SARS-CoV-2 transmission in schools in Korea: nationwide cohort study

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ABSTRACT

Objective There is an urgent public need to readdress the school closure strategies. We aimed to describe the epidemiology of COVID-19 in schools and school-aged children to understand their roles in transmitting SARS-CoV-2 in Korea.

Design Retrospective cohort study.

Setting All schools in Korea

Patients All school-aged children in Korea.

Interventions None (observational study).

Main outcome measures Incidence rate, proportion of affected schools.

Results Between February and December 2020, the incidence rate was lower among school-aged children (63.2–79.8 per 100 000) compared with adults aged 19 and above (130.4 per 100 000). Household was the main route of transmission (62.3%), followed by community (21.3%) and school clusters (7.9%). Among the schools in Korea, 52% of secondary schools had COVID-19 cases, followed by 39% of primary schools and 3% of kindergartens.

Conclusions We found that schools and school-aged children aged 7–18 years were not the main drivers of COVID-19 transmission. The major sources of transmission were households.

What is already known on this topic?

- ► School closure has significant negative impacts on children.
- ► School closure has been widely applied during the COVID-19 pandemic, despite limited evidence regarding the net public benefit.

What this study adds?

- ► Schools and school-aged children were not the main drivers of COVID-19 transmission, while the major sources of infection were households and adults.
- ► Households were the main route of transmission to students (62.3%), irrespective of school opening or closures.
- ► The incidence rate was the highest in secondary schools, followed by primary schools and kindergartens.

Globally, as of April 2021, there have been more than 140 million confirmed cases of COVID-19.[1] Many schools were closed in an attempt to contain the transmission, impacting more than 1.5 billion children, worldwide.[2] School closure has significant negative impacts on children. Children are deprived not only of opportunities in education but also growth and development.[3] Many other problems include gaps in childcare, rise in dropout rates, social isolation, etc. For many children who rely on schools for meals, nutrition is also compromised. Regardless of these concerns, school closure has been widely applied during COVID-19, despite limited evidence of the net public benefit of school closure.[4] Previous data that investigated the effect of school closures during the COVID-19 pandemic indicate that this was only marginally effective in reducing the transmission of SARS-CoV-2 virus.[5] Thus, there is an urgent public need to readdress the school closure strategies.

The Korean government also pursued a strategy of closing schools for an extended period of time at the outbreak of the pandemic to limit transmission between March and May of 2020, and has since ordered all schools to reopen; however, individual schools face intermittent closures due to additional waves of outbreaks. The centralised educational governance system controls the policy that is collectively applied to all schools (K-12) in Korea, which enables us to assess the net public health effect of the closure of schools at a national level.

In this study, we aimed to describe the epidemiology of COVID-19 in schools and school-aged children from February to December 2020, to clarify their roles in transmitting SARS-CoV-2.

METHODS

Study population and setting

This was a retrospective, observational study comprised of all school-attending children and staff working at schools who were diagnosed with COVID-19 through laboratory testing (reverse transcription PCR) in Korea from February 2020 to December 2020. Korea's population is estimated at 51 million in 2021, with approximately 5.9 million children attending K-12 schools and 680 000 staff working in the schools. Most Korean public and private schools have standardised semester systems, but there are slight variations in dates between individual schools and regions. The academic year usually starts at the beginning of March, and the first semester runs until late-July. After the summer break, the second semester generally starts at the mid-to-end of August and continues until mid-February with a winter break in January to mid-February.

We analysed the nationwide epidemiological data on age-based COVID-19 cases collected by the Korea Disease Control and Prevention Agency. Their potential route of transmission of students and staff was obtained from the data surveyed by the Ministry of Education. Schools were categorised as either: (1) kindergarten, mostly age 3–6 years; (2) primary school (grades 1–6), mostly age 7–12 years; and secondary school (grades 7–12), mostly age 13–18 years. The categorisation of a confirmed COVID-19 case was calculated based on their date of birth and date of diagnosis. The potential route of transmission for each COVID-19 case was extracted from epidemiological investigation data and was classified as either: household, community or school cluster. The index case was the first documented person confirmed with SARS-CoV-2 PCR in the defined cluster (two or more cases that are linked by space and time of exposure). For all index cases, epidemiological investigation and active monitoring are conducted by government officers on all school members including close contacts and non-close contacts.

School closure was defined as the cancellation of all classes in order to prevent children from attending school. In 2020, school closures were proactively enforced even before any transmission among students or staff had been identified. The school closure policy was implemented on a national basis. However, the level of closures (from complete closure to limiting crowd to less than two-thirds or one-third of the students) was determined by each school district based on the level of COVID-19 transmission within the locality.[6] During the school attendance period, infection prevention guidelines developed by the Ministry of Education were implemented in all public and private schools. These guidelines aligned with the following main principles: physical distancing, hygiene measures and self-quarantine of students with symptoms.[7] The guidelines enforced specific rules, including self-checking using a smartphone-based app, screening at the entrances, wearing masks, separating periods for attendance to minimise the mixing of students, and controlling the number of students present at schools by segregating the school timings for different classes. Throughout the study period, all contact tracing measures had been performed under the Infectious Disease Control and Prevention Act.3, which had not changed since then. The definition and working manual of the contact tracing measures were conducted based on the legal mandates.

Analyses

We calculated the COVID-19 prevalence proportion, incidence rates and incidence rate ratios among students and staff in kindergartens, primary schools and secondary schools. For the calculation of age-specific incidence of COVID-19 cases, denominators were derived from the census data.[8] We extracted the potential route of transmission of SARS-CoV-2 among the students and staff of each type of school using the epidemiological investigation database of the Ministry of Education. To estimate the prevalence of COVID-19 in schools and community, denominators were derived from student registry at the Ministry of Education. We calculated student-to-staff incidence rate ratio in each school to assess the risk difference between children and adolescent vs adults. Lastly, we identified the number of school clusters (documented transmission limited to schools) and the number of index cases with median secondary infection rates (SIRs; number of cases among contacts of primary cases/total population in the schools of the primary cases) across each school type.

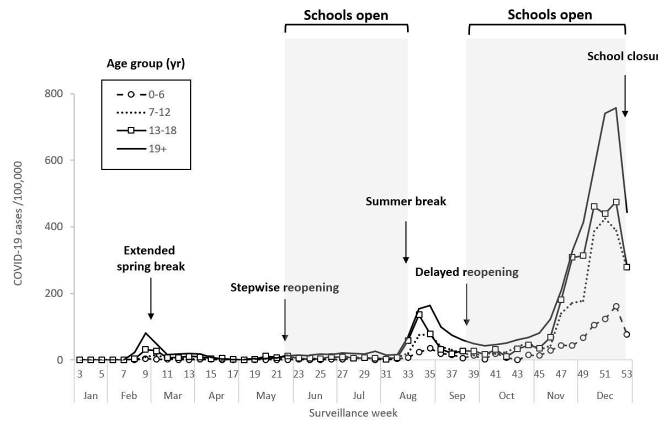

Figure 1 Weekly age-specific incidence of COVID-19 in relation to school attendance, South Korea, 2020.

This study used clustered data with anonymised personal information obtained from the public health response to the COVID-19 outbreak, it was therefore exempted from an ethics board review.

RESULTS

Between February and December 2020, there were a total of 62 166 COVID-19 confirmed cases reported in Korea, including 2164 (3.5%) children aged 0–9 years and 3885 (6.2%) children aged 10–19 years. During the monitored week, the prevalence proportion was highest among adults aged 19 and above (130.4 per 100 000), followed by teenagers aged 13–18 years (79.8 per 100 000), children aged 7–12 years (63.2 per 100 000) and kindergarten students aged 0–6 years (52.8 per 100 000).

Figure 1 shows the weekly age-specific incidence of COVID-19 relative to school attendance in 2020. The opening of schools was postponed in March and April, and a stepwise reopening was conducted from May to June. In 2020, most schools and kindergartens remained open from late June to mid-August, after which they had a summer break. Due to the resurgence of COVID-19 during the summer break, the start of the second semester was delayed until mid-September. During the first semester from late May to early August 2020, the weekly incidence rate was generally low at less than one per 100 000 of the population across all age groups. However, the second wave was noted during the summer break in late August and was followed by a third wave during late November across most age groups, especially adults aged 19 and above.

The weekly number of COVID-19 cases among students (K-12) by potential routes of transmission is shown in figure 2. In relation to the weekly national incidence rate for all ages, the number of cases among students peaked first during the summer break in late August and second from late November to December. In all monitored weeks, household was the main route of transmission, followed by community transmission and school clusters.

The COVID-19 incidence rate among students was the highest in secondary school (grades 7–12) students (7.6 per 100 000), followed by kindergarten students (3.76 per 100 000) and primary school (grades 1–6) students (3.45 per 100 000, table 1). The weekly incidence rate among staff members was the highest among the staff working in secondary schools (19.61 per 100 000), followed by kindergarten staff (16.5 per 100 000) and primary school staff (12.4 per 100 000). The student-to-staff incidence rate ratio was the lowest in kindergartens at 0.23 (95% CI 0.11 to 0.49, p<0.001), followed by primary schools at 0.28

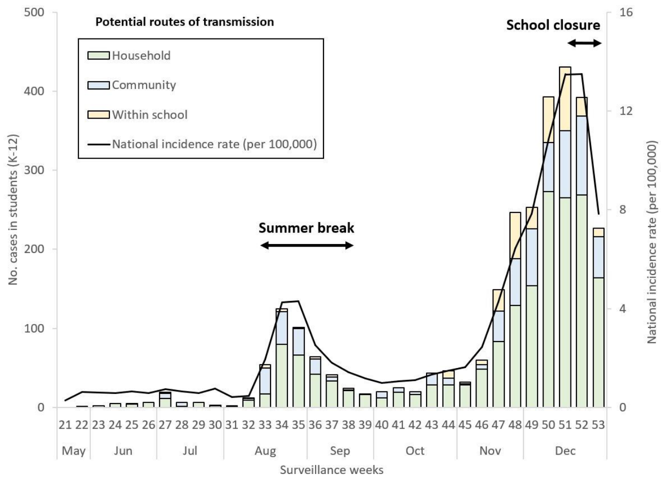

Figure 2 Weekly number of COVID-19 cases among students (K-12) by potential routes of transmission during academic weeks, South Korea, 2020. We confirm we have permission to reuse the image as this was created by authors.

(95% CI 0.19 to 0.42, p<0.001) and secondary schools at 0.39 (95% CI 0.29 to 0.53, p<0.001).

Schools accounted for 7.9% and 8.1% of potential transmission routes for students and staff, respectively (table 2). Households were the most common place of transmission among students (62.3%), whereas community was the most common route of transmission among staff (62.9%). The proportions were relatively similar across the types of schools in general. However, they were different for secondary school students (less household transmission, more community-related transmission) and kindergarten staff (more household transmission, less community-related transmission).

Among all 20415 schools in Korea, 52% of secondary schools had COVID-19 cases, followed by 39% of primary schools and 3% of kindergartens (table 3). This meant a total of 72.9% (n=14 874) of all schools (K-12) had no single documented case of COVID-19. In 2020, there were a total of 307 school clusters (1.5%, out of 20 415 schools): 63.8% were in secondary schools, 29.3% in primary schools and 6.8% in kindergartens. In all levels of schools, more student index cases were observed, with the highest percentage of student index cases in kindergartens (33.3%, 7/21), followed by primary schools (20.0%, 18/90) and secondary schools (19.9%, 39/196). The median secondary infection rate among students with identified intra-school transmission was 1.54% (95% CI 0.43 to 8.33) in kindergartens, followed by secondary schools (0.41%, 95% CI 0.08 to 8.15) and primary schools (0.25%, 95% CI 0.11 to 3.25).

DISCUSSION

In this study, we assessed the role of schools and school-aged students in transmitting SARS-CoV-2 in Korea during the first year of the COVID-19 pandemic. We found that schools and school-aged children were not the main drivers of COVID-19 transmission, while the major sources of infection were households. This finding supports previous findings from May to July 2020, which showed no elevated risk of COVID-19 transmission in the context of stringent school-based infection prevention measures in Korea.[6 7]

During the monitored period, households were the main route of transmission to students (62.3%), irrespective of school opening or closures, followed by transmission through community (21.3%) and school clusters (7.9%). The two distinctive waves of outbreak occurred in summer (late August) and in late fall (November), mostly driven by the adults aged 19+ years. Our data support the existing evidence that children do not appear to cause super spreading events and the opening of schools had an insignificant association with the community outbreak of COVID-19. During the earlier stages of the COVID-19 pandemic, a systematic review of the effectiveness of school closures included 16 articles. However, there was no information regarding the relative contribution of school closures on transmission control.[9] A modelling study from Canada that simulated disease transmission during school closures indicated that they had a limited impact on reducing the burden of COVID-19 in the absence of measures to interrupt the chain of transmission.[10] Another modelling study from Japan showed that school closures did not appear to lead to a decrease in the incidence of coronavirus infection. The effectiveness of the measure was calculated to be 0.08 (95% CI −0.36 to 0.65) as per the Japanese study.[11] On the other hand, an earlier model from Korea measuring the potential effects of school opening assumed the transmission rate between children would increase 10-fold due to the risk of group transmission. Additional cases were expected suggesting the risk of group transmission in children.[12] During the earlier stages of the COVID-19 pandemic in March 2020, Irish schools identified no paediatric transmission, which suggested that children do not appear to be drivers of transmission.[13] After the reopening of schools in Germany in April 2020, only a few, mostly small COVID-19 school outbreaks were reported, which suggested that the containment measures were sufficient to reduce spillover into the community.[14] Real-world data from Florida from August to December 2020 indicated that an estimated 60% of COVID-19 cases were not school-related, despite the schools being reopened. A higher rate of infection was observed in districts without mandatory mask-use policies, suggesting that school-based mitigation strategies can help reopen schools without causing a resurgence of COVID-19.[15] With effective case-contact testing and epidemic management strategies, SARS-CoV-2 transmission rates could be controlled effectively in educational settings, as seen in the UK and Australia.[16 17]

Table 1 COVID-9 incidence rates and incidence rate ratios of students and staff, South Korea, February–December 2020

	Incidence rate per 100000	95% CI	Incidence rate ratio	95% CI	P value
Kindergartens					
Students	3.76	2.38 to 5.63	0.23	0.11 to 0.49	<0.001
Staff	16.5	8.80 to 28.27			
Primary schools					
Students	3.45	2.79 to 4.23	0.28	0.19 to 0.42	<0.001
Staff	12.4	8.62 to 17.21			
Secondary schools					
Students	7.65	6.64 to 8.78	0.39	0.29 to 0.53	<0.001
Staff	19.61	15.07 to 25.09			

Table 2 Incidence of COVID-19 in school students and staff by potential route of transmission, South Korea, February–December 2020

	Kindergartens	Primary schools	Secondary schools	Total
Potential route of transmission	N (%)	N (%)	N (%)	N (%)
Students				
Schools	23 (9.0)	93 (5.5)	203 (9.7)	319 (7.9)
Households	192 (75.3)	1233 (72.6)	1094 (52.3)	2519 (62.3)
Community	29 (11.4)	298 (17.5)	536 (25.6)	863 (21.3)
Unidentified	11 (4.3)	75 (4.4)	258 (12.3)	344 (8.5)
Subtotal	255	1699	2091	4045
Staff				
Schools	13 (13.8)	35 (7.4)	63 (7.9)	111 (8.1)
Households	39 (41.5)	87 (18.3)	129 (16.1)	255 (18.6)
Community	29 (30.9)	298 (62.7)	536 (66.8)	863 (62.9)
Unidentified	13 (13.8)	55 (11.6)	74 (9.2)	142 (10.4)
Subtotal	94	475	802	1371
Total	349	2174	2893	5416

A school closure policy will have to be revised based on a risk–benefit analysis with the current available evidence.[18] However, during the early stage of pandemic, decisions were made with extreme caution due to the uncertain nature of the situation and extrapolated from experiences of other respiratory viruses. Between January and December 2020, most (72.9%) schools in Korea had not experienced a single case of COVID-19 and had a low median secondary infection rate. While 62.9% of staff were infected from the community, 62.3% of students were infected within their households. This suggests a differential route of transmission across age groups. During the observed period, there were three waves of SARS-CoV-2 community outbreak: the first was during February to March, which led to the nationwide extension of spring breaks; the second was during the summer break from August to September, which led to the delayed reopening of the schools; and the third wave occurred from November to December, which resulted in closures in late December.

It is important to recognise that the incidence and risk for COVID-19 varied across school types. The incidence rate ratio for students and staff was the highest in secondary schools, followed by primary schools and kindergartens. This suggests an incremental age effect among school-aged children. A study in Florida indicated that the reopening of schools was followed by increased COVID-19 incidence among school-aged children, especially those in high schools.[19] In northern Italy, after schools reopened from September to October 2020, the overall secondary attack rate was 3.2% and reached 6.6% in middle and high schools.[20] When schools in Israel fully reopened in May 2020, a major outbreak of COVID-19 occurred in a high school, but the cases were not epidemiologically linked, which suggested linkage with community transmission.[21]

Our study has some limitations. First, other additional non-pharmaceutical interventions, such as social distancing levels, contact tracing and early isolation, and quarantine measures, which were concurrently implemented with school closures, made it impractical to fully distinguish the potential effect of the closure and reopening of schools. Similarly, in a study from the USA that indicated that school closure was temporally associated with decreased COVID-19 incidence and mortality, other non-pharmaceutical measures made it difficult to disentangle the potential effect of each intervention.[22 23] Second, our study focused on the national level and did not investigate community-level transmission based on the policies of each school district. Given that individual schools have partial authority with respect to the control of crowding within schools, some schools may have different restrictive policies locally. Lastly, although the practice in contact tracing had not changed over the course of pandemic, identification of source of transmission and index case may have been misclassified due to the difference in monitoring level between community and schools.

Table 3 School clusters of COVID-19, South Korea, February-December 2020

	Kindergartens	Primary schools	Secondary schools	Total
Variables	N (%)	N (%)	N (%)	N (%)
Total schools (n)	8705	6120	5590	20 415
Schools with 0 case	8444 (97.0)	3747 (61.2)	2683 (48.0)	14 874 (72.9)
Schools with ≥1 case	211 (2.4)	1430 (23.4)	1811 (32.4)	3452 (16.9)
Schools with ≥2 cases	50 (0.6)	943 (15.4)	1096 (19.6)	2089 (10.2)
School clusters (n)*	21	90	196	307
Student index case	7 (33.3)	18 (20.0)	39 (19.9)	64 (20.8)
Staff index case	4 (19.0)	11 (12.2)	17 (8.7)	32 (10.4)
Unidentified index case	10 (47.6)	61 (67.8)	140 (71.4)	211 (68.7)
Median SIR (range)†	1.54 (0.43–8.33)	0.25 (0.11–3.25)	0.41 (0.08–8.15)	0.41 (0.08–8.33)

*Documented potential transmission within schools identified as of December 2020.
†Secondary infection rate in students in corresponding schools.
SIR, secondary infection rate.

Despite these limitations, an important lesson drawn from our findings is that children and schools were not the main drivers of the COVID-19 outbreak in Korea, where stringent infection control policies were adopted in the schools and community transmission was suppressed. This is supported by the apparent lack of impact of school closures in other countries with different COVID-19 epidemiology and higher incidence rates. Although timely school closures have been shown to reduce transmission of other respiratory viruses, such as influenza, the other implications of school closure and the viral properties of SARS-CoV-2 must be considered when making policy decisions.

The results of this study show that children and schools do not have a major impact on SARS-CoV-2 community transmission, and risks of transmission within schools and to the community are low in the presence of proper prevention measures. Therefore, school closure seems to be a relatively ineffective measure to contain the COVID-19 pandemic. The levels of transmission of SARS-CoV-2 within the community and among adults appear to be the two important factors which influence school transmission.

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