Identifying risk factors for COVID-19 cluster infections in schools in the Republic of Korea: a case-control study

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ABSTRACT

Objectives: No study has yet analyzed risk factors to determine whether students with confirmed coronavirus disease 2019 (COVID-19) infections may affect students at neighboring schools. Therefore, this study aimed to determine risk factors for COVID-19 transmission among schools within a community in the Republic of Korea.

Methods: An epidemiological investigation was conducted among 696 students and school staff members at 3 schools where COVID-19 clusters began on October 15, 2021. Interviews, visit history surveys, a facility risk assessment, and closed-circuit television were used to identify risk factors. The statistical significance of risk factors was also evaluated.

Results: We confirmed 129 cases (18.5%) among the individuals exposed to COVID-19 at the 3 schools, many of whom had a history of visiting the same multi-use facilities. The odds ratio of having visited multi-use facilities such as karaoke rooms was 1.90 (95% confidence interval, 1.03–3.50); the number of visits to a karaoke room and the visit durations were significantly higher among confirmed cases than non-confirmed cases (p = 0.02 and p = 0.03, respectively).

Conclusion: Having a history of visiting karaoke rooms often and spending a long time there were risk factors for COVID-19 infection and inter-school transmission. Thus, it is necessary to investigate the status of multi-use facilities frequently visited by adolescents and consider incorporating them into the scope of school quarantine to prevent infectious diseases at schools in a community.

Keywords: COVID-19; Disease outbreaks; Risk factors; Schools

Introduction

Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a respiratory disease that was first reported in China in December 2019 [1]. Owing to its rapid global spread, the World Health Organization declared...
COVID-19 a public health emergency of international concern on March 11, 2020. COVID-19 is primarily transmitted from human to human via droplets, aerosols, or direct contact, and it can spread via airborne transmission in confined spaces [2]. Clinical profiles range from asymptomatic to severe, and most children and teenagers have been reported to show no or mild symptoms [3]. The United Nations Educational, Scientific, and Cultural Organization estimated that by the end of April 2020, 192 countries had closed schools nationwide, and 90% of students globally (approximately 1.6 billion) had been affected by COVID-19-related disruptions in terms of physical, mental, and social health [4,5]. The long duration of school closures led to increased social costs and educational loss. After consensus was reached on the limited benefits of these closures, face-to-face classes were resumed in a staggered manner from the latter half of 2020 onward [6–9]. After the initial outbreak on January 20, 2020, schools in the Republic of Korea postponed the new semester that would have begun in March; instead, online classes began in April 2020 [10]. A complete return to normal school operations was observed in May 2021, and on July 19, 2021, COVID-19 vaccinations were administered to high school senior students [11]. Additionally, after classes resumed, school infection prevention measures were implemented. School staff members and students underwent temperature checks twice daily and were instructed to follow personal hygiene rules. If a confirmed case was identified, in-person classes were suspended for 14 days at the class, year, or school level based on epidemiological investigations and exposure risk assessments.

In 2021, patients aged <19 years with a confirmed COVID-19 diagnosis accounted for 18.7% of all confirmed cases in the Republic of Korea, which increased to 23.1% in 2022. Schools typically represent environments vulnerable to the 3Cs (closed spaces, crowded places, and close-contact settings); however, comprehensive analyses of risk factors for transmission within schools remain limited. Although few documented cases and risk factors in the Republic of Korea may be found regarding transmission among neighboring schools via infected students, it was possible to analyze transmission involving 129 individuals from 3 neighboring schools in a cluster outbreak. Through epidemiological investigations, this study aimed to investigate the risk factors associated with COVID-19 transmission among these schools within a single community.

Materials and Methods

Recognition of a Group Outbreak and Response Measures

The index patient was a student from A Middle School who first experienced upper respiratory symptoms, such as a cough and sore throat, on October 15, 2021. The student underwent a COVID-19 test on October 16 and received a positive confirmation on October 17. The public health center verified the confirmed patient’s history of visiting hagwons (private tutoring academies) and multi-use facilities and confirmed that the paths of many local students had overlapped. As a result, an expanded, full-school survey was conducted in nearby schools on October 19, and 38 additional patients were confirmed in 2 schools nearby. Thus, the outbreak was considered a cluster outbreak involving several schools in the same community, and an epidemiology investigation was conducted October 21–22.

The schools were temporarily closed and disinfected. Places the students had visited, such as hagwons, internet cafes, and karaoke rooms, were also partially closed and disinfected. Patients were transferred to hospitals or community treatment centers based on disease severity, and those who had had direct contact with the infected students underwent 14 days of self-quarantine and active monitoring.

Case Definition and Study Design

We used a case-control design for this study. The study period was set from October 7 (after the schools resumed session after a break) to October 19 (when the schools were closed). A confirmed case was defined as a student or staff member of A Middle School, B Middle School, or C High School who had a positive reverse transcription polymerase chain reaction test result with an upper respiratory sample for a SARS-CoV-2 E gene or RdRp gene, regardless of their clinical manifestations, per the COVID-19 Response Guidelines version 10-1 (designated for local government agencies) (CRG). The control group consisted of individuals at A

HIGHLIGHTS

- Inter-school COVID-19 transmission occurred among 129 students with confirmed COVID-19 cases at 3 schools, involving risk sources such as private tutoring academies and multi-use facilities.
- Epidemiological investigations highlighted a significant correlation between student visits to specific multi-use facilities, notably karaoke rooms, and heightened infection risk.
- School infection prevention measures should extend beyond the school premises to include local multi-use facilities that students frequently visit.

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Middle School, B Middle School, and C High School who were exposed during the study period and who responded to the survey without testing positive for a SARS-CoV-2 gene.

**Data Collection and Risk Factor Analysis**

Using the epidemiological investigation form provided in the CRG, interviews were conducted to gather information on the demographics (sex and age), school, name, status, and presence or absence of symptoms for individuals exposed in the cluster outbreak (both confirmed and non-confirmed groups). Using the collected data, the general characteristics were analyzed, and an epidemic curve was constructed based on the dates of diagnosis for the confirmed cases (Figure 1).

Through the epidemiological investigation, the visits of COVID-19-confirmed patients to hagwons and multi-use facilities, such as internet cafés and karaoke rooms, were tracked and represented in a diagram illustrating the transmission relationships. The CRG was also used in conducting a facility risk assessment of these establishments.

To gather the risk factors for transmission dependent on visits to hagwons and multi-use facilities, students with and without confirmed COVID-19 infections were surveyed for their usage of these facilities (excluding school staff members who did not visit these facilities during the relevant period). Next, logistic regression analysis was performed to

![Figure 1. Epidemic curve.](https://doi.org/10.24171/j.phrp.2023.0351)
identify the risk factors for transmission according to these visit histories, and the Mann-Whitney U test was performed to analyze the differences between individuals with and without confirmed COVID-19 infections according to their visit histories. Statistical significance was set at \( p < 0.05 \).

Additionally, to assess the risk of transmission within schools, we analyzed closed-circuit television (CCTV) footage from the entrances and hallways of each school to gauge adherence to indoor mask-wearing. The CCTV datasets were collected per Article 76, Clause 2 of the Infectious Disease Prevention Act and were analyzed by an investigator from the Korea National Police Agency. These datasets were protected by a security system, not accessible online, and immediately destroyed after analysis.

The CCTV analysis was performed using BriefCAM Investigator ver. 5.4 (BriefCAM Inc.). The epidemic curve was created in Excel ver. 2016 (Microsoft Corp.). Statistical analysis was conducted using R ver. 4.1.2 (R Foundation), and the transmission diagram was generated using Gephi ver. 0.10 (https://gephi.org/).

Institutional Review Board Approval
Data for this study were collected as part of the public health response to COVID-19 and were reviewed and approved by the Institutional Review Board of the Korea Disease Control and Prevention Agency (KDCA-2023-06-02-PE-01).

Results

General Characteristics and Epidemic Trend
In total, 696 members of the 3 schools in this study were exposed to COVID-19, of whom 129 tested positive, indicating an infection rate of 18.5% (Table 1). Of the 129 confirmed cases, 109 were male (84.5%). This predominance of male cases is attributed to C High School being an all-boys school. Distribution by year level was as follows: 64 middle school students (49.6%), 64 first- and second-year high school students (49.6%), 0 third-year high school students (0%), and 1 school staff member (0.8%). Notably, 36 cases (27.9%), 29 cases (22.5%), and 64 cases (49.6%) were confirmed among students attending A Middle School, B Middle School, and C High School, respectively. C High School had the most confirmed cases, whereas A Middle School had the highest incidence rate at 21.6%. Thirty-eight participants (29.5%) had no clinical symptoms. Of the 91 participants (70.5%) who had clinical symptoms, cough was the most common (\( n = 49, 53.8\% \)), followed by fever (\( n = 36, 39.6\% \)), headache (\( n = 30, 33.0\% \)), and sore throat (\( n = 29, 31.9\% \)) (Table 2).

As illustrated in the epidemic curve, following the identification of the index case on October 17, a mass screening was conducted on October 18. Consequently, the schools were closed temporarily, making October 19 the last exposure date (Figure 1). The final confirmed case was reported on November 2. After 14 days of monitoring with no additional cases, the outbreak was deemed to have ended.

Analysis of Transmission Risk Factors
The students with confirmed COVID-19 infections from A Middle School, B Middle School, and C High School visited a total of 11 hagwons, 3 internet cafés, and 1 karaoke room. One internet café and the karaoke room were visited by confirmed patients from all 3 schools (Figure 2). All samples were identified as belonging to the delta variant, thus confirming the associations among the case. When evaluated according to the on-site facility risk

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Contacts</th>
<th>Infected</th>
<th>Uninfected</th>
<th>Attack rate (%)</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total individuals</td>
<td>696 (100.0)</td>
<td>129 (100.0)</td>
<td>567 (100.0)</td>
<td>18.5</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>Male</td>
<td>533 (76.6)</td>
<td>109 (84.5)</td>
<td>424 (74.8)</td>
<td>20.5</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>163 (23.4)</td>
<td>20 (15.5)</td>
<td>143 (25.2)</td>
<td>12.3</td>
<td></td>
</tr>
<tr>
<td>Year levels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Middle school</td>
<td>246 (35.3)</td>
<td>64 (49.6)</td>
<td>182 (32.1)</td>
<td>26.0</td>
<td></td>
</tr>
<tr>
<td>High school (grades 10 and 11)</td>
<td>205 (29.5)</td>
<td>64 (49.6)</td>
<td>141 (24.9)</td>
<td>31.2</td>
<td></td>
</tr>
<tr>
<td>High school (grade 12)</td>
<td>98 (14.1)</td>
<td>0 (0)</td>
<td>98 (17.3)</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Teacher</td>
<td>147 (21.1)</td>
<td>1 (0.8)</td>
<td>146 (25.7)</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>School</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.34</td>
</tr>
<tr>
<td>A Middle School</td>
<td>167 (24.0)</td>
<td>36 (27.9)</td>
<td>131 (23.1)</td>
<td>21.6</td>
<td></td>
</tr>
<tr>
<td>B Middle School</td>
<td>144 (20.7)</td>
<td>29 (22.5)</td>
<td>115 (20.3)</td>
<td>20.1</td>
<td></td>
</tr>
<tr>
<td>C High School</td>
<td>385 (55.3)</td>
<td>64 (49.6)</td>
<td>321 (56.6)</td>
<td>16.6</td>
<td></td>
</tr>
</tbody>
</table>

Data are presented as \( n \) (\%).

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Table 2. Clinical symptoms of the 3 schools’ COVID-19 cases

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Total</th>
<th>A Middle School</th>
<th>B Middle School</th>
<th>C High School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>129</td>
<td>36</td>
<td>29</td>
<td>64</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>38</td>
<td>7</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Symptomatic cases as of the confirmed date</td>
<td>91 (100.0)</td>
<td>29 (100.0)</td>
<td>17 (100.0)</td>
<td>45 (100.0)</td>
</tr>
<tr>
<td>Fever</td>
<td>36 (39.6)</td>
<td>11 (37.9)</td>
<td>8 (47.1)</td>
<td>17 (37.8)</td>
</tr>
<tr>
<td>Cough</td>
<td>49 (53.8)</td>
<td>18 (62.1)</td>
<td>7 (41.2)</td>
<td>24 (53.3)</td>
</tr>
<tr>
<td>Sore throat</td>
<td>29 (31.9)</td>
<td>8 (27.6)</td>
<td>3 (17.6)</td>
<td>18 (40.0)</td>
</tr>
<tr>
<td>Sputum</td>
<td>19 (20.9)</td>
<td>2 (6.9)</td>
<td>2 (11.8)</td>
<td>15 (33.3)</td>
</tr>
<tr>
<td>Runny nose</td>
<td>7 (7.7)</td>
<td>4 (13.8)</td>
<td>0 (0)</td>
<td>3 (6.7)</td>
</tr>
<tr>
<td>Headache</td>
<td>30 (33.0)</td>
<td>6 (20.7)</td>
<td>3 (17.6)</td>
<td>21 (46.7)</td>
</tr>
<tr>
<td>Chills</td>
<td>14 (15.4)</td>
<td>4 (13.8)</td>
<td>2 (11.8)</td>
<td>8 (17.8)</td>
</tr>
<tr>
<td>Muscle aches</td>
<td>8 (8.8)</td>
<td>2 (6.9)</td>
<td>1 (5.9)</td>
<td>5 (11.1)</td>
</tr>
<tr>
<td>Loss of smell</td>
<td>5 (5.5)</td>
<td>0 (0)</td>
<td>3 (17.6)</td>
<td>2 (4.4)</td>
</tr>
<tr>
<td>Loss of taste</td>
<td>5 (5.5)</td>
<td>0 (0)</td>
<td>3 (17.6)</td>
<td>2 (4.4)</td>
</tr>
<tr>
<td>Diarrhea or vomiting</td>
<td>4 (4.4)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>4 (8.9)</td>
</tr>
<tr>
<td>Others(a)</td>
<td>7 (7.7)</td>
<td>3 (10.3)</td>
<td>0 (0)</td>
<td>4 (8.9)</td>
</tr>
</tbody>
</table>

Data are presented as \(n\) (%).

\(a\) Dizziness, chest pain, and difficulty breathing.

Figure 2. Transmission relationships of the infected individuals.

assessment criteria outlined in the CRG, schools were assigned a risk rating of 5 points, indicating a low risk. In contrast, internet cafés, which did not follow recommended mechanical and natural ventilation practices, received 7 points, indicating a medium risk (Table 3). Karaoke rooms, considering their enclosed nature and high propensity for droplet production, were allocated 8 points, also indicating a medium risk.

To identify the risk factors associated with visits to hagwons and multi-use facilities, the students with and without confirmed infections were surveyed. After adjustments were made for their year levels, the odds ratios (ORs) and 95% confidence intervals (CIs) were computed through logistic regression (Table 4). Although visiting a hagwon and visiting an internet café were not significant predictors, the OR for COVID-19 diagnosis was 1.90 (95% CI, 1.03–3.50) among those who had visited the local karaoke room compared to those who did not, reflecting a significant increase in risk.

Using the Mann-Whitney U test, we examined whether significant differences could be identified in the number and length of visits to hagwons and multi-use facilities depending on the diagnostic confirmation status (Table 5). Our findings indicated that the number of visits to hagwons and internet cafés and the time spent in internet cafés were higher among confirmed cases than non-confirmed cases; however, these differences were not statistically significant. In contrast, significant differences were observed regarding the number of visits to the local karaoke room and the length of time spent there, with both being significantly higher among confirmed cases than non-confirmed cases (\(p = 0.02\).
To assess the risk of inter-school transmission, video datasets were collected from the 3 schools for October 15, which was considered a critical day for viral spread. The CCTV footage was analyzed to determine the mask-wearing rates of school members. The rates were found to be 90.8% for A Middle School, 85.3% for B Middle School, and 20.8% for C High School, with C High School exhibiting the lowest adherence.

**Discussion**

Typically, when an infectious disease emerges in a school, its spread is limited to a specific class or year level and remains within the school boundaries. However, the situation examined in this study presents an unusual scenario where inter-school transmission occurred within a single community.

Among the confirmed cases, the proportion of students in middle school (grades 7, 8, and 9) and in high school (grades 10 and 11) was 1:1, with 64 students (49.6%) each. In contrast, no cases were observed among high school students in grade 12, and only 1 case (0.8%) was found among school staff members. The fact that some 12th graders did not become infected with COVID-19 despite visiting the same internet cafés and karaoke room could be attributed to reasons including preventing mass gatherings of 12th graders by assigning them to dorms, enforcing more strict personal hygiene measures for 12th graders to avoid disturbing their school and career preparations, and providing vaccinations for 12th graders and high school staff members nationwide from July 19, 2021.

This conclusion is consistent with prior research, indicating that vaccination mitigates the spread of COVID-19 within schools; therefore, it seems that vaccination effectively curbed a more extensive spread of the virus in this community.
during this cluster outbreak [12].

The on-site facility risk assessment undertaken in this study revealed that, despite the visitor temperature checks that schools and other multi-use facilities conducted in compliance with preventive measures, 72.1% of the confirmed cases in this cluster outbreak had no fever. This finding aligns with existing reports suggesting that monitoring body temperature alone is insufficient for preventing the spread of COVID-19 [13]. The most common symptom among the confirmed cases was a cough, followed by fever, headache, and sore throat. This suggests that preemptive monitoring for symptoms other than fever can help in the early prevention of spread.

Many confirmed patients visited a hagwon or multi-use facility, and the paths of confirmed patients from all 3 schools overlapped in these facilities (Figure 2). An analysis based on these visits showed that students who frequently visited the local karaoke room faced a risk of infection 190 times higher than those who did not. Singing is known to release more droplets than regular conversation. Notably, previous studies have emphasized the risk of airborne transmission during singing [14–16]. Considering that most karaoke rooms are enclosed spaces, they are considered sites of significant transmission risk [17]. The confirmed cases not only visited the karaoke room more frequently, but also spent extended periods there compared to the non-confirmed cases. This finding accords with earlier studies that have emphasized the heightened transmission risk associated with prolonged stays in karaoke rooms [18]. Consistent with prior research on COVID-19 outbreaks linked to karaoke visits [18,19], our study found that such visits carry a substantial transmission risk for COVID-19.

The facility risk assessment for internet cafés indicated a high degree of enclosure, density, and duration of stay, although these were not statistically significant. Additionally, prior research indicated that 21.3% of Korean teenagers frequently visit karaoke rooms and internet cafés during their leisure time. This underscores the importance of considering the usage of these multi-use facilities when devising school infection prevention strategies [20]. Assessing the conditions of multi-use facilities popular among teenagers and incorporating this data into school infection prevention measures are crucial for effective prevention and timely containment of potential school-based cluster outbreaks.

To investigate the within-school transmission risk, we assessed the mask-wearing rate of school members based on CCTV footage analysis, and C High School was found to have a very low adherence of 20.8%. Previous studies have demonstrated that wearing masks prevents the spread of infection within schools [21,22]. Low adherence to mask-wearing may have contributed to the cluster outbreak within C High School, especially considering that C High School is a boarding school and showed fewer visits to hagwons and multi-use facilities than A and B Middle Schools. This highlights the need to reinforce mask-wearing training for infection prevention. Since boarding schools have a dense population of teenagers often in contact with each other, once an infection enters, it can spread quickly and easily. Hence, thorough preventive measures and infection management are required to prevent infections from entering a school site [23].

This study had 2 main limitations. First, because the hagwon operators who were in contact with the students closed their hagwons for the duration, it was impossible to evaluate the individual exposure risks of each hagwon. Hence, differences in exposure environments may have existed across the various facilities frequently visited by the students, and caution is needed when interpreting our results. Second, the study identified risk factors based solely on the frequency and duration of visits to hagwons, internet cafés, and the local karaoke room without considering other risk exposure factors associated with the confirmed cases. In addition, the potential variations in the risk factors across middle school students, 10th graders, 11th graders, and 12th graders were not reflected. Therefore, further analysis and evaluation of inter-school risk factors for transmission within a community are deemed necessary. Despite these limitations, this study identified the characteristics of infectious disease transmission among 3 local schools. To our knowledge, it is the first study conducted in the Republic of Korea to analyze the risk factors for the transmission of infectious diseases among schools within a specific region.

**Conclusion**

We identified the COVID-19 exposure history of a community of teenagers in relation to various risk sources, such as hagwons and multi-use facilities. Our findings showed that inter-school transmission had occurred in the confirmed cases involving these risk sources. This suggests that the scope of school infection prevention measures should extend beyond the school premises and include multi-use facilities that local students frequently visit. Furthermore, to develop and implement in-school preventive measures, detailed monitoring, preemptive testing, and mask-wearing were found to be imperative. The current guidelines of the Ministry of Education recommend self-testing and mask-wearing for those with respiratory symptoms, and maintaining these measures is likely to be beneficial for school infection prevention. In the future, utilizing the results of this study in
relation to COVID-19, as well as other respiratory infectious diseases, is likely to contribute to establishing efficient school infection prevention strategies.

Notes

Ethics Approval
This study was approved by the Institutional Review Board of Korea Disease Control and Prevention Agency (KDCA-2023-06-02-PE-01) and performed in accordance with the principles of the Declaration of Helsinki.

Conflicts of Interest
The authors have no conflicts of interest to declare.

Funding
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Availability of Data
The datasets are not publicly available but are available from the corresponding author upon reasonable request.

Authors’ Contributions
Conceptualization: JC, SEL, YJP; Data curation: JC, SC, BL; Formal analysis: JHJ, SC; Funding acquisition: SEL; Investigation: JC, SC, BL, YJP, Methodology: JC, SEL, YJP; Project administration: JC; Resources: JC; Software: JC, SC, BL; Supervision: SEL; Validation: SEL; Visualization: JC; Writing—original draft: JC; Writing—review & editing: all authors. All authors read and approved the final manuscript.

Additional Contributions
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References