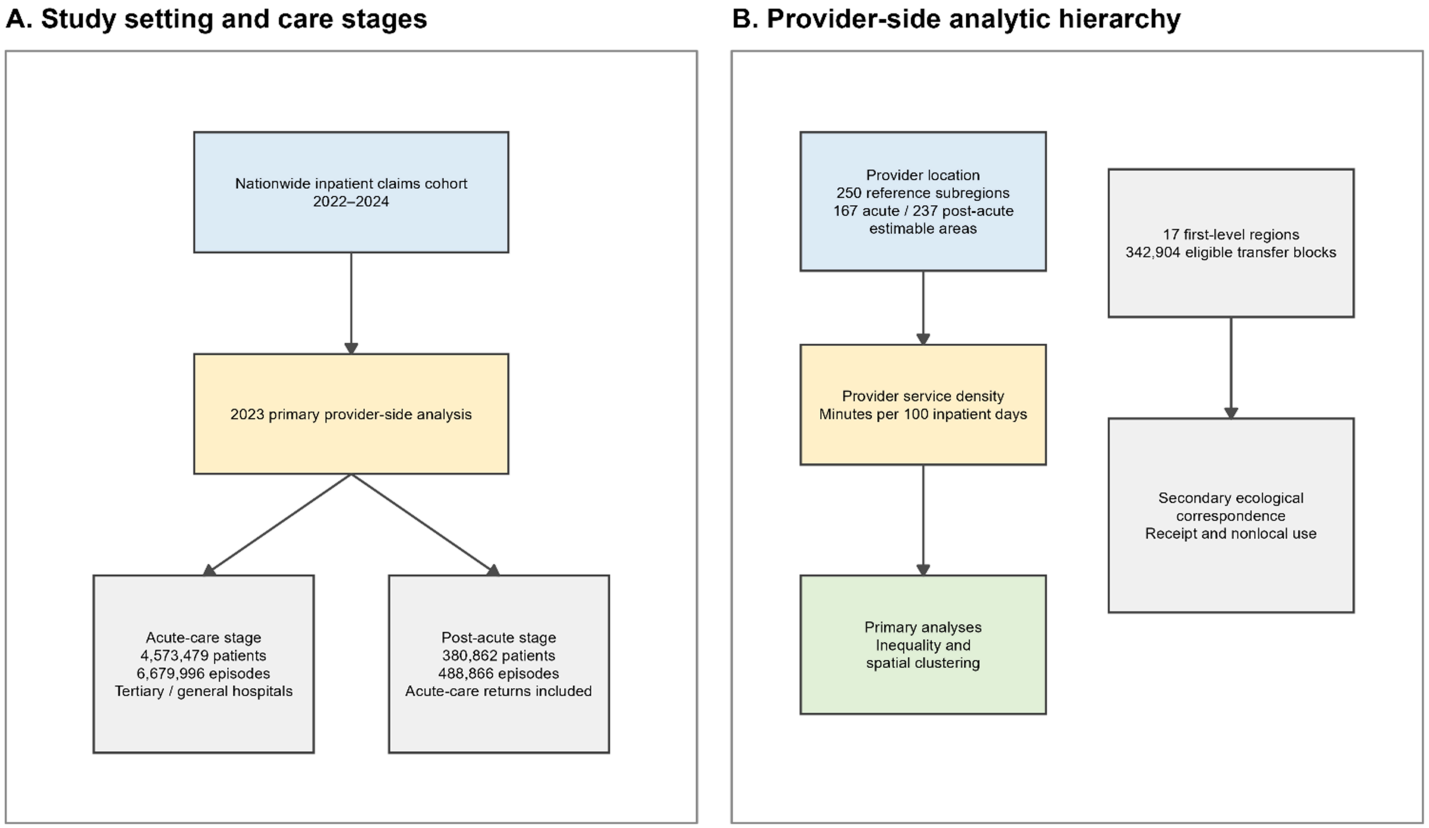


Figure 1

Study framework for provider-side rehabilitation geography.

(A) Study setting and analytic care stages in a nationwide claims cohort of patients admitted at least once to a tertiary or general hospital between January 1, 2022, and November 30, 2024. The primary provider-side analysis covered January–December 2023. Care stages were defined by provider type and inpatient pathways, not directly observed clinical recovery phases. Post-acute entry was the first admission to a non-acute provider after acute care within a transfer block; subsequent inpatient time remained in the post-acute stage, including returns to acute-care providers, within the 180-day observation window. (B) The primary analyses assessed provider-side service density, distributional inequality, and spatial clustering within a 250-subregion reference geography. Service density was defined as claims-derived specialized rehabilitation minutes per 100 inpatient days and was estimable in 167 acute-care and 237 post-acute provider areas. The 2023 acute-care stage comprised 4,573,479 patients and 6,679,996 inpatient episodes; the post-acute stage comprised 380,862 patients and 488,866 episodes. These stage-level patient groups are not mutually exclusive. The post-acute stage begins with the first non-acute inpatient entry and retains any subsequent return to an acute-care provider within that analytic segment. The separate secondary ecological analysis comprised 342,904 eligible complete-180-day transfer blocks across 17 first-level regions and compared provider-side post-acute density with rehabilitation receipt and the share of rehabilitation minutes delivered outside estimated residence.

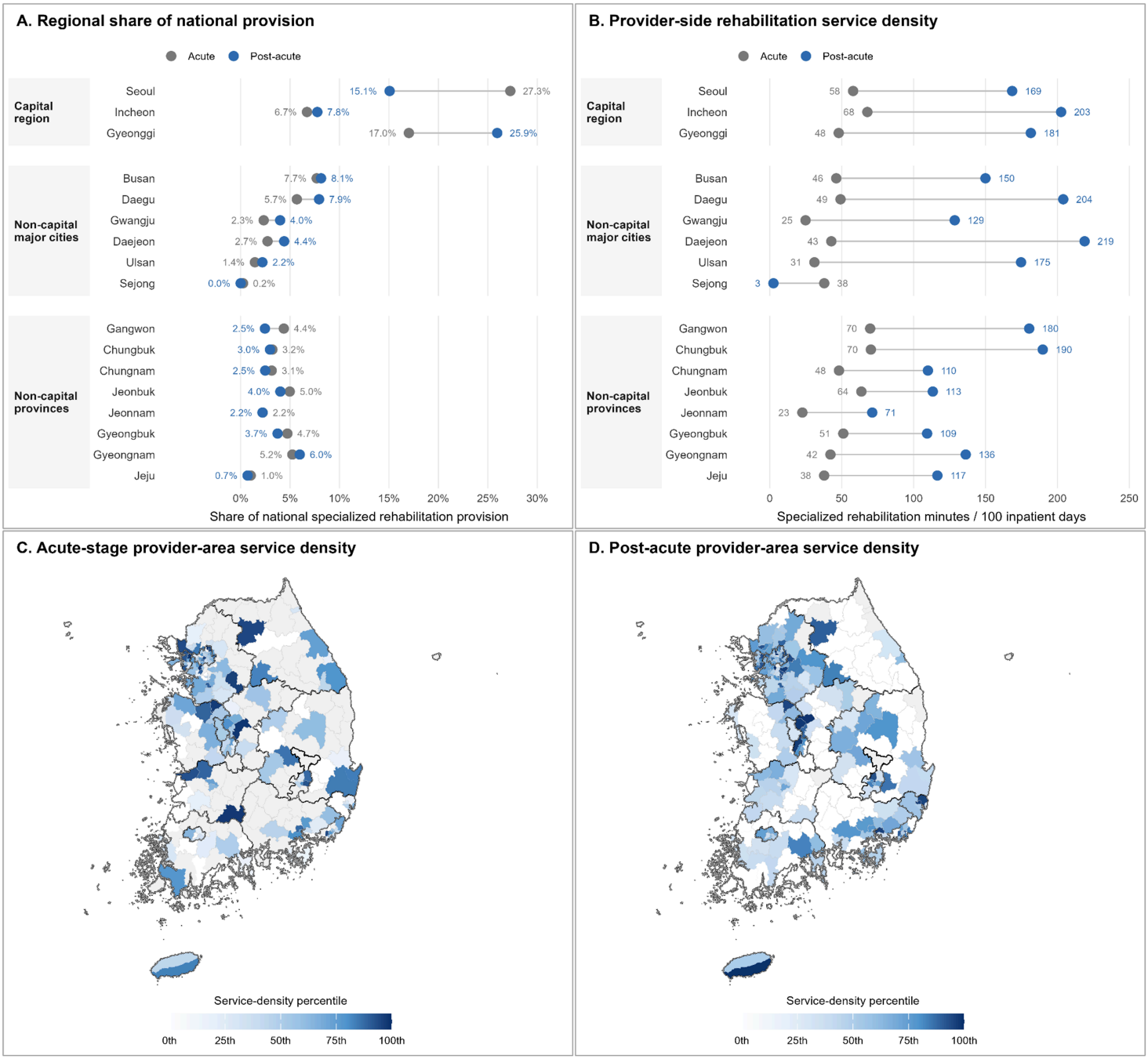


Figure 2

Provider-side geographic distribution and service density of inpatient specialized rehabilitation, 2023.

(A) Each first-level region's share of national claims-derived specialized rehabilitation minutes within the corresponding care stage and (B) regional provider-side service density, expressed as specialized rehabilitation minutes per 100 inpatient days, separately for acute-care and post-acute stages. Regional density was calculated as a ratio of summed minutes to summed inpatient days, not as a mean of subregional densities. Regions are grouped as the capital region, non-capital major cities, and non-capital provinces. Labels in panel A are rounded to one decimal place and those in panel B to whole minutes; a displayed share of 0.0% does not necessarily represent a true zero. (C–D) Service-density

percentiles among estimable provider areas in acute-care and post-acute stages, respectively. The same color does not represent the same absolute density across stages. The reference window is January–December 2023. Light grey areas are non-estimable and are not assigned zero density.

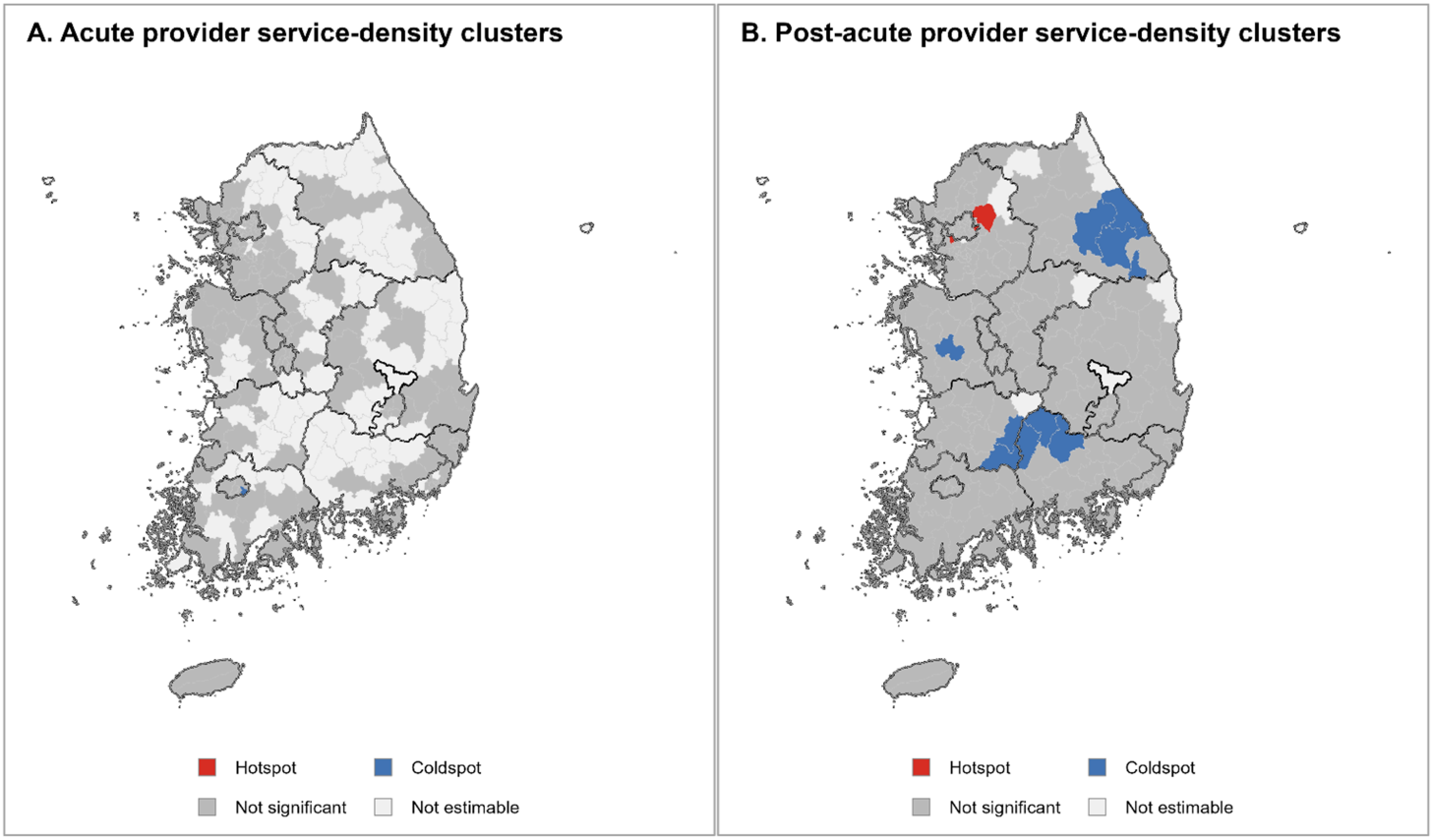


Figure 3

Local spatial clustering of provider-side rehabilitation service density, 2023.

Local Getis–Ord Gi* classifications of provider-side rehabilitation service density in (A) the acute-care stage and (B) the post-acute stage, January–December 2023. Analyses used log(1 + service density), stage-specific symmetric eight-nearest-neighbor graphs, binary weights including each focal area, and 9,999 total-randomization permutations. Two-sided permutation p values were adjusted using the Benjamini–Hochberg procedure separately within each stage. Hotspots (red) and coldspots (blue) had positive and negative standardized statistics, respectively, with adjusted $q<0.05$. Grey denotes non-significant areas and light grey denotes non-estimable areas. The analyses included 167 acute-care and 237 post-acute provider areas. Classifications describe spatial clustering under the specified neighborhood structure, not clinical need, quality, or individual access.

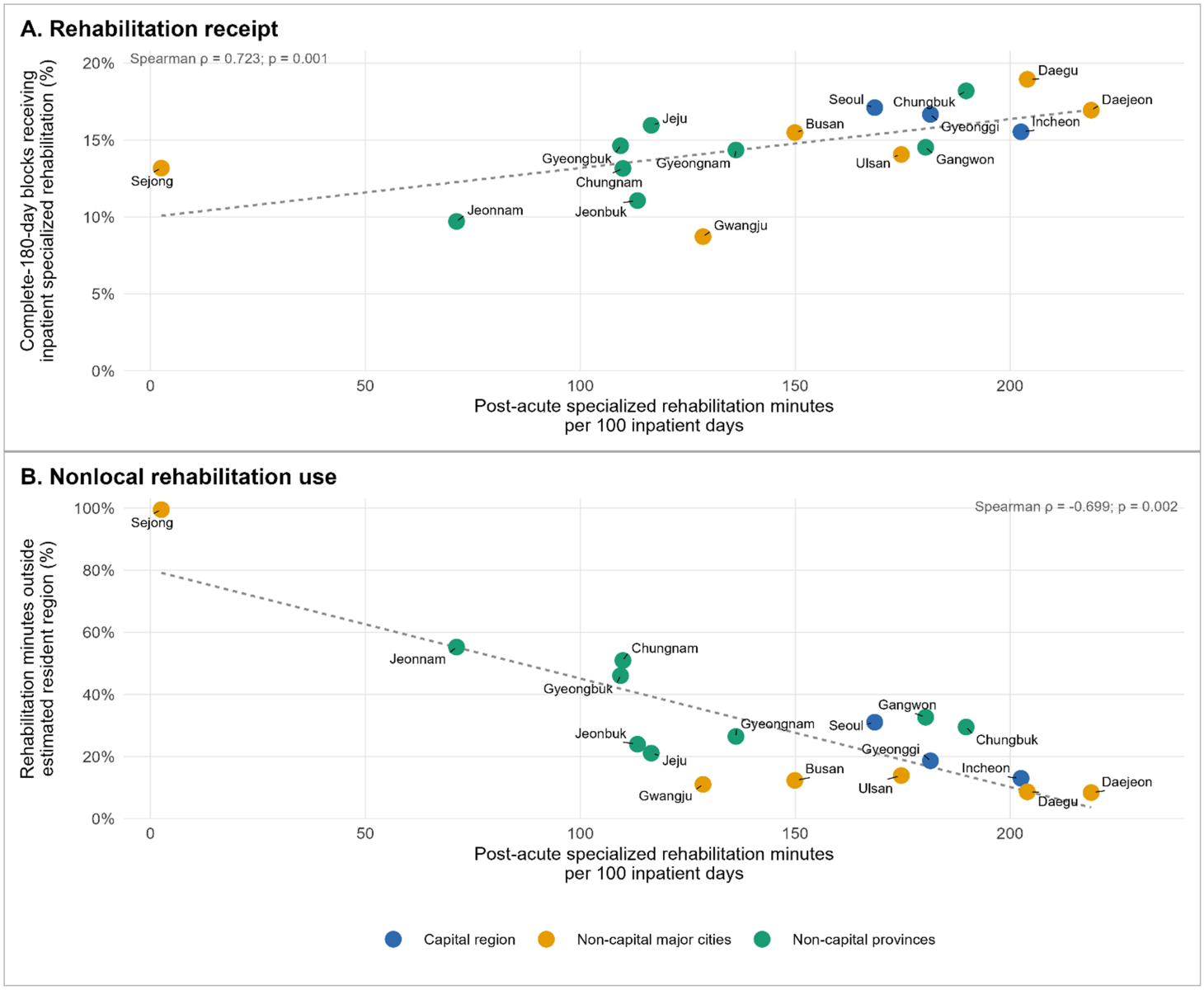


Figure 4

Secondary ecological correspondence between regional post-acute provider-side rehabilitation service density and estimated-residence-based use, 2023.

Each point represents one of 17 first-level administrative regions. The horizontal axis shows provider-side post-acute service density for January–December 2023, expressed as claims-derived specialized rehabilitation minutes per 100 inpatient days. The vertical axes show (A) the percentage of eligible transfer blocks entering post-acute care in 2023 with any inpatient specialized rehabilitation and (B) the share of their rehabilitation minutes delivered outside the estimated resident region. Use measures cover the first 180 calendar days from post-acute entry, counting entry as day 1 and including day 180, among blocks with administratively complete observation. This does not require survival or continuous hospitalization for 180 days. Panel B is a ratio of aggregated minutes, not a percentage of patients or an average of block-specific percentages. Provider-side measures use provider location; use measures use

residence estimated from healthcare utilization. Colors indicate the three broad regional categories. Reported Spearman correlations are ecological; grey dashed linear trend lines are visual guides, not the reported statistical models. The 180-day observation window is distinct from the 100-inpatient-day density unit.

Supplementary Files

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