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Sudden pertussis outbreaks in Guro-gu, Seoul: epidemiological characteristics and contributing factors in 2024

Woosuk Han[1,2], Heejin Kimm[3], Yeun Soo Yang[4], Jun Wook Kwon[5], Euncheol Son[6]

[1]Epidemiological Investigation Officer, Division of Community Health, Seodaemun-gu, Public Health Center, Seoul, Korea
[2]Researcher, Department of Epidemiology and Health Promotion, Graduate School of Public Health, Yonsei University, Seoul, Korea
[3]Professor, Department of Epidemiology and Health Promotion, Institute for Health Promotion, Graduate School of Public Health and Graduate School of Transdisciplinary Health Sciences, Yonsei University, Seoul, Korea
[4]Research Instructor, Department of Epidemiology and Health Promotion, Institute for Health Promotion, Graduate School of Public Health, Yonsei University, Seoul, Korea
[5]Research Professor, Department of Epidemiology and Health Promotion, Institute for Health Promotion, Graduate School of Public Health and Graduate School of Transdisciplinary Health Sciences, Yonsei University, Seoul, Korea
[6]Assistant Professor, Department of Physiology, University of Ulsan College of Medicine, Ulsan, Korea

Corresponding author
Euncheol Son
Department of Physiology, University of Ulsan College of Medicine, 93 Daehak-ro, Nam-gu, Ulsan 44610, Korea
Tel: +82-52-259-2385
E-mail: dmscjf31@ulsan.ac.kr; ecson24@naver.com

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Purpose: Although pertussis is a vaccine-preventable disease, its incidence increased rapidly in Guro-gu, Seoul, since May 2024. This study aimed to investigate the epidemiological characteristics of pertussis cases and outbreaks during this period.
Methods: Data from epidemiologic investigations of 355 laboratory-confirmed pertussis cases reported in 2024 in Guro-gu, Seoul, were analyzed using national surveillance records. Demographics, vaccination status, outbreak-associated educational settings, and symptom-to-test intervals were analyzed using descriptive statistics and non-parametric tests.
Results: Between May and December 2024, 355 cases were reported, 85.4% of which occurred among school-aged children and adolescents, representing a marked increase compared with previous years. Outbreaks were identified in two elementary schools, three middle schools, and four private academies, indicating clustered transmission in educational settings, with school-based attack rates ranging from 3.2% to 6.3%. Among 146 outbreak-associated school cases, 95.4% had completed age-appropriate vaccination on time. The symptom-to-test interval showed a right-skewed distribution (median, 6 days; interquartile range, 3–11), with longer delays observed in high school students.
Conclusion: The sharp increase in pertussis cases among school-aged children underscores the need for strengthened surveillance in educational settings and improved timeliness of testing to reduce transmission. Delays in symptom-to-test intervals and the occurrence of cases despite age-appropriate vaccination suggest possible waning immunity, highlighting the importance of evaluating booster vaccination strategies and targeted age-specific public health interventions.

Keywords: Epidemiology; Disease outbreaks; Vaccination; Whooping cough

INTRODUCTION

Pertussis is a highly contagious bacterial respiratory disease caused by *Bordetella pertussis*, characterized by paroxysmal cough and the characteristic "whooping" sound. It is primarily transmitted via respiratory aerosols and droplets, with a basic reproduction number (R_0) estimated at 12 to 17 [1,2]. Although most individuals recover fully from pertussis, it can be fatal to infants, especially those younger than 3 months [3].

In pediatric populations, pertussis may impose a substantial clinical and public health burden, while infants remain particularly vulnerable to severe outcomes [2,3]. Transmission can be amplified in school-related settings due to frequent close-contact interactions, and recent reports from Korea have documented outbreaks affecting school-aged children in educational environments [4-6]. Therefore, timely recognition and testing among children and adolescents are important for early control and prevention of onward spread.

In Korea, pertussis is designated as a nationally notifiable infectious disease (Class 2), meaning that all cases must be reported through a system managed by the Korea Disease Control and Prevention Agency (KDCA). Following the development and widespread use of vaccines, pertussis incidence declined substantially in many high-income countries. In Korea, the incidence rate steadily decreased through the 1990s after the introduction of diphtheria-tetanus-pertussis (DTaP) vaccination [7].

The pertussis vaccination schedule is designed to provide lifelong protection. Infants receive a primary series of DTaP vaccinations at 2, 4, and 6 months of age, followed by booster doses at 15–18 months and 4–6 years. Adolescents are recommended to receive a tetanus-diphtheria-acellular pertussis (Tdap) booster at 11–12 years of age, while adults are advised to receive a Tdap dose if not previously vaccinated, followed by tetanus-diphtheria (Td) or Tdap boosters every 10 years. Moreover, KDCA recently emphasized the need for pertussis vaccination to protect infants under 1 year old who are at high risk, including pregnant women, cohabiting family members, and caregivers [8,9].

Pertussis has resurged since the 2000s, with a notable increase among adolescents [7]. This resurgence has been attributed to multiple factors reported in prior literature, including waning immunity after vaccination, changes in awareness and diagnostic testing, and potential pathogen adaptation over time [2,7]. In Korea, reported cases rose markedly during 2016–2018 across multiple age groups [10] and subsequently declined during 2018–2022, decreasing from 980 cases in 2018 to 31 cases in 2022 [11]. Since October 2023, transmission and outbreaks have particularly affected school-aged children, initially reported in Gyeongsangnam-do and later spreading nationwide [4,5]. The KDCA also reported an infant death due to pertussis, underscoring the need to protect high-risk young infants [12]. In the first half of 2024, 5,497 pertussis cases were reported, compared with 4,603 cases in the first half of 2025 (as of June 30), indicating a decline but a sustained burden requiring continued public health responses [12].

Between 2016 and 2023, pertussis cases reported in Guro-gu were sporadic and occurred primarily among adults and older individuals. Only one case was identified among school-aged children during this period, and no cases were reported among adolescents or preschool-aged children (Supplement 1). In contrast to the preceding years, beginning in May 2024, a marked increase in pertussis cases was observed in this district, particularly among school-aged children.

Accordingly, this study aimed to describe the epidemiologic and clinical characteristics of pertussis cases reported in Guro-gu in 2024 and to characterize exposure sites and commonly frequented locations, focusing on educational institutions (schools and private academies). We also assessed patterns of symptom-to-test intervals across key groups (e.g., age and occupation/affiliation) to inform evidence-based measures for preventing further outbreaks.

METHODS

Ethical statements: This study was approved by the Institutional Review Board (IRB) of Yonsei University Health System, Severance Hospital (IRB No. 4-2024-1373). The requirement for informed consent was waived owing to the retrospective nature of the study.

1. Study Design

This was a retrospective cohort study using routinely collected surveillance and epidemiological investigation data from January 1 to December 31, 2024 in Guro-gu, Seoul, Republic of Korea. This study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

2. Data Sources and Samples

The study population comprised laboratory-confirmed pertussis cases reported to the KDCA surveillance system and investigated by the Guro District Public Health Center between January 1 and December 31, 2024. Pertussis is a nationally notifiable infectious disease, and all case reports and investigation records are registered in the KDCA's Integrated Disease Control Information System. Among 375 reported pertussis cases during the study period, 355 laboratory-confirmed cases were included in the analysis (Supplement 2).

This study used data routinely collected through national public health surveillance and epidemiologic investigations conducted by KDCA and the local public health center. Data were extracted from the KDCA system and epidemiological investigation records, including demographic characteristics, clinical symptoms, and affiliation/occupation and institution information. Investigations were conducted via telephone interviews as part of routine public health practice during the outbreak period. All records were assigned unique identifiers and de-identified prior to analysis.

Vaccination status was verified using both the Integrated Disease Control Information System and the Vaccination Registration System. Among the 355 laboratory-confirmed cases, vaccination status could not be confirmed for 35 cases. These cases were excluded from vaccination-related analyses but retained in all other analyses.

3. Variables

Key variables included sex, age, affiliation/occupation (with institution information when available), and clinical symptoms (respiratory and non-respiratory). Asymptomatic cases were defined as having no symptoms recorded in the investigation form. Vaccination status was categorized based on the national schedule and timing (Supplement 3).

Vaccination status was categorized as: (1) vaccinated (including delayed), (2) incomplete or unvaccinated, and (3) unknown. "Vaccinated" was defined as having received all age-appropriate doses up to the time of diagnosis, regardless of adherence to the recommended schedule. Among vaccinated cases, adherence to the recommended schedule was further classified as on-time or delayed according to whether doses were administered within the recommended age window. Vaccination status was considered unknown when no record was available in the investigation form or registry linkage. In vaccination-related analyses, cases with unknown vaccination status were excluded.

The symptom-to-test interval was calculated as the number of days between symptom onset and the specimen collection (test) date recorded in the investigation form. Symptom onset date was defined as the date of symptom onset recorded in the epidemiological investigation form; test date as the specimen collection (laboratory test) date; and diagnosis date as the date of confirmed pertussis case reporting in the KDCA surveillance system. Because the diagnosis date reflects case reporting/registration in the KDCA surveillance system and may lag behind testing, delay analyses in this study used the symptom-to-test interval (symptom onset to test date) as the primary measure of timeliness.

Attack rate was calculated for each school as the number of laboratory-confirmed cases divided by the total number of students enrolled in that school during the outbreak period.

4. Data Analysis

Descriptive statistics were used to summarize demographic characteristics, vaccination status, symptoms, and outbreak-associated institutions.

For analyses involving diagnostic delay, normality was assessed using the Shapiro-Wilk test. The distribution significantly deviated from normality ($W = 0.744$, $p < .001$), with substantial positive skewness (3.42) and high kurtosis (22.90). Therefore, non-parametric tests were applied for comparisons of this variable.

Group comparisons were performed using the chi-square test, independent t-test, Mann-Whitney U test, or Kruskal-Wallis test, depending on variable type and distribution. When the Kruskal-Wallis test indicated significant differences across groups, post-hoc pairwise comparisons were conducted using the Dwass-Steel-Critchlow-Fligner (DSCF) method to account for multiple comparisons. Analyses were conducted using SAS ver. 9.4 (SAS Institute Inc.), and a two-sided $p < .050$. was considered statistically significant.

RESULTS

1. Epidemiologic Characteristics of Pertussis in Guro-gu

Based on the week of report recorded in the KDCA surveillance system, the epidemic curve indicates that weekly

pertussis case counts began to increase in the last week of May 2024 and reached a peak in the first week of July (65 cases) (Figure 1). After early July, weekly counts declined, but cases continued to occur through December. Overall, the resurgence persisted for approximately 7 months (late May–December), with 355 cases reported during this period.

Elementary and middle school students accounted for approximately 75.5% of all pertussis cases. Including high school students, students accounted for approximately 85.4% of all pertussis cases in 2024. Approximately 96.6% of patients exhibited a cough, and respiratory symptoms were common. Non-respiratory symptoms, such as headache, dizziness, and diarrhea, were rare, affecting fewer than 2.0% of the patients (Table 1).

2. Characteristics of Pertussis Outbreaks in Schools and Private Academies

According to the epidemiological investigation records, the primary locations frequented by outbreak-associated cases included a total of nine sites: two elementary schools, three middle schools, and four private academies. Among these, two schools and four academies were located within the same administrative district (Supplement 4).

In the five schools with identified clusters, the attack rate ranged from 3.2% to 6.3%. Among 146 outbreak-associated patients in these school settings, 139 (95.4%) had completed age-appropriate vaccination on time (Table 2). No clear pattern was observed between school-level attack rates and the proportion of patients who had completed vaccination on time.

3. Vaccination Status

Of 355 cases, 305 (85.9%) were vaccinated (including delayed vaccination), 15 (4.2%) were incomplete or unvaccinated, and 35 (9.9%) had unknown vaccination status (Table 1). The distribution of vaccination status by dose number and adherence to the recommended schedule is presented in Supplement 5.

Analysis of vaccine types by dose number showed that DTaP was the predominant vaccine type for the initial fifth doses, accounting for 71.3% of cases. Smaller proportions received DTaP-IPV or DTaP-IPV/Hib combination vaccines.

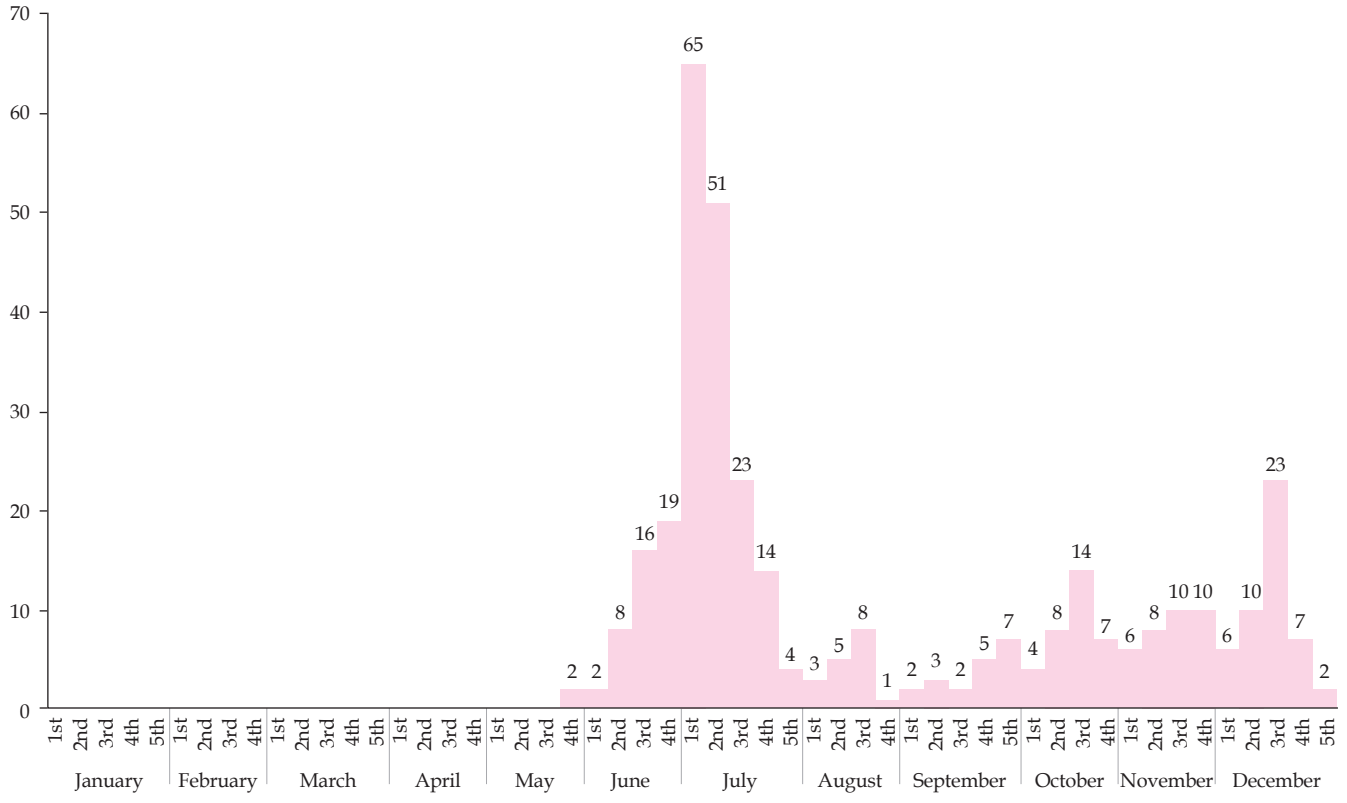

Figure 1. Epidemic curve of pertussis cases in Guro-gu, 2024. The epidemic curve is based on the week of report recorded in the Korea Disease Control and Prevention Agency surveillance system.

Table 1. Characteristics of pertussis patients in Guro-gu, Seoul, 2024 (N=355)

Characteristic	Category	No. (%)
Sex	Male	184 (51.8)
	Female	171 (48.2)
Age group and institution		
Children under school age	Childcare center	8 (2.3)
	Kindergarten	3 (0.8)
School-age children and adolescents	Elementary school	156 (43.9)
	Middle school	112 (31.5)
	High school	34 (9.6)
Adults	Workers	18 (5.1)
	Unemployed	24 (6.8)
Clinical manifestations	Asymptomatic	6 (1.7)
	Fever	34 (9.6)
Respiratory symptoms	Cough	343 (96.6)
	Sputum	42 (11.8)
	Sore throat	26 (7.3)
	Rhinorrhea	27 (7.6)
	Dyspnea	7 (2.0)
Non-respiratory symptoms	Headache	6 (1.7)
	Dizziness	4 (1.1)
	Diarrhea	4 (1.1)
	Nausea	3 (0.8)
Vaccination	Vaccinated (including delayed)	305 (85.9)
	Incomplete/unvaccinated	15 (4.2)
	Unknown	35 (9.9)

Respiratory and non-respiratory symptoms were calculated as multiple responses; percentages may exceed 100%.

For the sixth dose, 81.8% of vaccinated patients received Tdap, whereas 18.2% received Td (Supplement 6).

Among preschool-aged children, all cases were vaccinated on time. In elementary school students, 7.1% had delayed vaccination and 3.2% were incomplete or unvaccinated. Among adolescents, delayed vaccination was observed in 36.6% of middle school students and 20.6% of high school students, while incomplete or unvaccinated status accounted for 5.4% and 11.8%, respectively. Vaccination status was largely unknown among adults (Table 3).

Additional analysis comparing vaccination types and the interval from the sixth dose to diagnosis showed that the median interval was longer among Tdap recipients than among Td recipients; however, this difference was not statistically significant (Supplement 7).

4. Symptom-to-Test Intervals by School Level and Occupation

The symptom-to-test interval showed a right-skewed distribution, with a median of 6 days (interquartile range [IQR], 3–11) and a range of 0–84 days. Figure 2 displays the median values with IQRs among cases with available symptom onset and test dates across school levels and occupation groups. Median (IQR) symptom-to-test days were 12 (9.5–15.5) in childcare center children (n=8), 4 (0–21) in kindergarten chil-

Table 2. Characteristics of schools with pertussis outbreaks in Guro-gu, Seoul, 2024

Schools with pertussis outbreaks	No. of enrolled students	No. of pertussis patients	Attack rate (%)	No. of patients vaccinated on time (%)
A elementary school	1,009	58	5.7	55 (94.8)
B middle school	526	17	3.2	16 (94.1)
G middle school	490	25	5.1	23 (92.0)
H middle school	596	26	4.4	25 (96.2)
I elementary school	315	20	6.3	20 (100.0)
Sum	2,936	146	5.0	139 (95.4)

Table 3. Vaccination status of pertussis patients by age group (N=355)

Age group	School level/occupation	Total	On-time	Delayed	Incomplete/unvaccinated	Unknown
Children under school age	Childcare center	8 (2.3)	7 (87.5)	1 (12.5)	0 (0.0)	0 (0.0)
	Kindergarten	3 (0.8)	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
School-age children and adolescents	Elementary school	156 (43.9)	140 (89.7)	11 (7.1)	5 (3.2)	0 (0.0)
	Middle school	112 (31.5)	64 (57.1)	41 (36.6)	6 (5.4)	1 (0.9)
	High school	34 (9.6)	22 (64.7)	7 (20.6)	4 (11.8)	1 (2.9)
Adults	Workers	18 (5.1)	3 (16.7)	1 (5.6)	0 (0.0)	14 (77.8)
	Unemployed	24 (6.8)	1 (4.2)	4 (16.7)	0 (0.0)	19 (79.2)

Values are presented as number (%).

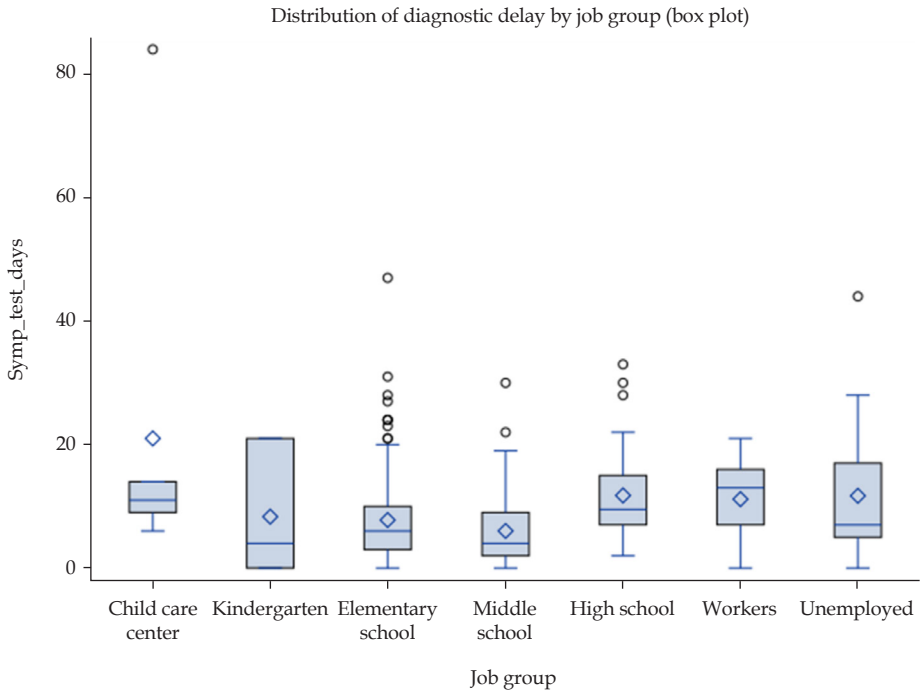

Figure 2. Symptom-to-test interval by school level and occupation. The symptom-to-test interval was defined as the number of days between symptom onset and the test date. The figure presents median values with interquartile ranges among cases with available symptom onset and test dates.

dren (n=3), 6 (3–10) in elementary school students (n=156), 4 (2–9) in middle school students (n=112), 9.5 (7–15) in high school students (n=34), 13 (7–16) in workers (n=18), and 7 (5–17) in unemployed individuals (n=24).

Distributions differed significantly across groups (Kruskal-Wallis $\chi^2=37.117$, degrees of freedom=6, $p<.001$). Detailed Kruskal-Wallis test results are presented in Supplement 8. In DSCF post-hoc comparisons, symptom-to-test delays were longer in high school students than in elementary school students ($p=.015$) and middle school students ($p<.001$), and longer in workers than in middle school students ($p=.011$); childcare center children also showed longer delays than middle school students ($p=.014$), although subgroup sample sizes were small.

DISCUSSION

This study examined the epidemiologic characteristics of the 2024 pertussis resurgence in Guro-gu, Seoul, with a particular focus on transmission patterns in educational settings and delays in testing following symptom onset. The findings indicate that the outbreak was concentrated among school-aged children and adolescents and that clusters were primarily associated with schools and nearby private academies. In addition, symptom-to-test intervals differed across school levels and occupation groups, with longer delays observed among high school students and working adults. These findings provide district-level insights into transmission dynamics and highlight the importance of timely testing and targeted prevention strategies in high-contact educational environments.

Pertussis clusters in this district were primarily identified in educational institutions, including schools and nearby private academies, suggesting that repeated close-contact interactions in these settings may facilitate transmission. Similar school-centered pertussis outbreaks have been documented elsewhere, including outbreaks occurring despite high vaccination coverage, where contact intensity and classroom mixing patterns were considered important contributors [13,14]. A distinguishing feature in our setting was the geographical clustering of schools and private academies within overlapping areas, which may have facilitated repeated exposures across multiple institutions. Enclosed spaces such as classrooms and study rooms may have promoted close contact, and attack rates ranged from 3.2% to 6.3% in affected schools. Although these descriptive findings cannot establish causal determinants, they are compatible with prior outbreak investigations indicating that dense, high-contact educational en-

vironments can amplify transmission once pertussis is introduced [13,14]. This highlights the importance of implementing preventive measures tailored to high-density educational environments to mitigate transmission risks.

Symptom-to-test intervals differed across levels and occupation groups in our analysis. High school students experienced longer delays than elementary and middle school students, and workers also showed prolonged delays. Prior studies have reported that missed opportunities to diagnose pertussis can vary by age and may be more frequent and prolonged among older adolescents and adults, supporting the plausibility of longer delays in these groups [15]. Recent Korean outbreak analyses have also emphasized challenges in promptly identifying and controlling transmission among school-aged populations in 2024 [16]. Together, these findings underscore the importance of timely referral and clear guidance on when and where to obtain pertussis testing for students and working adults in schools, private academies, and workplaces. However, the effectiveness of such approaches in reducing infectious periods or secondary transmission could not be assessed in this study and should be evaluated in future work.

Since October 2023, pertussis activity has re-emerged in Korea, with outbreaks initially reported in Gyeongsangnam-do often involving school-aged children and subsequently spreading nationwide [4,12]. In our district-level investigation, school-aged children and adolescents showed the highest incidence rates, whereas only one case occurred among infants in Guro-gu. This age distribution is consistent with recent reports from the Seoul metropolitan area and national surveillance summaries during the 2023–2024 resurgence [6,12,16]. In contrast to national-level descriptions that necessarily summarize broad patterns, our district data indicate that the 2024 burden was concentrated in interconnected educational settings with high contact intensity, reinforcing the need for timely recognition and control measures focused on schools and nearby private academies.

A high proportion of pertussis cases in our district occurred among vaccinated school-aged individuals. National data indicate that 96.9% of children entering elementary school had received a fifth DTaP vaccination, and 88.2% of children entering middle school had received a sixth Tdap or Td vaccination in 2024. Our findings provide supportive local evidence that many cases occurred despite high coverage; however, because vaccination status among non-cases was unavailable, vaccine effectiveness could not be directly estimated. The high proportion of vaccinated cases raises the possibility that protection against infection may decrease over time in some adolescents and school-aged children, consistent with waning immunity described in prior studies [14,17-19]. These findings highlight the need for continued evaluation of booster timing and vaccine performance in older children and adolescents, particularly in high-contact settings.

We further compared the interval from the sixth booster dose to diagnosis between Tdap and Td recipients and found no significant difference. While this comparison does not permit causal inference regarding comparative effectiveness, it suggests that the current booster strategy and timing may warrant careful re-evaluation, especially given growing evidence that protection may wane over time and vary between individuals [17-19].

Implications for pediatric nursing and school health practice emerge clearly from the school-centered transmission pattern observed in Guro-gu. The epidemic curve showed a term-vacation pattern, with case counts increasing during the school term and decreasing during vacation periods, suggesting that school-based contacts may play an important role in transmission. School health teachers, who maintain routine contact with students, are well positioned to recognize early warning signs during community resurgence. Because pertussis in older children and adolescents may present atypically or as persistent cough, recognition and testing can be delayed. Early and timely referral to clinics capable of pertussis testing may facilitate earlier diagnosis and reduce onward transmission within schools.

School health teachers also play a central role in implementing on-site infection control. Advising symptomatic students to wear masks, reinforcing respiratory etiquette, and coordinating exclusion from school during the recommended isolation period after initiation of appropriate antibiotics are practical measures to reduce exposure opportunities in group settings. In addition, verifying students' immunization histories and counseling families regarding catch-up vaccination or booster recommendations, particularly for students with incomplete vaccination or close contact exposure-may help reduce susceptibility in high-contact environments. Coordinated communication between school health personnel and public health authorities, including early reporting of suspected clusters and cooperation with contact monitoring, can further strengthen timely containment.

The modest increase in incidence among toddlers entering

group settings such as childcare centers and the first pertussis-related infant death reported in November 2024 underscore the vulnerability of young infants and the importance of maintaining protective strategies for high-risk groups [12]. The easing of coronavirus disease 2019 (COVID-19) restrictions in 2024 likely increased social interactions in schools and private academies, potentially creating more opportunities for pertussis transmission. Non-pharmaceutical interventions implemented during the pandemic, such as masking and respiratory hygiene, were associated with reduced transmission of respiratory infections in Korea [20] and may inform practical measures for pertussis control in educational settings. In particular, encouraging symptomatic students to wear masks and strengthening school-based hygiene practices may help mitigate transmission risk [20,21].

Our findings may suggest potential waning protection between booster doses, warranting further evaluation of optimal booster timing in school-aged populations. Whether shorter intervals or optimized booster schedules would improve vaccine effectiveness and reduce transmission requires careful assessment in future studies. The currently recommended interval between the fifth and sixth doses is approximately 5–8 years, and subsequent boosters are recommended every 10 years in Korea [22].

Pertussis epidemics continue to occur worldwide, and waning immunity after vaccination has been proposed as a major contributor to resurgence [17,18]. Our findings, including relatively short intervals between the most recent vaccination and diagnosis among vaccinated cases, are consistent with the need to re-examine booster timing in school-aged children and adolescents [17-19]. Shorter intervals or optimized booster schedules may improve protection in high-contact settings, but such changes require careful evaluation of safety, feasibility, and population-level impact.

Efforts to improve vaccination compliance in adolescents are also important. In our data, compliance decreased beginning in middle school, suggesting that school-based strategies potentially involving collaboration between school health personnel and public health centers could improve booster uptake. Ongoing monitoring of vaccine performance against circulating *B. pertussis strains* and variants remains essential to guide future immunization strategies [23-25].

This study has several limitations. First, although epidemiologic investigation was conducted during outbreaks, we could not estimate the basic reproduction number (R_0). Second, we could not obtain the vaccination status of uninfected students. Therefore, we could not calculate relative risk. Consequently, the ability to evaluate vaccine effectiveness was limited. Third, because this study was based on routinely collected surveillance and epidemiological investigation data, some pertussis cases may have been underreported, particularly those with mild or atypical symptoms. Access to diagnostic testing may also have varied across age groups and occupations, which could have influenced the observed symptom-to-test intervals. In addition, information from epidemiological investigations relied on patient recall and available records and may be incomplete or subject to misclassification. Finally, as this was an observational study, the findings should be interpreted as associations rather than causal relationships.

Moreover, we could not identify the specific mechanisms underlying breakthrough infections. Recent studies have reported circulating *B. pertussis strains* with polymorphisms in the pertussis toxin gene and variants in the pertactin (PRN) gene [23-25]. Continued molecular surveillance and evaluation of vaccine effectiveness against currently circulating strains in Korea are warranted.

Additionally, the marked decrease in pertussis cases during the COVID-19 pandemic suggests that preventive measures designed for COVID-19 could inform strategies for pertussis control. Research focusing on optimizing booster dose schedules and addressing delays in testing (symptom onset-to-test interval) to improve overall disease management is also necessary.

CONCLUSION

The findings from pertussis cases in Guro-gu, Seoul highlight the need for strengthened vaccination strategies and public health measures. Shortening booster intervals, enhancing vaccination adherence, and addressing delays in testing (symptom onset-to-test interval) may contribute to reducing the risk of further outbreaks. Strengthening community education and proactive preventive measures may also help control pertussis and similar infectious diseases. These findings provide practical insights for vaccination strategies and underscores the importance of coordinated public health responses.

ARTICLE INFORMATION

Authors' contribution

Conceptualization: WSH, ECS, HJK. Methodology: all authors. Validation: all authors. Formal analysis: all authors. Investigation: WSH, ECS. Data curation: WSH. Writing–original draft: all authors. Writing–review & editing: WSH, ECS, HJK. Visualization: WSH, ECS. Supervision: ECS, HJK. Project administration: ECS, HJK. Final approval of published version: all authors.

Conflict of interest

No existing or potential conflict of interest relevant to this article was reported.

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Data availability

Please contact the corresponding author (Euncheol Son) for data availability.

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AI use disclosure

The authors declare that ChatGPT (GPT-5.3) and Google Gemini were used solely for grammar and language editing. All scientific content, interpretation, and conclusions remain the sole responsibility of the authors. The authors reviewed and approved all content and take full responsibility for the integrity of the manuscript.

Supplementary material

Supplement 1. Characteristics of pertussis cases by age group in Guro-gu, Seoul, 2016–2024 (N = 369).
Supplement 2. Study cases.
Supplement 3. Pertussis vaccination schedule and vaccine types.
Supplement 4. Pertussis outbreaks from January to September in 2024 in Guro-gu.
Supplement 5. Pertussis vaccination status by dose number (N = 355).
Supplement 6. Frequency of vaccine types by dose number among pertussis patients.
Supplement 7. Comparison of the interval from 6th-dose vaccination to diagnosis by vaccine type (Td vs. Tdap).
Supplement 8. Symptom-to-test days by occupation group (Kruskal-Wallis test results) (N = 355).

ORCID and ResearcherID

Woosuk Han https://orcid.org/0009-0001-7658-0422
https://researcherid.com/rid/KOC-7599-2024
Heejin Kimm https://orcid.org/0000-0003-4526-0570
https://researcherid.com/rid/PWG-3828-2026
Yeun Soo Yang https://orcid.org/0000-0002-2729-3136
https://researcherid.com/rid/PWG-4098-2026
Jun Wook Kwon https://orcid.org/0009-0008-9287-4616
https://researcherid.com/rid/IAM-2026-2023
Euncheol Son https://orcid.org/0000-0002-5288-1490
https://researcherid.com/rid/JRX-9742-2023

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