



School closures during the coronavirus disease 2019 outbreak

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School closures during the coronavirus disease 2019 (COVID-19) pandemic have been outlined in studies from different disciplines, including economics, sociology, mathematical modeling, epidemiology, and public health. In this review, we discuss the implications of school closures in the context of the current COVID-19 pandemic. Modeling studies of the effects of school closures, largely derived from the pandemic influenza model, on severe acute respiratory syndrome coronavirus 2 produced conflicting results. Earlier studies assessed the risk of school reopening by modeling transmission across schools and communities; however, it remains unclear whether the risk is due to increased transmission in adults or children. The empirical findings of the impact of school closures on COVID-19 outbreaks suggest no clear effect, likely because of heterogeneity in community infection pressure, differences in school closure strategies, or the use of multiple interventions. The benefits of school closings are unclear and not readily quantifiable; however, they must be weighed against the potential high social costs, which can also negatively affect the health of this generation.

Key words: Coronavirus, School, Child

Key message

- Earlier modeling studies of the effects of school closures on severe acute respiratory syndrome coronavirus 2 were largely derived from the pandemic influenza model, resulting in conflicting implications.
- Observational findings suggest no clear effect of school closures on community transmission or overall mortality.
- School closures must be weighed against potential high social costs, which can also negatively affect children's health.

Introduction

As of March 14, 2021, the World Health Organization officially reported 119,220,681 confirmed cases of coronavirus

disease 2019 (COVID-19), including 2,642,826 deaths.¹⁾ The current data suggest that children under the age of 18 years represent less than 10% of reported cases, with relatively few deaths compared to elderly people.²⁾ The third wave of the pandemic at the end of 2020 has shifted the age proportion to younger individuals; however, students accounted for less than 15% of patients during all periods. Moreover, increasing empirical evidence suggests that schools are not the driving force of community outbreaks in many parts of the world.³⁾ In this context, global public health agencies are discussing their pandemic mitigation protocols that include school-related public health measures.⁴⁾

School closures are among the nonpharmaceutical interventions suggested for controlling pandemic influenza.⁵⁾ The rationales for school closures are that children may act as an important vector of transmission, and with high contact rates in schools, children may drive community outbreaks of influenza.⁶⁾ School closures may be beneficial depending on characteristics including age-specific attack rates.⁷⁾ However, in the current COVID-19 context, this logic does not apply since more than 90% of individuals infected with severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) are adults and many case clusters have occurred outside of schools. An early summary of data on school closures found that none of the included studies were designed to specifically examine their effectiveness and were of relatively low quality.⁸⁾ Therefore, it is worth discussing whether school closures during the COVID-19 community outbreak effectively break the chains of transmission despite the following potential harms: diminished educational rights of children; and inaccessibility to essential health care, which affects chronic diseases and mental health that instead contribute to reduced community-wide resilience.

School closures during the COVID-19 pandemic have been discussed in studies from different disciplines, including economics, sociology, mathematical modeling, epidemiology, and public health. In this review, we discuss the impact of school closures on the current COVID-19 pandemic.

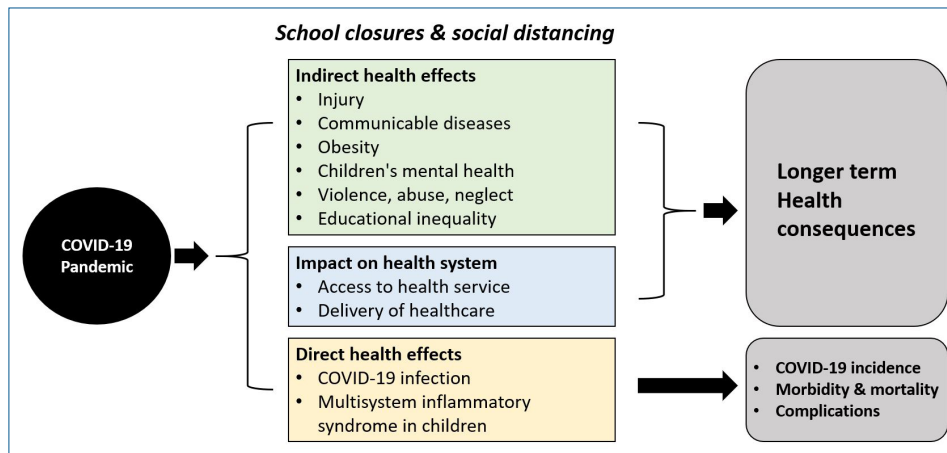
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Graphic abstract

Table 1. Mathematical models simulating the effects of school closures on coronavirus disease-associated health outcomes

Setting	Model	Implication	Reference
UK, US	Individual-based simulation model	Suppression will minimally require a combination of social distancing of the entire population, home isolation of cases and household quarantine of their family members, which may need to be supplemented by school and university closures, though it should be recognized that such closures may have negative impacts on health systems due to increased absenteeism.	9
Korea	Susceptible-exposed-Infectious-Recovered model	The increase in the number of children after school starts is likely to lead to the spread of the virus to parents, grandparents, and other adults around the children. An increase in incidence in the elderly age group is at risk of leading to an increase in mortality.	10
UK	Individual-based model (IBMIC)	Adding school and university closures to case isolation, household quarantine, and social distancing of over 70s would lead to more deaths compared with the equivalent scenario without the closures of schools and universities.	11
Canada	Susceptible-exposed-asymptomatic-infectious-recovered-hospitalized-isolated model	Though a slight increase in infections among adults (2.8%) and children (5.4%) is anticipated by the end of the year, safe school opening is possible with stringent nonpharmaceutical interventions decreasing the risk of transmission in the community and the household.	12

UK, United Kingdom; US, United States.

Mathematical modeling of health outcomes

Modeling studies of school closures due to SARS-CoV-2 have produced conflicting results (Table 1). One of the earliest models predicted that school and university closures would reduce the transmission of COVID-19 under the assumption that children transmit SARS-CoV-2 as much as adults.⁹⁾ However, the study reported that school closures may be insufficient to mitigate the epidemic in isolation in contrast to seasonal influenza, of which children are the key drivers of transmission. Similarly, assuming that the transmission rate among children would increase 10-fold after schools reopened, a Korean simulation study showed that school closures would be an essential nonpharmacological intervention to mitigate the COVID-19 epidemic.¹⁰⁾

Although earlier studies assessed the risk of school reopening by modeling transmission across schools and communities, it remains unclear whether the risk is due to increased transmission in adults or children. A subsequent model predicted that school closures would paradoxically increase the total number of deaths, suggesting that prompt interventions prolonged the epidemic, resulting in more deaths long term.¹¹⁾ One criticism of school closures is that reduced contact at school may lead to increased

contact at home, meaning that children would infect high-risk adults rather than low-risk children. A Canadian study found that the resurgence of COVID-19 in Toronto in the fall of 2020 mainly resulted from the increase in contact rates among adults in the community.¹²⁾ While community spread determined outbreak trajectory and school reopening was not a key driver of viral resurgence, brief school closures still reduced infections when transmission risk within the home was low.¹³⁾ Given that COVID-19-related mortality is highly skewed toward older age groups, it is reasonable to conclude that the optimal strategy differs from that anticipated for an influenza pandemic.

Empirical findings in mitigating outbreaks

Observational findings suggest that school closures have limited effects on the spread of or mortality due to SARS-CoV-2. This may have been due to heterogeneity in community infection pressure, different school closure strategies, or the use of multiple interventions. However, the transmission of SARS-CoV-2 seemed relatively infrequent in the school setting considering the volume of the population and time spent within the space. A

systematic review of 5 cohort studies comprising 3,345 contacts with 18 transmissions in schools resulted in an overall attack rate of 0.08% (95% confidence interval [CI], 0.00%–0.86%).¹⁴ In Ireland, of 1,001 child contacts of 6 confirmed index cases, there were no secondary cases of COVID-19, suggesting that schools were not drivers of transmission.¹⁵ In Germany, the reopening of schools in May 2020 showed that child-to-child transmission in schools/childcare facilities was very uncommon.¹⁶ The researchers estimated that there could be one secondary case per roughly 25 infectious school days. In the setting of increasing SARS-CoV-2 community transmission in France, the spread among children and adolescents remained lower than that observed among adults despite schools remaining open.¹⁷ Mandatory in-school COVID-19 testing was performed in a reopened all-girls private school (N=701) in New York, United States (US).¹⁸ A total of 2,439 tests administered from October 2020 to December 2020 resulted in 3 positive cases (2 students, 1 staff member) for an infection rate of 0.13%.

Despite these findings, the level of community transmission may affect the risk of in-school transmission of SARS-CoV-2. During the community transmission of SARS-CoV-2 in northern Italy, after school reopening in late 2020, the overall secondary case attack rate was 3.2%, reaching 6.6% in middle and high schools.¹⁹ Following the reopening of schools in Israel in May 2020, a major outbreak of COVID-19 occurred in a high school, resulting in 153 students (attack rate, 13.2%) and 25 staff members (attack rate, 16.6%) testing positive for COVID-19.²⁰

In this context, a pandemic preparedness plan is important to ensuring safe school reopening. In Norway, between August and November 2020, all in-school contacts were systematically tested twice during quarantine.²¹ With preventive measures implemented in schools, minimal child-to-child (0.9%, 2 of 234) transmission occurred, suggesting that children under 14 years of age are not drivers of SARS-CoV-2 transmission. In Australia, most schools remained open during the first COVID-19 epidemic wave when 15 schools had children or adults in attendance while infectious with 1,448 contacts monitored.²² Of them, 633 (43.7%) were tested, with 18 secondary cases identified, resulting in a low attack rate of 1.2%. In Santiago, Chile, a serosurvey following a school closure demonstrated antibody positivity rates of 9.9% (95% CI, 8.2%–11.8%) for 1,009 students and 16.6% (95% CI, 12.1%–21.9%) for 235 staff, suggesting that the teachers were more extensively affected during the outbreak and that younger children were at higher infection risk, likely because the index case were teachers and/or parents from the preschool.²³ Despite widespread community transmission in Hong Kong during July and August 2020, cases among school-aged children were reported but did not lead to school outbreaks, likely due to stringent infection control measures adopted by local schools during school resumption.²⁴

In line with the aforementioned countries, a stepwise reopening of schools in South Korea resulted in no sudden increase in pediatric cases, and the proportion of pediatric cases among all confirmed cases in the nation remained at less than 10%.²⁵ After

the schools reopened in South Korea in May 2020, a total of 127 pediatric COVID-19 cases were confirmed by July 12, 2020.²⁶ Of them, 59 children (46%) were exposed to COVID-19 through family and relatives, followed by 18 children (14%) through cram schools or private lessons, 8 children (6%) through multiuse facilities, and 3 children (2%) through school.

The results from South Korea and other countries indicate that keeping schools open had minor consequences for the overall transmission of SARS-CoV-2 in the community. The empirical results for global school closure/reopening in 2020 suggest that measures to sustain education are feasible if community transmission is under control and educational facilities have doable pandemic preparedness plans.

Impact of school closures on noninfectious health outcomes

School closures have significant noninfectious health consequences. The imminent health effects on various aspects of child health include injury, obesity, mental health, and domestic violence. The containment measures in responding to the COVID-19 pandemic have resulted in reduced patterns of healthcare utilization in pediatric emergency medicine in Italy,²⁷ Spain,²⁸ and the US.²⁹ In Korea, there was a striking decrease in pediatric emergency visits, especially among children in early childhood (66.5%), those with low acuity (55.2%–63.8%), and those visiting for noninjury complaints (64.9%).³⁰ Thus, the impact seemed larger in children than in adults, as during the outbreak in Daegu, Korea, the number of adult patients seeking emergency care decreased by 46.4%, whereas the decrease in children was 76.9%.³¹ The school closure also affected child obesity worldwide. In the US, the overall obesity prevalence in children increased from 13.7% (June to December 2019) to 15.4% (June to December 2020).³² As children were confined to their homes during lockdown in France, a profound decrease in their physical activity was noted.³³ A study from Korea suggested that child obesity during the COVID-19 pandemic was associated with the number of days after school closure ($P=0.004$).³⁴ From the early stage of the COVID-19 pandemic in 2020, research was urgently needed of children's mental health in relation to the adoption of school closures as a pandemic mitigation strategy.³⁵ School closures resulted in students spending more time with family; however, their sleep rhythms, eating habits, and physical activities were easily disrupted.³⁶ A recent systematic review showed that children and adolescents were more likely to experience high rates of depression and anxiety during and after a pandemic.³⁷ To address students' noninfectious disease-related health issues and strengthen their coping resources, the entire community should provide students with resources to improve their well-being.

Table 2. School guideline on COVID-19 control and prevention by the Ministry of Education

Situation	Instructions
Before coming to schools	Online education prior to school attendance about personal hygiene and virus prevention measures Self-health check list Diagnostic testing when having symptoms
In schools	Wear face masks and check their body temperature Ventilate classrooms, stagger break times, disinfect public surfaces and objects, provide safe meals
When a COVID-19 case is confirmed among school members	Quarantine the school members (students, teachers, and staff members) and transit all classes into online learning Initiate investigation to identify suspected cases in cooperation with health authorities

COVID-19, coronavirus disease 2019.

School COVID-19 preparedness plans in Korea

The Korean Ministry of Education announced its guidelines on COVID-19 control and prevention (Table 2)³⁸⁾ and stated that schools could reopen once able to implement “distancing in daily life.” The number of students attending classes was limited to avoid overcrowding in schools.

Students received online education prior to school reopening about personal hygiene, viral transmission prevention measures, and procedures to follow in case of suspected symptoms. COVID-19-related symptoms were listed on a self-health check list (i.e., fever, cough, sore throat, shortness of breath, and loss of smell and taste) that was to be thoroughly examined at home before children went to school. If students showed symptoms of COVID-19, they were guided to visit health clinics or screening centers for diagnostic testing.

All students and teachers were required to wear face masks and check their body temperatures twice daily. In addition, ventilating classrooms, staggering break times, and disinfecting public surfaces and objects such as desks and doorknobs were highly encouraged. To provide school meals safely, provisions were taken to limit the extent to which students mixed with each other, and all school cooks and cafeteria staff checked their health twice daily.

With these guidelines still in place, if a case of COVID-19 is confirmed among school members, students, teachers, and staff members are requested to self-quarantine. The school is requested to temporarily transition all classes to online learning and initiate investigations to identify suspected cases.

Future considerations in decision-making of school openings in Korea

In Korea, school openings, including the number of students attending classes and switching online and offline classes, differ according to the levels of social distancing.²⁵⁾ In March 2021, reports of COVID-19 outbreaks in children and adolescents increased in Korea. However, these mainly occurred through daycare centers and private classes, where preventive measures for transmission of SARS-CoV-2 were not strictly applied. There have been no reports of outbreaks in elementary schools, and preventive measures in schools are working well.³⁹⁾ Therefore,

a nationwide plan to maintain or expand in-person school openings despite COVID-19 community outbreaks is needed, as is thorough compliance with prevention policies in schools.

Some strategies to maintain school opening include the rapid detection of SARS-CoV-2 in school members. Within educational settings, rapid antigen detection tests can be applied for contact tracing and screening of staff or students in high-prevalence settings as part of a school-wide testing approach. Rapid antigen tests offer multiple benefits of speed, capacity, near-patient use (point-of-care), and low cost. However, rapid antigen tests have lower sensitivity and specificity than reverse transcription-polymerase chain reaction, so the validated performance criteria of rapid antigen tests and consideration of the overall prevalence of SARS-CoV-2 in the population should be considered. Trained personnel are needed to perform sampling, testing, and analyses and report the test results.⁴⁰⁾

There are issues with new variants of SARS-CoV-2 with increased transmissibility. New variants have emerged globally, and some are spreading rapidly. Early data on a new variant called B.1.1.7, first detected in the United Kingdom in November 2020, found that its proportions were higher in children than in people of other ages, suggesting that it was spreading more easily in children than in adults.⁴¹⁾ To date, the variant seems to spread more efficiently than other lineages in all age groups. However, if another new variant increases infection rates, especially in children, then the dynamics of transmission in schools should be reinvestigated. Nonetheless, school closures could have devastating social impacts in children, including lost education and potential adverse effects on health problems.⁴²⁾

Conclusion

Although schools were closed globally during 2020, substantial debate persists on whether school closure policies should be continued amid the COVID-19 pandemic.⁴²⁾ The recent consensus suggests a limited scale of benefits from school closures, and recent reviews highlighted the unexpected harm to child health. The benefits of closing are unclear and not readily quantifiable; however, they must be weighed against the potential high social costs, which can also negatively affect the health of this future generation.

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Conflicts of interest

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

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