TECHNICAL REPORT

COVID-19 in children and the role of school settings in transmission - second update

8 July 2021

What is new in this report?

- This document draws upon and updates evidence presented in the previous reports from ECDC on this topic, which were published in August 2020 and December 2020 [1,2]. This report presents updated scientific findings across all sections, prioritising surveillance data from 2021 and research published in 2021.
- The overall key messages are consistent with the previous ECDC report, but the messaging in this report addresses the current epidemiological context, which is quite different from December 2020. Notably, there is currently increased circulation of the more transmissible Delta variant in the EU/EEA, while at the same time an increasing percentage of adults in the EU/EEA are now fully vaccinated against COVID-19.
- This report presents original ECDC modelling work on the effectiveness of school closures for controlling the transmission of SARS-CoV-2. The models estimate that closing secondary schools has a larger effect on community transmission of SARS-CoV-2 than does closing primary schools or day nurseries.
- ECDC has updated its assessment of the susceptibility of children to SARS-CoV-2 infection, now noting that children appear to be equally susceptible to SARS-CoV-2 infection compared to other age groups (low confidence), although severe disease is much less common in children than in adults.

Key messages

- Increased transmissibility across all age groups has been reported for SARS-CoV-2 variants of concern (VOCs), most notably for the Delta variant. In regions where an increasing percentage of adults are fully vaccinated against COVID-19 but where children are not vaccinated, it may be anticipated that in the coming months increasingly greater proportions of reported SARS-CoV-2 cases will be among children.
- The majority of the studies referred to in this report were conducted prior to the emergence and widespread circulation of the Delta variant. This should be taken into account when interpreting reported study results.
- Children of all ages are susceptible to and can transmit SARS-CoV-2. Cases of SARS-CoV-2 in younger children appear to lead to onward transmission less frequently than cases in older children and adults. Recent increases in the share of reported cases among children probably represents increased case ascertainment of mild cases. Children aged between 1-18 years have much lower rates of hospitalisation, severe disease requiring intensive hospital care, and death than all other age groups, according to surveillance data. The exact burden of COVID-19 and its long-term consequences in the paediatric population is still to be determined and is a priority for further research.
- The general consensus remains that the decision to close schools to control the COVID-19 pandemic should be used as a last resort. The negative physical, mental and educational impacts of proactive school closures on children, as well as the economic impact on society more broadly, would likely outweigh the benefits. Given the likely continued risk of transmission among unvaccinated children, it is imperative that there is a high level of preparedness in the educational system for the 2021/2022 school year.

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Stockholm, July 2021

- In light of circulating SARS-CoV-2 VOCs, including Delta, combinations of non-pharmaceutical interventions (NPIs) in the form of physical distancing that prevent crowding as well as hygiene and other measures to reduce transmission risks will continue to be essential to prevent transmission in school settings. Measures should be adapted to levels of community SARS-CoV-2 transmission as well as to the educational setting and age group. Implementation of measures should consider the need to provide children with an optimal learning and social environment while also reducing transmission risks.
- It is important that testing strategies for educational settings aiming at timely testing of symptomatic cases are established to ensure isolation of cases and tracing and quarantine of their contacts. When positive cases are identified, the school should be informed, contact tracing should be initiated according to local guidelines, and communication to and the testing of close contacts, ideally with rapid diagnostic tests, should be considered.
- While a measure of last resort, school closures can contribute to a reduction in SARS-CoV-2 transmission, but are by themselves insufficient to prevent community transmission of COVID-19 in the absence of other nonpharmaceutical interventions and the expansion of vaccination coverage. The effectiveness of school closures appears to have declined in the second wave as compared to the first wave of the COVID-19 pandemic, possibly in part due to better hygiene measures in school settings.

Glossary

School structures within European Union/European Economic Area (EU/EEA) countries are heterogeneous, with children entering and moving through educational establishments at different ages [3]. Given this variation, it is not possible to define the age of attendance in EU/EEA educational establishments with complete consistency. Therefore, for the purposes of this report, the following classification has been used:

Adolescents	In this document, older secondary school students are, at times, referred to as adolescents in order to reflect the term used in the literature.
Children	Children are defined as those aged 1-18 years. This report does not explicitly assess infants (0-1 years), although in some cases children less than one year of age may have been included in reports on preschool or childcare settings.
Non-pharmaceutical intervention	Non-pharmaceutical interventions (NPIs) are public health measures that aim to prevent and/or control SARS-CoV-2 transmission in the community. NPIs can also be referred to as mitigation measures and public health responses.
Proactive school closures	Early and planned closure of schools and day-care facilities to limit local virus transmission and spread within schools and into the community. School closure might also include the provision of distance learning.
Reactive school closures	Closure in response to increased community transmission and/or a localised outbreak in a single educational facility and/or due to increased absenteeism among staff and students making it difficult to keep teaching going. School closure might also include the provision of distance learning.
Schools/educational settings	The generic term used to define all educational establishments within the scope of the document. This includes all three categories of schools referred to above, unless otherwise stated. The terms 'school' and 'educational setting' are used interchangeably in this document.
Preschools/day-care	Establishments including childcare and day-care centres, nurseries, and kindergartens for children approximately under five years, although these may include older children in some EU settings.
Primary schools	Establishments providing early-years compulsory education, which in most EU settings include children aged approximately 5–11 years.
Secondary schools	Education establishments for children aged approximately 12–18 years. Adolescents are included in this group.
Staff	Includes teachers, administrators and management, school nurses, janitors, cleaning and kitchen personnel, and other adults working in childcare and educational settings.

Scope of this document

The aim of this document is to provide an update on the knowledge surrounding the role of children in the transmission of SARS-CoV-2 and the role of schools in the COVID-19 pandemic, focusing in particular on the experience in EU/EEA countries since the beginning of the pandemic. This document also addresses transmission to and from staff in school settings, school-related mitigation measures including risk communication, testing, contact tracing, and the effectiveness and impacts of school closures. This document draws upon and updates evidence presented in the previous reports from ECDC on this topic, which were published in August 2020 and December 2020 [1,2]. This report does not consider educational settings related to young adults or adults, such as universities or vocational schools or any school with overnight stays, such as boarding schools.

Target audience

The target audience for this report is public health authorities in EU/EEA countries.

Background

As of 1 July 2021, the incidence of SARS-CoV-2 is declining in nearly all EU/EEA countries and is at the lowest rate since September 2020. Some of the decline in SARS-CoV-2 incidence that has occurred since January 2021, combined with reductions in hospitalisations and deaths, particularly in older age groups, is attributed to COVID-19 vaccines [4]. COVID-19 vaccines are being rolled out across the EU/EEA, however as of 1 July 2021, the majority of the EU/EEA population has not yet been fully vaccinated [5]. Select COVID-19 vaccines have been given conditional marketing authorisation by the European Medicines Agency (EMA) for 12-15-year-olds and adolescents 16 years and older [6], although vaccination roll-out to these age groups in the EU/EEA has thus far been limited. COVID-19 vaccines, as of July 2021, are currently yet to be authorised for use in the EU/EEA for children under 12 years.

The Delta (B.1.617.2) variant of concern (VOC) has been found to be more transmissible than previously dominant variants. ECDC estimates that Delta will represent 90% of all circulating SARS-CoV-2 viruses in the EU/EEA by the end of August 2021 [7]. As Delta can more easily infect unvaccinated individuals, as well as those who are only partially vaccinated, the importance of rapidly ensuring full vaccination coverage among vulnerable individuals while keeping an appropriate level of mitigation measures in place has been emphasised [8]. By the time schools reopen for the autumn 2021 term, children and adolescents will be the age groups with the lowest rates of COVID-19 vaccination coverage in the EU/EEA. Given the expected lower immunity in this population, concentrated circulation of SARS-CoV-2, including outbreaks in children and adolescents, are expected in the absence of strict adherence to effective public health mitigation measures. ECDC has estimated that younger age groups and younger adults (those <25 and 25-49 years) are projected to have the highest number of daily SARS-CoV-2 cases by September 2021 [8]. One implication of the current epidemiological projections is that detection and mitigation of SARS-CoV-2 transmission to and from children in community and educational settings will become increasingly important. In this context, evidence can support countries in outlining approaches to appropriately balance the broader physical and mental health needs of children and adolescents while ensuring adequate SARS-CoV-2 prevention and control in this population [9].

Methodological approach

This document is based on evidence presented in the ECDC report 'COVID-19 in children and the role of school settings in COVID-19 transmission - first update', published on 23 December 2020. In addition to the evidence presented there, this version draws on evidence from the following sources:

- Case-based epidemiological surveillance analysis from The European Surveillance System (TESSy);
- Grey, pre-print and peer reviewed scientific literature, focusing on studies published in 2021; and
- Modelling of the effects of closing schools on community transmission based on data from the ECDC-Joint Research Centre (JRC) Response Measures Database [10].

The main findings are summarised for each section and, where feasible, an assessment of the confidence in the evidence is presented (see Table 1). The overall confidence in the evidence for key summary points has been estimated in the 'summary' sections in this report. ECDC experts assessed key summary statements according to GRADE (Grading of Recommendations, Assessment, Development and Evaluations) criteria as well as the certainty/confidence of evidence (Table 1). Confidence in evidence was deemed to be lower where few empirical studies addressed a given topic or where a wide heterogeneity of study findings has been reported, and higher where multiple studies have consistently reported similar findings.

It is important to note that this document was not developed as a formal GRADE process. However, given the rapidly growing available evidence surrounding SARS-CoV-2 and COVID-19, it was deemed to be important to attempt to provide such assessments. As GRADE more generally notes: 'Quality of evidence is a continuum; any discrete categorisation involves some degree of arbitrariness. Nevertheless, advantages of simplicity, transparency, and vividness outweigh these limitations' [11].

Table 1. GRADE definitions for the ratings of the overall confidence of evidence [11]

Rating	Definition
High	This research provides a very good indication of the likely effect. The likelihood that the effect will be substantially different is low.
Moderate	This research provides a good indication of the likely effect. The likelihood that the effect will be substantially different is moderate.
Low	This research provides some indication of the likely effect. However, the likelihood that it will be substantially different (a large enough difference that it might have an effect on a decision) is high.
Very Low	This research does not provide a reliable indication of the likely effect. The likelihood that the effect will be substantially different (a large enough difference that it might have an effect on a decision) is very high.

1. What is the epidemiology of SARS-CoV-2 in children?

Summary

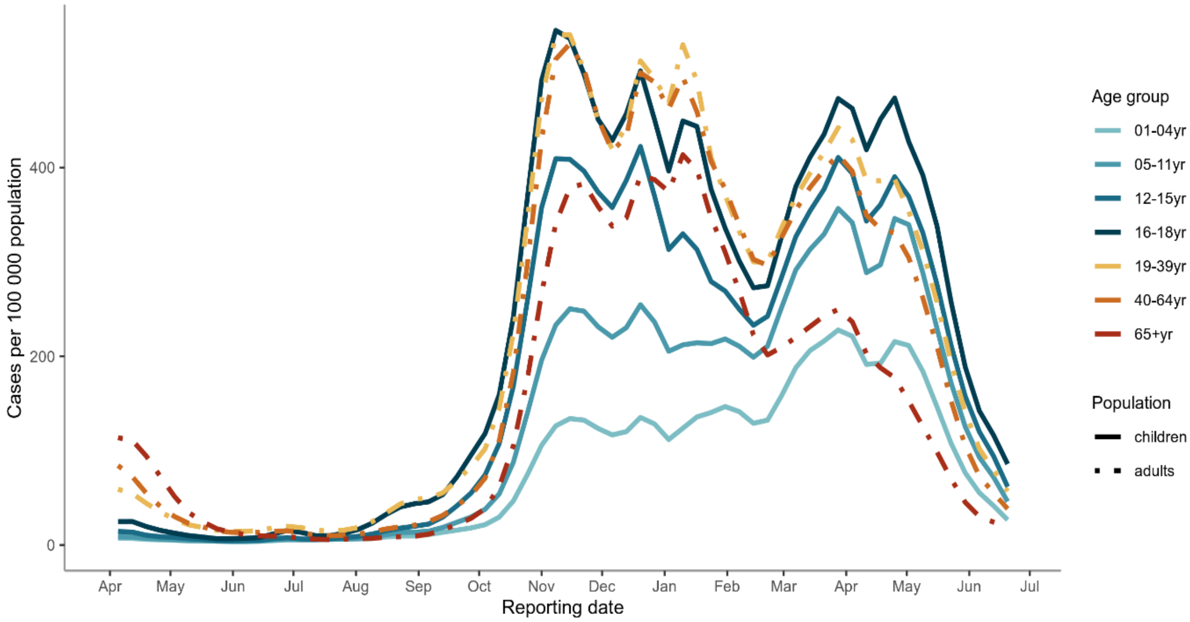
- Since the start of the vaccination roll-out in EU/EEA countries, children have made up an increasing proportion of weekly case numbers with the most noticeable increase among those aged 5-11 years. Still, children comprise a minority of all reported COVID-19 cases (high confidence). The increase in the share of reported cases among children probably represents increased case ascertainment of mild cases (moderate confidence).
- Since March 2021, case notification rates in children aged 16-18 years have increased more sharply than in other age groups, and this age group has had the highest case notification rate of all age groups since then, mirrored closely by rates in children aged 12-15 years. Increases were less steep and/or started later among the other childhood age groups (high confidence). Higher case ascertainment among this age group and increasing vaccination coverage in adult age groups are likely two of the explanatory factors behind this observation.
- Most children with COVID-19 have mild symptoms and very low risk of death. Although very rare, some children develop significant respiratory disease and require hospital admission. Those children who do require hospitalisation or who have more severe outcomes often have underlying chronic conditions (moderate confidence). There is no evidence of a difference by age or sex in the risk of severe outcomes among children, which contrasts with the strong age-sex association observed among adults (high confidence).
- A very small subset of children experiences paediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 (PIMS-TS), also referred to as Multisystem inflammatory syndrome in children (MIS-C), appearing 4-6 weeks after mild COVID-19 infection. The condition shares features with other paediatric inflammatory syndromes such as Kawasaki disease, toxic shock syndrome, and macrophage activation syndrome.
- Post-acute sequelae of SARS-CoV-2 are characterised by persistent symptoms such as fatigue, dyspnoea, chest pain, cognitive impairment, and sleeping disturbances that last up to several months after infection. However, the exact burden of COVID-19 and its long-term consequences in the paediatric population is still to be determined and is a priority for further research.

1.1 Age trends in notifications of COVID-19

Pooled data from over 16 million case-based records from 16 countries submitted to TESSy up to 20 June 2021 show that in the most recent peak of COVID-19 that started in March 2021, case notification rates in children aged 16-18 years increased the most sharply, remaining the highest rate seen among all age groups since then (Figure 1). The trend for this age group is mirrored most closely by rates in children aged 12-15 years. As observed previously, increases were less steep and/or started later among other childhood age groups, with decreasing age leading to shallower gradients and lower peak rates.

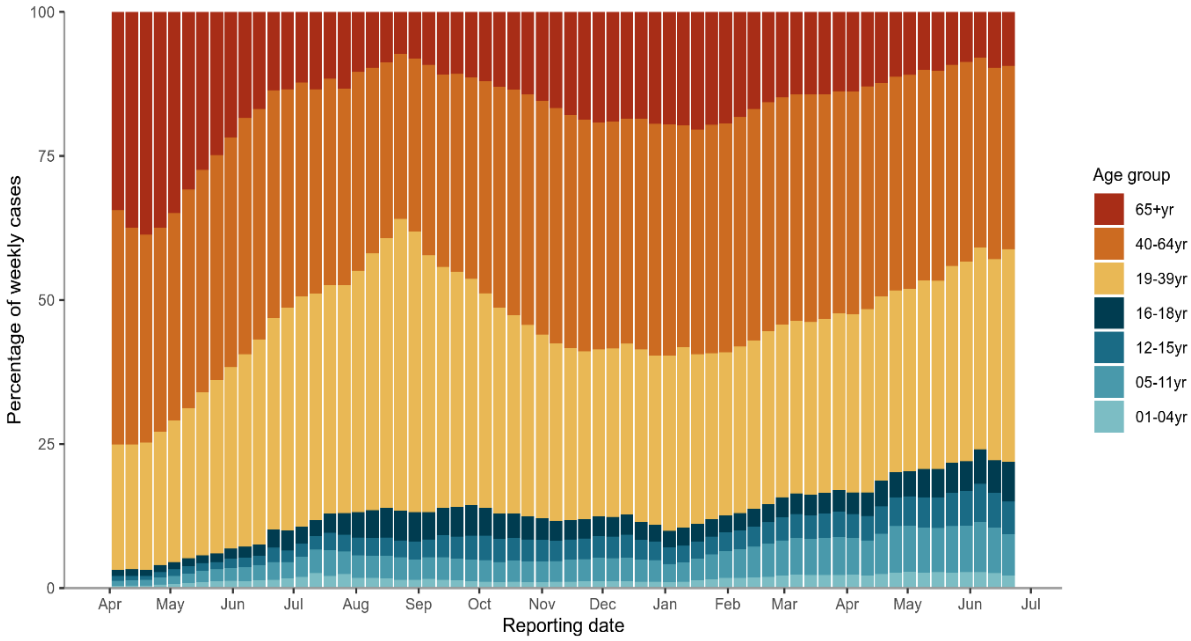
Since January 2021, which coincides with the start of the vaccination roll-out in the EU/EEA, children have made up an increasing proportion of weekly case numbers with the most noticeable increase among those aged 5-11 years (Figure 2). Still, children comprise a minority of all reported COVID-19 cases. As children often present with mild symptoms of COVID-19 and are less frequently tested than adults, it remains possible that this is one explanation for the under-representation of children in surveillance data.

Figure 1. 14-day age-specific COVID-19 case notification rate, selected EU/EEA countries, April 2020 to July 2021



Source: TESSy COVID-19 data submitted by Austria, Croatia, Cyprus, Czechia, Denmark, Finland, Germany, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia and Sweden

Figure 2. Weekly distribution of COVID-19 cases by age, selected EU/EEA countries, April 2020 to July 2021



Source: TESSy COVID-19 data submitted by Austria, Croatia, Cyprus, Czechia, Denmark, Finland, Germany, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia and Sweden

We analysed over 4.7 million case-based records for a subset of 10 EU/EEA countries submitted to TESSy with sufficiently complete data on severe outcomes for the reporting period 4 January 2021 to 23 May 2021 (period 2, Table 2) and compared them to the same analysis for cases reported for the period 1 August 2020 to 29 November 2020 (period 1) that was presented in the first update of this report in December [1]:

- A higher proportion of cases was reported among children aged 1-11 years (8.5%) in period 2 than in period 1 (5.5%). This is consistent with the observed increase in Figure 2. In period 2, the proportion of reported cases in children 1-11 years were closer to the population age distribution of children.
- In both periods 1 and 2, the proportion of cases in children aged 12-15 and 16-18 were roughly equal and slightly exceed, respectively, the proportion of the population in these age groups.

- Children remained very under-represented among cases experiencing severe outcomes, accounting for a similar proportion (<0.5% in all age groups) of all cases in periods 1 and 2.
- Age-specific attack rates (AR) for severe outcomes among children were lower in period 2 than in period 1 but were broadly constant among adults. This likely reflects more recent detection of mild cases among children in period 2.
- Crude attack rates for severe disease were higher among males than females in adults, but there was no difference observed by sex among children of the same age in period 2. This is consistent with the findings from period 1.

Table 2. Distribution and attack rates (AR) by age group, sex and severe outcome of cases in TESSy, 4 January 2021 to 20 June 2021

Age group (years)	Sex	Population distribution (%)	Total cases, n (%)	Hospitalised		Severe hospitalisation*		Fatal	
				n (%)	AR %	n (%)	AR %	n (%)	AR %
01-04	F	1.8	56 154 (1.2)	479 (0.2)	0.85	10 (0.0)	0.02	5 (0.0)	0.01
01-04	M	1.9	59 957 (1.3)	651 (0.2)	1.09	14 (0.0)	0.02	1 (0.0)	0.00
05-11	F	3.2	136 701 (2.9)	490 (0.2)	0.36	16 (0.0)	0.01	6 (0.0)	0.00
05-11	M	3.4	147 896 (3.1)	517 (0.2)	0.35	15 (0.0)	0.01	6 (0.0)	0.00
12-15	F	1.8	89 616 (1.9)	444 (0.2)	0.5	15 (0.0)	0.02	7 (0.0)	0.01
12-15	M	1.9	95 362 (2.0)	396 (0.1)	0.42	25 (0.1)	0.03	7 (0.0)	0.01
16-18	F	1.4	79 226 (1.7)	570 (0.2)	0.72	16 (0.0)	0.02	10 (0.0)	0.01
16-18	M	1.5	81 226 (1.7)	451 (0.2)	0.56	31 (0.1)	0.04	6 (0.0)	0.01
19-39	F	12.5	695 915 (14.5)	11 760 (4.0)	1.69	575 (1.4)	0.08	145 (0.2)	0.02
19-39	M	13.1	698 723 (14.6)	10 515 (3.6)	1.5	878 (2.1)	0.13	265 (0.3)	0.04
40-64	F	17.8	958 520 (20.0)	34 663 (11.8)	3.62	4 373 (10.4)	0.46	2 528 (3.2)	0.26
40-64	M	17.6	927 191 (19.4)	58 071 (19.8)	6.26	9 772 (23.3)	1.05	5 818 (7.3)	0.63
65+	F	12.1	420 666 (8.8)	84 310 (28.7)	20.04	10 362 (24.7)	2.46	32 346 (40.4)	7.69
65+	M	9.1	341 794 (7.1)	90 538 (30.8)	26.49	15 777 (37.7)	4.62	38 887 (48.6)	11.38
Total		100	4 788 947 (100)	293 855 (100)	6.14	41 879 (100)	0.87	80 037 (100)	1.67

** severe hospitalisation: hospitalised and requiring admission to ICU or respiratory support.*
Data were extracted reported up to 20 June 2021. The last four weeks of data were removed to allow for unknown severity or outcome of recently reported cases.

1.2 Severity of COVID-19 among children

Most children with COVID-19 have mild symptoms and a very low risk of death [12]. Very rarely, children develop significant respiratory disease and require hospital admission. Children who do require hospitalisation or who have more severe outcomes often have underlying chronic conditions [13]. The most common comorbidities in hospitalised children are diabetes, gastrointestinal, neurological, cardiac and pulmonary diseases, specifically asthma [14,15]. A significant proportion of hospitalised children with SARS-CoV-2 infection are also obese [16]. However, some of these commonly observed underlying conditions may not necessarily be causally associated with COVID-19 severity, and further research is needed.

Following the initial wave of COVID-19 hospitalisations, a novel syndrome with hyperinflammatory response in children emerged, initially identified by physicians in the United Kingdom (UK) in April 2020. The Royal College of Paediatrics and Child Health defined it as paediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 (PIMS-TS), while the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) in the United States (US) refer to it as Multisystem inflammatory syndrome in children (MIS-C) [17,18]. Unfortunately, there is currently no specific test available to diagnose this syndrome and only a preliminary international case definition in place [17]. Hence, the diagnosis of PIMS-TS/MIS-C is based on clinical signs and symptoms, as well as evidence of a previous SARS-CoV-2 infection or exposure. Children who develop the syndrome are generally previously healthy, and the primary infection with SARS-CoV-2 is usually mild or asymptomatic [19].

PIMS-TS/MIS-C is rare and shares common clinical features with other paediatric inflammatory syndromes such as Kawasaki disease, toxic shock syndrome, and macrophage activation syndrome. Children with PIMS-TS/MIS-C often present four to six weeks after infection, with a wide clinical spectrum including Kawasaki disease-like symptoms, life-threatening shock, and milder forms of illness such as persistent fever, inflammation, and gastrointestinal manifestations [19].

Most children with critical illness due to PIMS-TS/MIS-C have a favourable outcome and recover with intensive care support and appropriate treatment. According to studies, 60% of children with PIMS-TS/MIS-C need to be admitted to an intensive care unit (ICU) with an average length of ICU stay of around five days, while the total average hospital stay is around 10 days [16,20]. In a cohort of 286 children and adolescents from 55 centres across 17 European countries, high incidence (93%) of myocardial involvement was evident [20]. Critical illness is associated with increasing age of children in some studies [21,22]. The mortality associated with PIMS-TS/MIS-C was approximately 1% in a observational cohort study of young people admitted to the hospital with COVID-19 in the UK [15].

Early recognition and prompt treatment of PIMS-TS/MIS-C cases is essential. Limited evidence for treatment options supports intravenous immunoglobulin (IVIG), corticosteroids, inotropes and other biological immunomodulation agents [23,24].

As children often present with mild symptoms of COVID-19 and are less frequently tested than adults, the true proportion of cases that develop PIMS-TS/MIS-C remains unknown. There is no comprehensive overview of PIMS-TS/MIS-C cases in the EU/EEA. Germany and Switzerland have published data on case series of children with severe COVID-19 infection, leading to PIMS-TS/MIS-C and even death [25,26]. The French national surveillance system registered 111 children with PIMS-TS/MIS-C between April 2020 and January 2021, with a median age of eight years. Among them, 67% had a history of admission to a paediatric ICU [27]. In Spain, a paediatric COVID-19 registry, described that among the hospitalised children due to PIMS-TS/MIS-C, 61% developed cardiac complications [28]. Sweden has reported just over 200 children diagnosed with PIMS-TS/MIS-C and no deaths among them as of April 2021 [29]. A recent nationwide cohort study in Denmark estimated the occurrence of PIMS-TS/MIS-C cases among COVID-19-infected children as of one in 4 100 in children younger than 12 years and one in 3 700 in children older than 12 years [30].

Recently, cohorts of children with post-acute sequelae of SARS-CoV-2 (PASC), recognised as post-COVID-19 condition or 'long COVID' have been described in Italy, Sweden, and Russia [31-33]. PASC is characterised by persistent symptoms such as fatigue, dyspnoea, chest pain, cognitive impairment, and sleeping disturbances that last up to several months after infection. Prior history of allergic diseases and age above six years have been associated with a higher risk of developing PASC. In the small case series of children with persistent symptoms in the above countries, the median age was 11.4, 10.4, and 12 years, respectively. Data from the UK's National Statistics Office also shows a significant number of children reporting symptoms several weeks after their initial SARS-CoV-2 infection [34]. A recent national survey in the Netherlands showed that among the 89 children suspected of long COVID, 18% were admitted to the hospital due to their long-term symptoms [35]. The exact burden of the disease and long-term consequences in paediatric population is still to be determined and is a priority for further research.

2. What is known about children and transmission of SARS-CoV-2?

Summary

- SARS-CoV-2 transmission to, from and among children is impacted by multiple factors, including symptom type and severity, viral load and shedding duration, the viral variant, duration of exposure, mitigation measures in place in household, school, and community settings, and host factors that may modulate baseline susceptibility and immune response.
- Children are equally susceptible to SARS-CoV-2 infection compared to other age groups (low confidence), although severe disease is much less common in children. While multiple studies have suggested that children may be less susceptible to SARS-CoV-2 infection than adults, potential reporting biases due to lower-case ascertainment in children may contribute to this interpretation, particularly for studies published during 2020. Recent prevalence and seroprevalence studies have tended to conclude that there are no significant differences across age groups.
- Younger children (preschool- and primary school-aged) appear to transmit SARS-CoV-2 less often than adolescents and adults (low confidence), but younger children may also have been tested for SARS-CoV-2 less frequently than other age groups, while also having fewer opportunities for social mixing during periods of school closures than adolescents.
- Onward transmission by adolescents appears to occur as often as by adults in household and community settings, given similar social mixing patterns (moderate confidence).

2.1 Viral RNA shedding of SARS-CoV-2 among children

Following infection with SARS-CoV-2, the duration and magnitude of viral shedding are key determinants of the duration of infectiousness and onwards transmission risk. In a recent systematic review and meta-analysis of viral RNA shedding time (VST), pooled results of 3,385 participants across 35 studies, revealed that VST is significantly longer in symptomatic infections (19.7 days, 95% CI: 17.2–22.7) than in asymptomatic infections (10.9 days, 95% CI: 8.3–14.3) across all age groups. Sub-group analyses indicate that VST in children (9.9 days, 95% CI: 8.1–12.2, I2 = 85.74%) is significantly shorter than in adults (23.2 days, 95% CI: 19.0–28.4), with adults defined as those aged 18 years and above. Shorter VST was attributed to the higher proportion of asymptomatic infections and milder clinical symptoms widely observed in infected children compared with infected adults. Only two studies in this analysis evaluated non-respiratory tract samples, however, VST was found to be significantly longer in stool specimens (30.3 days, 95% CI: 23.1–39.2) than respiratory tract specimens (17.5 days, 95% CI: 14.9–20.6) across age groups [36]. Prolonged faecal viral RNA shedding has been reported among paediatric SARS-CoV-2 cases [37,38], but there is very limited evidence to support the faecal-oral route as a viable or significant mode for SARS-CoV-2 transmission among children [39].

With respect to the magnitude of viral RNA shedding observed among children infected with SARS-CoV-2, an early tertiary medical centre study with a small SARS-CoV-2 PCR (Polymerase Chain Reaction) positive cohort (n=145) indicated that significantly greater amounts of viral nucleic acid are detected in children younger than five years when compared to older children (5-17 years) and adults (>18 years) [40]. Despite the shorter viral shedding duration observed in children, this raised concerns that young children may pose a greater transmission risk. However, larger studies have now demonstrated no discernible difference in the amount of viral nucleic acid among young children and adults. A community study of 5 554 predominantly asymptomatic or mildly symptomatic SARS-CoV-2 PCR positive children and adults in the US analysed using three age categories – young children aged five years or younger (n=199), children aged five to 17 years (n=665), and adults aged 18 years and older (n = 4680) – with no significant differences in cycle threshold (Ct) values (which in a PCR assay indicates how much virus a sample contains) observed between age groups upon comparison of hospitalisation status or symptom status [41]. This finding is further supported by results from another community-based, cross-sectional study of 555 children and adults, where SARS-CoV-2 RNA levels, as determined by Ct values, although significantly higher in symptomatic individuals than in asymptomatic individuals, showed no significant age-related differences [42].

Transmission by children likely depends on multiple factors, including symptom type and severity, viral load and shedding duration, host factors (such as baseline susceptibility and immune responses), as well as the viral variant [43]. Overall, evidence suggests that peak respiratory tract viral load in children infected with SARS-CoV-2 does not differ from adults, but the duration of respiratory tract viral shedding is shorter in children when compared to the adult population. However, there is currently limited comparative data evaluating the impact of different highly transmissible SARS-CoV-2 VOCs on viral load dynamics in children.

2.2 Asymptomatic SARS-CoV-2 infection in children

Asymptomatic SARS-CoV-2 infection in children has been well documented [44,45], as detailed in the previous ECDC report on this topic [1]. A recently published observational study in southeast and south Asia from eight hospitals across seven countries reported an overall asymptomatic rate of 40% among children identified due to contact tracing or screening strategies [46]. In a systematic review of 20 studies from Asia, Europe and US among the 1810 participants (<21 y), 13% were asymptomatic [47]. Another recent meta-analysis described the clinical data from 2874 children with COVID-19 from 37 articles and found that asymptomatic infection accounted for 27.7% (95% CI: 19.7%–36.4%) of patients [48].

Several recent studies in paediatric populations have confirmed a previous infection by the presence of antibodies in serology tests [49]. Seroprevalence studies may facilitate the evaluation of exposure rates and infection characteristics in children. When compared with adult populations, lower seroprevalence in children has been reported in Spain [50], Switzerland [51], and Italy [52]. An Italian paediatric cohort showed that asymptomatic children develop the same immune response as symptomatic ones, in contrast to adults where severity of infection is dependent to antibody titres [53].

Distinguishing between children who remain asymptomatic throughout the course of infection and those that are asymptomatic at the time of testing but who go on to develop symptoms after a positive PCR test (presymptomatic) is extremely challenging, particularly in younger children, because of challenges in reporting or describing mild symptoms and loss to follow-up. Studies that enrol children based upon the presentation of symptoms will under-estimate the extent of asymptomatic infection and over-estimate severe outcomes.

2.3 Susceptibility of children to SARS-CoV-2 infection

It is well established that children and adolescents can be infected by, and transmit, SARS-CoV-2 [1]. While there is some heterogeneity in the literature, and although case ascertainment in children and adolescents may be lower than for other age groups [1,54], multiple studies have indicated an age gradient: children in the range of 10-14 years old and younger have been reported to be less susceptible to SARS-CoV-2 infection than older adolescents and adults [55,56].

However, as children tend to have less severe COVID-19 outcomes than adults (Section 1.1), children positive for SARS-CoV-2 may be under-represented in case-based reporting, particularly during the early portions of 2020, as well as in studies that have not tested asymptomatic contacts. Population-based studies, such as representative sampling, may help to address this knowledge gap. A nationwide seroprevalence study from Spain from April – May 2020 identified an age gradient with a gradual rise in seroprevalence from younger age groups into adulthood [57], although the study period coincided with a national lockdown that included school closures. Conversely and more recently, a prospective cohort study from Austria repeatedly tested over 10,000 staff and students for SARS-CoV-2 infection using a gargling solution and RT-qPCR [57]. The authors concluded that prevalence did not differ across age groups, pupils or teachers, or primary or secondary schools [57], but did observe an association between prevalence and regional community incidence and social deprivation. Similarly, seroprevalence testing in a prospective cohort study of 55 schools in Switzerland found no significant difference in seroprevalence between lower, middle and upper school children (6-9 years, 9-13 years, and 12-16 years, respectively) [58]. A preprint seroprevalence study from India from March-June 2021 has also concluded that children aged 2-17 years had similar seroprevalence rates to adults [59].

It is important to note that there may be a high volatility in SARS-CoV-2 prevalence among children, depending upon whether schools have been open or closed as well as on varying in-school mitigation measures [57]. In England, for example, the highest prevalence rates for any age group were among school-aged children between 13 November-3 December 2020 [60], but this declined sharply among 13-17-year-olds by February 2021 due in part to school closures [61].

Variants of concern show increased transmissibility across all age groups [62], and it is therefore important to note that both susceptibility and infectiousness of children aged between one to six years are substantially higher compared with the pre-VOC period [63]. Most currently published scientific studies were conducted prior to the emergence of SARS-CoV-2 variants such as Alpha and Delta.

The relative prevalence of SARS-CoV-2 infection among children will increasingly depend upon levels of vaccination uptake in older age groups, as well as circulating VOCs [64]. In England, between 20 May 2021 and 7 June 2021, a period in which vaccination roll-out was well underway and the Delta variant was the dominant circulating SARS-CoV-2 variant, there were 5-fold higher SARS-CoV-2 positivity rates among children aged 5-12 and young adults aged 18-24 compared to those 65 years and older [64]. It was hypothesised that these higher rates among younger people reflect increased social mixing as schools opened and lockdowns eased, alongside higher vaccination coverage among older age groups [64].

2.4 Transmission of SARS-CoV-2 by children in household settings

There is a high degree of heterogeneity among studies on household transmission by children, and published studies have been primarily conducted prior to the emergence of the Delta variant, and in periods with lower overall rates of vaccination coverage in the adult population.

Several studies do not identify children and adolescents as index cases or identified them as index cases less often than adults [62,65]. Evidence points towards the possibility for onward transmission by children with an increased likelihood with increasing age. However, there are some mixed results in the literature about whether adolescents are more or less likely to transmit SARS-CoV-2 than younger children or adults.

In a Korean study among 4 048 household clusters, within-age group infection dominated the overall household transmissions. Transmission was more common from adults to children than from children to adults [66]. For index cases 10-19 years, the secondary attack rate (SAR) was 18.6%, the highest rate across age groups in the study, but a follow-up study concluded that transmission was more common from adults to children than from children to adults [66]. In a retrospective observational study from Spain among children under 16 years, more than 70% (756/1040) of paediatric cases were secondary to an adult, whereas 7.7% (80/1040) were index cases. The secondary attack rate from paediatric index cases was lower in households during the school period than during the summer (33.3% vs 62.1%, p=0.02). In addition, the SAR was significantly lower in households with paediatric index cases compared to households with adult index cases (59.0% vs 67.6%, p=0.006) [67]. A single-centre retrospective study in the US of paediatric patients positive for SARS-CoV-2 and their household contacts identified no evidence of child to adult transmission [68]. A household study from the Netherlands estimated that secondary attack rates were lowest from 1-11-year-olds (35%), higher from12-17-year-olds (41%), and highest from adults 18 years and older (51%) [69]. A household seroprevalence study from Germany identified significantly higher secondary attack rates for index cases over 18 years than for index cases under 18 years (SAR 0.38 vs 0.15) [70].

In a large cohort with over 300 000 adults living in healthcare worker households in Scotland, adults with children aged 0-11 years were at lower risk of testing positive for SARS-CoV-2 and possibly also of developing COVID-19 requiring hospitalisation than adults living without children, although the identified association was not strong. After schools reopened to all children in August 2020, no association was seen between exposure to young children and risk of any COVID-19 [71]. A similar finding was reached in a cross-sectional study of 4664 healthcare workers in Switzerland, where living with children under 12 years was associated with a decreased risk of SARS-CoV-2 seropositivity (aOR 0.3, 95%CI 0.2-0.6) [72]. One possible explanation for the finding of these studies is that exposure to children may enhance cross-protective immunity through prior exposure to other respiratory viruses [71]. It is also possible that the explanation is due to confounding factors, such as that adults in households without young children behave differently, although the authors of the Scottish study did not find empirical evidence for this explanation [71].

In contrast to the above, studies have suggested relatively similar secondary transmission rates from children as from adults. A household study from the US found high secondary attack rates overall, but in contrast to the aforementioned studies, secondary transmission was found to be higher from index cases under 12 years (53%) than from index cases aged 12-17 years (38%), although this finding was based upon a very low number of index cases in the younger than 12 years age group [73]. Similarly, a national registry-based study from Norway has indicated that, while parents are more likely than children or adolescents to be index cases, SARs were higher when index cases were children 0-6 years (24%) than they were for when index cases were children 13-16-years (14%) or 17-20 years (11%) [65]. The authors of this study speculated that it may be because very young children cannot reduce contacts with other family members, even if a positive case is detected.

Further research is required to understand the contextual factors driving secondary attack rates from children in household settings. Irrespective of the relative differences in secondary attack rates between children and adults, research from Sweden [74] and from the US [75] has shown an elevated risk of SARS-CoV-2 infection to adults living in households with children attending schools in-person.

Notably, the strength of the association of this elevated risk was shown to increase with the grade that children attended in school, and to decrease according to the number of in-school mitigation measures in place [75]. The study from Sweden suggested that parental exposure to children attending open lower-secondary schools (ages 14-16) rather than closed upper-secondary schools (ages 17-19) resulted in an increase in confirmed SARS-CoV-2 infections (OR 1.17; 95%CI 1.03-1.32) [74]. A modelling study from the US based on self-reporting questionnaires concluded that living in a household with a child having in-person schooling is associated with a 30% increase for having a positive COVID-19 test in the 14 days before (aOR 1.30; 95%CI 1.24 to 1.35). The risk was highest with increasing school grade and was highest with children in grades 9 to 12 [75]. Importantly, however, this study also concluded that the risk to household members of in-school students can be managed through the implementation of mitigation measures within schools (see also Section 4.2) [75].

3. What is known about SARS-CoV-2 transmission in school settings?

Summary

- There is limited spread of SARS-CoV-2 in schools when appropriate mitigation measures are in place (moderate confidence). However, transmission of SARS-CoV-2 in school settings is inherently difficult to assess, particularly when community transmission is ongoing, as transmission attributed to schools could have occurred in community settings or vice-versa.
- With current community transmission of more transmissible SARS-CoV-2 VOCs, the susceptibility and infectiousness of children, adolescents, and educational staff are substantially higher compared with the pre-VOC period, and thus the likelihood of SARS-CoV-2 transmission in school settings is also higher.
- Secondary infections in school settings are more likely to occur if the index case is a teacher than a student, other factors being equal (moderate confidence).
- Educational staff and adults within school settings do not seem to be at increased risk of severe COVID-19 compared to the general population (low confidence), but appropriate measures, including full vaccination, should be taken to minimise the chances of infection of educational staff.

3.1 SARS-CoV-2 transmission in school settings

It has generally been concluded that SARS-CoV-2 transmission in school settings is not a primary determinant of community transmission [1,76]. During first and second waves of the pandemic, research showed limited spread of SARS-CoV-2 in schools. While outbreaks have been documented in preschools, primary schools and secondary schools, it has also been generally observed that there are low secondary attack rates in these settings when appropriate mitigation measures are in place [1,77,78], and that the risk of students affecting family members is also diminished if effective combinations of in-school mitigation measures are in place [75].

Consistent with the general hypothesis that SARS-CoV-2 transmission is more likely by older than younger children and adolescents, it has been assessed that there is likely to be a greater effectiveness in reducing community SARS-CoV-2 rates by temporarily closing secondary schools than primary schools [79-81]. Chapters 5 and 6 cover the impacts and effectiveness of school closures. The majority of studies indicate secondary infections in schools occurring more frequently when the index case is a teacher than a student [76,82].

Variants of concern show increased transmissibility across all age groups [83]. Investigations of German childcare centre outbreaks in March 2021 suggest that, as with other age groups, both susceptibility and infectiousness of children aged between one and six years are substantially higher compared with the pre-VOC period [63]. In the UK, in the four-week period up to 18 June, there were 181 confirmed SARS-CoV-2 outbreaks linked to primary and secondary schools that had at least one variant case linked to them. This represents around 0.8% of all schools [83,84]. By the end of June 2021, COVID-19-related pupil absence in England was increasing and at the highest rate since schools opened in March 2021 [85]. Pupil absence due to COVID-19 includes confirmed or suspected cases, as well as pupils self-isolating or whose schools are closed due to COVID-19. Case rates of the Delta variant in the UK were, as of the second week of June 2021, increasing in all age groups up to 70 years, but at a faster rate among 10-17-year-olds. This age group is one the largest remaining susceptible population groups, given that children have generally not been vaccinated so far. Any observed increase in outbreaks in schools may be due to these factors, alongside increased testing among this age group, the easing of lockdowns, and resultant increases in social mixing [64].

Younger adults and adolescents currently account for a high proportion of cases in many European countries. By the beginning of the 2021 autumn term, children will likely be the largest unvaccinated population. As a result, relatively more SARS-CoV-2 transmission is expected to occur in this group, as well as in school settings.

3.2 COVID-19 among educational staff

The risk of COVID-19 among teachers and other educational staff has been discussed since early on in the pandemic. Generally, there are different types of risks that can be assessed, such as the risk of acquiring a COVID-19 infection and risk of severe COVID-19 (e.g. hospitalisation or death). However, as already stated in ECDC's previous guidance, the transmission of SARS-CoV-2 at the workplace is difficult to assess, particularly when community transmission is ongoing, as transmission among adults could have occurred outside the workplace [1]. Teachers working outside their homes reported up to 80% more COVID-19-related outcomes in a self-reporting questionnaire in the US (aOR, 1.8; 95% CI, 1.5 to 2.2), comparable to percentages reported by healthcare workers [75].

Nonetheless, there is a growing evidence base on the role of educational staff on SARS-CoV-2 transmission in school settings. In a large cross-sectional study of SARS-CoV-2 transmission in educational settings in England, it was reported that staff had higher incidence than students, and that most cases linked to outbreaks were among staff members [78]. An investigation into SARS-CoV-2 transmission in schools in Georgia, US, concluded that educators may play a central role in in-school transmission networks [86], highlighting the importance of appropriate mitigation measures among educators. A preprint study from Germany stated that transmission was more likely from teachers than students, and that teachers caused four times more secondary cases than students [87].

While the likelihood of SARS-CoV-2 transmission appears to be higher from teachers than students in educational settings, studies have not generally revealed a higher occupational risk to educational staff. Evidence from Sweden from the early phase of the pandemic, where primary and lower secondary schools (covering children up to approximately 15 years) were kept open, suggests that teachers were not found to be at increased risk to receive intensive care for COVID-19 [88], while statistics from England and Wales further reveal that death rates in teachers and educational professions were not significantly increased when compared to rate of death among people of same sex and age [89]. Other studies looking at severity indicated that teachers are not at increased risk of severe COVID-19 outcomes. More precisely, two preprints found that teachers were not at increased risk of hospitalisation, even after schools had re-opened [90,91]. In addition, a preprint study from Norway published in January 2021 comparing occupational risk during the first (26/02/2020-17/07/2020) and second (18/07/2020 – 18/12/2020) waves of the pandemic found that, while teachers did not have an increased risk of confirmed SARS-CoV-2 infection during the first wave, they did have a moderate increased risk (~1.25 times) during the second wave compared to people aged 20-70 years without a registered Standard Classification of Occupation code [90]. The authors also report a higher percentage of teachers being tested in the reporting period compared to other occupations, and it cannot be definitively concluded whether all teachers were infected in the school setting. Transmission from school-children to adults was, furthermore, found to be minimal in the primary school setting in Norway [92]. Measures implemented in Norway during the study period included physical distancing and clear messaging to stay at home if symptomatic but did not include face mask usage recommendations. An Italian study supported the finding from Norway, while further adding that compared to an age-matched general population of one Italian region, teachers were not at increased risk of a SARS-CoV-2 infection [76]. As with other studies cited in this report, the aforementioned studies relate to periods prior to the emergence and widespread transmission of the Delta variant.

4. What can be done to prevent and respond to SARS-CoV-2 transmission in school settings?

Summary

- In the context of circulating SARS-CoV-2 variants, including Delta, and given that children will be the largest unvaccinated population group in the EU/EEA by autumn 2021, it is important to ensure that appropriate in-school mitigation measures are in place and to have a high level of preparedness in the educational system so as to minimise the likelihood of SARS-CoV-2 transmission among students and staff.
- Measures implanted in school settings should be adapted according to levels of community SARS-CoV-2 transmission as well as the educational setting and age group. Implementation of measures should also consider balancing the need to prevent transmission with the need to provide children with an optimal learning and social environment.
- Implementing combinations of multiple physical distancing and hygiene measures can significantly reduce the possibility of SARS-CoV-2 transmission in school settings (high confidence).
- Mitigation measures to be considered in school settings include approaches that prevent crowding (class room distancing, staggered arriving times, cancellation of certain indoor activities), especially in older age groups, together with hygiene and measures to minimise transmissions (hand-washing, respiratory etiquette, cleaning, ventilation, face masks in certain circumstances and for certain age groups). Measures should be implemented taking into consideration the age groups and the measures' impact on learning and psychosocial development.
- It is important that testing strategies for educational settings aiming at the timely testing of symptomatic cases are established to ensure isolation of cases and tracing and quarantine of their contacts. When positive cases are identified, the school should be informed, contact tracing should be initiated according to local guidelines, and communication to and the testing of close contacts, ideally with rapid antigen tests, should be considered.
- Risk communication activities should focus on the three key stakeholder populations in schools: staff; parents/caregivers; and the pupils. Messages should emphasise the need for continued adherence to preventive measures in schools, while also acknowledging that outbreaks may still occur and temporary, localised school closures may be needed.
- Community engagement efforts should be based on a true partnership between the public health and educational authorities and the school community. Efforts to build partnerships require the authorities to actively listen to the concerns of the different stakeholder groups, and then responding to any areas of concern that are identified.
- Over the longer term, schools have a key role to play in fostering critical thinking skills as well as science and health literacy as a means of countering misinformation about the pandemic and other health-related issues.
- There is an established set occupational safety and health rules that applies to workplaces, including educational establishments. Employers should carry out a workplace risk assessment and set preventive measures that will protect workers in educational establishments. This includes psychosocial risks and any changes to previously set preventive measures caused by mitigation measures set to prevent SARS-CoV-2 transmission. They should also consult their occupational health services and workers, their representatives, or the health and safety committee on the preventive measures. The workplace risk assessment needs to address vulnerable groups, such as those with chronic diseases and pregnant and breastfeeding workers.

4.1 Preparedness for school openings for the 2021/2022 school year

As noted in other sections in this report, the Delta variant is significantly more transmissible than other known SARS-CoV-2 variants and is expected to be the dominant circulating variant in the EU/EEA by September 2021. Moreover, as COVID-19 vaccines have not yet been recommended for children under 12, and as countries have not prioritised adolescents (12-18 years) over other age and risk groups for COVID-19 vaccines, it is to be expected that vaccination coverage among children and adolescents will be very low, meaning that they will constitute an increasing share of new SARS-CoV-2 cases.

The WHO European Technical Advisory Group for schooling during COVID-19 concluded in June 2021 that keeping schools open should be a key objective [9]. Given the plausible context described above and accounting for the numerous adverse impacts of school closures, it is imperative that there is a high level of preparedness in the educational system, taking into account the measures outlined in the remainder of this section, so as to minimise the likelihood of SARS-CoV-2 transmission among students and staff. Public health authorities may consider reviewing existing guidance to take into account the latest epidemiological context as well as the latest evidence on the effectiveness of mitigation strategies. Where feasible, identifying good practices and areas for improvement for the control of SARS-CoV-2 in educational settings may be achieved through, for example, targeted in-action reviews (IARs) [93,94].

Measures implemented in school settings should be adapted according to levels of community SARS-CoV-2 transmission as well as the educational setting and age group. Implementation of measures should also consider balancing the need to prevent transmission with the need to provide children with an optimal learning and social environment.

There is an established set of occupational safety and health rules applicable to educational settings, which lay down employer obligations and rights of staff in educational establishments, for example related to the protection from exposure to biological agents at work [95,96]. Employers have to carry out a workplace risk assessment and set preventive measures to protect workers from risks to their occupational safety and health. The workplace risk assessment should be adapted when measures for the control of SARS-Cov-2 are implemented, and it should address psychosocial risks as well as any risk arising for vulnerable groups, such as workers with chronic diseases and pregnant or breastfeeding workers. Preventive measures should be consulted with workers or their representatives and the health and safety committee, if in place, and employers should also consult preventive services on the measures to be taken. The European Agency for Safety and Health at Work provides guidance, for instance on the measures to be taken when returning to work after a lockdown, which is also applicable after a period of absence from school [97].

4.2 Non-pharmaceutical interventions relevant to school settings

There are relatively few studies that have documented the effectiveness of non-pharmaceutical interventions (NPIs) in school settings. However, some initial evidence is starting to emerge. A modelling study assessed the risks of having a positive COVID-19 test in members of households that had a child having full-time in-person schooling. The risk was easily mitigated by implementing layers of NPIs at schools. The study estimated that simple measures like use of face masks, restricted entry to school, daily symptom checking, reduced class size and cancelling extracurricular activities had a dose-dependent effect on mitigating the risk of COVID-19 outcomes in the children's households. Notably, each measure was associated with a 7% decrease of the risk of a COVID-19 positive test (aOR, 0.93; 95% CI, 0.92 to 0.94), with daily symptom checking associated with greater risk reductions than the average measure [75]. Physical barriers and part-time schooling were not associated with significant decreases [75]. A preprint modelling study from the Netherlands suggested that, for secondary schools, twice-weekly screening of students and teachers would be effective at lowering infection rates in this setting [98].

In a recent cross-sectional analysis, school-level prevention measures were assessed in Georgia, USA. After adjusting for levels of community transmission, COVID-19 incidence was 37% lower in schools that required teachers and staff members to wear masks, and 39% lower in schools that worked to improve ventilation [99]. However, the study design, which did not allow for conclusions about causal relationships, could not account for the compliance of mask usage, and relied upon self-reporting of COVID-19 cases.

The WHO European Technical Advisory Group for schooling during COVID-19 has suggested implementing changes in the school environment that are likely to be of overall benefit to infection control and child health [9], while striking a balance between enabling learning and social interactions on the one hand, and infection control on the other.

ECDC's COVID-19 guidelines for non-pharmaceutical interventions present public health measures that aim to prevent and/or control SARS-CoV-2 transmission in the community, many of which will also apply to the school setting [100]. These consist of physical distancing measures as well as safety and hygiene-related measures.

Physical distancing measures can be achieved with different approaches, including:

- cohorting of classes and groups;
- ensuring physical distance in the classroom (e.g. separating tables/chairs);
- reducing class sizes;
- staggering arrival times, as well as meal and break times;
- holding classes outdoors; and
- cancelling, where necessary, extracurricular activities that entail spending a lot of time indoors (e.g. theatre plays, choir practice).

Physical distancing measures should aim at decreasing the number of individuals and contacts in confined or closed spaces while ensuring schooling can take place. The selection of measures should consider the current knowledge of disease transmission in different age groups, and the feasibility and appropriateness of the measures for the age group, including the need to ensure learning and psychosocial development, as well as potential physical and mental disabilities. It is important to consider the interactions within facilities among children/students, and between educational staff and the children/students, as well as among the educational staff/adults.

Examples of safety and hygiene-related measures include:

- the promotion of a 'stay at home when sick' policy;
- the promotion of respiratory hygiene and hand hygiene among teachers and students, providing sufficient facilities;
- ensuring appropriate cleaning of the facility;
- ensuring appropriate ventilation;
- implementing the use of face masks among educational staff and children. Advice on the use of face masks for children in the community has been issued by WHO [101].

Detailed information on the measures described above, including considerations for their implementation, can be found in dedicated ECDC guidelines and guidance, including ECDC's COVID-19 guidelines for non-pharmaceutical interventions [56,100,102,103]. Furthermore, guidance on school prevention measures are available from a range of public health institutes within the EU/EEA, as well as from international organisations [104-111].

4.3 Testing at schools and other educational settings

Testing methods

The laboratory diagnosis of COVID-19 follows the same principles in children (aged 0 to 17 years) as adults using specimen obtained from upper respiratory tract, for either nucleic acid amplification test (NAAT) or detection of virus-specific antigens by rapid antigen detection tests (RADTs) [112]. Ideally, rapid diagnostic tests should be employed.

Within educational settings, rapid diagnostic tests can be applied in the following ways:

- In the context of contact tracing, rapid diagnostic tests allow for a more rapid identification of infectious contacts. Rapid diagnostic tests have been shown to be more efficient in detecting cases in up to five days after the onset of symptoms and should therefore be used within this window of time, when the viral load is highest. For asymptomatic contacts of cases, tests should be performed as soon as possible after the contact has been traced. If more than seven days have passed since a known exposure, there may be an increased risk of a false negative test result by rapid diagnostic test due to a reduction at the viral load. In such cases, the test should be repeated by RT-PCR as quickly as possible.
- Rapid diagnostic tests can be used for screening staff or students in high-prevalence settings for example a large outbreak in a school setting as part of school-wide testing approach. The validated performance criteria of rapid diagnostic tests, and the importance of considering the overall prevalence of SARS-CoV-2 in the population, should be considered [113]. The first positive cases identified in an outbreak can be confirmed by RT-PCR. It also needs to be noted that in low prevalence settings, the positive predictive value of the RADTs decreases, and therefore positive cases should be confirmed with RT-PCR.

The European Commission and ECDC have published recommendations for the use of rapid antigen tests in different settings [109,110][114]. ECDC has outlined considerations for the use of rapid antigen tests in settings of low and high infection prevalence and the need for confirmatory testing [109].

Ideally, trained healthcare or laboratory staff, or trained operators, should carry out sampling, testing, test analysis and reporting of test results to clinical staff and public health authorities at the local, regional, national and international level. However, under specific circumstances the self-testing approach when using RADTs can be considered for individuals above 10 years. Self-tests may contribute to decreasing the risk of transmission when used by asymptomatic individuals prior to social interactions relevant to specific settings, such as visits to family/friends, appointments, travel and participation in events, as the self-test would identify infectious cases at the time of testing. They may also contribute to decreased transmission risk when frequent testing is done in places with high risk of exposure and those with large numbers of close interactions between individuals (e.g. educational settings). By using self-tests frequently to ensure individuals are negative prior to their attendance at school or other similar setting, together with the continued use of NPIs, the risk of transmission is further decreased [115].

Proper sample collection is one of the most important steps in the laboratory diagnosis of SARS-CoV-2. The sampling approach in children, if performed by a healthcare professional, is the same as in adults. Self-sampling is not recommended in younger children (e.g. age <11 years) and in order to ensure the strict compliance to sampling and safety instructions, sampling should be performed by an instructed adult for these cases. If a specimen is not collected properly, this may cause false negative or inconclusive test results. The detection of viral RNA by NAATs is usually performed on respiratory specimens, especially nasopharyngeal swabs. However, the collection of nasopharyngeal swabs is invasive, ideally requires experience and clear instruction, and has a risk of viral transmission to the sample collector. In a situation where a nasopharyngeal or other upper respiratory specimen is not acceptable and/or to increase the acceptance of children being tested, saliva could be considered as an alternative specimen for RT-PCR testing. However, the available limited data do not give a clear picture on whether children can be reliably diagnosed based on saliva samples and more studies are needed [116]. Additionally, current limited evidence does not support the use of saliva as an alternative sample material for RADTs. However, samples obtained through gargling saline solution have been successfully used for SARS-CoV-2 RT-PCR testing [57].

If instructions are strictly followed, good quality samples for SARS-CoV-2 detection can be obtained from children, indicating that children can be safely tested at any age. Children can be included in testing strategies given that the performance of diagnostic tests in children is expected to be broadly similar to in adults, assuming the use of the same sample type and sampling time.

Should any staff of educational establishments be involved for example in the process of collecting samples, then occupational safety and health measures would need to be set by their employer and this should be consulted as mentioned above with workers or their representatives and occupational health services. Such tasks need to be addressed through a workplace risk assessment.

Testing strategies

Testing guidelines and how to apply them in schools have been outlined in previous ECDC publications: 'COVID-19 testing strategies and objectives' [117], 'Objectives for COVID-19 testing in school settings – first update' [118], and 'COVID-19 in children and the role of school settings in transmission - first update' [1].

Testing strategies in school settings should aim to keep schools safe and open [9]. ECDC recommends that testing efforts, in community settings generally and in educational settings specifically, are maximised with the aim of offering timely testing to all symptomatic cases in order to ensure isolation of cases and tracing and quarantine of their contacts [117]. Since the aforementioned documents were published, RADTs have been introduced by many EU countries to increase testing capacity or shorten turnaround times for testing. Testing should be part of active surveillance aimed at early detection of all symptomatic cases, and potentially infectious asymptomatic individuals. A strategy for testing should be developed, and adapted through an ongoing assessment of the local epidemiological situation and laboratory capacity [117]. In the context of schools, testing strategies should be developed that aim to minimise the duration of school absences for pupils self-isolating.

Discussions on the appropriate testing strategy should be initiated before their implementation either at school level or at the level of regional authorities, for instance, including employers, workers, occupational safety and health authorities, and public health authorities. When testing strategies are designed and implemented at schools, students and workers (or their representatives) should be consulted and clearly informed about the procedures. The health and safety committee, where available, and the occupational physicians or occupational health services should be involved in designing and implementing it. Furthermore, testing at the workplace should be clearly embedded in the occupational safety and health management approach, and the results of testing should be considered in the regular revision of the workplace risk assessment.

Detection of SARS-CoV-2 positive cases in the school setting

Schools can minimise the spread of SARS-CoV-2 and increase the possibility of remaining open for in-person learning by expecting and planning for the occurrence of individual COVID-19 cases or clusters of cases among students and/or staff. A clear mitigation plan will help schools to respond quickly when one or more cases are detected. When an individual is suspected to have COVID-19 in a given class or school, testing of the suspected case, including confirmatory PCR testing, should occur and the individual should stay home from school until test results are available. If a case is confirmed to be positive, the school should be informed, and contact tracing should be initiated according to section 4.4 below.

An outbreak in a school setting is often defined as two or more PCR-confirmed cases occurring at a school during a 14-day period where transmission is not known to have occurred outside of the school. An outbreak continues until 14 days have passed without detecting any additional cases. If an outbreak is detected, local authorities should be notified to support with outbreak management, including contact tracing and testing. Non-pharmaceutical measures including physical distancing and safety and hygiene measures (see section 4.2) should be strengthened and additional measures, such as enhanced regular testing, information to students and their families, should be considered. Further restricting movement or contact between class groups and limiting student activities to their classroom cohorts may also be considered.

A protocol for the investigation of COVID-19 clusters and outbreaks in schools and other educational settings is available as part of the World Health Organization's Unity studies. It describes the different steps to investigate SARS-CoV-2 transmission following the notification of a COVID-19 case in a school, and provides guidance and links to case definitions, study design, questionnaires for cases and contacts, and contact tracing [119].

4.4 Contact tracing in the school setting

Contact tracing is important in school settings to rapidly identify secondary cases in order to avoid large outbreaks and the interruption of school activities. ECDC has published general guidance for management of persons who have had contact with COVID-19 cases [120,121].

Contact tracing should be carried out by or in close collaboration with local public health authorities, who may work closely with school authorities to define the most appropriate response based on an assessment of the local situation. In the context of schools, contact tracing should be designed so as to have as little disruption as possible on students and staff. Authorities should seek to ensure that decisions are well understood by staff, students and guardians. Contact tracing should be initiated promptly following the identification of a confirmed case and should include contacts in the school (classmates, teachers and other staff), household and other relevant settings, in accordance with ECDC or national guidance. Contacts should be managed based on their exposure category. Table 4 provides a general classification of contacts in line with ECDC contact tracing guidance [120].

Table 4. Classification of a contact in school settings, based on level of exposure

High-risk exposure (close contact)	Low-risk exposure
A person: • having had face-to-face contact with a COVID-19 case within two metres for more than 15 minutes over a 24-hour period (even if not consecutive); • having had physical contact with a COVID-19 case; • having had unprotected direct contact with infectious secretions from a COVID-19 case (for example, by being coughed on); • having been in a closed environment (house, classroom, meeting room, hospital waiting room, etc.) with a COVID-19 case for more than 15 minutes; • having travelled together with a COVID-19 case for more than 15 minutes using any mode of transport.	A person: • having had face-to-face contact with a COVID-19 within two metres case for less than 15 minutes; • having been in a closed environment (house, classroom, meeting room, hospital waiting room, etc.) with a COVID-19 case for less than 15 minutes; • having travelled together with a COVID-19 case for less than 15 minutes using any mode of transport.

All contacts who already have symptoms or develop symptoms during follow-up (high-risk and low-risk exposure contacts) should be tested as soon as possible to allow for case isolation and further contact tracing. Additionally, testing of asymptomatic high-risk exposure contacts allows for prompt isolation of new potential cases and early initiation of contact tracing of these new cases. High-risk contacts in school settings should be quarantined and actively followed up by the school or public health authorities. ECDC guidance on contact tracing provides further details.

Whereas sharing a classroom can be considered a high-risk exposure, the presence of effective mitigation measures that would lower the risk of some children can be taken into account. In view of the increased transmissibility of some VOCs enhanced contact tracing measures should be considered for cases suspected to be infected with a VOC, for example through an epidemiological link or laboratory pre-screening [122]. These enhanced measures are outlined in the ECDC publication 'Risk related to the spread of new SARS-CoV-2 VOCs in the EU/EEA – first update' [62].

As outlined in the ECDC publication 'Interim guidance on the benefits of full vaccination against COVID-19 for transmission and implications for non-pharmaceutical interventions' [123], vaccinated contacts that have been exposed to a confirmed case should continue to be managed according to existing ECDC contact tracing guidance [120]. However, health authorities may consider undertaking a risk assessment on a case-by-case basis and subsequently classify some fully vaccinated high-risk exposure contacts as low-risk contacts. Factors that need to be taken into consideration in such assessments include, for example, the local epidemiological situation in terms of circulating variants, the type of vaccine received, the age of the contact, or the risk of onward transmission to vulnerable persons by the contact [123].

4.5 Vaccination in school settings

As of 15 June 2021, one vaccine against COVID-19, Comirnaty by BioNTech/Pfizer, had received a conditional marketing authorisation to be administered to individuals above the age of 12 years [6,124]. BioNTech/Pfizer have also recently started a phase 2/3 trial among children 5-11 years old, using a smaller dose than the one given to individuals 12 years old or older, with results expected in September 2021. A phase 1 study is also ongoing among children younger than five years and is expected to move to phase 2/3 in the coming weeks [125]. In addition, EMA are currently evaluating the use of COVID-19 Vaccine Moderna for use in individuals aged between 12 and 17 years [126]. A phase 2/3 trial of safety and efficacy of COVID-19 Vaccine Moderna among children aged 6 months to 12 years is ongoing and results are expected after the summer [127]. As of 11 June 2021, five EU/EEA countries are planning to expand vaccination to all adolescents and in 14 countries the vaccination of children younger than 12 years is currently under discussion and decisions will be made at a later time if EMA authorises any COVID-19 vaccines for that age group[1] [128].

On 1 June 2021, ECDC published interim public health considerations for vaccination of adolescents against COVID-19. This report highlighted that vaccination of adolescents against COVID-19 should be considered in the broader context of the COVID-19 vaccination strategy for the whole population, including its overarching goals, the status of implementation, and its priorities. The individual direct benefits from COVID-19 vaccination in adolescents are expected to be limited in comparison to older age groups and the overall direct benefits depends on the epidemiological situation in each country. When vaccination for children (also for those aged below 12 years) is available, it will be important to carefully assess the benefit-risk profile of COVID-19 vaccination in different age groups of children for the different vaccine products available. It will also be important to assess the estimated marginal impact of vaccinating children both in terms of overall SARS-CoV-2 viral circulation and burden of COVID-19 (i.e. overall morbidity and mortality in the population). Another important consideration when deciding on expanding vaccination to low risk groups is equity issues concerning vaccine availability and access, both on a national but also on an international level. The relevance of vaccinating children should also be assessed for its potential impact on the emergence of new vaccine escape variants by reducing viral transmission in this age group [129].

School staff had been indicated among prioritized groups in several EU/EEA countries and by the WHO SAGE group [130]. However, as vaccine roll-out is proceeding, an increasing number of countries either already have or are about to commence to open up vaccination for all adults, which would then include also this group. As of 11 June 2021, ten countries have already opened up vaccination to any adult individual irrespective of age, underlying condition, or priority group [128].

4.6 Risk communication and community engagement

Communication activities related to outbreak prevention and control

As vaccination campaigns progress throughout the EU/EEA and an increasing proportion of the population is vaccinated, a slowdown of the pandemic is expected. With the older, more vaccinated generations now less susceptible to infection, younger generations – who are at lower risk of severe disease – will almost inevitably account for an increasing proportion of those who are infected, even if the absolute numbers do not increase substantially [129,131]. Risk communication activities need to explain this shift to the population, and in particular to the three key target populations in schools: teachers and other school staff; parents and caregivers; and the pupils themselves.

Even as the overall pandemic eases in the EU/EEA, outbreaks in school settings can still be expected. Educational authorities should work together with national and regional public health experts and occupational safety and health authorities to ensure that each of the three key target populations in schools identified above receives messages about any outbreaks that are appropriate for their particular position within the educational system, and that the messages from the different organisations are consistent. Age-specific messages should be developed for pupils.

It is also important to bear in mind that staff, parents/caregivers, and pupils are likely to perceive the threat from COVID-19 in different ways, and they may also respond differently to the various prevention and control measures. Messages should be shaped accordingly, and they should be disseminated through channels that are accessible and well known to the respective target populations.

Risk communication activities should focus on:

- Providing information about the prevention of COVID-19 in schools, with easily accessed materials highlighting national recommendations and protocols (e.g. via dedicated webpages from public health and occupational safety and health authorities) [105,132,133];
- Informing the school community, in language appropriate to age and literacy levels, of the importance of continuing to adhere to personal hygiene and other preventive measures in order to keep their school safe. For this, the use of reminders, stories, videos, can be useful [134-136];
- Raising awareness in the school community about the prevailing risks and the possible need to reinstate more stringent measures should epidemiological conditions deteriorate. Transparent communication is needed to explain that even if prevention measures are implemented, more transmissible variants are

[1] The question was asked before the conditional market authorisation for Comirnaty in individuals aged 12-15 years.

circulating, and there is also the potential for breakthrough infection and onward transmission, including among those vaccinated: the risk of transmission cannot be completely eliminated [137]. In addition, it is important for people to understand that the potential severity of disease for different members of the school community may vary depending on age, overall health, and vaccination status.

- Providing clear, step-by-step instructions regarding what to do in the event of an outbreak. Such instructions could include a checklist or set of standard operating procedures that indicate what school communities may expect to happen over the course of an outbreak; which authorities they should contact and under which circumstances; and a description of any activities they may need to undertake during the outbreak and subsequently [138]. Such information should also be adapted to the specific audiences where applicable (teachers/staff, parents/caregivers, and pupils).

While the primary responsibility for communication during an outbreak of COVID-19 lies with the authorities, it is also essential for schools affected by an outbreak to communicate clearly and regularly with the parents and caregivers, as well as with the pupils. In the event that a school – or specific classes within it – has to be closed, information should be provided by school authorities about the practicalities of any online teaching, and a likely timeframe should be given for when it may be expected that pupils can return to face-to-face lessons [138].

Community and child engagement

The UN Committee on the Rights of the Child (CRC) [139] notes that States parties should ensure that 'adolescents are given a genuine chance to express their views freely on all matters affecting them'. The WHO Technical Advisory Group for schooling during COVD-19 advises that children and adolescents 'should be enabled to participate actively in the decision-making process at school', and that 'children and adolescents from different age groups and all backgrounds, especially those who are more vulnerable, should be asked to provide their perspectives on the measures affecting them and whether they are helping or hindering them' [9].

A key principle for successfully engaging with community partners in the prevention and control of outbreaks is that, since they have a significant stake in the outcome, they want to be seen as genuine partners in the process [9,140]. Within the context of COVID-19 in schools, such partnerships should be built on a transparent, two-way dialogue between the public health, educational and occupational safety and health authorities and the three key stakeholder groups identified above: teachers and other school staff; parents and caregivers; and the pupils themselves. In addition to the authorities providing all necessary information, efforts to build partnership also require the authorities to actively listen to the concerns of the different stakeholder groups, and then respond to any areas of concern that are identified. Such listening – which requires dedicated resources [141] – can be done through, for example, (virtual) meetings of parent-teacher associations, social media monitoring, conducting rapid assessments, or by documenting the topics raised on dedicated telephone hotlines.

Community engagement efforts could also extend to facilitating the vaccination of adolescents, if national strategies include them among the eligible groups, with schools considered as possible settings for vaccination. Studies on vaccine acceptance emphasise the importance of making vaccines available in safe, familiar, and convenient settings [142]. As such, schools are among the venues that may facilitate uptake [143,144].

Key role of schools in health literacy

The challenges of misinformation and disinformation (with the latter defined as the *deliberate* spread of misinformation) circulating online over the course of the COVID-19 pandemic have been widely highlighted by governments and health organisations. There is also recognition that the spread of this 'infodemic' can be as dangerous to human health and security as the pandemic itself [145]. However, schools can play an important role in the multi-stakeholder and multidisciplinary approaches to address this issue. A recent ECDC report [146] on countering online misinformation points to the need for pre-emptive interventions aimed, from an early age, at promoting critical thinking skills and increasing science, health and media literacy. The United Nations Educational, Scientific and Cultural Organization (UNESCO) also highlights the importance of addressing the denial of scientific knowledge and the need to actively fight misinformation, not least through having scientific literacy as a component of the educational curriculum [147]. In addition, health literacy itself is considered a key skill that should be included in a whole school approach and school curricula [148,149].

To this aim, public health authorities could work with educators to develop appropriate school-based curricula based on up-to-date scientific information [146]. Such skills-building, targeting all school age groups, could contribute to developing wider resilience to misinformation and its adverse impacts.

Gamification can act as a complementary approach to teaching such skills. One example, specifically in relation to misinformation about COVID-19, is Go Viral! (recommended for 15-year-olds and older) [150]. Another game, Bad News, teaches the mechanisms behind the spread of disinformation, and has a junior version, recommended for 14-year-olds and older, as well as information for educators who wish to use it as a teaching resource in class [151].

5. What are the social and economic impacts of school closures?

Summary

- School closures are one of the most disruptive measures implemented during the COVID-19 pandemic, as they have multiple adverse social, educational, health and economic impacts.
- The loss of learning due to prolonged school closures are estimated to be very large (high confidence) and include learning loss, reduced educational performance, increased risk of disengagement and school dropout
- Child and adolescent health have been negatively impacted by prolonged school closures (high confidence). Studies indicate an increase in mental health issues such as social isolation, psychological distress, anxiety and depressive symptoms. Screen time, social media use, sedentary behaviour, and unhealthy dietary habits have increased, while physical activity has decreased.
- Prolonged school closures have exacerbated existing inequalities in society, by having a disproportionate impact on more vulnerable children, caregivers, families, and communities (moderate confidence). In the event of future school closures necessitated by outbreaks, it is important that a remote learning infrastructure is designed to reach all students.
- The economic cost of prolonged school closures is estimated to be high (moderate confidence) and includes direct learning loss, lower skills in the labour force, less productivity, and loss of potential future earnings, as well as loss of parental productivity and income.

5.1 Health and educational impact on children due to disruptions in education

School closures are one of the most disruptive measures put in place during the COVID-19 pandemic. School disruptions (full or partial as well as temporary or prolonged closures) have multiple impacts. In 2020, prolonged school closures upended life for children, educators and families generating high social, educational, health and economic impacts for pupils, teachers' families, and society.

Educational impacts

The loss of learning due to prolonged school closures are estimated to be very large (high confidence). Remote learning quality and effectiveness is significantly lower than in school learning and varies greatly by context and learners' background. Educational impacts of school closure include direct loss of learning, reduced educational performance, increased risk of disengagement and school dropout and other challenges due to the interruption in learning [152]. Decreased motivation in school- and homework has also been described [153].

A study based on the eight-week school closure due to the pandemic in the Netherlands, reveal a learning loss equivalent to one-fifth of a school year, the same period that schools remained closed. Losses were up to 60% larger among students from less-educated homes, confirming worries about the uneven toll of the pandemic on children and families [154]. These results are from a setting with favorable conditions with a short lockdown, equitable school funding, and high broadband access. The UCL Institute of Education (US) estimates that children have been spending an average of only 2.5 hours a day on schoolwork, with 71% of state school children receiving no more than one online lesson a day [155,156]. The World Bank estimates that COVID-19 could result in a loss of 0.6 years of schooling adjusted for quality, bringing down the effective years of basic schooling that children achieve during their schooling life from 7.9 years to 7.3 years [157].

Children's learning experiences have been negatively impacted with large disparities across families in the amount of time spent learning, activities undertaken during this time, availability of resources to support learning and an increased dispersion of test scores [158]. Concurrent effects on the economy make parents less equipped to provide support, as they may struggle with economic uncertainty or demands of working from home [159].

The policy implications and measures required to recover learning loss due to the pandemic school closures are considered to be extensive [160].

Health impacts

Children and adolescent health have been negatively impacted by prolonged school closures (high confidence). Viner et al. performed a systematic review [161] on the short-term impacts of school closures on child health and well-being. Based on 72 studies included from 20 countries, results show school closures generate considerable impact on children and adolescent's mental health as between 18-60% of young people were found to be at risk for psychological distress, particularly anxiety and depressive symptoms. Screen time and social media use increased, physical activity was reduced while sedentary behaviour and unhealthy dietary habits increased.

A study based on the school closure in the UK in the spring and summer of 2020 shows a significant rise in emotional and behavioural difficulties among primary school children, a rise that was greater for children who were not prioritised to return to school for six weeks before the summer holiday. The study found a slight improvement in well-being once schools reopened in September, but not to pre-pandemic levels, and the gap between those who missed out on more versus less time in school during the summer term remained wide. This suggests that the potentially negative impacts of the rounds of school closures on children's mental health are likely to remain for longer time [162]. During the pandemic older children in the UK had much higher levels of emotional difficulties than would be expected at their age [163]. Apart from mental and emotional impact on child health, show negative impacts on parental well-being, stress and health related behaviours [164].

Modelling estimates suggests the school closures in 2020 are associated with a decrease in life expectancy for children in the US due to the reduced educational attainment [165]. Children have also been found to be at increased risk of domestic violence when schools are closed [165].

5.2 School closure and social inequalities

The fundamental challenges relating to social inequalities and the school closures implemented during the COVID-19 pandemic have been highlighted in a previous ECDC report [1]. Overall, school closures are associated with substantial adverse impacts in children, which tend to exacerbate existing inequalities in a society, by having a disproportionate impact on more vulnerable children, caregivers, families, and communities. Evidence has been presented on the unequal burden that school closures have placed on vulnerable populations in relation to food poverty [166], sub-optimal access to reading materials (physical and digital) [166], and limited opportunities for parental support with homework and other activities [167]. The particular burden of school closures on children living with disabilities and/or chronic conditions (and on their caregivers) has also been highlighted [167,168].

Subsequent evidence has confirmed that these core challenges remain essentially unchanged [169,170]. It is therefore important now to consider (i) the re-opening of schools in autumn 2021, bearing in mind that some outbreaks in schools are likely to occur and that localised and temporary school closures may therefore be necessary, with the risk that vulnerable children will likely continue to be disproportionately affected; and (ii) the longer term rebuilding of educational systems, with an aim of addressing the pre-existing inequalities that have been exacerbated over the course of the pandemic [171].

Addressing the first, shorter term issue would require implementation of programmes that ensure equity and that align resources with needs; that provide a remote learning infrastructure which is designed to reach all students; and that support teachers in these aims [171]. culture of innovation in addressing inequalities should also be encouraged, and lessons learned from national and international experiences in this area should be shared and implemented [171].

5.3 Economic impacts of school closures

The economic cost of prolonged school closures is estimated to be high (moderate confidence). The World Bank estimates that the generation of school pupils who suffered from school closures due to COVID-19 during 2020 will forego at least US$10 trillion in potential future earnings [157]. By this measure, the world could stand to lose as much as 16 percent of the investments that governments make in the basic education of this cohort of students. The estimate is based on a loss of between 0.3 and 0.9 years of schooling, bringing down the effective years of basic schooling that students achieve during their lifetime from 7.9 years to between 7.0 and 7.6 years. On average, students of this cohort face a reduction of 355 to 1 408 US dollars in annual earnings. In present value terms, this amounts to between 6 472 and 25 680 dollars in lost earnings over a typical student's lifetime.

The OECD assessed long-term GDP loss due to learning loss in 2020 of a third of a lost learning year among students in grades 1-12, which would lead to lower skills in the labour force and less productivity. The projected costs were substantial: over 3 087 billion US dollars (~2 546 billion Euros) for Germany and 2 137 billion US dollars (~1 762 billion Euros) for France [172]. Loss of parental productivity and income and the potential impact on job security due to prolonged school closures are also considered substantial which causes continued economic harm to families and to parental economic activity [173,174]. In addition, the impact of school closures on the labour market may differ by sex in some settings, further exacerbating existing inequities: research from the US, for example, found that the closure of state-level childcare facilities (children under 6) were associated with greater reductions in employment in women than men [175].

Implementing in-school mitigation measures for safe schooling in the pandemic is relatively affordable [176]. Investing in mitigation measures, capacity building and other supportive measures for schools and teachers to ensure continued learning is therefore strongly encouraged [160].

Increased use of remote teaching and disruptions caused by confinement measures linked to outbreaks may also put educational staff at strain. The European Agency for Safety and Health at work has published guidance on measures to reduce risks from teleworking and has collected good practice examples and guidance from across Europe to support educational establishments and teachers in protecting their health and safety [177,178]. Support is needed for teachers to implement distance learning and ensure smooth transitions between periods of distance learning and presential education. Educational establishments should include these issues into their workplace risk assessment and design appropriate measures.

6. What evidence is there for the effectiveness of school closures in containing COVID-19?

Summary

- While a measure of last resort, school closures can contribute to a reduction in SARS-CoV-2 transmission (moderate confidence), but by themselves are insufficient to prevent community transmission of COVID-19 in the absence of other non-pharmaceutical interventions (NPIs) and continued vaccination roll-out (moderate confidence).
- Consistent with the general hypothesis that SARS-CoV-2 transmission appears to be more likely by older than younger children in the school setting, there appears to be a greater effectiveness in reducing community SARS-CoV-2 rates by temporarily closing secondary schools than primary schools (moderate confidence).
- The effectiveness of school closures appears to have been higher during the first wave of the pandemic than in subsequent time periods (moderate confidence), perhaps in part because in-school mitigation measures improved with time.
- Modelling to estimate the effects of school closure on overall SARS-CoV-2 community transmission found that the closure of secondary schools had the strongest impact on community transmission (10% reduction of Rt; with 95% credible interval 2%-20%), followed by closure of higher education (8%; 1%-16%). Compared to this, closure of primary schools (4%; 1%-10%) and of day nurseries (2%; 0%-6%) had smaller estimated effects.

6.1 Effectiveness of school closures in containing SARS-CoV-2 transmission

The evidence on effectiveness of school closures have been highlighted in previous ECDC reports [1]. Based on assessments from the first waves of the COVID-19 pandemic in 2020, school closures were generally assessed to contribute to a reduction in SARS-CoV-2 transmission but not deemed sufficient to prevent the spread of COVID-19 [1,179].

The effectiveness of school closures is likely driven by two factors. Firstly, children at home have fewer social contacts, secondly and, potentially more significantly, school closures have the indirect impact of parents needing to stay home with their children and thus curtailing their social mixing. Importantly however, models have not generally been able to decipher between these two factors [180]. Moreover, as school closures have typically occurred alongside a wide range of additional mitigation measures, causal inference is highly challenging [1,76,181].

There appears to be an age gradient in the effectiveness of school closures. An age-structured model from the Netherlands concluded that, with unchanged non-school contacts, closing schools in November 2020 could reduce R_e by 8% for 10-20-year-olds, 5% for 5-10-year-olds, and by a negligible amount for 0-5-year-olds [81]. The biggest impact on community transmission was thus achieved by reducing contacts in secondary schools. Similarly, a modelling study from England concluded that reopening secondary schools would have a greater impact on SARS-CoV-2 transmission than would reopening primary schools [182].

Effectiveness estimates of closing schools during the first wave were generally measured relative to pre-pandemic behaviour. Results indicate that in the second wave, with in school mitigation measures in place, the effectiveness of closing schools has been assessed to have been lower than it was during the first wave [76,183]. Nonetheless, in the subsequent waves, with widespread community transmission of SARS-CoV-2 VOCs (with high transmissibility), the risk of onward transmission in schools is increased [184].

6.2 Effectiveness across different waves of the pandemic: ECDC modelling

We used modelling to estimate the effects of closure of four school systems (day nurseries, primary schools, secondary schools, higher education) on community transmission of SARS-CoV-2 in the EU/EEA. In brief, we fitted a Bayesian model of the time changing community transmission (measured as the instantaneous reproductive number, Rt [185,186]) as a function of school closures, while accounting for other non-pharmaceutical interventions (NPIs), between-country differences, and time-evolving effects (fatigue or seasonality). The model makes use of the ECDC-JRC Response Measure Database [10,187], which collates the implementation and timing of NPIs across the EU/EEA. To avoid confounding by different subnational policies, we included only those Member States where NPIs were implemented mostly on a national level (Austria, Czechia, Finland, Poland, Iceland, Slovenia, and Estonia).

Consistent with the discussion from 6.1, we found that closure of secondary schools compared to other school types had the strongest impact on community transmission (10% reduction of Rt; with 95% credible interval 2%-20%), followed by closure of higher education (8%; 1%-16%). Compared to this, closure of primary schools (4%; 1%-10%) and of day nurseries (2%; 0%-6%) had smaller estimated effects. These effects were estimates for the late part of 2020 (from 1 July until 30 November 2020), while for the early 2020 we find that the effects of school closure were around 1.1-times higher. These effect estimates contain substantial amounts of uncertainty, which is due to limited occurrences of school closures and because they were commonly implemented together with other NPIs. This also means that even as we account for other effects of NPIs, the potential for confounding remains.

These estimates are comparable to the estimates from other modelling studies: Brauner et al. [188] estimated for 41 countries including the EU/EEA that closure of all schools between January – May 2020 reduced Rt by around 37%, although this study could not disentangle the individual effects of closing only schools, or only universities [188]. Davies et al. [189] estimate this effect for the second wave in the UK to be around 13%, and Gandini et al. [76] did not find any conclusive effect of school closure on Rt during the second wave in different regions of Italy.

Many factors could explain a larger effect of school closure in the early part of 2020 as compared to later. In the first period of intense NPIs, apart from schools many other venues were closed. Thus, there were fewer options for social contacts outside of the households as compared to later in 2020, where places like malls or outdoor entertainment venues might have been open. Schools across countries have also implemented various measures to reduce transmission and avoid temporary closure. This baseline level of improved hygiene and social distancing measures may be an important contributor to a reduced effect of school closure in late 2020, highlighting the importance to keep such measures in future.

In the current context, with a greater dominance of more transmissible variants such as Delta, combined with the continued roll-out of vaccination among adult groups, SARS-CoV-2 circulation is expected to be increasingly predominant in younger people, who will remain the largest susceptible unvaccinated population (pending decisions regarding vaccination of adolescent or younger age groups). These factors could increase the relative effectiveness of school closures on community transmission in the future, vis a vis other NPIs which would have less effectiveness among fully vaccinated persons. However, given that vaccination of older age groups is expected to lead to reduced rates of overall community transmission, hospitalisation and mortality, blanket policies of school closures are unlikely to be needed as a measure to reduce overall community transmission under scenarios in which the healthcare burden from COVID-19 is much lesser than it has been thus far. Increased incidence in a given school settings can be addressed through testing, contact tracing and other outbreak management approaches (see Section 4), including time-limited closure of a class or school when transmission within the school is widespread and not possible to control through other means. If large community outbreaks occur or community transmission is not possible to control through other means, temporary reactive school closures may be considered as a last resort.

Limitations

This technical report is based on information and data available to ECDC at the time of publication. Many of the studies referred to in this report were conducted prior to the emergence of new VOCs of SARS-CoV-2, notably Delta.

Most case-based surveillance systems in the EU/EEA countries do not collect information that would allow public health authorities to identify outbreaks or clusters in specific schools without notification from the school itself. A key limitation from currently available household and community studies, particularly for those conducted during 2020, is that many were conducted when lockdowns and school closures were in full or partial effect, meaning that children had fewer than normal social contacts. Case identification in children may also have been limited, particularly during the 'first wave', where children may not have been prioritised for testing or medical care due to significantly less frequent severe outcomes than e.g. older adults. Many countries are not testing asymptomatic cases, so it is difficult to detect and understand transmission among mild or asymptomatic children and teachers. It is difficult to identify all potential routes of transmission within school settings as some activities have been limited (e.g. school sporting events, after-school activities, travel to and from school, children's play dates, mixed mass gatherings of students and adults such as school concerts, performances, and graduations, etc.). The potential impact of allowing such events to take place within the school setting is still unknown. Studies that have modelled and/or assessed the impact of school closures on the control of SARS-CoV-2 transmission are challenged due to the potential overlaps with many other NPIs introduced concomitantly, particularly during the first half of 2020. This document only considers school settings/educational facilities and therefore does not consider other settings where children may commonly gather when away from home.

Conclusions

The role of children and schools in SARS-CoV-2 transmission will continue to be an important area of attention in the 2021/2022 school year. As increasing numbers of adults are becoming fully vaccinated in the EU/EEA, children are expected to be the group with the lowest vaccination coverage – particularly for children under 12 years, for whom no vaccine has thus far been recommended. This context, in combination with the continued circulation of the Delta variant, which is significantly more transmissible than other known SARS-CoV-2 variants and is expected to represent 90% of all circulating SARS-CoV-2 in the EU/EEA by September 2021, means that children and adolescents will likely represent an increasing share of new SARS-CoV-2 cases during the upcoming school year.

Meanwhile, children and adolescents suffer much less frequently from severe outcomes for COVID-19 than do all other age groups, and there are many adverse societal impacts from school closures. Thus the consensus remains that school closures should be a measure of last resort during the COVID-19 pandemic [9]. It is nonetheless acknowledged that situations of high levels of community SARS-CoV-2 transmission, should they be combined with capacity shortages in the healthcare system, could necessitate that all possible NPI measures, including school closures and/or the transition to remote learning, end up being considered for implementation.

To prevent school closures from occurring, and to provide the highest level of protection to students, educational staff, and their family members, appropriate combinations of physical distancing and hygiene measures, as well as occupational safety and health measures, should be implemented in all school settings. Over the summer and prior to the beginning of the autumn school term, there is the possibility to reflect upon and identify good practices and areas for improvement within educational settings, so as to optimise societal prevention, preparedness and response efforts directed at the COVID-19 pandemic.

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All external experts have submitted declarations of interest, and a review of these declarations did not reveal any conflicts of interest.

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