

Changes in patient concentration and accessibility across 5 Pediatric Emergency Departments in Daegu, Korea

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Background: The coronavirus disease 2019 (COVID-19) pandemic has substantially altered Pediatric Emergency Department (PED) utilization. However, longitudinal changes across multiple PEDs after major policy transitions remain unclear.

Purpose: This study aimed to evaluate changes in utilization, patient distribution, accessibility to pediatric emergency care, and clinical characteristics across 5 participating PEDs in Daegu, Korea.

Methods: This multicenter retrospective study analyzed 140,017 visits among patients aged <16 years between January 2019 and May 2023. Concentration was assessed using monthly institutional shares and the Herfindahl-Hirschman Index (HHI), while the segmented interrupted time-series regression incorporated the Prais-Winsten correction and seasonal terms. The door-to-emergency room (door-to-ER) distance was defined as the WGS84 geodesic distance between the residential administrative-dong centroid and fixed coordinates of the visited PED. We also evaluated the Korean Triage and Acuity Scale (KTAS) score, proportion of ambulance arrivals, and Emergency Department length of stay.

Results: Median monthly population-standardized visit rates were 580.9, 315.8, and 500.1/100,000 child person-months in the pre-COVID, COVID, and post-COVID periods, respectively ($P<0.001$); the post-COVID rate did not differ significantly from the pre-COVID rate after Bonferroni adjustment. Center D's share increased from 25.7% in the pre-COVID period to 44.4% in the post-COVID period. The HHI showed no immediate level change but increased in slope after May 2022 ($\beta=0.00437/\text{mo}$; 95% confidence interval, 0.00072–0.00801; $P=0.020$). Median door-to-ER geodesic distance increased from 6.44 to 8.68 km, and visits originating ≥ 20 km away increased from 16.8% to 20.9%, with a more pronounced distance increase among Daegu residents. The proportion of KTAS level 3 visits increased from 44.9% to 60.5%, and that of KTAS

levels 1–2 from 3.0% to 4.3%.

Conclusion: These findings indicate patient redistribution across the 5 participating PEDs serving Daegu and Gyeongsangbuk-do. Visit volume recovered after the COVID period, whereas patient distribution became increasingly concentrated with longer door-to-ER distances and greater reliance on emergency medical services, suggesting reduced accessibility.

Key words: COVID-19, Pediatric Emergency Medicine, Health service accessibility, Regional healthcare system, Child

Key message

Question: Did sustained pediatric emergency department service restrictions after the coronavirus disease 2019 pandemic alter regional patient distribution and accessibility?

Finding: Pediatric emergency department visits became increasingly concentrated at specific institutions, with increased travel distance and a higher proportion of higher-acuity visits.

Meaning: Pediatric emergency care should be managed as a coordinated regional system rather than as independent institutional services.

Introduction

Emergency medical care is essential to healthcare infrastructure, providing timely evaluation and treatment for acute illness or injury. Pediatric emergency care requires age-appropriate expertise, equipment, medications, and coordinated processes to evaluate and stabilize acutely ill or injured children. Higher pediatric readiness in Emergency Departments (EDs) is linked to improved sur-

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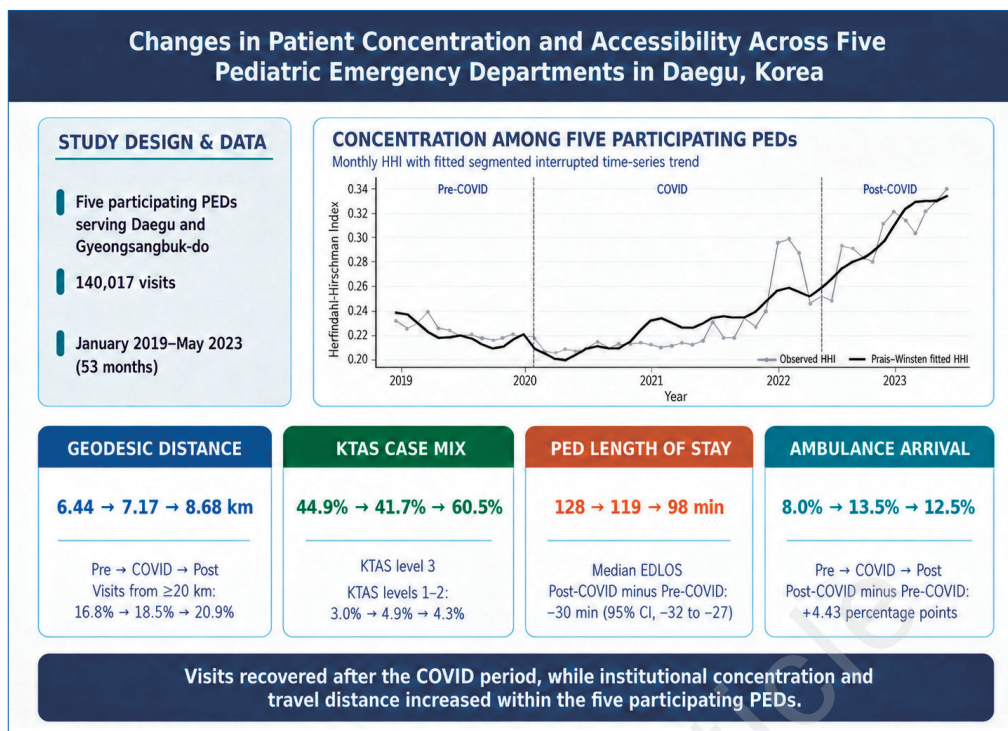
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Received: 14 July 2026, Revised: 18 August 2026, Accepted: 23 August 2026

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Graphic abstract. This multicenter retrospective study analyzed 140,017 pediatric visits to 5 PEDs from January 2019 to May 2023. Institutional distribution was assessed using the Herfindahl-Hirschman Index (HHI) and segmented interrupted time-series regression, while accessibility was evaluated by door-to-emergency room geodesic distance. Visit volume recovered after COVID-19, but increasing institutional concentration and travel distance suggested redistribution of patients and reduced accessibility to pediatric emergency care. PED, Pediatric Emergency Department; COVID-19, coronavirus disease 2019; KTAS, Korean Triage and Acuity Scale; EDLOS, Emergency Department length of stay.

vival among critically ill and injured children.^{1,2)} However, proximity to an ED does not necessarily ensure timely access to a facility equipped for high-level pediatric care and definitive acute and inpatient management.^{3–5)} Accordingly, evaluating pediatric emergency care requires consideration of individual ED availability and the regional distribution of pediatric capabilities and access to definitive care.

Efforts to strengthen pediatric emergency care in Korea include establishing designated pediatric emergency centers.⁶⁾ Although many Pediatric Emergency Department (PED) visits do not require hospitalization,⁷⁾ the emergency care system must also identify and stabilize children at risk of rapid deterioration and ensure access to definitive inpatient or critical care when needed. Thus, regional pediatric emergency care requires baseline pediatric readiness across EDs and timely access to facilities that provide definitive acute and inpatient care.^{3–5,8)}

The coronavirus disease 2019 (COVID-19) pandemic substantially altered PED utilization in Korea.^{9–16)} During the first regional outbreak in Daegu, infection-control measures, healthcare avoidance, cohort isolation, and administrative patient allocation may have influenced utilization across institutions. Declining interest in pediatrics as a specialty raises concerns about workforce

sustainability,¹⁷⁾ with some institutions reporting reduced pediatric emergency care hours.¹⁸⁾ Previous studies have focused on visit volume, demographics, acuity, and disease patterns, whereas longitudinal redistribution across multiple institutions within a single region remains poorly characterized.

Therefore, this study aimed to compare utilization patterns across 5 participating PEDs before, during, and after the COVID-19 pandemic. We examined monthly absolute visit volume, institutional shares, across the 5 institutions, accessibility to pediatric emergency care, and clinical characteristics. Inference was restricted to changes observed within the participating PEDs.

Methods

1. Patients and study design

This multicenter retrospective observational study included visits to 5 participating PEDs in Daegu, Korea, between January 1, 2019, and May 31, 2023. Eligible encounters involved patients aged <16 years who resided in Daegu Metropolitan City or Gyeongsangbuk-do, Korea. Repeated visits were considered independent encounters. After institutional review board approval, investigators at

each participating institution extracted study variables in August 2024 from institutional electronic medical records and National Emergency Department information System (NEDIS) submissions. Most variables followed NEDIS definitions and coding structures, with formats and category labels standardized across the 5 institutional datasets before integration. Extracted variables included age, sex, visit date and time, residential administrative-dong address, Korean Triage and Acuity Scale (KTAS) level, Emergency Department length of stay (EDLOS), arrival mode, and disposition.

Of 149,707 records initially screened, 9,690 were excluded for unclassifiable residence or record status ($n=2,587$), missing or invalid required data ($n=614$), residence outside Daegu Metropolitan City or Gyeongsangbuk-do ($n=6,349$), or other eligibility criteria ($n=140$). The final analysis comprised 140,017 visits (Supplementary Table 1).

We defined 3 study periods: pre-COVID (January 1, 2019–January 31, 2020), COVID (February 1, 2020–April 30, 2022), and post-COVID (May 1, 2022–May 31, 2023). February 2020 was selected because the first major Korean outbreak occurred in Daegu that month, and the national infectious disease crisis alert reached its highest level on February 23, 2020.¹⁹ May 2022 was designated as the first complete calendar month after the Korean government lifted major social-distancing restrictions on April 18, 2022.²⁰ Since these epidemiological and policy transitions likely influenced healthcare utilization, they were used to define the 3 study periods.

2. Measurement of variables

The primary measures were monthly visit volume, population-standardized monthly visit rate, institutional patient share, and visit concentration across the 5 participating PEDs. Monthly visit volume was defined as the monthly number of visits to each institution. Monthly pediatric population denominators were obtained from resident registration population statistics provided by the Ministry of the Interior and Safety.²¹ For each month, we summed the populations aged 0–15 years in Daegu Metropolitan City and Gyeongsangbuk-do. The monthly visit rate was calculated by dividing visit counts by the corresponding monthly pediatric population and expressed as visits per 100,000 child person-months. The integrated period rate was calculated as total visits divided by the summed monthly pediatric populations (child person-months), multiplied by 100,000. Institutional patient share represented the proportion of visits to each institution among all visits to the 5 participating PEDs in the corresponding calendar month or study period.

We assessed institutional concentration using the

Herfindahl-Hirschman Index (HHI), calculated as the sum of squared monthly institutional shares. Monthly concentration was also summarized using the 1-institution concentration ratio (CRI), defined as the largest institutional share; normalized HHI, calculated as $(HHI - 0.20)/0.80$; and the effective number of institutions, calculated as $1/HHI$. Since these measures are descriptive transformations of the same monthly institutional shares, temporal changes in concentration were assessed based on segmented interrupted time-series analysis of the HHI. Monthly visit volumes and institutional shares were examined to distinguish changes in relative distribution from changes in overall visit volume.

To ensure consistency in straight-line geospatial measurement, To ensure consistent straight-line (geodesic) distance measurement rather than road travel distance, geocoding was performed exclusively using the SGIS Geocoding (WGS84) OpenAPI. Residential addresses were analyzed at the administrative-dong level to achieve the greatest available spatial precision. We obtained the WGS84 coordinates of each administrative-dong centroid using the “Geocoding (WGS84)” OpenAPI provided by SGIS, Ministry of Data and Statistics, Republic of Korea.²² Each PED was assigned a prespecified fixed WGS84 coordinate used consistently throughout the study. Geocoding and distance calculations were successfully completed for all 140,017 visits in the final analytic cohort (100%). Door-to-ER distance was operationalized as the geodesic distance between the patient residential administrative-dong centroid and the fixed reference coordinate of the visited PED. Distances were calculated on the WGS84 ellipsoid using Python's pyproj.

We analyzed KTAS levels 1–2, level 3, and levels 4–5 separately because of differences in severity and resource requirements.^{23,24} Disposition was categorized as discharge, admission, transfer, or other/death. Ambulance arrival included transport by a 119 ambulance, hospital ambulance, other ambulance service, or air transport, and its proportion was compared across the study periods. EDLOS was defined as the time from ED arrival to ED departure, measured in minutes.

3. Statistical analysis

Continuous variables were summarized as medians with interquartile ranges, and categorical variables as frequencies and percentages. Study periods were compared using the Kruskal-Wallis test for continuous or ordinal variables and the chi-square test for categorical variables. Monthly population-standardized visit rates and door-to-ER distances were compared across the 3 periods using the Kruskal-Wallis test, followed by pairwise Mann-Whitney *U* tests with Bonferroni adjustment when the

overall test was significant. Distance-category distributions and the proportion of visits originating at least 20 km from the visited PED were compared using Pearson chi-square tests, with Cramér V reported as the effect size.

Distance analyses were repeated after stratification by residence in Daegu Metropolitan City versus Gyeongsangbuk-do. The overall distribution of visits across the 5 institutions was compared among the 3 study periods using a single 3×5 chi-square test. Separate tests of individual institutional shares were not performed because the 5 shares were mutually dependent and summed to 100%. Institution-specific KTAS distributions (levels 1–2, level 3, and levels 4–5) were compared across periods using chi-square tests, with Cramér V reported as the effect size. For direct post-COVID versus pre-COVID comparisons, effect sizes for KTAS categories, ambulance arrival, admission, and transfer were expressed as absolute percentage-point differences with 95% confidence intervals (CIs) calculated using the Newcombe hybrid-score method. The EDLOS effect was expressed as the difference in sample medians with a 95% percentile bootstrap CI based on 5,000 independent resamples. Rank-biserial correlation with an asymptotic CI was reported as a supplementary standardized effect size. Monthly HHI was analyzed using segmented interrupted time-series regression, with interruptions at February 2020 and May 2022. The model included continuous monthly time, indicators for each interruption, postinterruption slope terms, and paired sine and cosine terms representing annual and semiannual seasonality. First-order serial correlation was addressed using Prais-Winsten estimation. Model adequacy was assessed using the Durbin-Watson statistic and Ljung-Box tests of transformed residuals. Seasonal terms were

jointly assessed using a Wald test, and sensitivity analyses used models with 0 or 1 Fourier harmonic. Statistical analyses were performed using IBM SPSS Statistics ver. 26.0 (IBM Corp., USA) and Python ver. 3.14.8. Descriptive and comparative analyses were conducted using SPSS, whereas interrupted time-series analyses were performed in Python. All tests were 2-sided, with $P < 0.05$ considered statistically significant; Bonferroni-adjusted $P < 0.0167$ was used for each family of 3 pairwise comparisons.

4. Ethical statement

The study protocol was reviewed and approved by the Daegu Joint Institutional Review Board (IRB), which oversees the 5 participating hospitals (IRB No. 2023-07-002). The requirement for individual informed consent was waived because of the retrospective study design. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Results

1. Baseline characteristics

Of 149,707 records screened, 9,690 were excluded, leaving 140,017 visits: 47,399 during the 13-month pre-COVID period, 51,990 during the 27-month COVID period, and 40,628 during the 13-month post-COVID period. Mean monthly visit volumes were 3,646, 1,926, and 3,125, respectively. The corresponding population aged 0–15 years totaled 8,532,084, 16,749,762, and 7,634,243 person-months, yielding integrated period rates of 555.5, 310.4, and 532.2 visits per 100,000 child person-months, respectively. Median monthly visit rates were 580.9

Table 1. Characteristics of visits to the 5 participating PEDs by study period

Characteristic	Pre-COVID (n=47,399)	COVID (n=51,990)	Post-COVID (n=40,628)	P value	Cramér V
Mean monthly visit volume (n)	3,646	1,926	3,125	NA	NA
Population-standardized monthly visit rate per 100,000 child person-months	580.9 (518.8–628.6)	315.8 (270.4–357.1)	500.1 (458.1–574.7)	<0.001	NA
Age (mo)	38 (16–79)	41 (17–91)	39 (16–84)	<0.001	NA
Sex				<0.001	0.012
Male	27,144 (57.3)	30,173 (58.0)	23,011 (56.6)		
Female	20,255 (42.7)	21,817 (42.0)	17,617 (43.4)		
Disposition				<0.001	0.027
Admission	6,487 (13.7)	8,005 (15.4)	5,433 (13.4)		
Discharge	40,336 (85.1)	43,359 (83.4)	34,779 (85.6)		
Transfer	482 (1.0)	378 (0.7)	325 (0.8)		
Other/death	94 (0.2)	248 (0.5)	91 (0.2)		

Values are presented as median (interquartile range) or number (%).

PED, Pediatric Emergency Department; COVID, coronavirus disease; IQR, interquartile range; KTAS, Korean Triage and Acuity Scale; NA, not applicable.

Age and monthly population-standardized visit rates were compared using the Kruskal-Wallis test. Pairwise visit-rate comparisons were performed using Mann-Whitney *U* tests with Bonferroni adjustment. Categorical variables were compared using the chi-square test. Effect size was assessed using Cramér V. The population-standardized rate denominator was the corresponding monthly resident registration population aged 0–15 years in Daegu Metropolitan City and Gyeongsangbuk-do. The population denominator excluded foreign residents.

Boldface indicates a statistically significant difference with $P < 0.05$.

(518.8–628.6), 315.8 (270.4–357.1), and 500.1 (458.1–574.7) visits per 100,000 child person-months for the pre-COVID, COVID, and post-COVID periods, respectively (Kruskal-Wallis $H=34.382$, $P<0.001$). Pairwise comparisons were significant for pre-COVID versus COVID and COVID versus post-COVID (both Bonferroni-adjusted $P<0.001$), but not for pre-COVID versus post-COVID (adjusted $P=1.000$). Thus, the decline during the COVID period and subsequent recovery remained evident after accounting for the declining pediatric population (Table 1). Median age was 38 (16–79), 41 (17–91), and 39 (16–84) months for the pre-COVID, COVID, and post-COVID periods, respectively ($P<0.001$).

2. Concentration of patient distribution

The distribution of visits across the 5 participating PEDs differed significantly across the 3 study periods ($\chi^2=6,559.03$, $df=8$, $P<0.001$) (Table 2). During the pre-COVID period, institutional shares ranged from 9.9% at center C to 27.7% at center B. During the post-COVID period, center D accounted for 44.4% of all visits. In contrast, the shares of centers C and E decreased from 9.9% and 19.3% to 4.0% and 10.1%, respectively. The post-COVID shares of centers A and B were 18.6% and 22.9%, respectively (Fig. 1).

All monthly concentration measures indicated greater institutional concentration during the post-COVID period. Median monthly HHI increased from 0.222 to 0.304, median CR1 from 0.289 to 0.446, and median normalized HHI from 0.027 to 0.131, whereas the median effective number of institutions decreased from 4.51 to 3.29 (Table

2). Monthly HHI ranged from 0.206 in April 2020 to 0.341 in May 2023. In the seasonally adjusted Prais-Winsten model, neither the immediate level change in February 2020 ($\beta=-0.0102$; 95% CI, -0.0373 to 0.0170; $P=0.455$) nor that in May 2022 ($\beta=0.0064$; 95% CI, -0.0193 to 0.0321; $P=0.618$) was statistically significant. However, the HHI

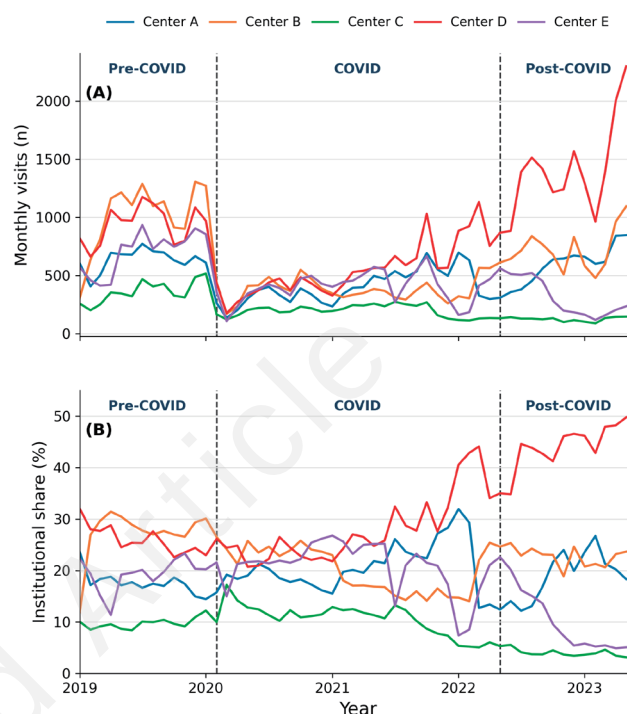


Fig. 1. Monthly visit volumes and institutional shares across the 5 participating Pediatric Emergency Departments. (A) Monthly visit volume for each institution. (B) Monthly institutional share among the 5 participating institutions. COVID, coronavirus disease.

Table 2. Distribution and concentration of visits among the 5 participating PEDs

(A) Institutional distribution

Institution	Pre-COVID	COVID	Post-COVID
Center A	8,243 (17.4)	10,861 (20.9)	7,577 (18.6)
Center B	13,143 (27.7)	10,196 (19.6)	9,305 (22.9)
Center C	4,670 (9.9)	5,302 (10.2)	1,616 (4.0)
Center D	12,197 (25.7)	14,858 (28.6)	18,040 (44.4)
Center E	9,146 (19.3)	10,773 (20.7)	4,090 (10.1)
Total	47,399 (100)	51,990 (100)	40,628 (100)

(B) Monthly volume and concentration

Monthly metric	Pre-COVID	COVID	Post-COVID
Total visits	3,823 (3,379–4,106)	1,976 (1,698–2,168)	2,947 (2,692–3,368)
CR1	0.289 (0.277–0.301)	0.265 (0.255–0.305)	0.446 (0.427–0.466)
HHI	0.222 (0.220–0.227)	0.215 (0.212–0.229)	0.304 (0.284–0.321)
Normalized HHI	0.027 (0.025–0.033)	0.018 (0.015–0.036)	0.131 (0.105–0.152)
Effective no. of institutions	4.51 (4.41–4.55)	4.66 (4.37–4.72)	3.29 (3.11–3.52)

The values in panel A are institution-specific totals and proportions calculated for each study period. The metrics in panel B are calculated separately for each calendar month and are presented as the median (interquartile range).

PED, Pediatric Emergency Department; COVID, coronavirus disease; CR1, 1-institution concentration ratio; HHI, Herfindahl-Hirschman Index.

The overall institutional distribution differed across the 3 periods ($\chi^2=6,559.03$, $df=8$, $P<0.001$).

The effective number of institutions is the reciprocal of the HHI and represents the equivalent number of equally sized institutions. However, this measure does not represent the actual number of operating or available institutions. The percentages may not total exactly 100.0% because of rounding.

slope increased after May 2022 ($\beta=0.00437$ HHI units/mo; 95% CI, 0.00072–0.00801; $P=0.020$), indicating a gradual increase in concentration rather than an abrupt change at the start of the post-COVID period. The annual and semiannual seasonal terms were not jointly significant (Wald $\chi^2=4.81$, $df=4$, $P=0.308$). The Durbin-Watson statistic for the transformed residuals was 1.74. Ljung-Box tests showed no residual autocorrelation at lag 6 ($P=0.244$), although a mild residual signal remained at lag 12 ($P=0.042$). The positive post-COVID slope change remained significant in sensitivity models with fewer seasonal terms ($\beta=0.00416$ – 0.00457 /mo; $P=0.016$ – 0.025) (Fig. 2; Supplementary Table 2).

3. Changes in door-to-ER distance

Median door-to-ER geodesic distance increased from 6.44 km (interquartile range [IQR], 2.74–13.63 km) in the pre-COVID period to 7.17 km (IQR, 3.16–15.02 km) during the COVID period and 8.68 km (IQR, 3.72–16.80 km)

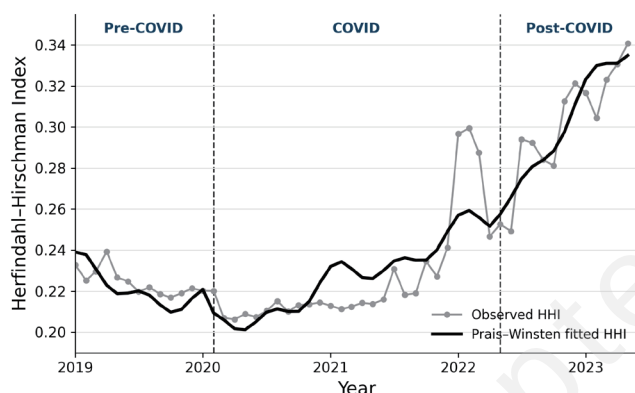


Fig. 2. Monthly Herfindahl-Hirschman Index and fitted segmented interrupted time-series trend across 5 participating Pediatric Emergency Departments. COVID, coronavirus disease; HHI, Herfindahl-Hirschman Index.

during the post-COVID period (Kruskal-Wallis $H=863.58$, $P<0.001$). All pairwise comparisons remained significant after Bonferroni adjustment (all adjusted $P<0.001$). The proportion of visits originating at least 20 km from the visited PED increased from 16.8% in the pre-COVID period to 18.5% during the COVID period and 20.9% during the post-COVID period ($P<0.001$; Cramér $V=0.042$), whereas the proportion originating within 5 km decreased from 40.6% to 37.5% and 33.7%, respectively ($P<0.001$). Among Daegu residents, median door-to-ER distance increased from 4.80 km (IQR, 2.38–8.34 km) in the pre-COVID period to 5.38 km (IQR, 2.44–8.76 km) during the COVID period and 6.27 km (IQR, 2.58–10.56 km) during the post-COVID period ($P<0.001$; all pairwise adjusted $P<0.001$). Among Gyeongsangbuk-do residents, the corresponding median distances were 25.73 km (IQR, 19.26–39.87 km), 26.48 km (IQR, 19.26–41.94 km), and 26.48 km (IQR, 20.32–39.87 km), respectively ($P=0.013$); none of the pairwise comparisons remained significant after Bonferroni adjustment (adjusted $P=0.052$, $P=0.019$, and $P=1.000$, respectively). The proportion of visits originating at least 20 km from the visited PED increased from 1.8% to 3.7% among Daegu residents and from 71.3% to 76.3% among Gyeongsangbuk-do residents (both $P<0.001$) (Table 3).

4. Acuity and ED care process measures

KTAS levels 1–2 accounted for 3.0%, 4.9%, and 4.3% of visits; KTAS level 3 accounted for 44.9%, 41.7%, and 60.5%; and KTAS levels 4–5 accounted for 52.1%, 53.4%, and 35.2% during the pre-COVID, COVID, and post-COVID periods, respectively ($P<0.001$). From the pre-COVID to post-COVID periods, the proportion of KTAS level 3 visits increased by 15.57 percentage points (95% CI, 14.92–16.23), whereas that of KTAS levels 1–2 increased by 1.30 percentage points (95% CI, 1.05–1.55). Ambulance arrival

Table 3. Door-to-ER geodesic distance according to study period and residential region

Measure	Pre-COVID	COVID	Post-COVID	P value
Overall door-to-ER distance (km)	6.44 (2.74–13.63)	7.17 (3.16–15.02)	8.68 (3.72–16.80)	<0.001
<5 km (%)	19,309 (40.7)	19,517 (37.5)	13,714 (33.7)	<0.001
5–<10 km (%)	12,672 (26.7)	13,998 (26.9)	9,130 (22.5)	<0.001
10–<20 km (%)	7,475 (15.8)	8,864 (17.0)	9,308 (22.9)	<0.001
≥20 km (%)	7,943 (16.8)	9,611 (18.5)	8,476 (20.9)	<0.001
Daegu residents (km)	4.80 (2.38–8.34)	5.38 (2.44–8.76)	6.27 (2.58–10.56)	<0.001
Daegu residents ≥ 20 km (%)	1.8	2.2	3.7	<0.001
Gyeongsangbuk-do residents (km)	25.73 (19.26–39.87)	26.48 (19.26–41.94)	26.48 (20.32–39.87)	0.013
Gyeongsangbuk-do residents ≥20 km (%)	71.3	72.6	76.3	<0.001

Values are presented as median (interquartile range) or number (%) unless otherwise indicated.

ER, emergency room; COVID, coronavirus disease; PED, Pediatric Emergency Department.

The door-to-ER distance was defined as the WGS84 geodesic distance from the residential administrative-dong centroid of the patient to a fixed reference coordinate of the visited PED. This measure does not represent road network travel distance or travel time.

Continuous distance distributions were compared using the Kruskal-Wallis test followed by pairwise Mann-Whitney U tests with Bonferroni adjustment. The <5-km and ≥20-km proportions were compared using Pearson chi-square tests. Cramér V was 0.070 for the 4-category distance distribution (<5, 5–<10, 10–<20, and ≥20 km) and 0.042 for the ≥20-km threshold.

Boldface indicates a statistically significant difference with $P<0.05$.

increased by 4.43 percentage points (95% CI, 4.02–4.83). Median EDLOS decreased by 30 minutes (95% bootstrap CI, -32 to -27; rank-biserial correlation, -0.132) (Table 4). KTAS distributions differed across periods at all 5 institutions (all $P<0.001$), with Cramér V ranging from 0.132 to 0.194. The patterns varied across institutions: the proportion of KTAS levels 1–2 increased from 6.8% to 32.2% at center C, whereas at center D the proportion of KTAS level 3 increased from 49.2% to 65.5% and that of KTAS levels 1–2 changed from 3.0% to 2.8% (Supplementary Table 3).

Discussion

The principal finding of this study was a marked redistribution of visits among the 5 participating PEDs during the post-COVID period. Absolute monthly visit volume and the population-standardized visit rate both declined sharply during the COVID period and subsequently recovered; however, the post-COVID monthly rate did not differ significantly from the pre-COVID rate. The share of center D increased from 25.7% to 44.4%, whereas that of centers C and E declined substantially. Interrupted time-series analysis showed no abrupt increase in institutional concentration at either period boundary. Rather, the HHI slope increased significantly after May 2022, suggesting that redistribution developed gradually rather than as a single abrupt change.

The concurrent recovery in monthly visit volume and increase in institutional concentration suggest that visits were not redistributed proportionally across the 5 participating institutions. Institution-specific KTAS analyses showed heterogeneous changes. Although center D experienced the largest increase in visit share, its proportion of KTAS levels 1–2 visits did not increase from

the pre-COVID to the post-COVID period. Accordingly, changes in institutional share should not be interpreted as evidence that the highest-acuity patients or overall clinical workload became concentrated at any particular institution.

Door-to-ER geodesic distance increased overall; however, stratification by residential region provided important context for this finding. The increase was more pronounced among Daegu residents, whose median door-to-ER distance increased from 4.80 to 6.27 km and whose proportion of visits originating at least 20 km from the visited PED increased from 1.8% to 3.7%. Among Gyeongsangbuk-do residents, the median distance was 25.73 km in the pre-COVID period and 26.48 km in both subsequent periods, with no pairwise comparison remaining significant after Bonferroni adjustment. Thus, the overall increase in door-to-ER distance was not explained solely by a greater proportion of visits from Gyeongsangbuk-do. Ambulance arrival was 4.43 percentage points higher in the post-COVID than in the pre-COVID period (95% CI, 4.02–4.83).

Although the KTAS distribution changed substantially, this finding should not be interpreted as evidence of increased clinical acuity alone. From the pre-COVID to post-COVID period, the proportion of KTAS level 3 visits increased by 15.57 percentage points, whereas the proportion of KTAS levels 1–2 visits increased by only 1.30 percentage points and that of KTAS levels 4–5 decreased by 16.87 percentage points. The difference in admission was small and its 95% CI included zero (-0.31 percentage points; 95% CI, -0.77 to 0.14), whereas transfer decreased slightly (-0.22 percentage points; 95% CI, -0.34 to -0.09) and median EDLOS decreased by 30 minutes. Collectively, these findings indicate a shift in case mix toward KTAS level 3 rather than clear evidence of increased severity or resource requirements.

Table 4. KTAS distribution and Emergency Department care measures by study period

Measure	Pre-COVID	COVID	Post-COVID	<i>P</i> value	Effect ^{a)} (95% CI) (pp)
KTAS 1–2	1,440 (3.0)	2,570 (4.9)	1,763 (4.3)	<0.001	+1.30 (1.05–1.55)
KTAS 3	21,282 (44.9)	21,656 (41.7)	24,569 (60.5)		+15.57 (14.92–16.23)
KTAS 4–5	24,677 (52.1)	27,764 (53.4)	14,296 (35.2)		-16.87 (-17.52 to -16.23)
Ambulance arrival	3,804 (8.0)	7,011 (13.5)	5,059 (12.5)	<0.001	+4.43 (4.02–4.83)
EDLOS (min)	128 (61–224)	119 (56–213)	98 (38–193)	<0.001	-30 (-32 to -27)
Admission	6,487 (13.7)	8,005 (15.4)	5,433 (13.4)	<0.001	-0.31 (-0.77–0.14)
Transfer	482 (1.0)	378 (0.7)	325 (0.8)	<0.001	-0.22 (-0.34 to -0.09)

Values are presented as number (%) or median (interquartile range).

KTAS, Korean Triage and Acuity Scale; COVID, coronavirus disease; CI, confidence interval; EDLOS, Emergency Department length of stay; pp, percentage points. The Kruskal-Wallis test was used for EDLOS, and the chi-square test was used for categorical variables across the 3 periods. Categorical effects are absolute percentage-point differences with a Newcombe hybrid score of 95% CI. The EDLOS analyses included 47,399; 51,990; and 40,628 visits in the pre-COVID, COVID, and post-COVID periods, respectively.

The EDLOS effect is the difference in sample medians with a 5,000-resample percentile bootstrap (95% CI). The rank-biserial correlation coefficient was -0.132 (95% CI, -0.140 to -0.124).

^{a)}The effect column reports post-COVID minus pre-COVID differences.

Boldface indicates a statistically significant difference with $P<0.05$.

Pediatric readiness remains important,^{4,5,8)} but the present findings do not establish that patients requiring the highest levels of clinical resources became concentrated at particular institutions.^{1,2)}

The findings should not be interpreted as supporting the concentration of pediatric emergency demand within 1 or 2 institutions. Interhospital transfer remains an important component of pediatric emergency care, and transfer status has been associated with differences in utilization patterns and outcomes, particularly among injured patients.²⁵⁻²⁷⁾ Rather, the observed redistribution supports continued evaluation of baseline pediatric readiness and interinstitutional coordination across the participating institutions.

Previous studies have focused primarily on visit volume and patient characteristics before and during the pandemic.⁹⁻¹⁶⁾ By jointly examining absolute visit volume, institutional shares, time-varying concentration, door-to-ER geodesic distance, and clinical characteristics, the present study provides a more comprehensive assessment of visit redistribution across 5 PEDs. Korean policy initiatives emphasize pediatric infrastructure and transport systems,²⁸⁻³⁰⁾ although this study did not evaluate the effects of specific policies or institutional operational changes.

This study has some limitations. First, as a retrospective analysis of institutional electronic medical records and NEDIS submission data, it remains subject to residual confounding and center-level differences in data recording despite the use of standardized variable definitions and coding structures. Second, institutional shares and HHI were calculated using only visits to the 5 participating PEDs. Visits to other EDs, outpatient clinics, after-hours clinics, and institutions outside the study network were not captured; therefore, the findings reflect redistribution within the participating institutions rather than region-wide concentration. The proportion of all regional pediatric emergency visits captured by these institutions could not be determined, and the population-standardized rate represents visits to the 5 participating PEDs rather than region-wide pediatric emergency utilization. The population denominator for children aged 0-15 years was based on resident registration data and excluded foreign residents. Third, door-to-ER distance was measured from the centroid of the residential administrative dong of the patient to a fixed hospital point-of-interest coordinate rather than from the exact residential location to a verified PED entrance. Within-dong positional error and ecological measurement error were therefore unavoidable, particularly in geographically large rural administrative units. The WGS84-based geodesic calculation also did not account for road net-

works, traffic conditions, or route selection and therefore should not be interpreted as actual travel distance or travel time. Fourth, institution-specific comparisons were limited to KTAS distribution; therefore, differences in other patient characteristics, resource requirements, and clinical workload across institutions were not assessed. Fifth, institution-level differences in operating hours, age restrictions, temporary service suspensions, staffing levels, bed capacity, inpatient resources, and cohort isolation or administrative patient-allocation practices during the early Daegu outbreak were not systematically captured. Finally, the study could not separate the effects of infection epidemiology, healthcare avoidance, social-distancing policies, institutional responses, and workforce availability or establish causal relationships among the observed changes. The available data could not determine the mechanisms underlying the increase in ambulance arrival, including bypass, referral, patient choice, or other factors. Similarly, the shorter EDLOS should not be interpreted as evidence of reduced workload or greater efficiency because data on staffing, crowding, inpatient bed availability, and clinical workflow were not available.

In conclusion, pediatric emergency visit volume and the population-standardized visit rate across the 5 participating PEDs declined during the COVID period and recovered thereafter, whereas visits became increasingly concentrated among the institutions. The post-COVID monthly population-standardized rate did not differ significantly from the pre-COVID rate. Redistribution was characterized by a gradual increase in HHI after May 2022, a substantial increase in the share of visits to 1 institution, and longer door-to-ER geodesic distances, particularly among Daegu residents. These changes indicate an increased geographic distance burden within the participating PED network. These findings reflect redistribution within the 5 participating PEDs and should not be interpreted as evidence of region-wide concentration or institution-specific changes in patient acuity or clinical workload.

Footnotes

Supplementary materials: Supplementary Tables 1-3 are available at <https://doi.org/10.3345/cep.2026.02054>.

Conflicts of interest: No potential conflict of interest relevant to this article was reported.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-

profit sectors.

Acknowledgments: The authors thank the Department of Medical Information, Kyungpook National University Hospital for technical assistance in standardizing residential administrative-dong information and preparing the geographic data. ChatGPT (OpenAI) was used to assist in the creation of the graphical abstract. The authors have reviewed and verified AI-assisted material and take full responsibility for the accuracy, integrity, and originality of the submitted work.

Author contribution: Conceptualization: CJY; Data curation: CHJ, JK, LDW, CJY; Formal analysis: YWB; Methodology: CHJ; Project administration: CJY; Visualization: YWB; Writing - original draft: YWB; Writing - review & editing: CJY

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How to cite this article: Yang WB, Jang K, Choi HJ, Lee DW, Choe JY. Changes in patient concentration and accessibility across 5 Pediatric Emergency Departments in Daegu, Korea. *Clin Exp Pediatr* [Epub ahead of print] <https://doi.org/10.3345/cep.2026.02054>.

Supplementary Table 1. Grouped cohort exclusions by institution

Exclusion category	Center A	Center B	Center C	Center D	Center E	Total
Records screened	28,043	34,132	12,939	47,042	27,551	149,707
Unclassifiable residence or record	2 (0.01)	193 (0.57)	43 (0.33)	10 (0.02)	2,339 (8.49)	2,587 (1.73)
Missing or invalid required data	11 (0.04)	42 (0.12)	392 (3.03)	169 (0.36)	0 (0)	614 (0.41)
Residence outside the study region	1,349 (4.81)	1,247 (3.65)	782 (6.04)	1,768 (3.76)	1,203 (4.37)	6,349 (4.24)
Other eligibility exclusions	0 (0)	6 (0.02)	134 (1.04)	0 (0)	0 (0)	140 (0.09)
Total excluded	1,362 (4.86)	1,488 (4.36)	1,351 (10.44)	1,947 (4.14)	3,542 (12.86)	9,690 (6.47)
Final analytic cohort	26,681 (95.14)	32,644 (95.64)	11,588 (89.56)	45,095 (95.86)	24,009 (87.14)	140,017 (93.53)

Values are presented as number (%) of records screened at the corresponding institution.
The exclusion criteria were mutually exclusive.

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Supplementary Table 2. Complete coefficients and diagnostics for main interrupted time-series model

Term	Estimate	SE	95% CI	P value
Intercept	0.22981	0.01222	0.20518–0.25445	<0.001
Baseline monthly trend	-0.00152	0.00160	-0.00474–0.00170	0.347
Level change at COVID onset	-0.01015	0.01347	-0.03731–0.01700	0.455
Slope change after COVID onset	0.00360	0.00181	-0.00004–0.00724	0.053
Level change at Post-COVID onset	0.00640	0.01274	-0.01929–0.03209	0.618
Slope change after Post-COVID onset	0.00437	0.00181	0.00072–0.00801	0.020
Annual seasonal component (sine term)	0.00420	0.00438	-0.00464–0.01304	0.343
Annual seasonal component (cosine term)	0.00327	0.00418	-0.00516–0.01170	0.439
Semiannual seasonal component (sine term)	0.00494	0.00287	-0.00084–0.01073	0.092
Semiannual seasonal component (cosine term)	0.00014	0.00290	-0.00570–0.00598	0.962

AR(1), first-order autoregressive process; SE, standard error; CI, confidence interval; *df*, degrees of freedom; HHI, Herfindahl-Hirschman Index.

The estimates are in HHI units. The main model was a Prais-Winsten segmented regression with first-order autoregressive errors, interruptions at February 2020 and May 2022, and annual and semiannual Fourier terms. The estimated AR(1) rho was 0.548 and the residual *df* was 43.

The transformed-residual Durbin-Watson statistic was 1.743. The Ljung-Box Q statistic was 7.916 at lag 6 ($P=0.244$) and 21.660 at lag 12 ($P=0.042$). The 4 seasonal terms were not jointly significant (Wald chi-square=4.806, $df=4$, $P=0.308$).

The post-COVID slope change remained significant in the zero-harmonic model ($\beta=0.00457$; 95% CI, 0.00088–0.00826; $P=0.016$) and one-harmonic model ($\beta=0.00416$; 95% CI, 0.00054–0.00778; $P=0.025$).

Supplementary Table 3. Institution-specific KTAS distribution by study period

Institution	Period	KTAS 1–2	KTAS 3	KTAS 4–5	P value	Cramér V
Center A	Pre-COVID	119 (1.4)	1,104 (13.4)	7,020 (85.2)	<0.001	0.148
	COVID	314 (2.9)	2,535 (23.3)	8,012 (73.8)		
	Post-COVID	368 (4.9)	2,568 (33.9)	4,641 (61.3)		
Center B	Pre-COVID	42 (0.3)	9,641 (73.4)	3,460 (26.3)	<0.001	0.134
	COVID	33 (0.3)	5,816 (57.0)	4,347 (42.6)		
	Post-COVID	39 (0.4)	7,250 (77.9)	2,016 (21.7)		
Center C	Pre-COVID	317 (6.8)	1,739 (37.2)	2,614 (56.0)	<0.001	0.194
	COVID	950 (17.9)	2,396 (45.2)	1,956 (36.9)		
	Post-COVID	520 (32.2)	604 (37.4)	492 (30.4)		
Center D	Pre-COVID	364 (3.0)	5,995 (49.2)	5,838 (47.9)	<0.001	0.132
	COVID	673 (4.5)	6,736 (45.3)	7,449 (50.1)		
	Post-COVID	512 (2.8)	11,823 (65.5)	5,705 (31.6)		
Center E	Pre-COVID	598 (6.5)	2,803 (30.6)	5,745 (62.8)	<0.001	0.138
	COVID	600 (5.6)	4,173 (38.7)	6,000 (55.7)		
	Post-COVID	324 (7.9)	2,324 (56.8)	1,442 (35.3)		

Values are presented as number (%) of all visits to the corresponding institution during the study period.

KTAS, Korean Triage and Acuity Scale; COVID, coronavirus disease.

P values are from institution-specific chi-square tests that compared the KTAS distributions across the 3 study periods. Cramér V was reported as the effect size.