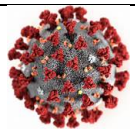
National COVID-19 Science Task Force (NCS-TF)	

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Contact person: Margarethe Wiedenmann, Marcel Tanner, Roman Stocker	
Comment on planned updates: This is a rapid review. The search was last updated on 6.8.2020.	
Title: The role of children and adolescents (0-18 years of age) in the transmission of SARS-CoV-2: a rapid review	

Questions:

The present policy brief represents an update of the brief from 10 May 2020. While the general questions were kept, more emphasis was placed on trying to distinguish the situation of children (0-12 years of age) from that of adolescents (13-16 years) and yound adults (>16 years).

1. Can children and adolescents get infected by SARS-CoV-2 and do they present with similar symptoms as adults?
2. Do children and adolescents more commonly present with asymptomatic than with symptomatic disease?
3. Is there an age-dependent risk of severe disease progression?
4. Can children and adolescents transmit SARS-CoV-2 and to what extent is this transmission driving the pandemic?
5. Is the risk of children and adolescents getting infected by SARS-CoV-2 comparable to the risk of adults?
6. Are school closures (i) creche (Kita)/kindergarten to 9th year of schooling (compulsory school) and/or (ii) high schools, universities, higher education institutions an effective way of slowing the pandemic?

Summary including new findings:

1. Children and adolescents can get infected by SARS-CoV-2 but usually develop milder symptoms than adults.
2. While there are asymptomatic pediatric SARS-CoV-2 cases, a majority of pediatric patients develops symptomatic disease.
3. To date there are only limited data and thus only inconclusive evidence for potential severe disease progression in infants <1 year old.
4. There is still limited evidence as to what extent children transmit SARS-CoV-2. However, all the available evidence shows that children are not the main drivers of this pandemic. Adolescents and young adults, however, appear more susceptible to infection, have higher viral loads, show great mobility as well as have many close contacts and hence in conjunction with the fact that they usually develop mild symptoms of SARS-CoV-2 they can play an important role in transmission. This has implications for social, cultural and recreational activities as well as higher education and professional training settings.
5. There are several studies showing that children are possibly less prone to getting infected by SARS-CoV-2. Adolescents might, however, be more susceptible to infection by SARS-CoV-2.
6. School closures can be an effective way of transmission control if a pandemic is driven by children. As this does not seem to be the case in the SARS-CoV-2 pandemic school closures for children only had and have little effect on slowing this pandemic.

Main text: The role of children and adolescents in the transmission of SARS-CoV-2 still contains uncertainties impacting policy decision especially concerning how to open schools, kindergartens or day care facilities and guidance for intergenerational contacts in general. While SARS-CoV-2 disproportionally affects the elderly (>65 years old), who have a higher risk of severe disease progression, children and adolescents usually develop mild and less severe symptoms (Ludvigsson (2020)a; Morand et al. (2020); Mustafa et al. (2020)). While this is of advantage for the pediatric individual, mildly symptomatic children are of public health interest if they unknowingly transmit the disease (Kelvin et al. (2020)).

Understanding the pediatric transmission factor and children's contribution to the pandemic progression is consequently important for adapting and improving the control measures.

We conducted a rapid systematic review by searching Pubmed up to 6 August 2020 and Embase and medRxiv up to 15 June 2020. We screened 1325 studies of which 35 were eligible. From a manual search we found another 40 articles (25 published, 15 not yet published or peer-reviewed or both), which we also analyzed. Of these 75 articles 37 were case reports, 15 were cross sectional studies, 2 were cohort studies, 14 were reviews or viewpoints and 7 were modelling studies (see also Annex with tables on search and qualification of studies).

Question 1. Can children and adolescents get infected by SARS-CoV-2 and do they present with similar symptoms as adults?

Pediatric SARS-CoV-2 cases were described from the beginning of the pandemic (Liu et al. (2020)a). Compared with adults, however, children and adolescents usually only develop mild symptoms of the disease (Ludvigsson (2020)a; Morand et al. (2020); Mustafa et al. (2020); Lu et al. (2020); Dong et al. (2020); Castagnoli et al. (2020)), which might lead to erroneously low estimates of case numbers in a population, as most countries only test or (at the beginning of the pandemic) tested the more severely sick or people at risk for severe disease. [1]

The reasons for this comparatively mild disease progression in children and partially in adolescents are still being invstigated but current evidence leads to the following possible explanations (Dong et al. (2020)):

- Reduced maturity and lower function of the ACE2 receptor on host cells in children than in adults (necessary for SARS-CoV-2 to infect cells)
- Children and adolescents often experiencing respiratory infections (e.g. respiratory syncytial virus, other coronaviruses) in winter and thus possibly having higher levels of crossreactive immunity against SARS-CoV-2 than adults
- Young children potentially displaying a different immune response to pathogens (compared to adults) as their immune system is still developing
- Young children having less developed immunity hence also less immunopathology

Question 2. Do children and adolescents more commonly present with asymptomatic than with symptomatic disease?

As children present with a milder disease version and are thus not the main focus of medical interventions, there is comparatively little data about pediatric disease progression and the available data might therefore not represent the whole spectrum. Data from Italy, for example, show that children only account for 1.2% of all reported cases, but the low number might just shows that children present with a milder disease and do thus not get tested as often (Livingston et al. (2020)).

The percentage of asymptomatic children is described in several publications, all relatively small in size (30<n<172), as 15-39% (e.g. Lu et al. (2020); Qiu et al. (2020); Chen et al. (2020) (not yet peer-reviewed); Sun et al. (2020)). However, it appears that primarily treated or hospitalized patients were analyzed in China, thus potentially skewing the data as children not fitting the testing criteria at that point might not have been included.

A larger China-wide case series performed by Dong et al. (2020) analyzing suspected and confirmed pediatric SARS-CoV-2 cases (<18 years old) indicates that only 1.9-6.5% of these cases are completely asymptomatic, with the highest rate of asymptomatic patients in the 11-15 year age bracket and the lowest rate in the <1 year olds. As 2/3 of the study population is not laboratory confirmed but just suspected due to clinical symptoms, blood counts indicative of a viral infection or suspicious chest imaging results, this data could be

[1] For further information about the clinical presentation of SARS-CoV-2 in children we recommend the respective literature/policy briefs.

distorted by other respiratory viruses. Nevertheless, when just analyzing the confirmed cases only 12.9% of these are completely asymptomatic, while a majority displays mild (43.1%) or moderate (40.9%) symptoms.

This is supported by a review by Choi et al. (2020), which shows that only a minority of the infected children and adolescents (<18 years of age) is asymptomatic (0-12%), while a majority has at least symptoms of an upper respiratory tract infection (20-65%) or a mild pneumonia (26-80%). Lu et al. (2020) also show that a majority of pediatric patients (<16 years of age) presents with the symptoms of an upper respiratory tract infection (19.3%) or pneumonia (64.9%), while Sun et al. (2020) shows a majority of children (<16 years of age) presenting with cough (55.4%) or fever (51.4%). Sun et al. (2020) see the highest rate of asymptomatic children having a median age of 3 years, while the lowest rate is in the median age group of 1 month (58.3% vs. 11.5%). As the median age group of 3 years has the lowest case numbers (n=12) in an already small study (n=74), this could be skewed.

It needs to be highlighted that the proportion of children and adults with asymptomatic infection should be assessed from studies that include sufficient follow-up to exclude those who are pre-symptomatic, i.e. asymptomatic at the time of initial testing but go on to develop symptoms. This information is not given for the aforementioned studies potentially skewing the data. A systematic review of asymptomatic SARS-CoV-2 infections compared the proportions of children and adults in studies done in hospital settings in which patients were followed through the course of infection. The proportions with asymptomatic infection were 27% in children (10 studies, 285 children) and 11% in adults (10 studies, 3228 adults) (Buitrago-Garcia et al. (2020)). As studies in hospital settings are at risk of bias as they preferentially include people with more severe disease, these studies might underestimate the proportions of asymptomatic infection in both the pediatric and adult population.

Despite this and due to a majority of children still presenting with symptomatic disease children do not appear to be silent virus spreaders.

Question 3. Is there an age-dependent risk of severe disease progression?

While most children are usually only mildly sick (see Question 1), infants <1 year olds seem to have a higher rate of severe or critical disease (10.6% for <1 year olds vs. 7.3% for 1-5 year olds) (Dong et al. (2020)). As mentioned in the discussion of Question 2, this study could have been distorted by other respiratory viruses as 2/3 of patients are only suspected and not laboratory confirmed. It seems however to be supported by a report from the United States Centers for Disease Control and Prevention (CDC) highlighting that the worse disease progression in children occurs in <1 year olds, as these patients "accounted for the highest percentage (15-62%) of hospitalization among pediatric patients" (Bialek et al. (2020)). [2] Since more detailed data about children's hospitalization

[2] Jones et al. (2020)b reported the first case of an infant presenting with classic Kawasaki diseae, who also tested positive for SARS-CoV-2. In addition, NHS England (based on a single cluster in South East England described by Riphagen et al. (2020)) reported a small increase in critically ill children presenting with "features of toxic shock syndrome and atypical Kawasaki disease with blood parameters consistent with severe COVID-19 in children". ("PICS Statement Regarding Novel Presentation of Multi-System Inflammatory Disease." Paediatric Intensive Care Society, April 27, 2020. https://picsociety.uk/wp-content/uploads/2020/04/PICS-statement-re-

status are missing (only known in 29% of all pediatric cases) this estimate might be biased. A case series by Mannheim et al. (2020) also shows that younger children have a higher hospitalization rate (median age of hospitalized children: 3.5 years vs. 12.5 years of non-hospitalized children). All hospitalized children had preconditions or coinfections. Due to the small sample size of hospitalized children (n=10) the clinical significance of the study is limited. It needs to be mentioned, however, that hospitalization of young children is often motivated by the wish for monitoring rather than disease severity which might add further bias.

Despite there only being case reports or studies with low patient numbers, the risk for neonates to develop severe disease on the other hand seems to be low. Two systematic reviews by Gordon et al. (2020) and by Dumpa et al. (2020) both describe 11 cases of neonatal SARS-CoV-2 infection (considering overlapping 17 different case studies), all presenting with mild disease. The respiratory symptoms described in some patients were generally consistent with their gestational age and could thus not be attributed to SARS-CoV-2. This is supported by small additional retrospective studies describing the mild SARS-CoV-2 disease progression in neonates (Wei et al. (2020); Zhang et al.(b)).

A case report by Nathan et al. (2020) describes five SARS-CoV-2 positive infants "with poorly tolerated and isolated fever" and neurological symptoms, who recovered quickly and could be discharged in between 1-3 days after admission. This could indicate that even if an infant develops severe SARS-CoV-2 they seem to tolerate and recover from it much better and much faster than adults. Whether this reflects distinct immune reactivity still needs to be established.

Consequently, there is no conclusive evidence that young age is a risk factor for severe disease. Preliminary results from the Dutch National Institute for Public Health and the Environment (RIVM) even suggest that underlying health conditions do not seem to increase the risk of severe pediatric disease progression "*with the possible exception of children with severe obesity and or diabetes*". The suggestion that even profound underlying health conditions are no risk factors for severe SARS-CoV-2 disease is supported by multiple smaller reports from around the globe describing the mild SARS-CoV-2 disease progression as well as comparably low hospitalization rates in pediatric cancer patients and otherwise immunosuppressed children (Balduzzi et al. (2020); Ferrari et al. (2020); Marlais et al. (2020); Boulad et al. (2020); Hrusak et al. (2020); Minotti et al. (2020)). It is also supported by the observations of the PIGS (Pediatric Infectious disease Group of Switzerland), whose member collect and share observations of severe cases.

novel-KD-C19-presentation-v2-27042020.pdf.) It needs to be highlighted that while only some of these patients tested positive for COVID-19, Kawaski syndrome usually presents after a viral infection. The syndrome has since been named multisystem inflammatory syndrome in children (MIS-C). According to Dufort et al. (2020) the highest hospitalization rates for SARS-CoV-2 positive children or children with past SARS-COV-2 presenting with MIS-C are the 6-12 year olds. MIS-C has, however, not yet been extensively studied and no causality with SARS-CoV-2 has been established so far.

Question 4. Can children and adolsecents transmit SARS-CoV-2 and to what extent is this transmission driving the pandemic?

Children and adolescents can transmit SARS-CoV-2, but there is no conclusive evidence as to what extent they do so. Due to their greater mobility and due to them having more close contacts adolescents have a higher risk of transmitting SARS-CoV-2 than children. On the contrary there is only sparse evidence that children infect adults. Cao et al. (2020) and Cai et al. (2020) report "*what is probably the first evidence indicating children as a source of adult infection*" this cannot be confirmed when checking the report's original source (in Chinese). Cao et al. (2020) also state that the "*accumulated cases from adult and pediatric populations strongly supports [sic] the transmission dynamics of pediatric patients*" namely the potential spread within schools as a connector among community nuclei (e.g. families) by analyzing only indirect evidence of the epidemic in China.

Most importantly and in contrast, analysis of a majority all available data from family clusters indicate that children were infected by adults first (and not by children, who brought the infection into the family from the outside or from schools) (Qian et al. (2020); Danis et al. (2020); Qiu et al. (2020); Li et al. (2020)b; Su et al. (2020)). It needs to be considered, however, that lockdown measures or school holidays at the beginning of the pandemic in Wuhan, China, or the worldwide spread of SARS-CoV-2 due to adult travelers does not exclude potential pediatric transmission.

Jones et al. (2020)a and L'Huillier et al. (2020) (both not yet peer-reviewed) indicated the possibility (without statistical evidence) of no differences in viral loads between age groups, including children and adolescents. Neither study is, however, conclusive. First, Jones et al. (2020)a did not specify the specimen from which the viral RNA was isolated. As Zou et al. (2020), Yu et al. (2020) and Wang et al. (2020) showed, Ct (cycle threshold) values, which were used to calculate the viral loads of different specimens, are not comparable. Second, Jones et al. (2020)a performed their tests on two different testing systems, where an association of increasing age and increasing viral loads was seen on one (Roche cobas system), while showing a negative association on the other system (Roche LC480 system). Third, L'Huillier et al. (2020) analyzed the viral load of 23 symptomatic infants, children and teenagers, but no adults. The infants, children and teenagers showed viral loads comparable to those of adults in other studies in other locations. Virus isolation, as a marker for infectiousness, however was only successful in 12 of these 23 cases with the small sample size limiting the power of the study.

Viral load levels of symptomatic children or adolescents should, however, not influence the decision of how to reopen schools as they should be advised to stay at home (Ludvigsson (2020)b). In Sweden, which only closed upper secondary schools and universities, there are no reported outbreaks at primary schools or kindergartens, which could indicate that asymptomatic children are not driving the SARS-CoV-2 pandemic (Ludvigsson (2020)b). This is supported by several studies showing that severity of disease is directly associated with infectiousness, viral loads and thus SARS-CoV-2 transmission (Luo et al. (2020) (not yet peer-reviewed); Liu et al. (2020)b; Han et al. (2020); Zheng et al. (2020)).

In another case, a suspected SARS-CoV-2 cluster is described in a school in Oise, northern France with a higher infection attack rate (IAR) for adolescents (15-17 years old) than for adults ($\geq$18 years old) (Fontanet et al. (2020) (not yet peer-reviewed)). Having a

closer look at the data shows that Fontanet et al. (2020) must have included other children and adolescents (probably siblings) in the student population. Thus, an analysis of the attack rate generated for this mixed groups of students and (probably) siblings (most likely not enrolled at the school as they would otherwise not have counted as contacts of the respective students) cannot support a conclusion that transmission started and spread at the school. Additionally, the 2 index cases were not laboratory confirmed but appear to have been only clinically diagnosed with SARS-CoV-2 related symptoms after having been in contact with a laboratory confirmed case. As (i) they could thus also have had another non-SARS-CoV-2 infection and (ii) as there is no further information about their status (e.g. student, teacher, school staff) or with whom they interacted more closely (e.g. class mates, sport groups), the SARS-CoV-2 cluster at the school might not have been caused by them. Further studies by Szablewski et al. (2020) and Stein-Zamir et al. (2020) also describe suspected clusters in an overnight camp in Georgia, USA, and a school in Israel. The study describing the overnight camp (Szablewski et al. (2020)) did not test any other close contacts before or after the camp, meaning that the children were very likely infected outside the camp. While Stein-Zamir et al. (2020) describe the infection of 87 close contacts of the originally infected school children, they give no further information about which contacts they tested (only symptomatic ones or everyone etc.) and whether the positive contacts had themselves contact to other positive cases elsewhere, meaning that this outbreak could equally and very likely have originated outside the school. These limitations do not allow to add further or new evidence to the role of children and adolescents in SARS-CoV-2 transmission.

There is, however, evidence that children might not be as infectious as adults when infected with SARS-CoV-2. Danis et al. (2020) describe a pediatric patient who was infected while on holidays in France and despite him being symptomatic did not infect even close contacts while visiting three schools when coming back to the UK. It is not further discussed in the paper why this child visited three schools. Further support comes from a not yet peer-reviewed study by Zhu et al. (2020) which analyzes SARS-CoV-2 household clusters world-wide and could show that only 9.7% of the clusters were started by a pediatric index case (<18 years old). Even if accounting for asymptomatic index cases or traveling to a high risk area (which is more likely to be undertaken by an adult) this changed to 21% respectively 9% of all cases. As children and adolescents are not part of all households these results might however be skewed.

Preliminary results from a report of the RIVM (Dutch National Institute for Public Health and the Environment) also indicate that children might be less infectious as data from contact tracing showed children and adolescents (0-19 years old) not infecting others. Even staff working in childcare and primary education was hardly affected compared to the general population (excluding healthcare workers) (positive staff vs. positive general population: 2.5% vs. 8.2%). RIVM tested a low number of children and adolescents but a relatively high number of staff, thus increasing their study's significance. Case studies by Wongsawat et al. (2020) and Nassih et al. (2020) further support the hypothesis that children might be less infectious by describing three mildly symptomatic/asymptomatic children (<10 years old) not infecting their caretakers, with whom they were isolated. Wongsawat et al. (2020) describe that basic hygienic recommendations were made to wash hands regularly and not share personal items, while facemasks were offered, but not

regularly used due to low compliance. Nassih et al. (2020) report airborne and contact precautions but do not go into further detail.

Question 5. Is the risk of children and adolescents getting infected by SARS-CoV-2 comparable to the risk of adults?

A retrospective cohort study by Bi et al. (2020), analyzing 1286 close contacts of 391 index cases, showed that the secondary attack rate for children <10 years was similar to adults (7.4% vs. 6.6%). Close contacts were defined as people who lived, traveled, had a meal, or socially interacted (no closer definition) with an index patient. On the other hand, there is evidence that children do not get infected by SARS-CoV-2 as easily as adults. A cohort study by Li et al. (2020)a analyzing 392 household contacts of 105 index patients, calculated a much lower secondary attack rate (SAR) for children than for adults (4% vs. 17.1%), meaning that their risk of getting infected was lower than for adults. It is particularly interesting that the risk for younger children (aged 0-5 years) was lower than for older children (aged 6-17 years) (SAR: 2.3% vs. 5.4%, respectively).

Jing et al. (2020) analyzed 195 clusters from the epidemic in China and also found that the probability of infection among children (<20 years old) was 0.23 times the probability of infection among the elderly (>60 years old). While this is a substantial reduction in probability, it must also be considered that the number of contacts among children – especially in schools – is considerably higher than among the elderly (e.g., Ferguson et al (2020) assumed the per-capita contacts within schools to be double those elsewhere), partially offsetting their reduced probability of infection in daycare facilities and schools. Mizumoto et al. (2020) (not yet peer-reviewed) also showed that the attack rate in household acquired cases was much lower for children (0-20 years of age) (3.8%(females) - 7.2%(males)) than for adults aged 50-59 years (AR 21.9% (females) - 22.2%(males)). This was confirmed by Zhang et al. (2020)a who, analyzing the susceptibility of infection of close contacts, reported a lower risk of infection for children (0-14 years old) compared to people older than 15 years of age. Somekh et al. (2020) also saw children (aged 5-17 years) in family household settings in Israel being 61% less likely to be infected with SARS-CoV-2 compared to adults, with the risk for younger children 0-4 years of age being 47% lower than the risk for adults. Contrasting this is a study from Yung et al. (2020)a describing an association of increasing secondary attack rate and increasing age in household settings with 213 children and 13 SARS-CoV-2 infected children (0-4 years old: 1.3% vs. 10-16 years old: 9.8%). Hua et al. (2020) describe the incidence of infection in children (<14 years old) being significantly lower than the incidence of adults living in the family clusters (13.2% vs. 21.2%). A stochastic model by Dattner et al. (2020) (not yet peer-reviewed) based on data from household settings in Israel found that susceptibility for <20 year-olds is 45% the susceptibility of adults, while infectivity is 85%.

A population-based study in Iceland by Gudbjartsson et al. (2020) also demonstrated that children (<10 years old) were less often infected with SARS-CoV-2 than individuals >10 years old. This was the case not only for the general population but also for higher-risk individuals (symptomatic, returning travelers from high-risk areas or contacts of infected people). In Vo', Italy, only 0.5-1.2% of the cases were 11-20 years of age and there were no cases in the 0-10 year age bracket, despite some children living together with

confirmed adult cases (Lavezzo et al. (2020)) (not yet peer-reviewed). Similar results were seen in a large cross-sectional study by Debatin et al. (2020) who analyzed antibody levels as a sign of past infection in German household settings and described more adults/parents presenting with antibody levels suggestive of past SARS-CoV-2 infection when compared to their respective children (seroprevalence in children aged 1-5 years: 0.6% vs. seroprevalence in parents 1.8%). Due to lockdown conditions children were most likely infected by their parents (except children from essential workers, who could still attend daycare facilities), which might enforce the assumption that children are less prone to infection even in close contact settings. This can also be seen in a study by Torres et al. (2020) who analyzed a school outbreak of 52 positive cases in Chile. The index case was a staff member, who most likely infected parents and colleagues during parent-teacher conferences, while the students were in turn infected by their parents or respective teachers. While 16.6% of adults presented with antibodies, only 9.9% of the children did. A higher percentage of younger children had antibody levels compared to high school students (12.3% vs. 5.7%), which is probably due to more of them being taught by SARS-CoV-2 positive teachers. All in all, this study reinforces the hypothesis that children are less prone to SARS-CoV-2 infection.

This is supported by a study from Singapore describing three index cases (two students and one staff at a preschool) in three different schools (preschools and secondary schools) not infecting any of their close contacts at the schools (Yung et al. (2020)b). A report of the National Centre for Immunisation Research and Surveillance (NCIRS) in New South Wales, Australia, describes 18 initial cases (9 students and 9 teachers) in 15 different schools (primary and high schools) had close contact to 735 fellow students and 128 staff. None of the 128 staff contracted SARS-CoV-2 and the 2 initial cases (1 student and 1 staff) only infected two fellow students (one in a high school, and one in a primary school). Australia did not close schools but advised children to receive online learning at home, which resulted in fewer children physically attending the schools. This reduced attendance could in turn have influenced the results of the study. Heavey at al. (2020), however, present similar results from Ireland (before preemptive school closures) describing six index cases (three students, aged 10-15 years, and three adults) not infecting any of the 1001 children they had contact with (924 school contacts, 77 non-school-related contacts). This study is limited by the small number of index cases, but by not finding more positive cases despite testing even mildly symptomatic they give more weight to the hypothesis that overall there does not seem to be a major risk of infection in schools and kindergartens.

It should be noted that Lazzerini et al. (2020) have observed that some parents are delaying potentially life saving treatments for their children fearing SARS-CoV-2 infections leading to severe disease and deaths. As children mostly present with mild disease, seem to be less prone to infection while potentially being less infectious when infected, there seems to be a higher risk of the perceived danger of SARS-CoV-2 and the consequent delay in life-saving treatment than the virus’s actual danger to children.

Question 6. Are school closures (i) creche (Kita)/kindergarten to 9th year of schooling (compulsory school) and/or (ii) high schools, universities, higher education institutions an effective way of slowing the pandemic?

In a modeling study that was not peer-reviewed, but frequently cited, Ferguson et al (2020) compare different non-pharmaceutical interventions finding that school closures alone would reduce total deaths by 2-4% and peak ICU bed demand by 14-21%. However, their modeling results apply for a high reproductive number R0 of 2.2 and 2.4 and suggest that for a lower reproductive number of 1.0 or 0.6 (as is currently the case in Switzerland)[3] school closure alone could reduce total deaths by 16-20%[4].

Zhang et al. (2020)a claim in another mathematical model that "social distancing alone, as implemented in China during the outbreak, is sufficient to control" SARS-CoV-2 with proactive school closures as part of other control measures potentially only further delaying the pandemic by reducing peak incidence by 40-60%. They showed that school closures alone could not stop the pandemic. They do however not explain what social distancing measures were analyzed and were using mixing patterns during school holidays and during regular weekdays excluding school contacts for their model. This limits the significance of the study as children do still socialize in these settings compared to the setting of social distancing. Another mathematical modeling study by Auger et al. (2020) calculates school closures to having led to a relative decline in COVID-19 incidence of 62% per week and mortality of 58% per week. It needs to be highlighted, however, that these are just temporal associations and that there is no sign of causation as further nonpharmaceutical interventions (e.g. closure of non-essential business, stay-at-home orders, etc.) were inacted at around the same time making it almost impossible to determine the effects of each action.

In contrast, Davies et al. (2020) showed in another mathematical model (also not yet peer-reviewed) that school closures only have a limited effect in transmission and control of the pandemic in countries like Italy or the United Kingdom if children are as susceptible to infection as adults (independently of the transmission rate of asymptomatic patients). The effect is higher in countries with a higher proportion of children (like Zimbabwe).

A modeling study by Banholzer et al. (2020) (not yet peer-reviewed) also only sees a small influence of school closures on the course of the pandemic in 20 countries (e.g. the United States of America, the EU-15 countries, Canada) when compared to other public health measures, while a report by the Scientific Advisory Group for Emergencies describes no increase in cases in Norway, Sweden, Finland and the Netherlands when schools reopened. School reopenings did also not lead to an increase in cases in Switzerland. This could however also be due to the already low case numbers. Viner et al. (2020) saw no impact of school closures on transmission control during the SARS coronavirus epidemic. As school closures would only work if there is a high attack rate in children and if they have a high rate of transmitting the virus in schools (no evidence for previous coronavirus outbreaks) and due to the immense socio-economic cost of closing

[3] On 3 August 2020 the effective reproductive number R_e was 0.95 in Switzerland (https://ncs-tf.ch/en/situation-report)

[4] This estimate is not contained in the paper by Ferguson et al, but obtained through a simple linear extrapolation of the reproductive number.

schools, Viner et al. (2020) propose a more gradual approach similar to Taiwan where schools are closed locally in case of an outbreak at school.

Conclusions:

1. Children are susceptible to SARS-CoV-2 infection but are not the main drivers of this epidemic. The risk of being involved in transmission, however, probably increases with age, particularly from 13 years onwards. The precise role of children and adolescents in the overall transmission still requires further clarification, especially as there is a lack of more detailed epidemiological information for the age group from 13 to 15 years of age.

And

2. Given these findings and due to the expected long-term duration of the SARS-CoV-2 pandemic it is of importance to implement measures to allow greatest possible unrestricted access to education, while at the same time accommodating high-risk students, family members and school personnel.

Authors: Margarethe Wiedenmann, Roman Stocker, Marcel Tanner

Recommendations from the Task Force:

The absence of final conclusive evidence for the role of children in transmission, together with the importance of developing policies for schools and other children-related activities on rapid timescales**, *creates a situation of "decision under uncertainty". It is likely that children transmit SARS-CoV-2 but due to their mild disease progression they are probably much less infectious than adults. In the face of this uncertainty, we consider the adoption of a precautionary principle to be the appropriate stance,* *i.e.*** we must accept that children show a lower susceptibility to SARS-CoV-2 infection, but can be infected and may transmit the virus. Thus we recommend setting-specific measures to minimize the consequences of this potential transmission.

The question of whether, when and how to open schools and keep them open under conditions of uncertainty is a conflict of values. All children have a right to free and *adequate* basic education that is *available to all children* (Art. 19 and 62 of the Constitution). Pre-primary and primary education in distance learning is not easily sustainable and negatively affects the equality of chances. It also greatly disturbs the life and work capacity of the parents. The longer the epidemic is expected to last, the more important it becomes to enable the right to education to be implemented without waiting for complete safety to return. In order to decrease the risks and moral cost of opening schools and keeping them open, measures aimed at diminishing transmission within schools will need to be implemented in addition to the basic measures of hygiene and distancing. Accommodations for high-risk students, students living with high risk family

members, and high-risk school staff will also need to be devised and may include the continuation of distance learning in some cases. All approaches that are adopted should ensure equal access for disabled and low-income students.

Suggested policy measures for schools

Maintaining the usually recommended social distancing (> 1.5 m distance among individuals) in schools is challenging or nearly impossible, both due to the often-constrained spaces available and to the difficulty of children respecting social distances, particularly over extended periods of time. Due to the comparably higher infectiousness of teachers, staff and parents, school re-openings should be accompanied by substantial measures to minimize transmission within these adult groups. These measures should be clearly communicated to both school personnel and parents. Constant monitoring of transmission in schools (by children, parents, teachers or staff) should be the basis for further adapting these measures.

Basic measures include:

- Children, adolescents and young adult students with symptoms stay at home[5]
- Students from upper secondary and tertiary education onwards wear masks when in class rooms, where and when social distancing cannot be adhered to
- Children in compulsory education do not wear masks
- Teachers to possibly instruct from a distance of 1.5 meters when seated and wear a mask when standing and moving around in the classrooms
- Parents minimize time spent on school premises and strictly adhere to hygiene and social distancing rules
- Teacher and staff minimize the time interacting with colleagues and do otherwise also strictly adhere to hygiene and social distancing regulations
- Recommend the use of the SwissCovid App in higher education settings

Additional measures should be strongly considered. A non-exhaustive list of measures to be considered but tailored to the specific school settings (infrastructure and resources) includes:

- Ventilate closed rooms such as class rooms and halls regularly (e.g. before starting school in the morning or afternoon and in every break)
- Prevent in principle mixing among classes during recess, for example by staggering the time of recess by grade or defining separate recess areas
- Restrict high-contact activities or activites with close proximity to other students in upper secondary and tertiary education (e.g. team sports with tackling such as basketball and football, choirs, etc.)
- Stagger lunch hours or allow children to go home for lunch, including day schools
- Consider continuing partial distancing learning for an additional time period for universities and higher education settings (e.g. for practical excercises consider segmenting students into groups)

[5] It needs to be accepted that clinically distinguishing COVID-19 versus the frequent upper respiratory tract pediatric pathogens is/will not easily be possible this fall/winter.

These measures should at all times be supplemented with ***strict hygiene measures*** with frequent hand washing mandated by the schools, complemented by

- compulsory equipping of schools with hand-washing and -disinfection stations,
- no handshaking with teachers,
- more rigoros frequent cleaning of the school; particularly toilets and changing rooms.

Open points for further discussion:

The the current state of evidence on the role of children in transmission further highlights the urgency of obtaining robust data on this matter. This is recognized both nationally and internationally (e.g., Kelvin et al. (2020); Lu et al. (2020); Fineberg (2020)). Robustly determining the absence of a role of children in transmission will allow full school reopening, render social distancing measures in children less severe, and exclude that schools will negatively affect the reproductive number of the epidemic.

Thus, we urge that the re-opening of schools after the summer break be accompanied by a real-time, rapid research protocol within a sentinella system. This should involve following of cohorts with repeated PCR and antibody testing among a sample of schoolchildren, teachers and other adult school employees to ascertain the presence of infection and the rate of acquisition of new infection among the children, and the monitoring of infection among the adults in closest contact with large groups of children. This approach can provide an early indication of a possible spread of infection among and from schoolchildren.

References

Auger, Katherine A., Samir S. Shah, Troy Richardson, David Hartley, Matthew Hall, Amanda Warniment, Kristen Timmons, et al. “Association Between Statewide School Closure and COVID-19 Incidence and Mortality in the US.” *Jama*, July 29, 2020. https://doi.org/10.1001/jama.2020.14348.

Balduzzi, Adriana, Erica Brivio, Attilio Rovelli, Carmelo Rizzari, Serena Gasperini, Maria Luisa Melzi, Valentino Conter, and Andrea Biondi. “Lessons after the Early Management of the COVID-19 Outbreak in a Pediatric Transplant and Hemato-Oncology Center Embedded within a COVID-19 Dedicated Hospital in Lombardia, Italy. Estote Parati.” Bone Marrow Transplantation, April 20, 2020. https://doi.org/10.1038/s41409-020-0895-4.

Banholzer, Nicolas, Eva Van Weenen, Bernhard Kratzwald, Arne Seeliger, Daniel Tschernutter, Pierluigi Bottrighi, Alberto Cenedese, Joan Puig Salles, Werner Vach, and Stefan Feuerriegel. “Impact of Non-Pharmaceutical Interventions on Documented Cases of COVID-19.” *MedRxiv Preprint*, 2020. https://doi.org/10.1101/2020.04.16.20062141.

Bi, Qifang, Yongsheng Wu, Shujiang Mei, Chenfei Ye, Xuan Zou, Zhen Zhang, Xiaojian Liu, et al. “Epidemiology and Transmission of COVID-19 in 391 Cases and 1286 of Their Close Contacts in Shenzhen, China: a Retrospective Cohort Study.” The Lancet Infectious Diseases, April 27, 2020. https://doi.org/10.1016/s1473-3099(20)30287-5.

Bialek, Stephanie, Ryan Gierke, Michelle Hughes, Lucy A. Mcnamara, Tamara Pilishvili, and Tami Skoff. “Coronavirus Disease 2019 in Children — United States, February 12–

April 2, 2020." *MMWR. Morbidity and Mortality Weekly Report* 69, no. 14 (April 10, 2020): 422–26. https://doi.org/10.15585/mmwr.mm6914e4.

Boulad, Farid, Mini Kamboj, Nancy Bouvier, Audrey Mauguen, and Andrew L. Kung. "COVID-19 in Children With Cancer in New York City." *JAMA Oncology*, May 13, 2020. https://doi.org/10.1001/jamaoncol.2020.2028.

Buitrago-Garcia, Diana C, Dianne Egli-Gany, Michel J Counotte, Stefanie Hossmann, Hira Imeri, Aziz Mert Ipekci, Georgia Salanti, and Nicola Low. "Asymptomatic SARS-CoV-2 Infections: a Living Systematic Review and Meta-Analysis." *MedRxiv Preprint*, 2020. https://doi.org/10.1101/2020.04.25.20079103.

Cai JH, Wang XS, Ge YL, Xia AM, Chang HL, Tian H, et al., First case of 2019 novel coronavirus infection in children in Shanghai. Zhonghua Er Ke Za Zhi, 2020, 58: E002 [Article in Chinese]

Cao, Qing, Yi-Ching Chen, Chyi-Liang Chen, and Cheng-Hsun Chiu. "SARS-CoV-2 Infection in Children: Transmission Dynamics and Clinical Characteristics." Journal of the Formosan Medical Association119, no. 3 (2020): 670–73. https://doi.org/10.1016/j.jfma.2020.02.009.

Castagnoli, Riccardo, Martina Votto, Amelia Licari, Ilaria Brambilla, Raffaele Bruno, Stefano Perlini, Francesca Rovida, Fausto Baldanti, and Gian Luigi Marseglia. "Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Infection in Children and Adolescents." *JAMA Pediatrics*, April 22, 2020. https://doi.org/10.1001/jamapediatrics.2020.1467.

Chen, Chuming, Mengli Cao, Ling Peng, Xiaoyan Guo, Fangji Yang, Weibo Wu, Li Chen, Yang Yang, Yingxia Liu, and Fuxiang Wang. "Coronavirus Disease-19 Among Children Outside Wuhan, China." SSRN Electronic Journal (Preprints with The Lancet), 2020. https://doi.org/10.2139/ssrn.3546071.

"Children and COVID-19." RIVM. Accessed May 28, 2020. https://www.rivm.nl/en/novel-coronavirus-covid-19/children-and-covid-19.

Choi, Soo-Han, Han Wool Kim, Ji-Man Kang, Dong Hyun Kim, and Eun Young Cho. "Epidemiology and Clinical Features of Coronavirus Disease 2019 in Children." Clinical and Experimental Pediatrics63, no. 4 (2020): 125–32. https://doi.org/10.3345/cep.2020.00535.

Danis, Kostas, Olivier Epaulard, Thomas Bénet, Alexandre Gaymard, Séphora Campoy, Elisabeth Bothelo-Nevers, Maude Bouscambert-Duchamp, et al. "Cluster of Coronavirus Disease 2019 (Covid-19) in the French Alps, 2020." Clinical Infectious Diseases, 2020. https://doi.org/10.1093/cid/ciaa424.

Dattner, Itai, Yair Goldberg, Guy Katriel, Rami Yaari, Nurit Gal, Yoav Miron, Arnona Ziv, Yoram Hamo, and Amit Huppert. "The Role of Children in the Spread of COVID-19: Using Household Data from Bnei Brak, Israel, to Estimate the Relative Susceptibility and Infectivity of Children." *MedRxiv Preprint*, 2020. https://doi.org/10.1101/2020.06.03.20121145.

Davies, Nicholas G, Petra Klepac, Yang Liu, Kiesha Prem, Mark Jit, and Rosalind M Eggo. "Age-Dependent Effects in the Transmission and Control of COVID-19 Epidemics." MedRxiv Preprint, 2020. https://doi.org/10.1101/2020.03.24.20043018.

Debatin, Klaus-Michael, Philipp Henneke, Georg Friedrich Hoffmann, Hans-Georg Kräusslich, and Hanna Renk. "Prevalence of COVID-19 in Children in Baden-Württemberg - Preliminary Study Report." Accessed June 18, 2020. https://www.klinikum.uni-heidelberg.de/fileadmin/pressestelle/Kinderstudie/Prevalence_of_COVID-19_in_BaWu__.pdf.

Dong Y, Mo X, Hu Y, Qi X, Jiang F, Jiang Z, Tong S, Epidemiology of COVID-19 Among Children in China, Pediatrics, 2020, 145: e20200702.

Dufort, Elizabeth M., Emilia H. Koumans, Eric J. Chow, Elizabeth M. Rosenthal, Alison Muse, Jemma Rowlands, Meredith A. Barranco, et al. “Multisystem Inflammatory Syndrome in Children in New York State.” *New England Journal of Medicine* 383, no. 4 (June 29, 2020): 347–58. https://doi.org/10.1056/nejmoa2021756.

Dumpa, Vikramaditya, Ranjith Kamity, Alexandra N Vinci, Estela Noyola, and Asif Noor. “Neonatal Coronavirus 2019 (COVID-19) Infection: A Case Report and Review of Literature.” *Cureus*, May 17, 2020. https://doi.org/10.7759/cureus.8165.

Ferguson NM et al., Report 9: Impact of non-pharmaceutila interventions (NPIs) to reduce COVID-10 mortality and healthcare demand, Imperial College COVID-19 Response Team, 16 March 2020

Ferrari, Andrea, Marco Zecca, Carmelo Rizzari, Fulvio Porta, Massimo Provenzi, Maddalena Marinoni, Richard Fabian Schumacher, et al. “Children with Cancer in the Time of COVID-19: An 8-Week Report from the Six Pediatric Onco-Hematology Centers in Lombardia, Italy.” *Pediatric Blood & Cancer* 67, no. 8 (May 26, 2020). https://doi.org/10.1002/pbc.28410.

Fontanet, Arnaud, Laura Tondeur, Yoann Madec, Rebecca Grant, Camille Besombes, Nathalie Jolly, Sandrine Fernandes Pellerin, et al. “Cluster of COVID-19 in Northern France: A Retrospective Closed Cohort Study.” MedRxiv Preprint, 2020. https://doi.org/10.1101/2020.04.18.20071134.

Gordon, Morris, Taher Kagalwala, Karim Rezk, Chris Rawlingson, M Idris Ahmed, and Achyut Guleri. “Rapid Systematic Review of Neonatal COVID-19 Including a Case of Presumed Vertical Transmission.” *BMJ Paediatrics Open* 4, no. 1 (May 25, 2020). https://doi.org/10.1136/bmjpo-2020-000718.

Gudbjartsson, D.F., A. Helgason, H. Jonsson, O.T. Magnusson, P. Melsted, G.L. Norddahl, J. Saemundsdottir, et al. “Spread of SARS-CoV-2 in the Icelandic Population.” The New England Journal of Medicine, April 14, 2020. https://doi.org/10.1056/NEJMoa2006100.

Han, Mi Seon, Moon-Woo Seong, Namhee Kim, Sue Shin, Sung Im Cho, Hyunwoong Park, Taek Soo Kim, Sung Sup Park, and Eun Hwa Choi. “Viral RNA Load in Mildly Symptomatic and Asymptomatic Children with COVID-19, Seoul.” *Emerging Infectious Diseases* 26, no. 10 (June 4, 2020). https://doi.org/10.3201/eid2610.202449.

Heavey, Laura, Geraldine Casey, Ciara Kelly, David Kelly, and Geraldine Mcdarby. “No Evidence of Secondary Transmission of COVID-19 from Children Attending School in Ireland, 2020.” *Eurosurveillance* 25, no. 21 (May 28, 2020). https://doi.org/10.2807/1560-7917.es.2020.25.21.2000903.

Hrusak, Ondrej, Tomas Kalina, Joshua Wolf, Adriana Balduzzi, Massimo Provenzi, Carmelo Rizzari, Susana Rives, et al. “Flash Survey on Severe Acute Respiratory Syndrome Coronavirus-2 Infections in Paediatric Patients on Anticancer Treatment.” *European Journal of Cancer* 132 (April 7, 2020): 11–16. https://doi.org/10.1016/j.ejca.2020.03.021.

Hua, Chun-Zhen, Zi-Ping Miao, Ji-Shan Zheng, Qian Huang, Qing-Feng Sun, Hong-Ping Lu, Fei-Fei Su, et al. “Epidemiological Features and Viral Shedding in Children with SARS-CoV-2 Infection.” *Journal of Medical Virology*, June 15, 2020. https://doi.org/10.1002/jmv.26180.

Jing, Qin-Long, Ming-Jin Liu, Zhou-Bin Zhang, Li-Qun Fang, Jun Yuan, An-Ran Zhang, Natalie E Dean, et al. “Household Secondary Attack Rate of COVID-19 and Associated

Determinants in Guangzhou, China: a Retrospective Cohort Study." *The Lancet Infectious Diseases*, June 17, 2020. https://doi.org/10.1016/s1473-3099(20)30471-0.

Jones, Terry C, Barbara Mühlemann, Talitha Veith, Guido Biele, Marta Zuchowski, Jörg Hoffmann, Angela Stein, Anke Edelmann, Victor Max Corman, and Christian Drosten. "An Analysis of SARS-CoV-2 Viral Load by Patient Age." *MedRxiv Preprint*, 2020a. https://doi.org/10.1101/2020.06.08.20125484.

Jones, Veena G., Marcos Mills, Dominique Suarez, Catherine A. Hogan, Debra Yeh, J. Bradley Segal, Elizabeth L. Nguyen, Shiraz Maskatia, Roshni Mathew, and Gabrielle R Barsh. "COVID-19 and Kawasaki Disease: Novel Virus and Novel Case." Hospital Pediatrics (Pre-Publication Release), 2020b. https://doi.org/10.1542/hpeds.2020-0123.

Kelvin AA, Halperin S, COVID-19 in children: the link in the transmission chain, The Lancet, 2020, Published online March 25, 2020, DOI: 10.1016/S1473-3099(20)30236-X

L'Huillier, Arnaud G, Giulia Torriani, Fiona Pigny, Laurent Kaiser, and Isabelle Eckerle. "Shedding of Infectious SARS-CoV-2 in Symptomatic Neonates, Children and Adolescents." MedRxiv Preprint, 2020. https://doi.org/10.1101/2020.04.27.20076778.

Lazzerini, Marzia, Egidio Barbi, Andrea Apicella, Federico Marchetti, Fabio Cardinale, and Gianluca Trobia. "Delayed Access or Provision of Care in Italy Resulting from Fear of COVID-19." The Lancet Child & Adolescent Health4, no. 5 (April 9, 2020). https://doi.org/10.1016/s2352-4642(20)30108-5.

Li, Peng, Ji-Bo Fu, Ke-Feng Li, Yan Chen, Hong-Ling Wang, Lei-Jie Liu, Jie-Nan Liu, et al. "Transmission of COVID-19 in the Terminal Stage of Incubation Period: a Familial Cluster." International Journal of Infectious Diseases, 2020b. https://doi.org/10.1016/j.ijid.2020.03.027.

Li, Wei, Bo Zhang, Jianhua Lu, Shihua Liu, Zhiqiang Chang, Peng Cao, Xinhua Liu, et al. "The Characteristics of Household Transmission of COVID-19." Clinical Infectious Diseases, 2020a. https://doi.org/10.1093/cid/ciaa450.

Liu, Weiyong, Qi Zhang, Junbo Chen, Rong Xiang, Huijuan Song, Sainan Shu, Ling Chen, et al. "Detection of Covid-19 in Children in Early January 2020 in Wuhan, China." New England Journal of Medicine382, no. 14 (February 2020a): 1370–71. https://doi.org/10.1056/nejmc2003717.

Liu, Yang, Li-Meng Yan, Lagen Wan, Tian-Xin Xiang, Aiping Le, Jia-Ming Liu, Malik Peiris, Leo L M Poon, and Wei Zhang. "Viral Dynamics in Mild and Severe Cases of COVID-19." *The Lancet Infectious Diseases* 20, no. 6 (March 19, 2020b): 656–57. https://doi.org/10.1016/s1473-3099(20)30232-2.

Livingston, Edward, and Karen Bucher. "Coronavirus Disease 2019 (COVID-19) in Italy." Jama323, no. 14 (March 17, 2020): 1335. https://doi.org/10.1001/jama.2020.4344.

Lu X et al, SARS-CoV-2 Infection in Children, The New England Journal of Medicine, 2020, DOI: 10.1056/NEJMc2005073

Ludvigsson, Jonas F. "Children Are Unlikely to Be the Main Drivers of the COVID-19 Pandemic – A Systematic Review." *Acta Paediatrica* 109, no. 8 (May 19, 2020b): 1525–30. https://doi.org/10.1111/apa.15371.

Ludvigsson, Jonas F. "Systematic Review of COVID-19 in Children Shows Milder Cases and a Better Prognosis than Adults." Acta Paediatrica, 2020a. https://doi.org/10.1111/apa.15270.

Luo, Lei, Dan Liu, Xin-Long Liao, Xian-Bo Wu, Qin-Long Jing, Jia-Zhen Zheng, Fang-Hua Liu, et al. "Modes of Contact and Risk of Transmission in COVID-19 among Close Contacts." *MedRxiv Preprint*, 2020. https://doi.org/10.1101/2020.03.24.20042606.

Mannheim, Jonathan, Stephanie Gretsch, Jennifer E Layden, and Marielle J Fricchione. “Characteristics of Hospitalized Pediatric Coronavirus Disease 2019 Cases in Chicago, Illinois, March–April 2020.” *Journal of the Pediatric Infectious Diseases Society*, June 1, 2020. https://doi.org/10.1093/jpids/piaa070.

Marlais, Matko, Tanja Wlodkowski, Marina Vivarelli, Lars Pape, Burkhard Tönshoff, Franz Schaefer, and Kjell Tullus. “The Severity of COVID-19 in Children on Immunosuppressive Medication.” *The Lancet Child & Adolescent Health* 4, no. 7 (May 13, 2020). https://doi.org/10.1016/s2352-4642(20)30145-0.

Minotti, Chiara, Francesca Tirelli, Elisa Barbieri, Carlo Giaquinto, and Daniele Donà. “How Is Immunosuppressive Status Affecting Children and Adults in SARS-CoV-2 Infection? A Systematic Review.” *Journal of Infection* 81, no. 1 (April 23, 2020). https://doi.org/10.1016/j.jinf.2020.04.026.

Mizumoto, Kenji, Ryosuke Omori, and Hiroshi Nishiura. “Age Specificity of Cases and Attack Rate of Novel Coronavirus Disease (COVID-19).” MedRxiv Preprint, 2020. https://doi.org/10.1101/2020.03.09.20033142.

Morand A, Fabre A, Minodier P, Boutin A, Vanel N, Bosdure E, Fournier PE, COVID-19 virus and children: What do we know? Archives de Pédiatrie, 2020, 27: 117-118.

Mustafa, Naira M, and Laila A Selim. “Characterisation of COVID-19 Pandemic in Paediatric Age Group: A Systematic Review and Meta-Analysis.” *Journal of Clinical Virology* 128 (2020): 104395. https://doi.org/10.1016/j.jcv.2020.104395.

Nassih, H., K. El Fakiri, and I. Ait Sab. “Absence of Evidence of Transmission of Coronavirus Disease 2019 from a Young Child to Mother Despite Prolonged Contact.” *The Indian Journal of Pediatrics*, June 13, 2020. https://doi.org/10.1007/s12098-020-03382-0.

Nathan, Nadia, Blandine Prevost, and Harriet Corvol. “Atypical Presentation of COVID-19 in Young Infants.” The Lancet, April 27, 2020. https://doi.org/10.1016/s0140-6736(20)30980-6.

National Centre for Immunisation Research and Surveillance (NCIRS). “COVID-19 in Schools – the Experience in NSW (Prepared by the National Centre for Immunisation Research and Surveillance (NCIRS)),” April 26, 2020.

Qian, Guoqing, Naibin Yang, Ada Hoi Yan Ma, Liping Wang, Guoxiang Li, Xueqin Chen, and Xiaomin Chen. “COVID-19 Transmission Within a Family Cluster by Presymptomatic Carriers in China.” Clinical Infectious Diseases, 2020. https://doi.org/10.1093/cid/ciaa316.

Qiu, Haiyan, Junhua Wu, Liang Hong, Yunling Luo, Qifa Song, and Dong Chen. “Clinical and Epidemiological Features of 36 Children with Coronavirus Disease 2019 (COVID-19) in Zhejiang, China: an Observational Cohort Study.” The Lancet Infectious Diseases, 2020. https://doi.org/10.1016/s1473-3099(20)30198-5.

Riphagen, Shelley, Xabier Gomez, Carmen Gonzalez-Martinez, Nick Wilkinson, and Paraskevi Theocharis. “Hyperinflammatory Shock in Children during COVID-19 Pandemic.” The Lancet, May 6, 2020. https://doi.org/10.1016/s0140-6736(20)31094-1.

Scientific Advisory Group for Emergencies. “TFC: Risks Associated with the Reopening of Education Settings in September, 8 July 2020.” GOV.UK. GOV.UK, July 24, 2020. https://www.gov.uk/government/publications/tfc-risks-associated-with-the-reopening-of-education-settings-in-september-8-july-2020.

Somekh, Eli, Alexadra Gleyzer, Eli Heller, Miriam Lopian, Lior Kashani-Ligumski, Shelly Czeiger, Yehudit Schindler, Joseph. B. Lessing, and Michal Stein. “The Role of Children in the Dynamics of Intra Family Coronavirus 2019 Spread in Densely Populated

Area." *Pediatric Infectious Disease Journal* 39, no. 8 (June 5, 2020). https://doi.org/10.1097/inf.0000000000002783.

Stein-Zamir, Chen, Nitza Abramson, Hanna Shoob, Erez Libal, Menachem Bitan, Tanya Cardash, Refael Cayam, and Ian Miskin. "A Large COVID-19 Outbreak in a High School 10 Days after Schools' Reopening, Israel, May 2020." *Eurosurveillance* 25, no. 29 (2020). https://doi.org/10.2807/1560-7917.es.2020.25.29.2001352.

Su, Liang, Xiang Ma, Huafeng Yu, Zhaohua Zhang, Pengfei Bian, Yuling Han, Jing Sun, et al. "The Different Clinical Characteristics of Corona Virus Disease Cases between Children and Their Families in China – the Character of Children with COVID-19." Emerging Microbes & Infections 9, no. 1 (January 2020): 707–13. https://doi.org/10.1080/22221751.2020.1744483.

Sun, Dan, Feng Zhu, Cheng Wang, Jing Wu, Jie Liu, Xue Chen, Zhisheng Liu, et al. "Children Infected With SARS-CoV-2 From Family Clusters." *Frontiers in Pediatrics* 8 (June 23, 2020). https://doi.org/10.3389/fped.2020.00386.

Szablewski, Christine M., Karen T. Chang, Marie M. Brown, Victoria T. Chu, Anna R. Yousaf, Ndubuisi Anyalechi, Peter A. Aryee, et al. "SARS-CoV-2 Transmission and Infection Among Attendees of an Overnight Camp — Georgia, June 2020." *MMWR. Morbidity and Mortality Weekly Report* 69, no. 31 (August 7, 2020): 1023–25. https://doi.org/10.15585/mmwr.mm6931e1.

Torres, Juan Pablo, Cecilia Piñera, Verónica De La Maza, Anne J Lagomarcino, Daniela Simian, Bárbara Torres, Cinthya Urquidi, María Teresa Valenzuela, and Miguel O'Ryan. "SARS-CoV-2 Antibody Prevalence in Blood in a Large School Community Subject to a Covid-19 Outbreak: a Cross-Sectional Study." *Clinical Infectious Diseases*, July 10, 2020. https://doi.org/10.1093/cid/ciaa955.

Viner, Russell M, Simon J Russell, Helen Croker, Jessica Packer, Joseph Ward, Claire Stansfield, Oliver Mytton, Chris Bonell, and Robert Booy. "School Closure and Management Practices during Coronavirus Outbreaks Including COVID-19: a Rapid Systematic Review." The Lancet Child & Adolescent Health, 2020. https://doi.org/10.1016/s2352-4642(20)30095-x.

Wang, Wenling, Yanli Xu, Ruqin Gao, Roujian Lu, Kai Han, Guizhen Wu, and Wenjie Tan. "Detection of SARS-CoV-2 in Different Types of Clinical Specimens." Jama, March 11, 2020. https://doi.org/10.1001/jama.2020.3786.

Wei, Min, Jingping Yuan, Yu Liu, Tao Fu, Xue Yu, and Zhi-Jiang Zhang. "Novel Coronavirus Infection in Hospitalized Infants Under 1 Year of Age in China." *Jama* 323, no. 13 (February 14, 2020): 1313. https://doi.org/10.1001/jama.2020.2131.

Wongsawat, Jurai, Visal Moolasart, Punyavee Srikirin, Chaisiri Srijareonvijit, Nutcharin Vaivong, Sumonmal Uttayamakul, and Arom Disthakumpa. "Risk of Novel Coronavirus 2019 Transmission from Children to Caregivers: A Case Series." *Journal of Paediatrics and Child Health* 56, no. 6 (June 22, 2020): 984–85. https://doi.org/10.1111/jpc.14965.

Yu, Fengting, Liting Yan, Nan Wang, Siyuan Yang, Linghang Wang, Yunxia Tang, Guiju Gao, et al. "Quantitative Detection and Viral Load Analysis of SARS-CoV-2 in Infected Patients." Clinical Infectious Diseases, March 28, 2020. https://doi.org/10.1093/cid/ciaa345.

Yung, Chee Fu, Kai-Qian Kam, Chia Yin Chong, Karen Donceras Nadua, Jiahui Li, Natalie Woon Hui Tan, Sashikumar Ganapathy, et al. "Household Transmission of Severe Acute Respiratory Syndrome Coronavirus 2 from Adults to Children." *The Journal of Pediatrics*, July 4, 2020a. https://doi.org/10.1016/j.jpeds.2020.07.009.

Yung, Chee Fu, Kai-Qian Kam, Karen Donceras Nadua, Chia Yin Chong, Natalie Woon Hui Tan, Jiahui Li, Khai Pin Lee, Yoke Hwee Chan, Koh Cheng Thoon, and Kee Chong Ng. “Novel Coronavirus 2019 Transmission Risk in Educational Settings.” *Clinical Infectious Diseases*, June 25, 2020b. https://doi.org/10.1093/cid/ciaa794.

Zhang, Juanjuan, Maria Litvinova, Yuxia Liang, Yan Wang, Wei Wang, Shanlu Zhao, Qianhui Wu, et al. “Changes in Contact Patterns Shape the Dynamics of the COVID-19 Outbreak in China.” Science, April 29, 2020a. https://doi.org/10.1126/science.abb8001.

Zhang, Zhi-Jiang Xiang, Xue-Jie Xiang Yu, Tao Xiang Fu, Yu Xiang Liu, Yan Xiang Jiang, Bing Xiang Yang, and Yongyi Xiang Bi. “Novel Coronavirus Infection in Newborn Babies Under 28 Days in China.” European Respiratory Journal, April 8, 2020b, 2000697. https://doi.org/10.1183/13993003.00697-2020.

Zheng, Shufa, Jian Fan, Fei Yu, Baihuan Feng, Bin Lou, Qianda Zou, Guoliang Xie, et al. “Viral Load Dynamics and Disease Severity in Patients Infected with SARS-CoV-2 in Zhejiang Province, China, January-March 2020: Retrospective Cohort Study.” *Bmj*, April 21, 2020, m1443. https://doi.org/10.1136/bmj.m1443.

Zhu, Yanshan J, Conor D Bloxham, Katina E Hulme, Jane Wei Marcus Sinclair, Zhen E Tong, Lauren C Steele, Ellesandra Yih Noye, et al. “Children Are Unlikely to Have Been the Primary Source of Household SARS-CoV-2 Infections.” MedRxiv Preprint, 2020. https://doi.org/10.1101/2020.03.26.20044826.

Zou, Lirong, Feng Ruan, Mingxing Huang, Lijun Liang, Huitao Huang, Zhongsi Hong, Jianxiang Yu, et al. “SARS-CoV-2 Viral Load in Upper Respiratory Specimens of Infected Patients.” New England Journal of Medicine382, no. 12 (March 19, 2020): 1177–79. https://doi.org/10.1056/nejmc2001737.