UNMC | NEBRASKA MEDICINE

GLOBAL CENTER FOR HEALTH SECURITY

The Science of COVID-19 in Children and Schools

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EXECUTIVE SUMMARY

As we approach the opening of the 2021-2022 school year, research and experience has provided us with much better understanding of the transmission dynamics of COVID-19 in pediatric populations and school environments, as well as of mitigation strategies that are most effective in maintaining a school environment that is healthy for students, school employees, and the community at large. Appropriate mitigation strategies for schools are especially important this year, as the consensus necessity for in-person school attendance is in tension with the increased transmissibility and severity of disease associated with the Delta variant severe acute respiratory syndrome coronavirus – 2 (SARS-CoV-2). To control transmission of Delta variant during full in-person attendance in schools, maximum vaccination rates as well as layered non-pharmaceutical interventions (NPIs) are supported by science. A full assessment of current scientific data confirms that many previous assumptions regarding the burden of COVID-19 in children and adolescents, the risk of transmission in schools, and the effect of school-aged case rates on communities were incorrect as they were based upon studies with insufficient data or confounded analyses. Based upon the most up-to-date data, it is evident that:

- Children are equally susceptible to infection with SARS-CoV-2 (COVID-19) as are adults, but a higher likelihood of no or mild symptoms and testing discrepancies lead to much lower rates of ascertainment (recognition) of cases in the pediatric population.
- COVID-19 fatalities are relatively rare in individuals under 18 years old, but many in this age group are ill enough to require hospitalization and may have long-lasting detrimental effects from COVID-19 or its associated multisystem inflammatory syndrome in children (MIS-C).
- The rate of long-COVID and prolonged after-effects of SARS-CoV-2 infection have been under-appreciated in children and adolescents. Based upon current studies, it is likely that tens-of-thousands (or more) of U.S. children have suffered long-term consequences of COVID-19 lasting at least several months.
- Because the vast majority of school surveillance studies did not regularly test asymptomatic students, the extent of school-associated COVID-19 cases has been significantly under-estimated.
- Studies that rigorously examined the association of in-person school operations and community COVID-19 impact found a direct correlation between schools operating with in-person learning and higher rates of community cases and deaths.
- Studies that measured school COVID-19 transmission rates in the setting of aggressive layered NPIs (universal face mask rules, de-densification, enhanced air-exchange and environmental hygiene, etc.) found relatively low rates of COVID-19 by active surveillance testing.
- Universal wearing of face masks is a highly effective intervention for limiting COVID-19 transmission in communities and has been shown to be effective in schools.

In summary, Delta variant will provide a dramatically increased challenge for safe in-person schooling during the coming fall semester. In addition to high rates of vaccination in eligible populations, layered NPIs (including universal masking) are evidence-based strategies for the 2021-2022 school year.

Introduction and Background:

The role of children in COVID-19 transmission and the impact of disease on pediatric populations remain some of the most misunderstood features of the pandemic. Early observations regarding COVID-19 in children rested on confounded epidemiological studies that did not account for under-testing and under-ascertainment in pediatric populations or for the fact that adolescents and younger children are much more likely to experience infection with mild or no symptoms compared to their adult counterparts. These features led many public health officials to believe that SARS-CoV-2 infection was much less common in children, children were less likely to spread the disease, and the risk of transmission in school settings was low. With additional evidence and experience from 18 months of COVID-19 spread in communities, it is now clear that these early assumptions were mistaken. The incidence of SARS-CoV-2 infection in children is as high as in adults, if not higher. COVID-19 mortality is relatively low in children, but **the impact of COVID-19 hospitalization and long-term morbidity in children is much higher than initially assumed**. Transmission of COVID-19 among school-aged children and in schools happens much more frequently than is reflected in studies of passive case ascertainment, and **high rates of infection in school-aged children can be a driving factor for transmission in the community resulting in overall elevated rates of cases, hospitalizations, and deaths.**

Although schools represent an inherently high-risk environment for COVID-19 transmission, in-person schooling is paramount for healthy child development. Community and public health leadership across the U.S. emphasize that in-person schooling must be prioritized during the ongoing COVID-19 response. Research and experience from the 2020–2021 school year provide evidence that layered non-pharmaceutical interventions (NPIs) can significantly reduce the risk of COVID-19 transmission in school settings, making school attendance possible in periods of elevated community transmission.

Targeted and layered mitigation measures, including vaccination in eligible children and broadly implemented NPIs, are essential in limiting risk for in-person education for children and young adults. These interventions have become more important in the face of the Delta variant and other more transmissible, more virulent SARS-CoV-2 variants of concern. Guidance documents from the Centers for Disease Control and Prevention (CDC) and the American Academy of Pediatrics (AAP) clearly state that NPIs, including universal face masks, will be critical in reducing risk for in-person schooling this year[i] [ii].

Scientific Evidence:

This paper provides the scientific underpinnings for current guidance on facemasks and NPIs for schools and lays out evidence to dispel much of the misinformation and myth that still permeates public discussion regarding COVID-19 in school-aged children.

1. The burden of COVID-19 in adolescents and children is much higher than previously recognized.

Official case counts (from laboratory-confirmed testing data) have underestimated the frequency of infection in children, because (1) COVID-19 testing has been reserved for higher-priority (older) populations in times of scarcity, (2) testing is usually triggered by symptomatic disease, (3) children more frequently experience mild or no symptoms with COVID-19, and (4) many parents refuse to present children for COVID-19 testing[iii],

- Children under 18 account for 12.7% of the total confirmed COVID-19 cases in the U.S., although they comprise 22.3% of the population, giving the appearance that pediatric infection rates are much lower than those in adults[iv].
- Seroprevalence (antibody) data show that the age group of 0–17 years has substantially higher rates of SARS-CoV-2 infection than any other age demographic[v].
- Targeted seroprevalence studies have confirmed significant under-ascertainment of cases in pediatric populations – one study from Mississippi found that actual pediatric infections were likely more than 12-fold higher than what was reported in official public health statistics[vi].
- Rather than the roughly 3.6 million officially reported COVID-19 cases in persons 0–17 years old in the U.S., CDC epidemiological analysis estimates 26.8 million infections in kids[vii].

Morbidity in children is also much higher than previously appreciated. It is thankfully true that overall COVID-19 mortality in the U.S. pediatric population has remained low—with only 540 recorded deaths[viii]. The number of children who have been ill enough to be hospitalized with COVID-19 is not small, however:

- Data from AAP and Children's Hospital Network surveillance indicate that pediatric patients account for over 2% of all COVID-19 hospitalizations[ix].
- The CDC estimates more than 209,000 COVID-19 hospitalizations in U.S. children since the beginning of the pandemic[x].

The immediate impact of hospitalized pediatric COVID-19 remains unclear. Still, studies suggest that more severe COVID-19 infection and cases of multisystem inflammatory syndrome in children (MIS-C) can significantly impact short and long-term health and well-being.

- A study published this month in *The Lancet Child & Adolescent Health* documented that one-third of pediatric patients hospitalized with neurological manifestations of COVID-19 had residual deficits after discharge[xi].

Evidence continues to grow regarding long-term, post-COVID sequelae on the health and well-being of children.

- A recent study found that 24% of children hospitalized with COVID-19 had long-lasting symptoms, including fatigue, sleep disturbance, and sensory deficits seven months after discharge[xii].
- For non-hospitalized children with COVID-19, a UK study from their January, 2020 epidemic wave of the Alpha variant found that 4.4% had persistent symptoms lasting at least a month. A Swiss study found that 4% of children and adolescents had symptoms beyond three months[xiii] [xiv].
- A recently-published study from Norway found that 52% of 16-20 year-olds with non-hospitalized COVID-19 had persistent post-COVID symptoms at six months, most commonly loss of smell, fatigue, shortness of breath, loss of memory, and difficulty concentrating[xv].

Until we have more data about the full impact in children of acute COVID-19 and MIS-C, including residual morbidity, long-COVID syndrome, and potential long-term developmental, neurocognitive, and behavioral effects, we should be careful in adopting a cavalier attitude about SARS-CoV-2 infection in children.

2. Experts initially underestimated COVID-19 incidence in schools and its effect in augmenting transmission in communities.

Similar to how pediatric COVID-19 cases are underestimated in the community, lower incidence of symptomatic infection and limited testing has significantly confounded school-based epidemiological studies and under-represented the burden of COVID-19 in schools[xvi]. Studies frequently cited as demonstrating lower cases and clusters in schools compared to the community relied on standard symptom identification and contact tracing for case ascertainment among children. As the CDC notes, this approach dramatically underestimates infection rates in children, and epidemiological studies that have systematically tested children regardless of symptoms have found rates equal to or greater than those of adults in the community[xvii]. In the few studies that have used systematic surveillance testing of school-aged children without regard to symptoms or documented contact, COVID-19 rates have far exceeded what is detected through standard surveillance.

- A pilot study by UNMC found a six-fold higher rate of COVID-19 in children monitored by regular surveillance testing compared to standard ascertainment[xviii].
- A recurrent nationwide surveillance study in the UK (REACT) similarly found rates roughly 10-times higher than in school-aged children when school is in session compared to national laboratory reporting of weekly cases[xix].
- REACT Round 12 analysis documented the early predominance of school-aged children in driving the rise of the current UK wave of Delta variant infection[xx].

Ample evidence now exists to dispel the misperception that children do not readily transmit COVID-19, and the ability of children and adolescents to effectively infect contacts is well established.

- Extensive contact tracing studies in South Korea demonstrated that secondary household transmission was highest when index cases were 10–19 years old[xxi].
- A CDC study of household transmission in two U.S. states found secondary household transmission rates were equally high when index cases were under 12 years old compared to adults[xxii].

School-associated transmission can result in school clusters as well as accelerating transmission in local communities. Large school outbreaks are well-documented; one of the best characterized being an outbreak in a secondary school in Israel that resulted in 13% and 16% of students and staff being diagnosed with COVID-19 within two weeks of school opening[xxiii]. A variety of studies demonstrate an association between increased community COVID-19 and in-person attendance in schools:

- One study from Sweden showed increased incidence of COVID-19 in parents and teachers of in-person primary school learners[xxiv].
- Another study of Ohio counties showed a significant correlation between on-premises school attendance and COVID-19 deaths during the fall of 2020[xxv].
- An analysis of more than 3,000 U.S. counties demonstrated lower calculated COVID-19 effective reproductive number (R_{eff}) in counties without full in-person learning[xxvi].
- A recent publication in *Science* led by Justin Lessler from Johns Hopkins University described a study of survey results from 2.1 million Americans showing a significant increase in COVID-19 illness in households with a child engaged in full-time, in-person schooling[xxvii].

3. Delta variant creates more urgency for efforts to protect children and schools from outbreaks.
The Delta variant (B.1.617.2) has rapidly replaced other forms of SARS-CoV-2 in areas where it has become established and is causing rapidly expanding epidemics in the U.S. This virus is a major departure from previous coronaviruses that cause COVID-19 – it is dramatically more infectious and causes more severe disease. The increased transmissibility and virulence of the Delta variant have also helped to unmask the importance of child and adolescent COVID-19.

- Studies from Scotland, Singapore, and Canada indicate that Delta variant is two to four times more likely to result in hospitalization, oxygen requirement, intensive care unit admission, and death[xxviii xxix xxx].
- Delta variant has been associated with higher rates of re-infection in UK surveillance[xxxi].
- Delta variant transmission during the current wave in the UK was primarily driven by cases in children, adolescents, and young adults[xxxii]. UK schools were in session until late July.

The impact of the Delta variant is now being felt in the U.S., particularly in states in the South, Midwest, and Mountain West that have relatively low vaccination rates. Many states report hospitalization rates that mirror the fall/winter 2020 wave, with increased hospitalizations under 60 years of age. As of August 6th, Louisiana, Arkansas, and Florida have a higher number of COVID-19 ICU admissions than at any other time in the pandemic.

4. Layered NPIs effectively reduce transmission risk in schools.
A layered strategy of NPIs will be required to reopen schools with full in-person attendance while avoiding increased morbidity in children and amplified epidemics in communities. Vaccination is the most important intervention to limit transmission in schools. A high percentage of vaccination among students and staff reduces the effective reproductive number (R_{eff}) and limits opportunity for rapid growth. High vaccination rates in family and community members around schools reduces virus introduction into school populations. Therefore, maximizing vaccine uptake remains crucial to safe school operation. In addition, research and experience from the last year provide evidence that a combination of NPIs can mitigate the risk of school-associated transmission and reinforce the importance of such interventions in making in-person learning as safe as possible:

- While the Lessler study showed increased household COVID-19 associated with in-person schooling, it also demonstrated a "clear dose-response relationship with the number of mitigation measures implemented and the risk of COVID-19 outcomes" with more mitigation measures resulting in lower incidence of COVID-19[xxxiii].
- A surveillance testing study of 14 schools in Zurich in December 2020 found low incidence of infection in students and staff. All schools had multiple NPIs in place at the time[xxxiv].
- A contact tracing and testing investigation in schools in Salt Lake City found evidence of low rates of transmission in elementary schools that had implemented multiple NPIs, including high rates of face mask use[xxxv].
- A New Jersey boarding school implemented a comprehensive mitigation strategy with layered NPIs, including surveillance testing, isolation/quarantine, and universal face mask wearing. The school experienced very low rates of student and staff infections despite high community transmission[xxxvi].

5. Universal wearing of face masks is a critical component of layered NPIs for high-risk environments such as schools.

Vaccination is the most effective intervention to protect individuals against COVID-19; when applied across a population, it can substantially reduce transmission. Unfortunately, COVID-19 vaccination is currently unavailable to children of primary school age (under 12 years), and vaccination rates in secondary school students and staff in Nebraska remain well below the ~85% theoretical herd immunity threshold for Delta variant. Therefore, universal masking will remain a critical component of NPIs to reduce risk in schools.

Mask wearing is essential in higher-risk group settings because of the nature of transmission of COVID-19:

- The preponderance of evidence now confirms that most SARS-CoV-2 transmission events come from individuals who are without symptoms at the time[xxxvii] [xxxviii].
- Small, airborne respiratory particles that can travel over distance are a significant mode of transmission for SARS-CoV-2[xxxix] [xl].
- Concentration of people (and exhaled breath) in a volume of air is a more important gauge of risk than physical distancing. Indoor environments increase this risk while reducing the concentration of exhaled (and inhaled) particles with masks decrease the risk[xli].
- The epidemiology of COVID-19 is characterized by a high dispersion factor of the reproductive number (R), explaining how super-spreading events play a critical role in community propagation. Simply speaking, a small number of infected individuals are responsible for the majority of onward transmission. Thus COVID-19 transmission usually occurs in clusters. Targeted NPIs that focus on high-risk venues for super-spreading (e.g., schools) have a disproportionately large effect in reducing community rates[xlii][xliii].

Scientific evidence for the effectiveness of face masks in reducing the risk of SARS-CoV-2 transmission is overwhelming. Because mask-wearing can limit both virus shedding from (often asymptomatic) sources and exposure to virus-containing particles in susceptible individuals, universal masking is essential in reducing new cases of COVID-19.

- During the large USS Theodore Roosevelt outbreak, sailors who reported wearing a face covering had 70% less risk of being infected than those who did not[xliv].
- A study of household transmission of COVID-19 in Beijing demonstrated that when all household members used face masks, they were 79% effective in reducing transmission from index cases to family[xlv].
- A large case-control study from contact tracing in Thailand found that wearing masks at all times during contact resulted in greater than 74% lower risk for SARS-CoV-2 infection; wearing a mask only sometimes did not yield statistically reduced infection risk[xlvi].

Available face masks for general use span a range of materials, quality, and filtering characteristics. While this has been the subject of debate regarding optimal face masks for community use, the preponderance of data indicates that most commercially available face masks provide adequate filtering and protection:

- An Australian study comparing filtration efficiency provided by 12 various masks (cloth, surgical, and KN95) found 90-99% efficiency for aerosol-sized particles in 11 of the masks of all fabrics and types, with only silk masks showing reduced (63%) filtration efficiency[xlvii].

- A study from the University of North Carolina showed that commercial cloth masks provide equivalent filtering efficiency to surgical masks (up to 80%) and that good fit is generally more important than material in face mask performance.[xlviii]

Studies of community implementation of mandatory face mask use show the beneficial collective effect of face masks as an NPI:

- An analysis of community COVID-19 incidence across German regions with differing face mask requirements showed strong correlation of compulsory mask orders and lower transmission ten days after implementation, reducing the daily growth rate of reported infections by 40% compared to regions without mask requirements[xlix].
- In a study of county-based masking ordinances in Kansas, researchers found that counties with mask mandates experienced a 60% reduction in COVID-19 cases compared to counties without mandates over the same period. At the time of implementation, counties that adopted face mask ordinances had had a 1.4-fold higher rate of COVID-19 deaths. By the end of the analysis, that ratio more than reversed, and counties that did not require face masks had death rates that were 1.8 times greater[l].

Finally, the few rigorous studies assessing COVID-19 prevalence in schools that implemented layered school NPIs have found that these interventions (specifically universal face mask policies for staff and students) avoided widespread symptomatic and asymptomatic cases.

- A study of two large private schools showed relatively low in-school transmission rates with aggressive NPIs and universal face mask use. In the school that experienced six cluster events, 72% percent of the in-school transmission cases were associated with noncompliance with school mask-wearing rules. Unsurprisingly, most cases in students were asymptomatic (>97% in one lower school) and only detected by universal surveillance testing[li].
- In another study, Vanderbilt University pediatric, infectious disease, and laboratory diagnostics experts partnered with an independent school to implement layered NPIs for the fall 2020 semester – including universal mask wearing and regular surveillance PCR testing. With these measures in place, they found student rates that were generally lower than surveillance screening rates for pediatric appointments at Vanderbilt University Hospital and low incidence of cases from in-school transmission. The one identified in-school cluster was linked to a classroom that had not followed the school's universal face mask policy[lii].

The CDC's scientific briefing on the use of cloth masks to control the spread of COVID-19 provides a solid overview of additional existing evidence supporting the effectiveness of face masks against COVID-19 transmission[liii].

Summary:

In-person school is important for children and adolescents' appropriate development and well-being, and universal attendance is a high priority for the upcoming 2021–2022 school year. The importance of in-person learning during the COVID-19 pandemic is complicated by current scientific evidence that highlights the previously underestimated burden of COVID-19 in children and adolescents and recognizes that congregate school settings represent a high risk for transmission among children and amplified transmission in the surrounding community. Effective mitigation of COVID-19 risk in schools involves layered NPIs (including universal face mask use) in addition to high vaccination rates among those who are currently eligible for vaccines. The increased transmissibility and virulence of the Delta

variant create additional urgency to implement evidence-based, effective, layered NPIs that can protect students, staff, and community residents.
This document is based upon the most up-to-date data, and will be updated as indicated by data and changes in the virus.

[i] https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/k-12-guidance.html

[ii] https://services.aap.org/en/news-room/news-releases/aap/2021/american-academy-of-pediatrics-updates-recommendations-for-opening-schools-in-fall-2021/

[iii] https://jamanetwork.com/journals/jama/fullarticle/2772860

[iv] https://covid.cdc.gov/covid-data-tracker/#demographics

[v] https://covid.cdc.gov/covid-data-tracker/#national-lab

[vi] https://www.cdc.gov/mmwr/volumes/70/wr/mm7009a4.htm

[vii] https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/burden.html

[viii] https://covid.cdc.gov/covid-data-tracker/#demographics

[ix] https://downloads.aap.org/AAP/PDF/AAP%20and%20CHA%20-%20Children%20and%20COVID-19%20State%20Data%20Report%207.29%20FINAL.pdf

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[xiii] https://www.thelancet.com/action/showPdf?pii=S2352-4642%2821%2900198-X

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[xv] https://www.nature.com/articles/s41591-021-01433-3

[xvi] https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(20)30927-0/fulltext

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[xx] https://www.imperial.ac.uk/media/imperial-college/institute-of-global-health-innovation/react1_r12_preprint.pdf

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[xxvi] https://www.medrxiv.org/content/10.1101/2020.10.29.20221036v1.full.pdf

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[xxxiv] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8007924/

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[xlii] https://www.nature.com/articles/s41591-020-1092-0

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