COVID-19, children and schools: overlooked and at risk

Children may be more susceptible than originally thought and could play a role in community transmission

An early cause for hope in the coronavirus disease 2019 (COVID-19) pandemic was the observation that children are much less likely to experience severe illness than adults.[1] This remains true, but has created a perception that children are less susceptible to infection and do not play a substantial role in transmission. In Australia, this perception has been reinforced by assurances from the Prime Minister that schools are safe and that physical distancing is unnecessary in this setting.[2] However, emerging research suggests greater caution is needed.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in children is generally characterised by mild illness.[1] Only a minority of children require hospitalisation and the case fatality rate is very low (≤ 1%),[3,4] although a small fraction of children can experience a severe post-infectious multisystem inflammatory syndrome.[5]

Although limited cases in children were reported at the beginning of the pandemic, this may have been because strong infection control measures in China halted the epidemic there before it could spread widely in this age group. The expansion phase coincided with the Lunar New Year holiday period, during which schools were closed, and schools remained closed thereafter. Additionally, cases in children were likely missed, as those with mild — or absent — symptoms were unlikely to receive testing.[1] It is notable that in the early phase of the epidemic in China, infected children were largely identified by contact tracing.[6,7]

More recent data paint a different picture. In a seroprevalence study of over 61 000 people from Spain, 3.4% of children and teenagers had antibodies against SARS-CoV-2 as measured by a point-of-care test, compared with 4.4–6.0% of adults. In a subset of almost 52 000 people who underwent immunoassay testing, the gap narrowed to 3.8% compared with 4.5–5.0%.[8] These findings could suggest that children are less susceptible to infection than adults, but may alternatively reflect shielding. Spain's schools closed in March. In Sweden, where schools largely remained open, no significant difference was observed in seroprevalence to mid-June between people aged 0–19 and 20–64 years (6.8% *v* 6.4%).[9] Seroprevalence was lower in people aged ≥ 65 years (1.5%), whom the country attempted to shield.

Household contact studies provide an alternative way to estimate the susceptibility of children. Some report lower attack rates in children compared with adults,[10,11] while others show no difference.[12–15] In a study of 58 United States households (58 index cases plus 188 household contacts), children and partners of index cases were more likely to be infected than other household members including siblings, parents and extended family members.[13] This suggests that children and adults may be similarly susceptible to infection, and that behavioural and environmental factors may underlie any difference in attack rate.

The role that children play in transmission is less certain, but children do not appear to be less infectious than adults. In a study of symptomatic people with mild to moderate COVID-19, the amount of viral RNA detected in the nasopharyngeal swabs of children aged 5–17 years was similar to that of adults: median cycle threshold values (interquartile range, 11.1 (6.3–15.7) *v* 11.0 (6.9–17.5). However, young children (aged < 5 years) had lower cycle threshold values (median, 6.5; interquartile range, 4.8–12.0), indicating levels of RNA 10–100 times higher.[16] The detection of viral RNA does not equate to the presence of infectious virus, and it is unclear whether the duration of viral shedding is similar in children and adults. Children appear more likely to be asymptomatic, and given that the duration of viral shedding may be shorter in asymptomatic cases,[17,18] it is possible that children may be infectious for a shorter period. However, the viral load of asymptomatic and symptomatic cases does not appear to differ,[18,19] and infectious virus is readily cultured from both.[20] Importantly, the likelihood of successfully culturing virus is unrelated to age.[20]

Children therefore have the potential to play a role in community transmission, particularly given the large number of contacts children have in close contact settings such as childcare centres and schools. In a contact tracing study comprising 5706 index cases and 59 073 contacts in South Korea, non-household contacts of child index cases were as likely to be infected as contacts of young adult index cases (attack rate, 1.0% *v* 1.1%). Within the household, contacts of young paediatric index cases (< 10 years of age) were less likely to become infected than those of adults (attack rate, 5.3% *v* 11.7%), but the attack rate for the contacts of older children and teenagers (18.6%) was higher than that of any other group.[21] In a subsequent study, the authors noted that almost all of the child index cases shared the same exposure as their adult contacts.[22] Thus, while the children developed symptoms first, it is possible that some may not have been true index cases. However, preliminary data from Italy are also concerning. In the heavily affected province of Trento, contacts of children aged under 15 years were more likely to be infected than those of adults at a time when schools were closed (attack rate, 22.4% *v* 10.6–17.1%).[23] This suggests that transmission can be expected in schools, which is borne out by reports of large clusters in these settings.[24–26]

The government of Israel mandated complete closure of the country's schools in mid-March. A cautious reopening was attempted less than 2 months later,

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and all schools reopened for face-to-face teaching on 17 May. Ten days later, the first major outbreak occurred in a high school.[24] Two cases without an epidemiological link were detected in students on 26 and 27 May, and mass testing of the school community occurred over the following days. A total of 153 students (attack rate, 13.2%) and 25 staff members (attack rate, 16.6%) tested positive. By mid-June, a further 87 cases among close contacts had been detected, including siblings attending other schools, parents, and the family members of staff. Interestingly, the outbreak coincided with an extreme heatwave during which students were exempted from wearing face masks and air conditioning was used continuously.[24]

A similarly rapid spread occurred in a private school catering for students from pre-primary to high school age in Chile.[25] The school year began on 4 March, after which parent–teacher meetings were held over the following days. The next week, two cases were detected in staff. By 6 April, 52 members of the school community had tested positive and one death had occurred. Serological testing was conducted 8–10 weeks after the start of the outbreak, in which 1009 students (38%) and 235 staff (74%) participated. Overall, 9.9% of students and 16.6% of staff were seropositive. Students from preschool to middle school age were most affected. The index case was a staff member who worked with all of the preschool and primary school staff, likely explaining the higher seroprevalence among staff and younger children. Notably, 18% of staff and 40% of students were asymptomatic, indicating the potential for silent spread among children.[25]

In Sweden, a school outbreak led to 18 of 76 staff testing positive and the death of one teacher.[27] Children are not routinely tested in Sweden,[27] severely limiting the ability to determine their role in outbreaks there. However, 70 cases of multisystem inflammatory syndrome have been reported, suggesting that substantial transmission to children has occured.[28] This figure is about ten times that of neighbouring Finland and Norway combined,[29–31] which unlike Sweden, closed schools.

The United States closed schools in all 50 states in March. A population-based time series analysis found school closure was temporally associated with a marked decrease in COVID-19 incidence and mortality, and the effect was greatest in states which acted earlier when cases were low.[32] While adjustments were made for other non-pharmaceutical interventions, some residual confounding is likely and these findings should be interpreted carefully. However, data from France strongly support the role of schools in community transmission. In a retrospective analysis of a high school cluster, incident cases dropped dramatically and abruptly after the start of the school holidays, and again after wider lockdown measures were introduced in the region.[26]

A study of COVID-19 in educational settings in New South Wales appears to suggest a small role for schools at first glance, with limited transmission reported between January and April, although a large outbreak occurred in a childcare centre.[33] A strength of this particular study is its prospective nature. However, there are also substantial limitations. Schools switched to distance learning for most students in March, after which school attendance fell to 5%. Additionally, only 44% of close contacts were tested (the majority after developing symptoms), so cases in children may have been missed. Further, the majority of cases in the state were acquired overseas at the time of the study, and there was minimal community transmission. A school cluster comprising 21 cases, including at least 11 students, four teachers and two social contacts of school community members has since emerged in Sydney.[34,35]

Detecting paediatric cases may be particularly difficult because of the high prevalence of asymptomatic infection in children. In a prospective seroprevalence study of the children of health care workers in the United Kingdom, 50% of infections were asymptomatic.[36] In a study of paediatric cases largely identified via contact tracing in South Korea, 66% of symptomatic children had symptoms which had been mild enough to go unrecognised, and only 9% were diagnosed at the time of symptom onset.[17]

These findings suggest a need to re-evaluate school safety. The situation in Victoria should give pause for thought. As community transmission grew, clusters arose in educational settings catering for children of all ages.[37,38] Notably, an epidemiological link was found between a school cluster and a major outbreak in Melbourne's public housing towers,[39] prompting dramatic measures to curtail transmission. School clusters may be complicated, however, by the role of the school as a community hub, as occurred in New Zealand, where the country's third largest cluster was associated with a cultural event which took place at a school.[40] Some school-related transmission can therefore be confounded by the clustering of associated community members.

Investigation of children has frequently been poor, with insufficient testing performed. Additionally, most studies of COVID-19 and children have been conducted during lockdown periods — which are not normal conditions — or at a time of low community transmission. Adult travellers seeded epidemics and the virus initially circulated among their contacts, delaying children's exposure. In some countries, cases were rapidly isolated and quarantined away from home, further limiting spread to children. Testing was initially limited, excluding those not fitting clinical criteria. This is of particular relevance given the high prevalence of asymptomatic infection among children, and also increases the likelihood that index cases in children will be missed. Paediatric cases may only be detected after transmission from a child to a second person (often an adult). The child may then be tested as a contact, and either mistakenly thought to be a secondary case, or missed entirely if the child's viral load has declined by this point. In some countries, children are not routinely tested unless seriously ill.[27,41] Finally, limited transmission by children in some studies[33] is not cause for reassurance. About 80%

Summary of Healthy Buildings Program risk reduction strategies for schools[43]

Area	Recommendations
Classrooms	• Students and staff should wear face masks • Wash hands frequently • Move class outdoors if possible and repurpose large unused spaces as temporary classrooms • Reduce class sizes if possible, and practise physical distancing • Keep class groups as distinct and separate as possible • Regularly disinfect shared surfaces
Buildings	• Increase ventilation by bringing in more fresh outdoor air • Filter indoor air • Supplement with portable air cleaners • Use plexiglass as a physical barrier around desks • Improve toilet hygiene and keep toilet lids closed, especially when flushing
Activities	• Hold physical education classes outdoors • Replace high risk activities (eg, choir practice) with safer alternatives
Schedules	• Stagger school arrival and departure times and class transitions • Modify school start times to allow students who use public transport to avoid rush hour
Policies	• Form a COVID-19 response team and plan • Prioritise staying home when sick • Encourage viral testing any time someone has symptoms, even if mild • Support remote learning options • Protect high risk students and staff

of secondary COVID-19 cases are generated by about 10% of individuals.[42] It is therefore unsurprising to find examples where children have not transmitted the virus; many adults do not transmit the virus either.

Schools are clearly neither inherently safe nor unsafe. The risk associated with these settings depends on the level of community transmission and must be continuously evaluated. Schools must not remain open for face-to-face teaching in the setting of substantial community transmission. In regions where community transmission is low, risk reduction strategies should be implemented in schools as a matter of urgency. Comprehensive guidelines have been developed (Box),[43] but at a minimum, interventions should include the wearing of face masks by staff and students, increasing ventilation and indoor air quality, and the regular disinfection of shared surfaces.

While some interventions — particularly school closures — may be burdensome, this must be weighed against other potential harms. A substantial proportion of adults living with school-aged children have risk factors for severe COVID-19, as do many teachers.[44] A recent epidemiological investigation into three childcare clusters in the US found that infected children transmitted the virus to one-quarter of their household contacts, resulting in the hospitalisation of one parent.[45]

Measures have been enacted to protect schools in Australia, such as excluding students with respiratory symptoms, restricting interschool mixing, and prohibiting high risk activities such as overnight camps.[46] These are to be commended but are insufficient as they do not fully address source control. Notably absent is a requirement for face masks in regions with ongoing community transmission. The World Health Organization recommends that face masks be worn by children aged 12 years and older, and that masks should be considered for those aged 6–11 years.[47] The Society for Virology recommends masks for all schoolchildren, including during lessons.[48] Such measures have already been enacted in many Asian countries. In Singapore, students from pre-primary to high school age are required to wear masks.[49]

An important, remaining question is whether children's risk of infection and transmission is age stratified. Nasal angiotensin-converting enzyme 2 expression increases with age,[50,51] suggesting that younger children could be less susceptible to infection than older children. This is supported by some studies[8,13] but questioned by others which show similar attack rates.[12,15,36] Whether young and older children transmit the virus similarly is unknown and requires urgent clarification. Until better understood, precautions in kindergartens, primary schools and secondary schools should be similar.

There is clear evidence that children and schools are at risk, with wider implications for the community. Additionally, serious outcomes in children will become increasingly common — at least in absolute terms — if the virus is allowed to spread. We can no longer afford to overlook the role children play in transmission if we hope to contain the virus.

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