Children's Task and Finish Group: Update on Children, Schools and Transmission

SAGE has advised previously that the opening and closing of schools is likely to have an impact on transmission and R, and that policymakers will need to consider the balance of risks and harms: including the potential direct health risks to children and staff from COVID-19 and the wider impact of school opening on community transmission; and the direct risks to student mental health, wellbeing, development, educational attainment and health outcomes from school closure.

In the second wave, prevalence has risen significantly in school age children, with the rise increasing initially among those in school year 12 (age 16/17) – age 24 and young people (e.g. secondary school age). The rising prevalence was first visible around the time that schools reopened. While this may be indicative of a potential role for school opening, causation, including the extent to which transmission is occurring in schools, is unproven and difficult to establish.

Impacts on children and young people

- There continues to be strong evidence that children and younger people (<18 years) are much less susceptible to severe clinical disease than older people (high confidence).
- There is clear evidence of the negative educational impact of missing school, particularly for younger children, as investments in children's learning tend to accumulate and consolidate over time (high confidence).
- There is evidence that the pandemic has negatively impacted the mental health of children and young people, and that school closures cause impairment to the physical and mental health of children. Evidence suggests that the mental health of adolescents is particularly affected (high confidence).

Impacts on teachers and school staff

- ONS data from 2 September to 16 October show no difference in the positivity rates of pre-school, primary and secondary school teachers and staff, relative to other workers of a similar age (medium confidence).

Role of children, young people and schools in transmission

- ONS COVID-19 Infection Survey (CIS) and REACT-1 data show continued increases in the prevalence of infection in those aged 2-24 between September and October, with earlier increases and higher prevalence in those in school year 12 (age 16/17) – age 24 and school year 7-11 (high confidence).
- Evidence suggests that mixing outside the home continued to occur during school closures. Following school opening in September, the reported number of contacts for children aged 5-11 and 12-17 in England increased overall and in schools (medium-high confidence). Overall reported contacts at this time occurred primarily within schools, but also in the home and community (low confidence).
- The increases in infection levels among children and particularly young adults occurred at about the same time as the opening of schools (medium-high confidence).
- Epidemiological data and modelling show that there were signals of increasing transmission, and epidemic growth, in the wider population before the reopening of schools (medium confidence).

- Education is a major part of children and young people's lives, but transmission to children and young people can occur in household, community and educational settings (high confidence). We cannot separate out the infection risk from behaviours and contacts within schools from the wider 'end to end' behaviours and contacts associated with school attendance but taking place outside the school.
- Since schools reopened in Sept 2020, PHE indicate that there have been more than 1000 instances where there have been two or more test-confirmed cases of COVID-19 in educational settings. There is no current direct evidence that transmission within schools plays a significant contributory role in driving increased rates of infection among children, but neither is there direct evidence to suggest otherwise (low confidence).
- There is some evidence from contact tracing studies that pre-school and primary aged children are less susceptible to infection than adults (low-medium confidence). The evidence is more mixed for secondary aged children and older children seem to have similar rates to adults.
- Children can transmit within households as well as in educational settings. As the prevalence of infection in children aged 12-16 increased between September and October, ONS analysis suggests that children aged 12-16 played a significantly higher role in introducing infection into households (medium confidence). The difference is less marked for younger children (medium confidence). The relative rate of external exposure (i.e. bringing infection into the household) for children aged 2-16 was found to be higher than for adults. For those aged 12-16 there was a marked increase in the period after schools opened.
- No two schools are the same, with differences for example in class sizes, structures and ventilation, among other things. Differences in the school environment and the level of mitigations in place will influence the potential for transmission in schools. Mitigations such as ventilation (and others) are important in all school settings.
- The age of children, and the feasibility of effectively implementing infection controls will influence the balance of risks and benefits to children, and should be clearly considered in policy.

Background, previous advice and aims

As stated in previous advice, policymakers have the challenge to differentiate and balance any COVID-19 related health risks to children and staff related to educational settings, as well as any role of children and schools in wider transmission, with the risks and harms to mental health, wellbeing, development, educational attainment, and health outcomes associated with school closures or other interventions.

SAGE has previously advised that the opening or closing of schools is likely to have an impact on transmission[1], with potential increases associated with school opening being related to changes in behaviour and contacts both inside or outside of schools. This could occur directly, as children mix with others on their way to and from, and in school; or indirectly, if the opening of schools also enables other mixing to occur (such as parents being able to go to work, or socialising after dropping off children at school). For this reason, the role of schools in community transmission cannot be easily considered in isolation from wider measures[2]. SAGE has advised that there is low immediate risk to children of suffering severe clinical disease from COVID-19. There are significant educational, developmental and mental health harms from schools being closed[3].

Aims of this paper:

A feature of the "second wave" of the SARS-CoV-2 epidemic in the UK has been a rapid increase in infection rates among school age children as well as young adults relative to other age groups. This paper aims to assess the evidence on three questions arising from this:

- The risk to children, both from infection and from missing schooling were schools to be closed in an effort to reduce community transmission.
- The risk to teachers/school staff; i.e. whether teaching is a higher-risk occupation with respect to SARS-CoV-2 infection than other forms of employment (excluding health and social care workers).
- The role of children and schools in the wider epidemic in the community, in general and in the second wave.

Wherever possible, the evidence has been disaggregated by age groupings and/or settings between children (e.g. pre and primary) and young people (e.g. secondary school).

[1] E.g. https://www.gov.uk/government/publications/sage-minutes-coronavirus-covid-19-response-1-may-2020

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/903374/S0621_Risks_associated_with_the_reopening_of_education_settings_in_Sept.pdf

[3] https://www.gov.uk/government/publications/sage-46-minutes-coronavirus-covid-19-response-9-july-2020

Risks to children and young people from COVID-19 and from missing school

There is still strong evidence that children and younger people (<18 years) are less susceptible to severe clinical disease than older people (high confidence). As agreed at SAGE31 and by the TFC group in July[4] and updated to 3 July[5]; at that time only 0.9% of over 69,000 hospital patients with COVID-19 were under the age of 19. Of this cohort only six died, all with profound co-morbidity. However, a non-trivial proportion of the hospitalised children and young people (11% of the 0.9%) met the WHO preliminary case definition for multisystem inflammatory syndrome. In this cohort, the all-cause case fatality rate of those under 19 already in hospital was strikingly lower (at 1%) than that for all ages (27%); and even in older adults those over 80 years have been described as over 10 times more likely to die than those under 50 years[6].

There is clear evidence of the negative educational impact of missing school, particularly for younger children and disadvantaged students (high confidence). As noted in the accompanying SPI B paper[7] and previous advice from SAGE, educational outcomes are seriously at risk as a result of school closures, particularly for disadvantaged pupils. Vulnerable children are most likely to be affected, with risk of harm and abuse higher due to isolation and financial stress. Even a relatively short period of missed school could have consequences for skill growth, particularly for younger children, given that investments in children's learning tend to be complementary over time[8]. A period of learning at home is likely to reinforce inequalities between children[9]. Extended periods away from school could mean that emerging learning problems are missed by educational psychologists. Additionally, an important minority of students do not have access to devices and the internet.

There is evidence that the pandemic has negatively impacted the mental health of children and young people, particularly for adolescents (high confidence). Recent ONS/NHSD work found a significant increase in children aged 5-16 identified as having a probable mental disorder; to one in six in 2020 from one in nine in 2017[10]. Children and young people with a probable mental disorder were more likely to say that lockdown had made their life worse (54.1% of 11-16 year olds; and 59% of 17-22 year olds) than those unlikely to have a mental disorder (39.2% and 37.3% respectively)[11]. **There is evidence[12] that school closures cause impairment to the physical and mental health of children (high confidence). Cognitive, social and emotional developmental outcomes are also at risk (medium confidence).**

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/903374/S0621_Risks_associated_with_the_reopening_of_education_settings_in_Sept.pdf
[5] https://www.bmj.com/content/370/bmj.m3249
[6] https://www.bmj.com/content/369/bmj.m1985
[7] Benefits of remaining in education: Evidence and considerations. SPI-B and DfE, Nov 2020
[8] https://rs-delve.github.io/reports/2020/07/24/balancing-the-risk-of-pupils-returning-to-schools.html#report-findings
[9] See Royal Society paper and annex A
[10] https://blog.ons.gov.uk/2020/10/22/mental-health-of-children-and-young-people-in-the-pandemic/
[11] https://digital.nhs.uk/data-and-information/publications/statistical/mental-health-of-children-and-young-people-in-england/2020-wave-1-follow-up
[12] Benefits of remaining in education: Evidence and considerations. SPI-B and DfE, Nov 2020

Risks to teachers and school staff

ONS data from 2 September (start of school) to 16 October show no difference in the positivity rates of primary and secondary school teachers and other worker groups (medium confidence). This is the same when including household members of such groups.

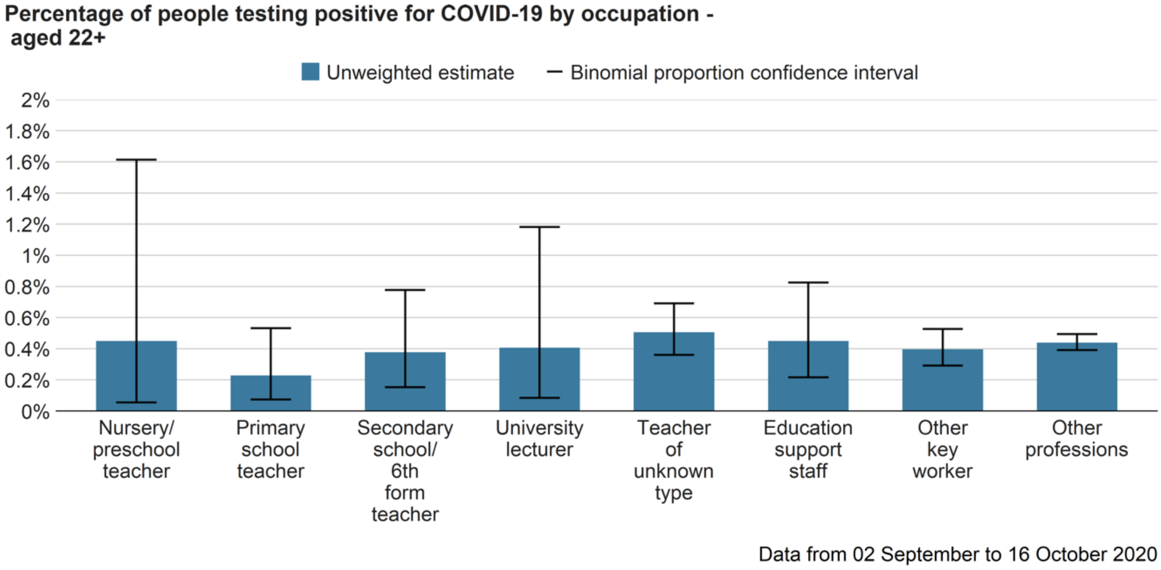

Figure 1: ONS, percentage of people testing positive for COVID-19 by occupation, aged 22+

Trends in the prevalence of COVID-19 infection in children and young people, and the timing of school opening

Population based studies (ONS COVID-19 Infection Survey (CIS) and REACT data[13]) show increases in the prevalence of infection in children and young people aged 2-24 across Sept-Oct (high confidence). In ONS data, these increases were seen first in children aged 16/17-24, followed by increases in younger (school year 7-11 and age 2-school year 6) age groups (see below for detail). REACT-1 rounds 5[14] and 6[15] (see annex) also show continued increases in age groups 5-12, 13-17 and 18-24, with the second highest prevalence in those aged 13-17 (after 18-24). **According to local authority set dates in England provided by DfE[16], the majority of school terms started between the 1st-7th September 2020.**

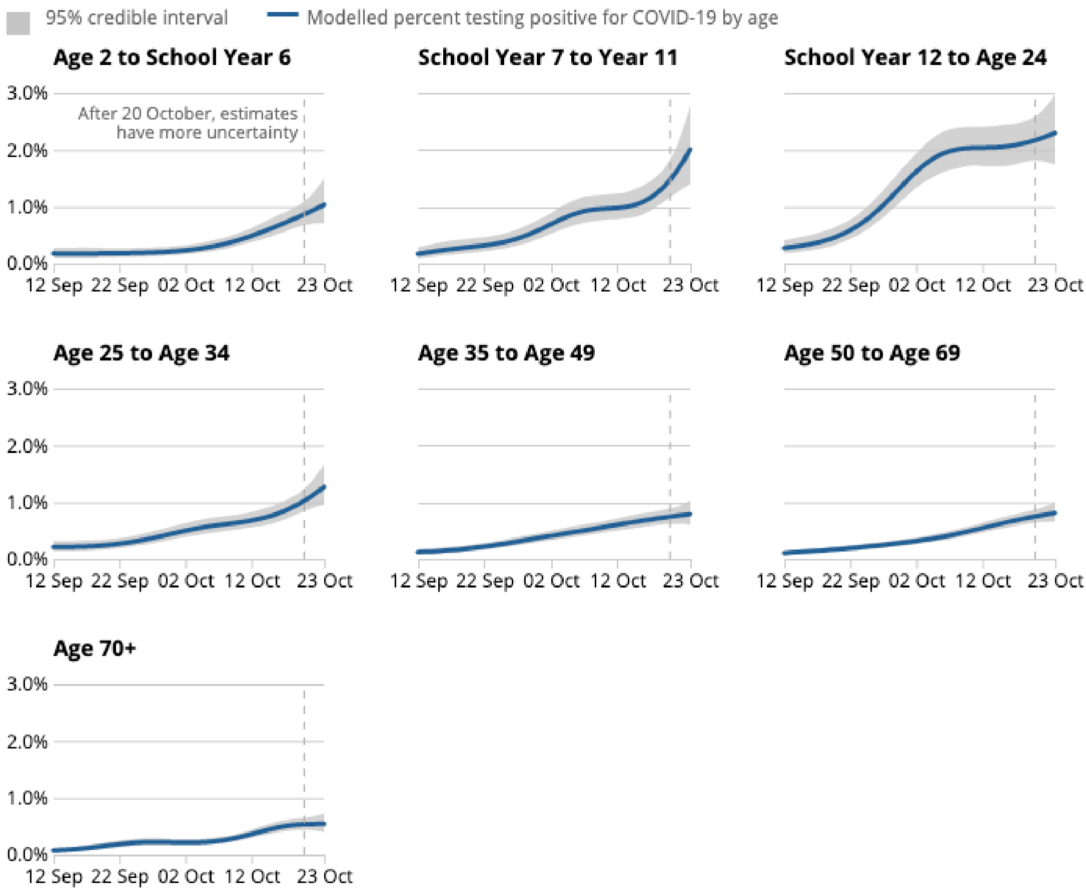

Figure 2: ONS, estimated percentage of the population testing positive for COVID-19, daily, by age group since 12 Sept 2020

[13] Wed 28 Oct COVID-19 Infection Survey Report, ONS; Interim Report 18: REACT, 22nd Oct 2020
[14] 18th Sept-5th Oct
[15] Interim results, 16-25th Oct
[16] Internal data provided by DfE; some local arrangements may differ

Table 1: Summary of ONS CIS data by age group; data to Oct 23 2020

Age:	**Age 2 – school year 6**	**School years 7 - 11**	**School Year 12 – Age 24**
Continued increases seen since:	Mid Sept to Oct, particularly between late Sept and early Oct. For example, rising from 0.40%, (0.29-0.53% 95% CI) in data from 26 Sept – 9 Oct to 0.97% (0.8-1.17%) in data from 10 Oct-23 Oct.	Late Aug to Oct, particularly between mid-Sept and early Oct. For example, rising from 0.45%, (0.27-0.66% 95% CI) in data from 12-15 Sept to 1.03%, (0.81-1.29%) in data from 26 Sept-9 Oct.	Mid-Aug to Oct, particularly between mid-Sept and early Oct. For example, rising from 0.66%, (0.45-0.92% 95% CI) in data from 12-15 Sept to 2.43%, (2.10-2.80%) in data from 26 Sept-9 Oct.
Estimated percentage of the population testing positive for COVID-19 as of 23rd Oct (%, CI):	Fourth highest prevalence across all age groups (0.97%, 0.8-1.17%)	Second highest prevalence across all age groups (1.66%, 1.39-1.96%)	Highest prevalence across all age groups (2.95%, 2.61-3.34%)

The increases in infection levels among children and young adults occurs at about the same time as the opening of schools (medium-high confidence). Considering signals of increasing transmission in the wider population, there is some evidence that epidemic growth restarted before the reopening of schools. The reproduction number R was rising for several weeks before schools opened (see Annex A, Figure 9 for England and Scotland). The inflection point for a return to rise in hospital admissions was also before schools opened in England and Scotland, but less clear in Wales (Annex A, Figure 10). Hospital admissions in particular is a lagged indicator of community transmission, so any change driven by schools would be a few weeks after their return.

Internationally, there is no consistent pattern between school openings and increases in case numbers (medium confidence). In many cases, initial increases in overall reported case numbers across European countries began weeks before schools reopened. But in others, such as Denmark and the Netherlands, cases appear to have accelerated after schools re-opened, including in younger age groups. Importantly, this is based on case numbers which do not capture the levels of infection as fully as population representative data (e.g. ONS and REACT), particularly for asymptomatic or paucisymptomatic cases.

Role of children, young people and schools in transmission

As the prevalence of infection in children aged 12-16 increased between September and October, analysis of ONS data suggests that the children aged 12-16 played a significantly higher role in introducing infection into households (medium confidence). The difference is less marked for younger children (medium confidence). Analysis of ONS data[17] indicates clearly that children can bring infection into the household and transmit to other household members. For example, see figure 2 below, where many households only have child positives, which would not be possible if children did not bring infection into the household. Although this does not necessarily mean that the infected children were infected in schools.

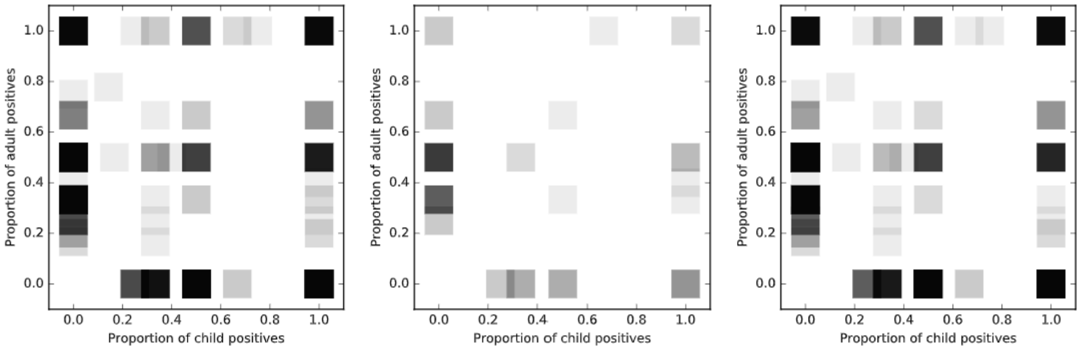

Figure 3: Households in the ONS data with at least one positive and one child in the household. A translucent square is placed for each household according to the proportion of children (under 16) and adults who are swab positive (age ranges as in ONS CIS)

Modelling using this ONS CIS data up to either 7th Sept 2020 or 8th Oct 2020 indicates that the transmissibility from children aged 2-11 and 12-16 is no different or very similar to that from adults. **The relative rate of external exposure (i.e. bringing infection into the household) for children aged 2-11 and 12-16 was found to be higher than for adults. For those aged 12-16 this increased significantly when the analysis was run to include the period after schools opened** (analysis to Sept – relative rate 1.69, 1.01-2.82 CI; to Oct – relative rate 8.08, 4.92-13.27)[18].

[17] Provided by Thomas House to SAGE; Oct 2020
[18] See figure 3 below; analysis of ONS data provided to SAGE by Thomas House

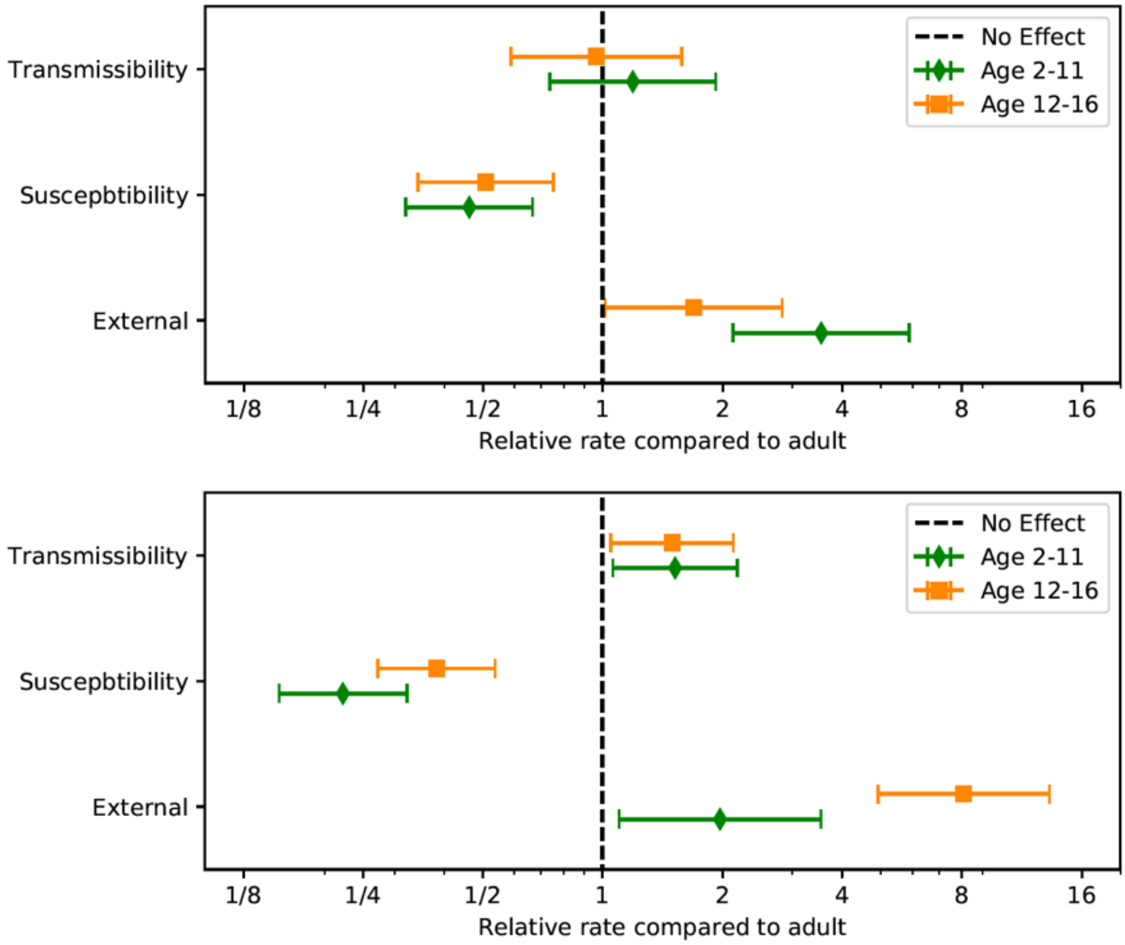

Figure 4: Fitted household transmission model using ONS CIS data. Top: effect sizes with data to 7 Sept. Bottom: effect sizes with data to 8 Oct.

There is some evidence from contact tracing studies that pre-school and primary aged children are less susceptible to infection than adults (low-medium confidence). The evidence is more mixed for secondary aged children[19]. A household analysis of ONS data[20] also found that susceptibility to infection of children aged 2-11 and 12-16 was lower than adults when the analysis was run to September and October (see figure above). The pattern of seroprevalence by age depends on contact patterns in the population as well as susceptibility, and as such age-specific seroprevalence alone does not give a clear signal of susceptibility (for example, REACT-2 rounds 2 and 3 show higher antibody prevalence in younger age groups).

The increases in infection among children coincided with the timings of the opening of schools. Education is a major part of young people's lives, and transmission to children and young people can occur in household, community and educational settings (high confidence). **There is no direct evidence that transmission within schools plays a significant contributory role in driving increased rates of infection among children (low**

[19] https://www.medrxiv.org/content/10.1101/2020.05.20.20108126v2 ; https://jamanetwork.com/journals/jamapediatrics/fullarticle/2771181
[20] Provided by Thomas House to SAGE; Oct 2020

confidence). A systematic review of mostly international literature[21] indicates that transmission occurs in schools only to a limited degree. However, most studies included were done at times of low background prevalence and with mostly younger children (<13 years). The ONS data currently available cannot separate school from household or community transmission. There is clear evidence that individual significant outbreaks in schools can occur. Since schools reopened in Sept 2020, PHE indicate there have been more than 1000 clusters and outbreaks reported in educational settings (note that clusters are defined as involving two or more test-confirmed cases of COVID-19 associated with a specific non-residential setting[22]).

7 school population-based studies, which had near-full ascertainment of school cases in the review cited above (see Annex B) also have important and contrasting findings. On the one hand, several large serological studies in schools failed to find large clusters of cases. On the other, the only study that swabbed children every week did find evidence of 12 onward transmissions amongst 253 contacts of 30 infected children in a school-like setting (a summer camp; secondary attack rate was 4.7%); 22 child index cases transmitted to no-one, 5 to 1 contact, 2 to 2 and 1 to 3 contacts. In that study, where children were quarantined if they had a positive swab, chains of transmission in school were not self-sustaining.

We cannot separate out behaviours and contacts within schools from the 'end to end' behaviours and contacts associated with school attendance (high confidence). 'End to end' behaviours include, for example, travel to/from school and activities around school. We also cannot be sure how these may change or be displaced were schools to close. **Evidence suggests that mixing outside the home continued to occur during school closures[23]; however, an increase in number of contacts for children following school opening has also been reported**[24] (although these were reported by parents)[25]. As previously noted by SAGE the quality, duration and nature of contacts are also important in transmission risk, as are the nature of any mitigations; findings of limited transmission in schools in the published literature could reflect high levels of mitigations in place (low confidence).

The differences in conclusions coming from population representative data (e.g. ONS and REACT) and other literature/studies, including recent PHE data, are likely due to more complete ascertainment of levels of infection, which includes asymptomatic cases. Whilst recent PHE data suggests they do not have evidence to support or refute transmission within the educational setting[26], it is important to note that since Sept 2020 surveillance data available based on pillar 1 and 2 testing may not ascertain asymptomatic or paucisymptomatic infection.

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[21] Russell Viner; systematic review update provided to SAGE, Oct 2020
[22] See e.g. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/923668/Weekly_COVID19_Surveillance_Report_week_40.pdf
[23] The impact of unplanned school closure on children's social contact: Rapid evidence review - Rubin et al, 2020
[24] See annex A
[25] https://cmmid.github.io/topics/covid19/reports/comix/CoMix%20Weekly%20Report%2024.pdf
[26] SARS-CoV-2 infection and transmission in educational settings; Summary Oct 2020; PHE

Annex A: additional data and figures

Variable	Category	Round 5 Positive	Round 5 Total	Round 5 Prevalence	Round 6 Positive	Round 6 Total	Round 6 Prevalence
Gender	Male	387	78,565	0.65% (0.57% , 0.75%)	387	39,319	1.31% (1.13% , 1.53%)
	Female	437	96,380	0.54% (0.48% , 0.62%)	476	46,648	1.25% (1.10% , 1.43%)
Age	05-12	59	13,771	0.60% (0.43% , 0.84%)	55	5,513	1.49% (0.98% , 2.26%)
	13-17	59	10,480	0.70% (0.49% , 1.00%)	60	5,169	1.58% (1.08% , 2.31%)
	18-24	83	6,852	1.59% (1.18% , 2.13%)	53	3,091	2.25% (1.47% , 3.42%)
	25-34	86	15,683	0.69% (0.53% , 0.90%)	97	7,186	1.62% (1.25% , 2.08%)
	35-44	121	22,954	0.58% (0.47% , 0.73%)	98	10,079	1.29% (0.98% , 1.68%)
	45-54	157	29,380	0.58% (0.48% , 0.70%)	137	13,009	1.22% (0.99% , 1.51%)
	55-64	116	31,885	0.37% (0.30% , 0.46%)	167	15,768	1.20% (0.99% , 1.46%)
	65+	143	43,944	0.35% (0.28% , 0.43%)	196	26,156	0.81% (0.68% , 0.96%)

Figure 5: weighted prevalence of swab-positivity by gender and age for rounds 5 and 6 (partial) of REACT-1

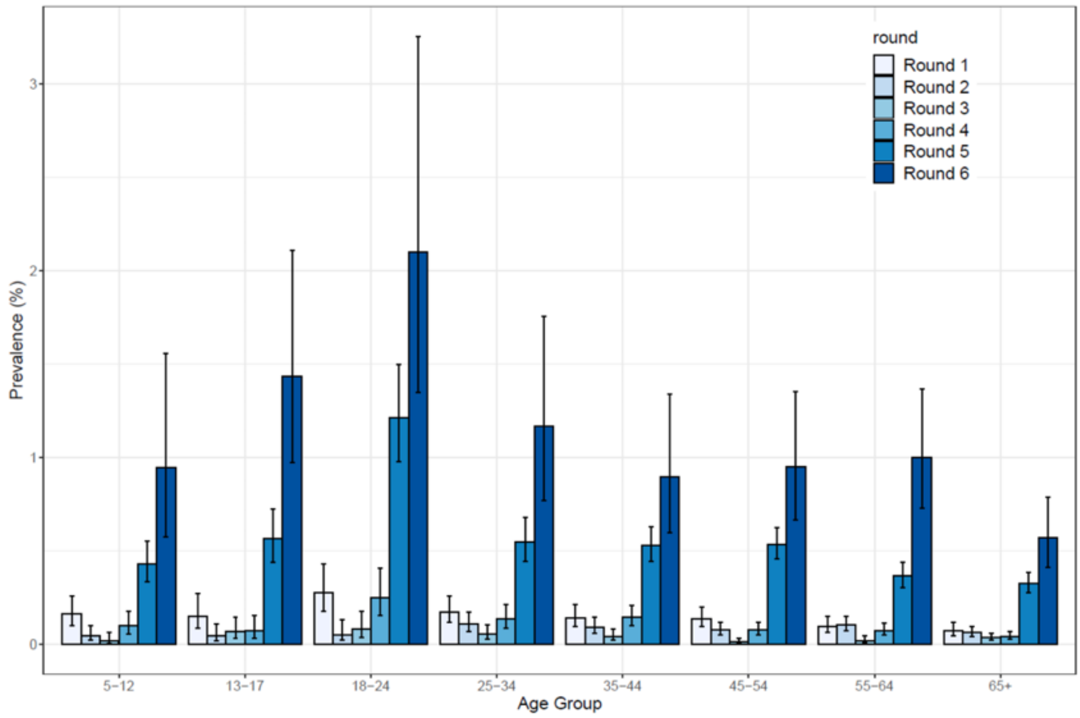

Figure 6: REACT-1, unweighted prevalence of swab positivity by age by round; round 5 from 18th Sep- 5th Oct, interim results from round 6 16th-15th Oct.

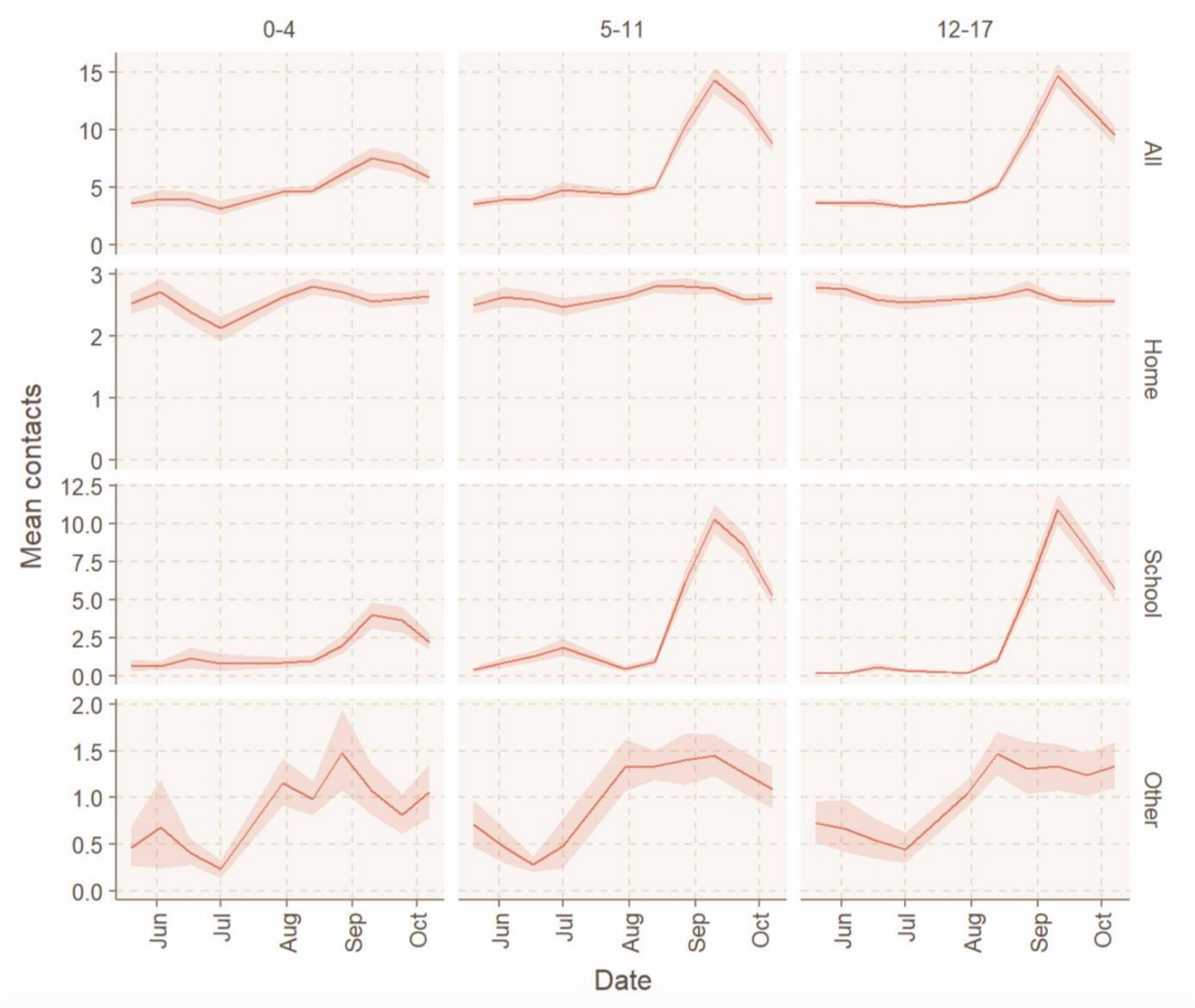

Figure 7: changes in number of contacts of children of different ages over time in different settings as reported by their parents in the CoMix social contacts survey[27]

[27] https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-020-01597-8 ; figure from CoMix week 31 report

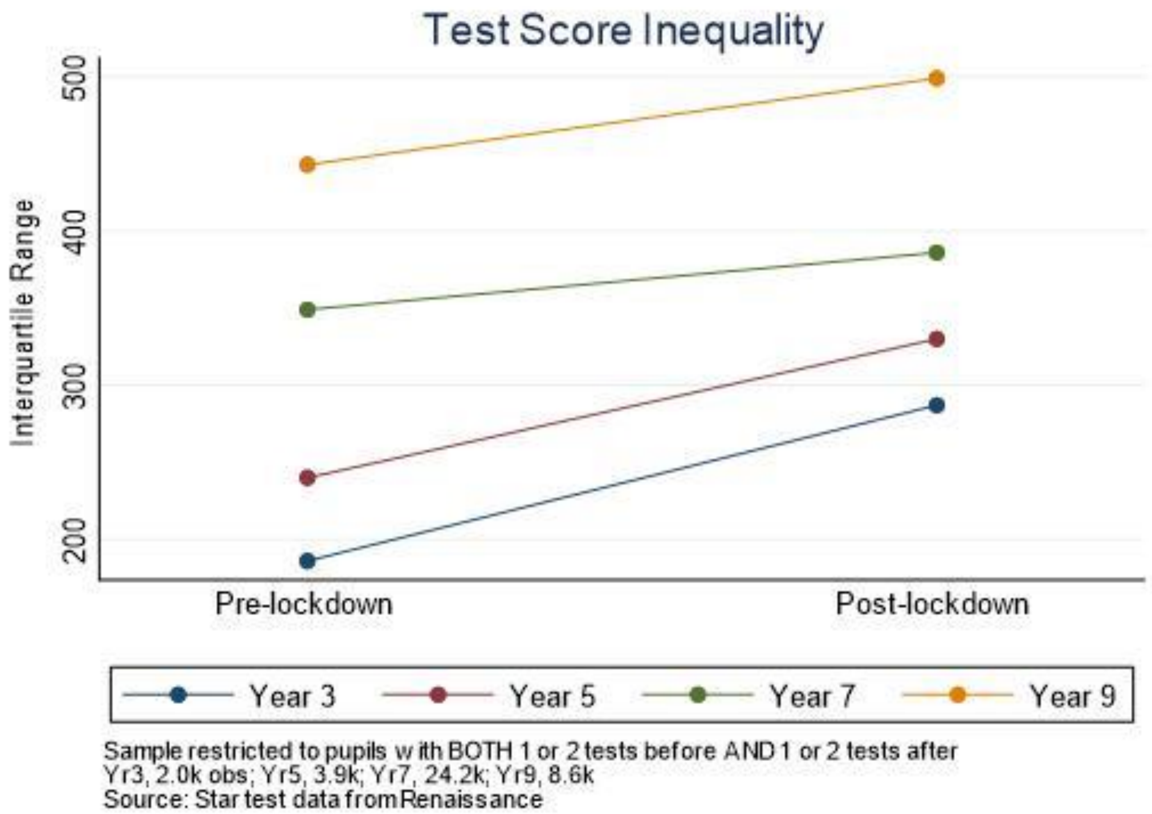

Figure 8: Royal Society Delve; test score inequality pre and post lockdown, showing that the difference between test-scores for high performers and low performers increased before and after lockdown for a group of young people taking Star tests on reading and understanding through an online learning platform (see https://rs-delve.github.io/reports/2020/07/24/balancing-the-risk-of-pupils-returning-to-schools.html)

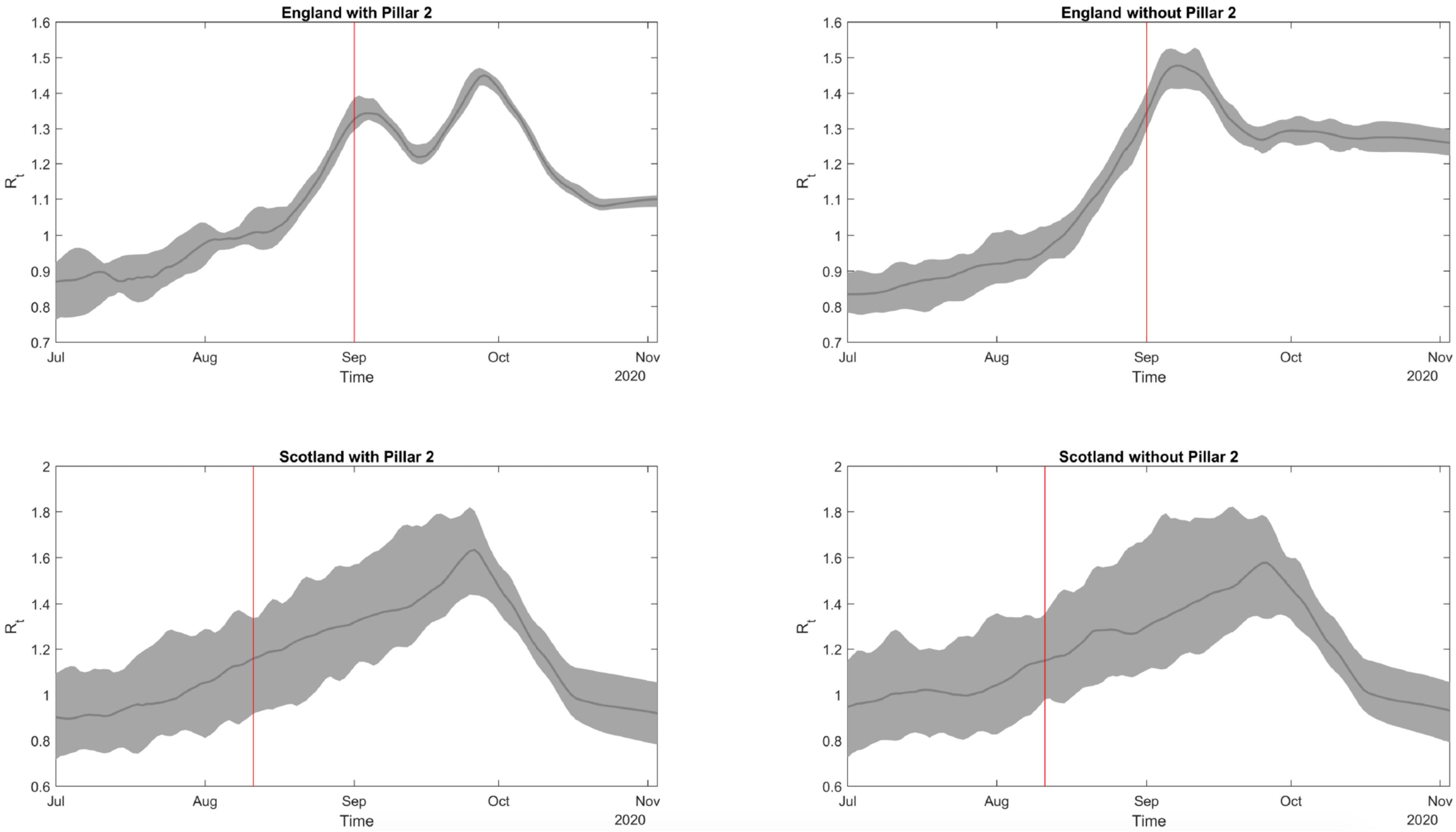

Figure 9: Inferred Rt against time, red line marks approximate school opening; COVID modelling consortium. R was increasing through July and August, and most of the increase happened before schools returned. Please note that these are retrospective estimates of Rt for the given time period, and not a time-series of past estimates of current Rt. These will differ due to data availability. These are estimates from one modelling group and will not be consistent with the history of the weekly estimates of R, as published by HMG.

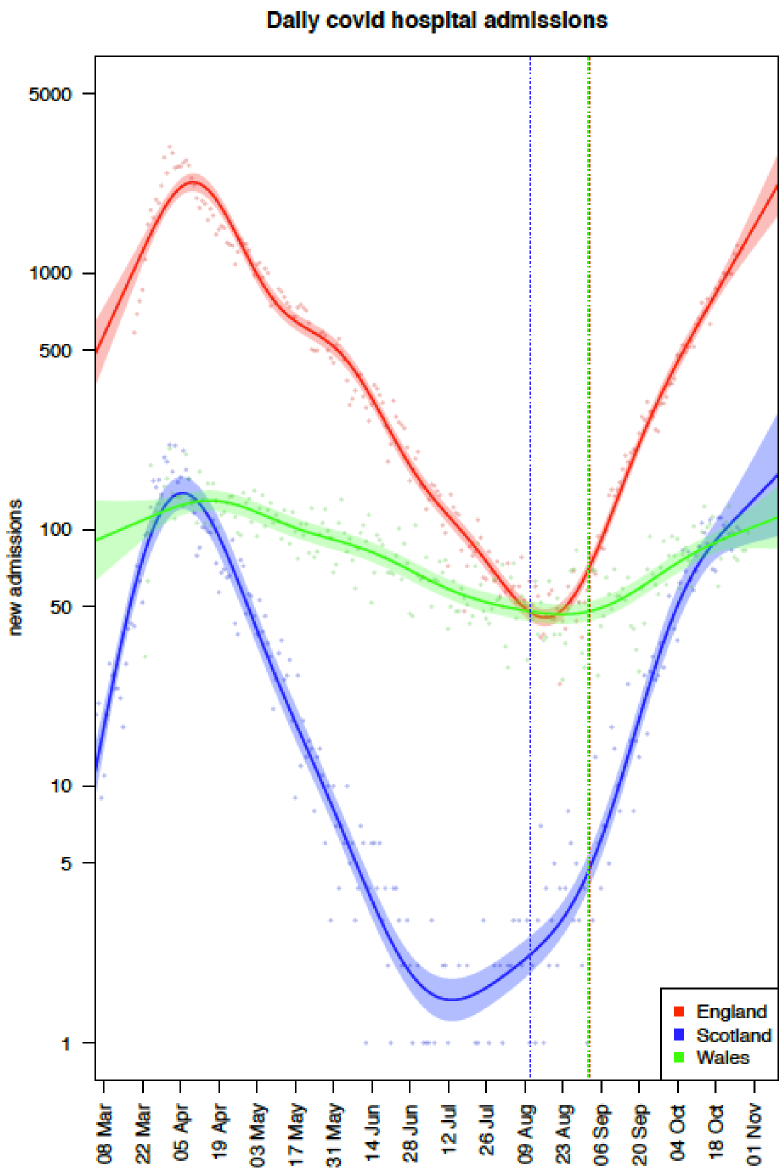

Figure 10: Daily new hospital admissions of Covid-19 patients in England, Scotland and Wales. Shared ribbons are GAM splines fitted to logged numbers, including 95% confidence intervals, for each nation. Approximate school opening dates shown as vertical dashed lines. Inflection points representing the first growth in admissions since the initial epidemic all occur prior to school opening. As admissions lag infection, any impact of school opening would not be expected to be seen immediately; COVID modelling consortium; data source, UK COVID-19 dashboard

Annex B: School transmission studies of SARS-CoV-2 : extract from systematic review

Russell Viner
29 October 2020

Searches undertaken to 25 October across PubMed, medRxiv and a range of professional sources

32 studies included
Studies starting from a population = 7
Studies starting from infection/disease = 19
Studies providing relevant/inferential data = 6

A. Starting from a population: Population-based studies of infection prevalence in schools

Study	Country, dates	Findings
Ladhani et al.[1]	England, June-July	SKIDS: undertook prospective surveillance including 12,026 participants in 131 schools including early years settings in England after the reopening of schools from 1 June to early July 2020. Students were primarily of primary school age as only limited years were open in most secondary schools. 86 schools took part in weekly swabbing (for RT-PCR testing) and 45 schools participated in serology testing. 43,039 swabs were taken - 23,358 (59.3%) from students and 16,052 (40.7%) from staff. In total 1 student and 5 staff had detectable SARS-CoV-2 on their nose or throat swabs. Household and school contacts of the 6 were all quarantined and offered testing, with no further cases identified. Seropositivity found in 10.6% of students and 12.7% of staff; positivity was not associated with school attendance during lockdown (for vulnerable children or children of key-workers). Note only 20% of seropositive children reported any symptoms.
Ulyte et al.[2]	Switzerland, June-July	Population-based seroprevalence study (CiaoCorona study) of 2500 students 6-16y in 100 classes from 55 randomly selected schools in the canton of Zurich in mid-June to mid July 2020. Overall seroprevalence was 2.8% - similar to adults at the time. Of the 100 classes, 67 had no positive cases, 29 had one, 3 classes had 2 and 1 class had 3 cases. They concluded there is little clustering in classes i.e. evidence of minimal transmission within schools.

Fontanet et al.[3]	France, April	Population-based study in 6 French primary schools (n=510 children, 820 adults) in a city that had previously experienced an outbreak in the local high-school found seropositivity in 8.8% of primary school children, 7.1% of teachers and 11.9% of parents, whereas 61% of parents of an infected pupil were seropositive, suggesting transmission occurred primarily within households.
Armann et al.[4]	Germany, June	seroprevalence study in 1538 students and 507 teachers in 13 secondary schools in Eastern Saxony after schools reopened (SchoolCoviDD19 study) - May 25th and June 30th, 2020. They did not identify a single cluster of infection in participating schools, and found positive antibodies in 0.7% of teenagers and 0.2% of teachers. and noted that only 1 of 22 children from households with previous PCR-positive cases was seropositive. Background rate = 139 cases per 100,000.
Jurkutat et al.[5]	Germany, June	seroprevalence study in Saxony in the cities of Dresden, Leipzig, Zwickau, Borna and Werdau, studying 1884 students and 803 staff in 18 schools (10 high schools and 9 grammar schools) in late May and June 2020. PCR testing conducted in 2599 and serology in 2344. They found 0 positive samples on PCR. Seroprevalence was 14/2344=0.6% overall. They reported a lower seroprevalence in children than adults but provided no data to support this.
Jordan et al.[6]	Spain, July-August	studied SARS-CoV-2 prevalence and transmission in 1905 children 3-15 years attending 22 summer and sports camps in Barcelona and region, plus >400 adult staff. The camps were described as school-like (non-residential; frequent hand washing, small bubble groups, use of a mask) however they were predominantly outdoors. All children and adults were tested (saliva PCR) weekly for 5 weeks. Those who tested positive were quarantined. Identified 39 new cases (30 children, 9 adults). The 30 children had 253 close contacts in their bubble groups in the camps. 12/253 of contacts had secondary infections – SAR=4.7%. 22 child index cases transmitted to no-one, 5 to 1 contact, 2 to 2 and 1 to 3 contacts. They found no age-differences in transmission. They calculated an R of 0.3 whereas general population at the time was 1.7-2.
Blaisdell et al.[7]	USA, June to August	Studies 4 residential summer camps in Maine, USA,. The camps operated with mitigations including prearrival quarantine, pre- and post-arrival testing and symptom screening, cohorting, use of face coverings, physical distancing, enhanced hygiene measures, cleaning and disinfecting, and maximal outdoor programming. Approximately 75% of usual enrolment. All attendees quarantined with families for 14 days before arrival. All attendees were PCR-negative on arrival but also quarantined for 14 days in cohorts of 5-44 attendees. 642 children aged 7 -18 years and 380 staff attended over the 2 months. From 41 US states. All were retested 4-9 days after arrival. 3 (2 staff and 1 child) at 3 different camps were positive. The one positive child tested positive on day 3 of camp and had a cohort of 30 – who were all tested twice on days 3 & 4 after exposure. No secondary cases were identified

Note there are other population-based seroprevalence studies across the whole population e.g. ENE-COVID (Spain), Sweden and other more regional studies (e.g. Geneva). I have not included these here as they don't directly address schools.

B. Starting from infection: contact-tracing and outbreak studies

B1. School contact-tracing studies

Study	Country, dates	Findings
(a) Testing of all contacts regardless of symptoms		
Yoon et al.[8]	South Korea, April to July	examined impact of school closing and opening on national cases amongst children. School opening was delayed twice in March (usually new year opens 2 March). Schools reopened online on 9 April and face-to-face (with restrictions) in four steps on May 20, May 27, June 3, and June 8. They identified no change in the % of national cases that were CYP after schools opened from 20 May – stayed stable at 7.0-7.1% through to 11 July (there was a gradual increase in cumulative cases but similarly no sudden increase). They also report investigation of child index cases identified in schools between 20 May and 11 July. As of 11 July: 45 children 4-18y from 40 schools (K-12) were identified to be RT-PCR positive in school and assumed to be potential index cases. Source data were available for 32 of these, of whom 78% (25/32) had a household source, 2 from a church outbreak and 5 high school students infected from an outside-school acting academy outbreak. Extensive contact testing and tracing conducted in the 40 schools – with 10,903 students and staff tested (PCR). Only one additional student was found to be infected in the same classroom. 5 kindergarten children had 670 contacts (children and staff) tested – all negative. Primary school: 19 children had >2453 contacts tested – with 2 positive secondary cases (both infected by same child). Middle and high school (13-18y): 21 students had >7500 contacts tested, with no secondary cases. They note that the very efficient TT system in SK means they are confident that few asymptomatic cases have been missed. Note that schools were partially open throughout and with mitigations in place.
Ehrhardt et al.[9]	Germany, May - July	Contact tracing of all cases identified in schools/child-care in the state of Baden-Wurttemberg, Germany, after schools reopened May with mitigations in place through to school closing end July 2020. There were 557 cases (PCR) cases 0-19y in the state, of whom 81% (453) had data on school attendance. 4 students were infected by 2 teachers, whereas the remaining 437/453 (96.5%) of child positive cases were infected outside educational facilities. 137 cases attended school/cc for 1 or more days during infectious period. All contacts (2300 were tested. Known secondary cases = 11 children. The estimated there was 1 secondary case per 25 infectious school days (assuming the index cases spent an average of 2 infectious days at school).
(b) contacts tested if symptomatic		
Macartney et al.[10]	NSW, Australia, Jan-April	school surveillance and contact-tracing study in New South Wales, Australia, over the period before and after schools closed, using state public health data. The initial analysis cover January to 9 April 2020 – note schools were dismissed from 22 March. Note contacts were largely tested on the basis of symptoms except in certain schools where all were tested. 44% of all contacts were tested. They identified that 27 primary cases (15 staff, 12 children) across 25 schools or early-years nurseries who had attended schools whilst infectious, resulted in 18 secondary cases (10 children; 8 adults) in 4 settings. 3 children were infected in one school each, and 7 children were infected in an outbreak in one early-years setting initiated by a staff member with no evidence of child to adult

		transmission. The SAR was 1.2% (18/1448) overall, 5/1411=0.4% excluding the early-years outbreak and 2.8% (18/633) in those tested. Child to child transmission rate was 2/649 = 0.3% and child to adult = 1/103 (1.0%), whilst adult to adult was 7/160 = 4.4%.
Macartney et al.[11]	NSW, Australia, April-July	A second analysis by in all NSW schools between 10 April and 3 July 2020 (once schools reopened) found 6 PCR-positive index cases (4 students (1 early-years; 1 primary; 2 high-school); 2 staff) in 6 schools in the state who had attended school whilst infectious. All index cases were identified to have contracted the infection outside schools. 521 contacts were traced: (459 children and 62 staff) – 61% (319) had PCR testing. Nil were positive. Note setting specific data: early years: 1 child index, contacts=102 (84 children; 18 staff) – 81% of contacts tested; primary: 1 child index, 231 contacts (210 students, 21 staff); secondary 2 child indexes, 188 contacts (165 students, 23 staff).
Fong et al.[12]	Hong Kong, May-July	national surveillance data on schools after schools reopened in late May (secondary) and early June (primary). There were no cases in school-aged children in May and June. Community transmission surged in HK in July and there were 20 cases identified amongst 5-17 year olds between 1 and 18 July. Schools closed on 13 July for the summer but the great majority of cases attended school whilst symptomatic. 15/20 cases were thought to be predominantly household transmission-related, whilst there were 2 education-related clusters: 2 cases in a tutorial centre and 3 cases in one secondary school. They undertook school-wide testing (assumed PCR) for the two clusters and on a further 7 cases with no positive further cases identified.
Heavy et al.[13]	Ireland, March	national contact-tracing study before schools closed on 12 March 2020, and identified 6 primary cases (3 children). Contacts were tested (PCR) only if symptomatic. There were 0 secondary cases resulting from child index cases amongst 1001 child contacts (924 from schools) and 101 adult school contacts. (although 1 staff-member infected another adult outside the school setting)
Yung et al.[14]	Singapore, Feb-March	national CTS in schools using national surveillance registry data before schools closed. They identified only 3 potential seeding incidents in educational settings, with 3 child index cases (2 preschools, 1 secondary-school) attending school whilst infectious. Each of the children was infected through household contacts. All student close contacts were quarantined for 14 days and tested twice if symptomatic. A total of 109 child contacts were tested (PCR). Nil child contacts were positive. Note that an outbreak in a preschool resulted in a teacher infecting 16 adult staff but 0/77 children.
Dub et al.[15]	Finland, March	Studied outcomes of two individual cases identified in schools in Helsinki, one a 12 year old child and one a staff member, both attended school for some days whilst infectious, before schools closed in mid March. They traced close contacts for both (121 contacts for child (112 children; 10 adults); 63 for the adult (52 pupils and 11 staff)). Contacts for the child had PCR-testing on day 14 (82/121) and serology on day 15 (82/121) – ALL were negative – no secondary cases. Contacts for the staff member had serology at >28 days after exposure (42/52 children, 9/11 staff) and again at 3 months (24/52): positive serology in 14% (6/42) children and 1 had a positive PCR soon after exposure- secondary attack rate 17% (7/42). In adult contacts, 11% (1/9) had positive serology. At 3 months, no new cases identified; all previous cases were still positive.
Link -Gelles et al.[16]	Rhode Is, USA, June-July	public health surveillance of all potential cases from child-care facilities in the state. Data were obtained from 666 child-care programs - with 101 possible cases reported: 49 were negative, 33 were PCR-positive and 19% were probable but not tested. Most cases were from July when community transmission was rising. Contacts of the potential cases (687 children and 166 staff members) were quarantined for 14 days, although contacts were not routinely tested. No child-care associated cases were identified between 1 June-

		14 July (there were some positive cases but child-care related transmission as excluded in all). From 15-30 July, as community transmission rose, there was potential child-care-related transmission in 17 cases in 4 of the 666 programs. Cases were approximately half adults and children. No clear transmission from children was identified but this could not be excluded.
Lopez et al.[17]	Salt Lake City, USA, April-July	public health surveillance including contact-tracing in child-care facilities in the city. Contact tracing data used to retrospectively contract transmission chains from reported child-care facilities. Outbreaks were defined as ≥2 lab-confirmed cases within 14 days. Cases defined as RT-PCR positive. Contacts quarantined for 14 days and only tested if symptomatic. 17 child-care facilities were identified in Salt Lake County with 2 or more cases; the report describes 3 facilities with possible transmission and relatively complete contact investigation. The index case in each of the 3 facilities was an adult. One facility had transmission only to other adults and in two facilities there was transmission to adults and children. In two facilities they concluded there was likely transmission by some children to their households: in one facility 2 positive siblings likely infected their 2 parents; in a second facility, 10 positive children likely infected 5 household contacts).

B2. Population-level studies of outbreaks in educational settings

Study	Country, dates	
Ismail et al.[18]	England, 1-30 June	PHE national surveillance data involving educational settings after schools and early-years settings in England partially reopened with mitigations in place from 1 to 30 June 2020. They identified 101 PCR-positive events in schools: there were 67 single confirmed cases, 4 co-primary cases and 30 COVID-19 outbreaks (≥2 cases) – involving in total 70 cases in children and 128 in staff members. 53% of outbreaks were 2 cases only i.e. one presumed secondary case in addition to the index. They estimated a risk of 4.8 events per 1000 schools per month. There was a strong correlation between number of outbreaks and regional COVID-19 incidence (0.51 outbreaks for each SARS-CoV-2 infection per 100,000 in the community; p=0.001). Staff members had an increased risk of SARS-CoV-2 infections compared to students in any educational setting, and the majority of cases linked to outbreaks were in staff. Of the 18 primary school outbreaks, 9 involved staff only, 7 staff and students and 2 students only. All 7 early years outbreaks had staff member as index case as did the other 5 outbreaks. The probable transmission direction for the 30 outbreaks was: staff-to-staff (n=15), staff-to-student (n=7), student-to-staff (n=6) and student-to-student (n=2 likely but not confirmed).
Russell et al.[19]	Victoria, Australia, March-August	State of Victoria: total of 1635 cases linked with educational settings; 66% were single cases and 91% involved <10 cases. Estimate that 373 out of >1 million students acquired infection through educational settings.
Otte im Kampe et al.[20]	Germany, Jan to August	used German national surveillance data on positive PCR testing in 6-20 year olds from 28 January to 31 August 2020. Schools closed nationally week 12/2020 except for Saxony and Hesse where schools remained "open" for students who could not be cared for at home. Partial reopening of secondary schools occurred from 20/04/2020 and primary schools from two weeks later – and continued till late June/early July when summer holidays began. Nationally, 48/8841 (0.5%) outbreaks (≥2 cases) occurred in schools and included 216 cases – with 102 cases amongst staff (aged≥21y), 30 in 6-10yo, 45 11-14y, 39 in 15-20yo. One-fifth (10/48) of outbreaks were in staff only. Only 2 outbreaks were of >10 cases, both occurring in early March before lockdown; the largest being 25 cases (20 students and 5

		staff) in a secondary school and the second outbreak being almost entirely staff in a secondary school, with only 1 infected student. The weekly number of school outbreaks was lower when schools were partially open (2.2 outbreaks and 4 cases per week) compared with when schools fully open before lockdown (3.3 outbreaks and 6 cases per week) although these differences were not significant. Noted class sizes were 20-25 students.
Wada et al.[21]	Japan, June-July	national surveillance data from primary (6-12y) and junior secondary (13-15y) schools to study SARS-CoV-2 cases after schools reopened from 1 June to 31 July, with basic mitigations in place. 207 positive ('tested', assumed PCR) cases identified amongst >9.5 million students in approximately 30,000 schools nationally. Most judged to originate from household transmission; only 1/105 (1%) in primary school and 6/63 (10%) in junior high were judged to be due to school transmission. There were 39 positive cases amongst teachers, although the route of transmission was unknown in the great majority.
Cornelissen et al.[22]	Belgium, March-June	national surveillance of infections in school-children (6-18y) undertaken by the national health institute Sciensano, from 15 March until 28 June. 378 positive cases (PCR) were reported at schools, of which 270 were pupils and 108 staff members. 4715 contacts of these cases were quarantined (4472 students; 243 staff) – the testing strategy is not stated but assumed symptomatic only. 36 students and 11 staff members were reported to have secondary infections, however only 24/36 students had a positive test with 12 having suggestive symptoms only. Low quality.

B3. Single institution outbreak studies

There are four published single-institution outbreak studies from educational settings (3 from schools and 1 from a residential camp)

1. Torres et al.[23] – Chile private school https://academic.oup.com/cid/advance-article/doi/10.1093/cid/ciaa955/5869860
2. Fontanet et al.[24] -French high school https://www.medrxiv.org/content/10.1101/2020.04.18.20071134v1
3. Stein-Zamir et al:[25] - Israel https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2020.25.29.2001352
4. Szablewski et al.[26] Georgia Overnight Camp http://dx.doi.org/10.15585/mmwr.mm6931e1external icon

C. Inference studies: studies of adult/whole age populations informative regarding school transmission

Study	Country, dates	Findings
Isphording et al.[27]	Germany, August-September	Used causal inference to study impact of staggered reopening of schools across German states on daily whole-population case counts for all 401 German counties, adjusted for changing mobility patterns. Found a significant negative effect of school reopening on national cases – effects concentrated on population up to age 34y. Note that during this time national cases were highest amongst 15-34 year olds as in UK second wave.

ECDC report[28]	Europe, to August	Report on outbreaks across educational settings in 15 countries; noted few outbreaks in most countries, all of limited size. Countries where schools had reopened had not witnessed an increase in all-age cases subsequent to reopening.
Vlachos et al.[29]		Swedish national registry data were used to compare infection rates in parents and teachers from lower secondary schools, which remained open in Sweden, with those from upper secondary schools which were dismissed and moved to online education. Data used March 25 to 15 June. For parents, exposure to open high schools resulted in a small increase in PCR-confirmed infections (OR 1.15 (1.03, 1.27) compared with closed schools. This was more significant for teachers (OR 2.01 (1.52, 2.67).
Sweden-Finland comparison report[30]	Sweden, Finland, March to July	Comparison of impact of school closing in Finland (March till mid May) and primary and lower secondary schools remaining open in Sweden. Reported no difference in 1) incidence of cases in <20 year olds; 2) hospitalisations or deaths in <20 year olds. In Sweden there was no difference in cases between teachers (primary, secondary or day-care) and other professions.
Gilliam et al.[31]	USA, May-June	examined exposure to child-care and PCR-positivity (self-report; amongst N=57,335 (69% of invited) child-care providers in 28 states across the USA. They adjusted for a range of sociodemographic factors. 51% reported no child-care contact during period i.e. their service was closed = control group. Analyses results unmatched and using propensity score matching. Unmatched analyses – no association of child-care exposure with caseness; matched analysis – no overall association similarly. They did find an association between being a home-based child-care provider (i.e. informal child care) and infection.
Forbes et al. OpenSAFELY[32]	England,	[early data was provided to SAGE]

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