**Lessons learnt during the COVID-19 pandemic: Why Australian schools should be prioritised to stay open**

Archna Koirala,1,2,3 Sharon Goldfeld,4,5,6 Asha C Bowen,7,8,9,10,11,12 Catherine Choong,9,11,13 Kathleen Ryan,5 Nicholas Wood,1,2,14 Noni Winker,1,15 Margie Danchin,6,16,17 Kristine Macartney,1,2,18 and Fiona M Russell6,17

1National Centre for Immunisation Research and Surveillance Kids Research, Sydney Children’s Hospitals Network, 14Department of Paediatrics, The Children’s Hospital at Westmead, 16Department of Infectious Diseases, The Children’s Hospital at Westmead, Westmead, 2School of Child and Adolescent Health, University of Sydney, Sydney, 3Department of Infectious Diseases, Nepean Hospital, Kingswood, New South Wales, 4Centre for Community Child Health, Royal Children’s Hospital, 5Population Health, Murdoch Children’s Research Institute, 6Department of Paediatrics, The University of Melbourne, 7Department of General Medicine, Royal Children’s Hospital, 17Infection and Immunity, Murdoch Children’s Research Institute, Parkville, Victoria, 8Department of Infectious Diseases, Perth Children’s Hospital, 9Wesfarmers Centre for Vaccines and Infectious Diseases, Telethon Kids Institute, 10Department of Endocrinology, Perth Children’s Hospital, Nedlands, 11School of Medicine, The University of Western Australia, 12Centre for Child Health Research, The University of Western Australia, Perth, 13Institute for Health Research, The University of Notre Dame Australia, Fremantle, Western Australia, 14Menzies School of Health Research, Charles Darwin University, Darwin, Northern Territory and 15National Centre for Epidemiology and Population Health, Research School of Population Health, Australian National University, Canberra, Australian Capital Territory, Australia

In 2020, school and early childhood educational centre (ECEC) closures affected over 1.5 billion school-aged children globally as part of the COVID-19 pandemic response. Attendance at school and access to ECEC is critical to a child’s learning, well-being and health. School closures increase inequities by disproportionately affecting vulnerable children. Here, we summarise the role of children and adolescents in Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) transmission and that of schools and ECECs in community transmission and describe the Australian experience. In Australia, most SARS-CoV-2 cases in schools were solitary (77% in NSW and 67% in Victoria); of those that did progress to an outbreak, >90% involved fewer than 10 cases. Australian and global experience has demonstrated that SARS-CoV-2 is predominantly introduced into schools and ECECs during periods of heightened community transmission. Implementation of public health mitigation strategies, including effective testing, tracing and isolation of contacts, means schools and ECECs can be safe, not drivers of transmission. Schools and ECEC are essential services and so they should be prioritised to stay open for face-to-face learning. This is particularly critical as we continue to manage the next phase of the COVID-19 pandemic.

School closures were implemented as an early pandemic management strategy to reduce the transmission of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), affecting over 1.5 billion learners globally in 2020.1 This initial precautionary principle was informed by influenza transmission, where children are key drivers of transmission across all age groups.2 However, evidence emerging throughout 2020 suggested that the transmission dynamics of SARS-CoV-2 were quite different from those of influenza. Whereas in influenza, children have the highest rate of disease notification across the age spectrum, for SARS-CoV-2, paediatric notifications are the lowest.3–5

The greatest impact of the COVID-19 pandemic on children and adolescents, especially for the most disadvantaged, has been the closure of educational facilities. Closures create an education gap, with children from lower socioeconomic backgrounds less likely to have access to online classes than their peers from higher socioeconomic backgrounds,6 especially in low and middle-income countries.7 School closures can cause engaged youth to completely disengage from education; as many as 10 million children are predicted to never return to school, and 2.5 million girls may be at risk of child marriage in the next 5 years.8

In addition to the educational disadvantages, school closures affect children in many ways. The United Nations Educational, Scientific and Cultural Organization (UNESCO) recognises that school closure, even if temporary, can have high social and economic costs.9 The structure and face-to-face support that schools provide are vital for students with disabilities and mental health issues, and a safe haven for those experiencing domestic violence.10–15 A mental health survey conducted on Australian youth found adolescents aged 12–17 years, particularly those who started high school in 2020, reported higher psychological distress rates and poorer coping strategies than similar-aged adolescents surveyed in 2018.16 School and early childhood educational centre (ECEC) attendance also offsets the risk of families experiencing poverty17 as children receive meals18 and for caregivers to maintain employment.19

Acknowledging that school closures have a wide impact globally on child and adolescent education and health, peak health bodies including the World Health Organization (WHO) state that schools should be prioritised for reopening for face-to-face learning during the pandemic.20,21
The Role of Children and Adolescents in Transmission

The majority of children develop asymptomatic or mild disease and hospitalisation and death are rare. Transmission of the virus to vulnerable household members and teachers has been a concern around reopening schools. Household and seroprevalence studies show children are infected at lower or equal to adults. Studies show children aged <5 years with mild or moderate COVID-19 had a high viral load, similar to adults, which suggests that young children could potentially be important drivers of SARS-CoV-2 transmission. However, being infected does not necessarily equate with having the ability to transmit the virus and it remains unclear how long children shed infectious virus. In another study, compared with adults, children with nasopharyngeal swabs that were SARS-CoV-2 positive were less likely to culture live virus compared with adults. Age-related immunological differences in response to the infection may also explain the difference in severity of infection and infectivity rates, including early activation of the innate immune system in children, allowing the virus to be cleared before it can replicate. That said, evidence from school camp outbreaks and India suggest children transmit to a similar degree as adults, especially in settings that are crowded and where mitigation strategies are challenging.

Older adolescents, on the other hand, have similar or higher rates of infections, which is unsurprising, given their complex social and physical mixing patterns with their peers. Whether biological age-related changes contribute to higher infectivity rates compared to younger children is unknown.

Regarding the risk to the household, a UK study of 9 million people aged <65 years and 2 million >65 years, household infection was not increased by living with children less than 12 years old and mildly increased while living with an adolescent aged 12–18 years. The study was repeated between 1 September 2000 and 12 December 2020, at the time of the second wave and showed a small increase in the risk of infection and hospitalisation in members of households with children and adolescents. In intergenerational households, as in India, index cases aged between 0–4 years were more likely to spread it amongst their own age group rather than to the elderly. In Victoria, it was similarly very uncommon for the elderly to be linked to any infection from a school or ECEC.

Box 1 Lessons learnt from the Australian ECEC and school experience

1 COVID-19 cases increases in schools and early childhood settings when there is community transmission.
2 Australian data suggests that SARS-CoV-2 transmission within school settings is low and can be mitigated through COVID-19 safe practices and effective measures to test, contact trace and isolate.
3 School closures negatively impact the wellbeing, psychosocial aspects and education of students; have economic costs to families; and should be avoided wherever possible.

Box 2 Recommendations

1 ECEC and schools need to be seen as essential services and prioritised for staying open to guarantee equitable learning environments and lessen social and educational effects of school closure. Closing ECEC and schools should be a last resort, especially for ECEC and primary schools as children in these age groups are less likely to transmit and be associated with an outbreak.
2 A coordinated, consistent public health response (test, contact trace and isolate) is required to respond to a case attending a school/ECEC. In anticipation of virus re-introduction/outbreaks States’ and Territories’ school mitigation plans should be prepared in advance.
3 There should be a staged mitigation approach in school/ECEC proportionate to the local COVID-19 incidence rates.
4 The mental health and well-being of children should be monitored in schools with regular wellbeing surveys.
5 A cyclical review of the recommendations every 6–12 months depending on the Australian epidemic, new global evidence and vaccination programs.
6 ECEC and school staff should be prioritised for COVID-19 vaccines.

A critical observation regarding age groups most responsible for transmission comes from Israel, where high coverage of Pfizer/BioNTech mRNA vaccine in people aged >16 years has led to a decrease in rates of infection in non-vaccinated children and adolescents aged <16 years. It seems this vaccine may interrupt transmission in adults, which prevents infection in age groups too young to be vaccinated.

Transmission in School and ECECs

SARS-CoV-2 introductions into schools and ECECs will occur when there is virus circulating in the community. Transmission studies within schools and ECEC however have reassuringly shown that in the majority of settings, where public health mitigation strategies are in place, such as tracing and isolating close contacts, the secondary attack rates are low (Table 1). An exception was an outbreak in an Israeli high school, which resulted in 178 secondary cases originating from 2 index cases. Large class sizes of 30–35 students in small poorly ventilated classroom settings were likely contributing factors to spread. However, this single outbreak did not have substantial impact on community transmission, and there was no increase in COVID-19-related hospitalisations and deaths after schools reopened.

The health of school staff also needs consideration. However, the evidence available is mixed, which makes assessing their level of risk challenging. Transmission within the school or ECEC occurs most commonly between staff members or high school students. A survey of 57 335 childcare workers in the USA found no difference in the rates of COVID-19 among those who worked or did not work during the pandemic. Educators working in home daycare reported a higher risk of COVID-19, perhaps as these settings mimic conditions seen in household settings, which have been associated with transmission rates ranging from...
Table 1  Outbreak investigations of SARS-CoV-2 in schools and ECECs outside Australia

| Educational facility | Location       | Period (2020) | Community incidence rate (2020) | Mitigation strategies                                                                 | Findings                                                                 |
|----------------------|----------------|---------------|---------------------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| ECECs                |                |               |                                 |                                                                                       |                                                                        |
| Rhode Island, USA46  | 1 Jun–31 Jul   | 271/100 000   | Masks for adults, daily symptom screening, enhanced cleaning and disinfection | 52 cases (30 students, 20 staff, 2 parents), in 29 ECECs                              |
|                      |                |               |                                 | In 20 (69%) settings no transmission occurred, secondary transmission likely occurred in 4 (7%) settings, one of which had poor compliance to implemented mitigation strategies |
| Salt Lake City, USA47| 1 Apr–10 Jul   | 860/100 000   | Mask use in adults, hand hygiene, frequent cleaning/disinfection of high touch surfaces | 17 ECECs had an outbreak†                                                               |
|                      | (Utah)         |               |                                 | 3 outbreaks described: primary cases were all staff                                   |
|                      |                |               |                                 | 19 secondary cases: (7 staff members, 12 students); 1 ECEC had 14 secondary cases      |
| Schools              |                |               |                                 |                                                                                       |                                                                        |
| Israel44             | May 2020       | 63/100 000    | Daily health reports, hygiene, facemasks, social distancing and minimal interaction between classes | 2 index cases                                                                         |
|                      |                |               |                                 | 178 secondary cases                                                                  |
|                      |                |               |                                 | Large class sizes of 30–35 students in small poorly ventilated classroom settings were likely contributing factors to spread |
| Ireland48            | 1 Mar–13 Mar   | 2/100 000     | No mitigation strategies        | 6 cases (3 students and 3 adults) attended 6 schools.                                  |
|                      |                |               |                                 | No secondary cases                                                                    |
| South Korea49        | 20 May–11 Jul  | 1/100 000     | Universal mask use, plastic barriers between desks, increased hand hygiene            | 44 student cases in 38 schools                                                        |
|                      |                |               |                                 | More than 13 000 students and staff were tested                                         |
|                      |                |               |                                 | Transmission only occurred in 1 primary school setting (2 secondary cases)             |
| Italy50              | 14 Sep–5th Oct | 64/100 000    | Mask use, hand hygiene, physical distancing                                       | 1350 COVID-19 primary cases (1059 students, 145 teachers, 146 other staff members) attended 1212 schools |
|                      |                |               |                                 | No secondary cases in 90% of settings                                                 |
|                      |                |               |                                 | Only 1 high school had a cluster of more than 10 cases.                                |
| Germany51            | 28 Jan–31 Aug  | 295/100 000   | Hygiene measures, staggering timetables, restricting class sizes, face masks, physical distancing | 48 outbreaks† described                                                                |
|                      |                |               |                                 | 2 high schools had >10 cases                                                          |
| Norway46             | 28 Aug–11 Nov  | 299/100 000   | Hygiene measures, physical distancing,                                            | 13 primary student cases (8 aged between 5–10 years and 5 aged 11–13 years)           |
|                      |                |               |                                 | Total 292 school contacts                                                            |
|                      |                |               |                                 | There were 3 secondary cases (2 students and 1 adult)                                  |
| Finland52            | Mar 2020       | 26/100 000    | None specified                   | 2 primary cases (1 student and 1 adult)                                               |
|                      | (Helsinki)     |               |                                 | 184 contacts; 140 tested                                                              |
|                      |                |               |                                 | 7 secondary cases (all from staff primary case)                                        |
Studies from Sweden, Scotland, UK and Norway comparing rates of COVID-19 and hospitalisation suggest that teachers did not have a higher rate of COVID-19 infection compared to the community. A French study of 22 ECEC showed that childcare staff had comparable seropositivity rates to health-care workers and double the rate to that of preschool children. Importantly, there was no increase in the risk of school or ECEC staff contracting SARS-CoV-2 following exposure to a child with COVID-19. Both children and adult staff were more likely to be seropositive if they had a positive confirmed case in a household member.

### Role of ECEC and Schools in Community Transmission

School closure prevents the introductions of SARS-CoV-2 into schools, but there is less evidence, beyond modelling studies, that school closure has a dampening effect on community transmission. Moreover, in 2020, many European countries such as Iceland, England and Spain have been able to drive down their rate of community transmission while keeping schools open. Ireland was still able to keep schools open between October and December 2020 despite enforcing a hard lockdown. In England, SARS-CoV-2 rates had started to increase from August, initially in young adults, followed by younger age groups, prior to school reopening. In November 2020, a national lockdown was implemented whilst keeping schools open and was associated with rapid declines in SARS-CoV-2 infection rates. In both settings, an upsurge in cases during the December–January holiday period delayed school reopening. The European Centre of Disease Control (ECDC) conducted a review up to March 2021 and found that the return to school by children around mid-August 2020 did not appear to have driven the upsurge in cases from October 2020.

### The Australian Perspective

Evidence from two large studies in New South Wales (NSW) and Victoria during 2020 has demonstrated that the number of cases identified in individuals attending schools and ECEC settings is proportionate to the rate and geographic location of community transmission.

NSW (population 8.1 million; 1.8 million aged 18 years or younger) had had the highest rate of disease notifications (34/100000) during the first of four school terms, Term 1 (25 January to 10 April) 2020. A prospective study conducted throughout 2020 in all educational facilities in this state found that during Term 1, 12 students and 15 staff members who had COVID-19 attended 15 schools and 10 ECECs while infectious. Of 1448 close contacts, the secondary transmission rate was only 1.2%, with 633 (43.7%) of close contacts tested.
Term 2 saw a near absence of community transmission and only six schools/ECECs had a primary case and no secondary transmission.72

In Term 3 (21 July to 25 September), while community transmission (10/100000) occurred at a low rate, it was associated with more primary cases in educational settings (32 students, 7 staff members and 3821 close contacts in 34 settings) than in Term 1. The cases mainly occurred in areas of increased community transmission. Secondary transmission rates were comparable to (0.9%) Term 1, and highly valid, noting close contact testing rates (using nucleic acid testing and serology) were 95%.73

In Term 4 (26 September to 18 December), there were 10 primary cases (1 staff member and 9 students), with contact testing rate of 98.7% and secondary transmission rate of 1.2%.74 Overall, transmission in primary schools/ECECs with a child primary case was 0.4% and in a high school with a child primary case 0.9%; transmission in any setting with a staff primary case was 1.7%.72–75

Victoria (population 6.6 million; 1.5 million aged 18 years or younger)70 experienced the greatest number of SARS-CoV-2 cases in Australia with 19 109 COVID-19 infections identified over 2 separate waves between 25 January and 23 November August 2020.76 Schools and ECECs were mostly closed for face-to-face learning during this period but remained open for children of essential workers throughout. The main reason for closure was to restrict the movement of adults to prevent adult-adult transmission.

A retrospective study between 25 January and 31 August identified 1635 infections linked with schools and ECECs.42 Introduction of cases occurred in local government areas with the highest number of community cases but there was limited onward transmission within these schools/ECECs. When infections occurred in schools, outbreaks were uncommon, with 67% of events involving a single case in a staff member or student. When outbreaks did occur, most were small with 92% of events involved 10 cases or less. Primary cases involving young children were less likely to progress to an outbreak (defined as two or more cases) compared with older adolescents and staff. If the primary case was aged 0–5 years, 14.1% of ECECs recorded additional cases, compared to 30.5% (6–12 years), 33.3% (13–15 years), 42.9% (16–18 years) in older children. Transmission occurred in 39.1% of settings when the first case was a staff member.42 The rapid public health response of testing, tracing and isolation of cases, is likely to have contributed to this lack of onward transmission.

In Western Australia, there have been <5 cases of community transmission since 13 April 2020 due to effective public health mitigation strategies and strict border closures. A program to swab asymptomatic students and staff attending schools was instituted to reassure the public throughout school Terms 2 and 3 (29 April–25 September). Of 13 988 swabs collected in 40 schools across three rounds of testing, there were no cases of SARS-CoV-2 infection detected and planned transmission studies were not activated.77 Fear of community spread from a single community case in early 2021 led to a lockdown which included a 1-week delay in restarting school.

School Mitigation Measures and Do They Work?

Three broad intervention strategies are required to maintain face-to-face learning: organisational, structural/environmental and surveillance and response.78 Public Health England surveillance found that wider public health mitigation strategies and access to early universal viral testing resulted in a decrease in outbreaks within school and ECEC settings.79 Strategies such as wearing masks, staying home if sick and student cohorting have been effective measures in reopening US schools.80 In Europe’s second wave, school closures were to shown to have a lesser effect on reducing SARS-CoV-2 transmission than during the first wave, with safer operation of schools possible if strict safety measures such as symptom screening, sanitisation, adequate classroom ventilation and reducing group sizes were adopted.81 Together with COVID-19 safe practices, key to keeping schools and ECECs open has been outbreak control through free and timely access to viral testing and a public health system capable of tracing and isolating close contacts.80,71

SARS-CoV-2 Variants

Since September 2020, there have been SARS-CoV-2 variants with higher transmissibility (B.1.1.7, B135, P1) circulating globally.82 Early data on B.1.1.7 from a January 2021 Public Health England report83 suggest that children do not have a higher infection rate than other age groups. More so, children under the age of 10 years are half as likely to transmit the variant virus compared to adults. Transmissibility of the variant virus in educational settings is yet to be determined.

What Should Australian ECEC and Schools Be Doing Now?

Introductions of the virus into schools and ECECs will occur until elimination has been achieved. With the impact of school closure on students wellbeing and health, including broad psychosocial and educational impacts,64,65 well established alongside the growing data that children and schools are not key drivers of infection, keeping schools and ECECs open must remain a critical factor during further outbreaks.42,86,87 Australia’s ability to control community transmission of SARS-CoV-2 has been impressive, and our ongoing work in schools and ECECs has been pivotal to understanding transmission of SARS-CoV-2 in these settings. We have shown that we can suppress outbreaks even with schools remaining open by implementing strict public health strategies (Box 1).

Several Australian states have closed schools as part of their 5-day circuit breaker lockdown. The concept of the ‘Precautionary Principle’88 is relevant here and while it is important to be vigilant and have the agility to interrupt community transmission, especially when we have SARS-CoV-2 variants being introduced into Australia, it is vital that we regard schools as essential services, anticipate these events and be pandemic ready. We need to act in accordance with jurisdictional health and education guidelines89 that can be scaled up and down dependent on rates of community transmission, avoiding hasty closures. This is what was recommended in Victoria.42

Keeping schools open also means maintaining capacity for widespread testing and the ability for public health officials to respond to school cases. To do this, we recommend that all Australian States and Territories institute a national strategy and
commitment to keeping schools open with agreed systems and adequate funding in place to measure its effectiveness (Box 2), especially in the setting of emerging SARS-CoV-2 variants. Teachers and school staff should also be prioritised for COVID vaccines, especially in settings with higher incidence of COVID-19. Our kids depend on it.

Acknowledgements

The authors thank NSW Health and Education and Ms Deepika Jindal. FM Russell and AC Bowen are supported by NHMRC investigator grant. Sharon Goldfeld is supported by NHMRC Practitioner Fellowship (1155290). The authors did not receive any funding for this manuscript.

Conflict of Interest

None declared.

References

1 Viner RM, Russell SJ, Croker H et al. School closure and management practices during coronavirus outbreaks including COVID-19: A rapid systematic review. Lancet Child Adolesc Health 2020; 4: 397–404.
2 Jackson C, Vynnycky E, Hawker J, Olowokure B, Mangtani P. School closures and influenza: Systematic review of epidemiological studies. BMJ Open 2013; 3: e002149.
3 Department of Health. National notifiable diseases surveillance system; 2020. Available from: http://www9.health.gov.au/cda/source/cda-index.cfm [accessed 5 January 2021].
4 European Centre for Disease Prevention and Control. Data on the 14-day age-specific notification rate of new COVID-19 cases; 2020. Available from: https://www.ecdc.europa.eu/en/publications-data/covid-19-data-14-day-age-notification-rate-new-cases [accessed 21 December 2020].
5 Chiu C, Dey A, Wang H et al. Vaccine preventable diseases in Australia, 2005 to 2007. Commun. Dis. Intell. Q. Rep. 2010; 34: 51–5167.
6 Flack CB, Walker L, Bickerstaff A, Margetts C. Socioeconomic Disparities in Australian Schooling During the COVID-19 Pandemic. Melbourne, Australia: Pivot Professional Learning; 2020.
7 Viner RM, Bonell C, Drake L et al. Reopening schools during the COVID-19 pandemic: Governments must balance the uncertainty and risks of reopening schools against the clear harms associated with prolonged closure. Arch. Dis. Child. 2021; 106: 111–3.
8 Cousins S. 2.5 million more child marriages due to COVID-19 pandemic. Lancet 2020; 396: 1059.
9 United Nations Educational SaCO. Education: From disruption to recovery; 2020. Available from: https://en.unesco.org/covid19/educationresponse/ [accessed 21 December 2020].
10 Betz CL. COVID-19 and school return: The need and necessity. J. Pediatr. Nurs. 2020; 54: A7–9.
11 Caffo E, Scandroglio F, Asta L. Debate: COVID-19 and psychological well-being of children and adolescents in Italy. Child Adolesc Mental Health 2020; 25: 167–8.
12 Lee J. Mental health effects of school closures during COVID-19. Lancet Child Adolesc Health 2020; 4: 421.
13 World Health Organization. Mental health and psychological resilience during the COVID-19 pandemic; 2020. Available from: https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/mental-health-and-psychological-resilience-during-the-covid-19-pandemic;~:text=Children%20are%20at%20risk%20to%20be,mental%20well%20being%20 [accessed 26 November 2020].
14 Xie X, Xue Q, Zhou Y et al. Mental health status among children in home confinement during the coronavirus disease 2019 outbreak in Hubei Province, China. JAMA Pediatr 2020; 174: 898–900.
15 Young Minds. Coronavirus: Impact on young people with mental health needs; 2020. Available from: https://youngminds.org.uk/about-us/reports/coronavirus-impact-on-young-people-with-mental-health-needs/ [accessed 26 November 2020].
16 Headspace. Insights: youth mental health and wellbeing over time. Headspace National Youth Mental Health Survey 2020; 2020. Available from: https://headspace.org.au/assets/uploads/insights-youth-mental-health-and-wellbeing-over-time-headspace-National-Youth-Mental-Health-Survey-2020.pdf.
17 Andrew A, Cattan S, Costa-Dias M, et al. Learning during the lockdown: real-time data on children’s experiences during home learning; 2020. https://www.ifis.org.uk/publications/I14848 [accessed 5 February 2021].
18 Levinson M, Cevik M, Lipsitch M. Reopening primary schools during the pandemic. N. Engl. J. Med. 2020; 383: 981–5.
19 Van Lancker W, Parolin Z. COVID-19, school closures, and child poverty: A social crisis in the making. Lancet Public Health 2020; 5: e243–e4.
20 World Health Organization. Considerations for School-Related Public Health Measures in the Context of COVID-19: Annex to Considerations in Adjusting Public Health and Social Measures in the Context of COVID-19. World Health Organization; 2020.
21 Centers for Disease Control and Prevention. Schools and child care programs; 2021. Available from: https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/index.html [accessed 12 March 2021].
22 Mehta NS, Mytton OT, Mullins EW et al. SARS-CoV-2 (COVID-19): What do we know about children? A systematic review. Clin Infect Dis 2020; 71: 2469–79.
23 Galow L, Haag L, Kahre E et al. Lower household transmission rates of SARS-CoV-2 from children compared to adults. J. Infect. 2021; 50163-4453: 00209-7.
24 Lei H, Xu X, Xiao S, Wu X, Shu Y. Household transmission of COVID-19: A systematic review and meta-analysis. J. Infect. 2020; 81: 979–97.
25 Madewell ZJ, Yang Y, Longini IM Jr, Halloran ME, Dean NE. Household transmission of SARS-CoV-2: A systematic review and meta-analysis. JAMA Netw Open 2020; 3: e2031756-e.
26 Wood R, Thomson E, Galbraith R et al. Sharing a household with children and risk of COVID-19: A study of over 300 000 adults living in healthcare worker households in Scotland. Arch Dis Child 2021. https://doi.org/10.1136/archdischild-2021-321604.
27 Guddbjartsson DF, Helgason A, Jonsson H et al. Spread of SARS-CoV-2 in the Icelandic population. N. Engl. J. Med. 2020; 382: 2302–15.
28 Hippich M, Holthaus L, Assfalg R et al. A public health antibody screening indicates a 6-fold higher SARS-CoV-2 exposure rate than reported cases in children. Med 2021; 2: 149-63.e4.
29 Viner RM, Mytton OT, Bonell C et al. Susceptibility to SARS-CoV-2 infection among children and adolescents compared with adults: A systematic review and meta-analysis. JAMA Pediatr. 2021; 175: 143–56.
30 Ladhani SN, Baawuah F, Beckmann J et al. SARS-CoV-2 infection and transmission in primary schools in England in June-December, 2020 (sKIDs): An active, prospective surveillance study. Lancet Child Adolesc. Health. 2021; 52352-4642[1]: 00061-4. https://doi.org/10.1016/S2352-4642(21)00061-4 (forthcoming).
31 Heald-Sargent T, Muller WI, Zheng X, Rippe J, Patel AB, Kociolek LK. Age-related differences in nasopharyngeal severe acute respiratory syndrome coronavirus 2 SARS-CoV-2 levels in patients with mild to moderate coronavirus disease 2019 (COVID-19). JAMA Pediatr. 2020; 174: 902–3.
32 Madera S, Crawford E, Langelier C et al. Nasopharyngeal SARS-CoV-2 viral loads in young children do not differ significantly from those in older children and adults. Sci. Rep. 2021; 11: 3044.
33 Han MS, Choi EH, Chang SH et al. Clinical characteristics and viral RNA detection in children with coronavirus disease 2019 in the Republic of Korea. JAMA Pediatr. 2021; 175: 73–80.
34 Bullard J, Funk D, Dust K et al. Involvement of severe acute respiratory syndrome coronavirus 2 in children compared with adults. CMAJ 2021; 193: E601–66.
35 Zimmermann P, Curtis N. Why is COVID-19 less severe in children? A review of the proposed mechanisms underlying the age-related difference in severity of SARS-CoV-2 infections. Arch Dis Child 2020; 106: 429–439. archdischild-2020-320338.
36 Zhu Y, Chew KY, Karawita AC et al. Pediatric nasal epithelial cells are less permissive to SARS-CoV-2 replication compared to adult cells. bioRxiv 2021. https://doi.org/10.1101/2021.03.08.434300 (forthcoming).
37 Neelander MR, Bannister S, Clifford V et al. Innate cell profiles during the acute and convalescent phase of SARS-CoV-2 infection in children. Nat. Commun. 2021; 12: 1084.
38 Szablyowski CM, Chang KT, Brown MM et al. SARS-CoV-2 transmission and infection among attendees of an overnight camp—Georgia, June 2020. MMWR Morb. Mortal. Wkly Rep. 2020; 69: 1023–5.
39 Laxminarayan R, Wahl B, Dudala SR et al. Epidemiology and transmission dynamics of COVID-19 in two Indian states. Science 2020; 370: 691–7.
40 Guilamo-Ramos V, Benzekri A, Thimm-Kaiser M, Hidalgo A, Perlman DC. Reconsidering assumptions of adolescent and young adult severe acute respiratory syndrome coronavirus 2 transmission. Clin. Infect. Dis. 2020; (forthcoming); 71: 51–3.
41 Forbes H, Morton CE, Bacon S et al. Association between living with children and outcomes from covid-19: OpenSAFELY cohort study of 12 million adults in England. BMJ 2021; 372: n628.
42 Russell F, Ryan KE, Snow K, Darchin M, Mulholland K, Goldfeld S. COVID-19 in Victorian Schools: An analysis of child-care and school outbreak data and evidence-based recommendations for openings schools and keeping them open; 2020. Available from: https://www.mcri.edu.au/sites/default/files/media/covid_in_schools_report_final_10112020.pdf [accessed 15 January 2021].
43 Milman O, Yelin I, Aharony N et al. SARS-CoV-2 infection risk among unvaccinated is negatively associated with community-level vaccination rates. medRxiv 2021; 2021.03.26.21254394. https://doi.org/10.1101/2021.03.26.21254394 (forthcoming).
44 Stein-Zamir C, Abramson N, Shoo H et al. A large COVID-19 outbreak in a high school days after schools reopening, Israel, May 2020. Euro Surveill. 2020; 25: 2001352.
45 Brandal LT, Ofsteserova TS, Meijerink H et al. Minimal transmission of SARS-CoV-2 from paediatric COVID-19 cases in primary schools, Norway, August to November: Euro Surveill. 2021; 26: 2002011.
46 Link-Gelles R, DelaGrotta AL, Molina C et al. Limited secondary transmission of SARS-CoV-2 in child care programs – Rhode Island, June 1–July 31, 2020. MMWR Morb. Mortal. Wkly Rep. 2020; 69: 1170–2.
47 Lopez AS, Hill M, Antezano J et al. Transmission dynamics of COVID-19 outbreaks associated with child care facilities—Salt Lake City, Utah, April–July 2020. MMWR Morb. Mortal. Wkly Rep. 2020; 69: 1319–23.
48 Heavey L, Casey G, Kelly C, Kelly D, McDarby G. No evidence of secondary transmission of COVID-19 from children attending school in Ireland, 2020. Euro Surveill. 2020; 25: 2000903.
49 Yoon Y, Kim K-R, Park H, Kim S, Kim Y-J. Stepwise school opening and an impact on the epidemiology of COVID-19 in the children. J. Korean Med. Sci. 2020; 35: e414.
50 Buonsenso D, De Rose C, Moroni R, ValentinI P. SARS-CoV-2 infections in Italian schools: Preliminary findings after 1 month of school opening during the second wave of the pandemic. Front. Pediatr. 2021; 8: 609.
51 Kampe EOI, Lehfeld A-S, Buda S, Buchholz U, Haas W. Surveillance of COVID-19 school outbreaks, Germany, March to August 2020. Euro Surveill. 2020; 25: 2001645.
52 Dub T, Erna E, Hagberg L et al. Transmission of SARS-CoV-2 following exposure in school settings: experience from two Helsinki area exposure incidents. medRxiv 2020. https://doi.org/10.1101/2020.07.20.20156018.
53 Varma JK, Thamakkattaksem J, Whittimore K et al. COVID-19 Infections Among Students and Staff in New York City Public Schools. Pediatrics 2021; 147: e2021050605.
54 Ismail SA, Saliba V, Lopez Bernal J, Ramsay ME, Ladhani SN. SARS-CoV-2 infection and transmission in educational settings: A prospective, cross-sectional analysis of infection clusters and outbreaks in England. Lancet Infect. Dis. 2021; 21: 344–53.
55 Larosa E, Dujic O, Cassinadri M et al. Secondary transmission of COVID-19 in preschool and school settings in northern Italy after their reopening in September 2020: A population-based study. Euro Surveill. 2020; 25: 2001911.
56 Yung CF, Kam K-Q, Nadua KD et al. Novel coronavirus 2019 transmission risk in educational settings. Clin. Infect. Dis. 2020; 72: 1055–8.
57 Somekh I, Shohat T, Boker LK, Simões EAF, Somekh E. Reopening schools and the dynamics of SARS-CoV-2 infections in Israel: A nationwide study. Clin. Infect. Dis. 2021. https://doi.org/10.1093/cid/cia035.
58 Gilliam WS, Malik AA, Shafigh M et al. COVID-19 transmission in US child care programs. Pediatrics 2020; 147: e2020031971.
59 Ludvigsson JF, Engerström L, Nordenhäll C, Larsson E. Open schools, Covid-19, and child and teacher morbidity in Sweden. N. Engl. J. Med. 2021; 384: 669–71.
60 Scotland Public Health. COVID-19 Antibody Survey of Education Staff (CASS) Report 2. Scotland, 2021.
61 England Public Health. COVID-19 Schools Infection Survey Round 2. England: December 2020; 2020.
62 Magnusson K, Nygård K, Vold L, Telle K. Occupational risk of COVID-19 in the 1st vs 2nd wave of infection. 2020. 2020.10.29.20200426.
63 Lachassinne E, de Pontual L, Caseris M et al. SARS-CoV-2 transmission among children and staff in daycare centres during a nationwide lockdown in France: A cross-sectional, multicentre, seroprevalence study. Lancet Child Adolesc. Health 2021; 5: 256–64.
64 Li Y, Campbell H, Kulkarni D et al. The temporal association of introducing and lifting non-pharmaceutical interventions with the time-varying reproduction number of SARS-CoV-2: A modelling study across 131 countries. Lancet Infect. Dis. 2021; 21: 193–202.
65 Scudellari M. How Iceland hammered COVID with science. Nature 2020; 587: 536–9.
66 Mensah AA, Sinnathamby M, Zaidi A et al. SARS-CoV-2 infections in children following the full re-opening of schools and the impact of national lockdown: Prospective, national observational cohort surveillance, July–December 2020, England. J. Infect. 2021; 82: 67–74.
67 Catalá Sabaté M, Cardona Iglesias P, Prats Soler C, et al. Analysis and Prediction of COVID-19 for EU-EFFTA-IK and Other Countries. Barcelona: UPCommons; 2020. https://upcommons.upc.edu/handle/2117/341450 [accessed 31 March 2021].
68 Health Protection and Surveillance Centre. COVID-19 cases in Ireland; 2021. Available from: https://www.hpsc.ie/a-z/respiratory/coronavirus/novelcoronavirus/casesinireland/epidemiologyofcovid-19inireland/ [accessed 27 March 2021].
69 European Centre for Disease Prevention and Control. COVID-19 in children and the role of school settings in transmission – First update. Stockholm; 2020.
70 Australian Bureau of Statistics. National, state and territory population; 2020; Available from: https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/jun-2020 [accessed 15 March 2021].
71 Macartney K, Quinn HE, Pillsbury AJ et al. Transmission of SARS-CoV-2 in Australian educational settings: A prospective cohort study. Lancet Child Adolesc. Health 2020; 4: 807–16.
72 National Centre for Immunisation Research and Surveillance. COVID-19 in schools and early childhood education and care services – the Term 2 experience in NSW; 2020. Available from: https://www.ncirs.
82 Center for Disease Control and Prevention. Science brief: Emerging SARS-CoV-2 variants; 2021. Available from: https://www.cdc.gov/coronavirus/2019-ncov/more/science-and-research/scientific-brief-emerging-variants.html. [accessed 11 March 2021]

83 Public Health England. Investigation of novel SARS-CoV-2 variant. Variant of concern 202012/01 technical briefing 6. https://www.gov.uk/government/publications/investigation-of-novel-sars-cov-2-variant-variant-of-concern-20201201#history [accessed 3 March 2021]

84 Lancet COVID-19 task force. Safe work, safe schools and safe travel, 2020.

85 Commission for Children and Young People. New findings reveal massive impact of COVID for children and young people in Victoria; 2020. Available from: https://ccyp.vic.gov.au/news/new-findings-reveal-massive-impact-of-covid-for-children-and-young-people-in-victoria/ [accessed 26 November 2020].

86 Bell F. WA schools resume for term two after coronavirus shutdown amid new health measures; 2020. Available from: https://www.abc.net.au/news/2020-04-29/wa-children-return-to-school-after-coronavirus-shutdown/12198208 [accessed 29 April 2020].

87 NSW Department of Education. Lessons from the COVID-19 pandemic; 2020. Available from: https://education.nsw.gov.au/content/dam/main-education/en/home/covid-19/lessons-from-the-covid-19-pandemic-jan-july-2020.pdf [accessed July 2020].

88 Isaacs D. The precautionary principle, the AstraZeneca COVID-19 vaccine and mixed messaging. J. Paediatr. Child Health 2021; 57: 472–3.

89 Australian Health Protection Principal Committee. Australian Health Protection Principal Committee (AHPPC) advice on reducing the potential risk of COVID-19 transmission in schools (24 April 2020); 2020. Available from: https://www.health.gov.au/news/australian-health-protection-principal-committee-ahppc-advice-on-reducing-the-potential-risk-of-covid-19-transmission-in-schools-24-april-2020 [accessed 25 November 2020].

90 Ritchie H, Ortiz-Ospina E, Beltekian D, et al. Daily new confirmed COVID-19 cases per million people. Coronavirus (COVID-19); 2021. https://ourworldindata.org/coronavirus#coronavirus-country-profiles [accessed 29 April 2021].

91 New York Time. Coronavirus World Map: Tracking the Global Outbreak. 2021. https://www.nytimes.com/interactive/2020/world/coronavirus-maps.html. Data sourced from: Local governments; The Center for Systems Science and Engineering at Johns Hopkins University; National Health Commission of the People’s Republic of China; World Health Organization. [accessed 28 April 2021].

92 Dipartimento della Protezione Civile, Development of number of Coronavirus cases: Emilia-Romagna, Italy; 2021. https://coronalevel.com/italy/Emilia-Romagna/ [accessed 28 April 2021]