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RAPID REVIEW

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COVID-19 Pandemic School Closure and Reopening Impacts

Key Findings

- While limited, the literature indicates that school closures contribute to the effectiveness of non-pharmaceutical interventions (NPIs) for reducing Coronavirus Disease 2019 (COVID-19) transmission. In the majority of modelling studies, school closures reduced the reproductive number (R_0) of COVID-19 and reduced the total or cumulative number of cases. Some models estimated that school closures, while effective, did not impact R_0 as much as other NPIs.

- Several studies noted that school closures could have impacts on parents, including healthcare workers, through an increase in unmet childcare needs. School closures can also have negative impacts on family expenses, lead to poor nutrition (due to missed school-provided meals), education, school-based healthcare services, mental health and emotional well-being.

- The literature to date has not demonstrated widespread outbreaks of COVID-19 in school settings. It is not clear if this lack of spread in schools is because most schools closed relatively quickly after the pandemic was declared. Currently, the data suggest that children are less efficient as spreaders of COVID-19, particularly in the context of low community transmission.

- While research on COVID-19 pandemic school closures is only emerging, it is important to consider evidence on relative effectiveness of school closures on COVID-19 transmission in the context of evidence of important negative impacts to child and family health. For planning purposes, other NPIs could be prioritized to maintain low rates of community transmission, in conjunction with NPIs within schools, to avoid future large-scale school closings.

Objectives and Scope

- School closures have been implemented in Ontario since March 13, 2020, combined with multiple other layers of individual and community-based public health measures. This rapid review aims to equip decision-makers with evidence to support decision-making during the pandemic as it relates to a comprehensive perspective on school closures as a public health measure.

- This rapid review addresses the following questions:

    - What is the effectiveness of school closures on reducing transmission of COVID-19 and non-COVID-19 pathogens?

- What are the negative impacts of school closures due to COVID-19 and non-COVID-19 pathogens on children and families?
- What impacts do the reopening of schools have on COVID-19 transmission?

Background

Role of School Closures

The evidence in support of school closures, as one component of a multi-layered approach to public health measures, has come primarily from observational and modelling studies from the influenza literature suggesting that proactive school closures may reduce transmission and delay/flatten the epidemic peak, if implemented early and for a sufficient duration.[1-3] Influenza modelling research has found that closures may decrease peak incidence, but not total case counts, to help address a short-term surge in demand for health care.[2] These findings are consistent with the rationale for public health measures applied in Ontario. The multiple actions taken have successfully flattened the epidemic curve, preserving healthcare system capacity. Moving forward, societal priorities are reopening schools successfully and safely, relying on other NPIs to control community transmission.

Much of the existing literature on school closures is derived from influenza. While this has been informative, there are important differences between influenza and COVID-19 and there are important knowledge gaps in COVID-19 transmission dynamics. Children are recognized to be important drivers of community-based transmission of influenza. In contrast, school-aged children appear to be far less important drivers of COVID-19 transmission than adults.[4-6] Due to a clinical spectrum in children that tends to be milder than adults,[7,8] there has been speculation about the potential role of children in acquiring mild or asymptomatic COVID-19 infection and transmitting the virus to family members or high-risk adults in the community. Although most transmission appears to be driven by individuals with symptoms, transmission from asymptomatic or pre-symptomatic individuals is well-accepted.[9,10]

Societal disruption due to public health measures such as school closures will need to be weighed against the role they play in contributing to spread in Ontario communities. It is recognized that the impact of school closure measures are likely to be unevenly distributed across the population and the explicit acknowledgement of ethical principles, including health equity, are important in decision-making.[11] Furthermore, there is an increasing recognition of the disproportionate impacts of school closures on at-risk children and populations.

Ontario Epidemiology and Context Relevant to Pediatric Populations

As of mid-July, the number of confirmed COVID-19 cases in Ontario continues to decrease. Currently (as of July 22, 2020), children ≤19 years represent 5.3% (2,039/38,210) of all COVID-19 cases in Ontario, with one death reported.[12] Available evidence from other jurisdictions suggests that school-age children and adolescents infected with COVID-19 can experience mild illness and may be less important contributors to spread.[5,11,13-15] Most children are at low risk of severe disease, although a small proportion develop a severe post-COVID-19 condition referred to as multisystem inflammatory syndrome in children.[16-19]

Methods

- In considering feasibility, scope, and the need for responsiveness, a rapid review was chosen as an appropriate approach to address the research questions. A rapid review is a type of knowledge synthesis wherein certain steps of the systematic review process are compromised in order to be timely.[20]

- PHO is actively monitoring, reviewing and assessing relevant information related to COVID-19. This document is intended to provide a rapid review of the evidence related to school closures and reopening impacts of COVID-19.

- On July 11, 2020, PHO Library Services developed and conducted three separate searches related to COVID-19 and school closures: 1) MEDLINE; 2) Supplemental (i.e., Embase, PsycINFO, CINAHL, Global Health and Scopus); and 3) Pre-Print (i.e., medRxiv and bioRxiv) (**Appendix A**). Records from each search were combined and duplicates were removed. Scientific grey literature (e.g., ProMED, CIDRAP, Johns Hopkins Situation Reports) and media reports, where appropriate.

- English-language peer-reviewed and grey literature records that described the following were included: effectiveness of school closures on reducing COVID-19 or non-COVID-19 disease transmission; negative impacts of school closures due to COVID-19 or other diseases; and impacts of school reopening on COVID-19 transmission. No restrictions were placed on the year of publication.

- Titles and abstracts were screened by two reviewers, and the application of the eligibility criteria was reviewed by the senior author. Full-texts of peer-reviewed literature were divided into two sets with each set screened independently by a single reviewer. Articles of unclear relevance as well as the list of full-text articles that met inclusion criteria were collated and reviewed by the senior author for eligibility. The senior author synthesized relevant data. Critical appraisal of the methodological quality was not performed due to time constraints. PHO subject-matter experts reviewed this rapid review before posting.

- As the COVID-19 pandemic continues to evolve and the scientific evidence rapidly expands, the information provided in this document is only current as of the date of posting.

Results

Relative Effectiveness of School Closure Measures during COVID-19

An important concern regarding school closures due to COVID-19 is how to balance the need to reduce transmission with societal impacts (e.g., childcare for parents, child nutrition, mental health of children.[21-27] We concentrated on the public health impact of school closures on COVID-19 transmission; however, this impact must be balanced against the overall health of children and the importance of full-time schooling to their mental health and wellbeing. For a full summary of the negative consequences of school closures, please see PHO's Negative Impacts of Community-Based Public Health Measures during a Pandemic (e.g., COVID-19) on Children and Families.[28]

The modelling studies below are based on wave 1 of the pandemic, which may have important differences to future waves and during times of stable community transmission rates. This section does not address cost-effectiveness for various public health measures for mitigating COVID-19.

- In a modelling study of NPIs against COVID-19, Davies et al. showed that school closures, when compared to an unmitigated epidemic, decreased the total number of cases by 20-30% and delayed the peak of the epidemic by an average of 3-8 weeks. However, when school closures are used alone (e.g., in absence of social distancing or self-isolation), R_0 will not be kept low enough to sustain low transmission.[29] Closing schools reduced deaths from 120,000 (95% prediction interval [PI]: 380-270,000) to 65,000 (95% PI: 150-260,000) and reduced the peak intensive care unit (ICU) beds required from 53,000 (95% PI: 190-170,000) to 29,000 (95% PI: 580-140,000).
    - The authors note that if children have one additional contact per weekday with older adults, then deaths increased to 79,000 (95% PI: 160-290,000) and increased the peak ICU beds required to 35,000 (95% PI: 560-160,000).
- Juni et al. demonstrated that school closures (ratios of risk ratios [RRR]: 0.63, 95% confidence interval [CI]: 0.52-0.78) were effective at slowing epidemic growth of COVID-19 worldwide.[30]
- In a modelling study of interventions in Singapore, Koo et al. reported that school closures lead to a reduction in the median cumulative number of infections by 10,000 (interquartile range [IQR]: 200–28,000), 80 days into the epidemic.[31] In this model, the baseline median cumulative number of infections on day 80 was 279,000 (IQR: 245,000-320,000) (with R_0=1.5). Combining interventions (quarantine, workplace distancing and school closures) decreased the median cumulative infection count to 1,800 (IQR: 200-23,000) 80 days into the epidemic, representing a 99.3% (IQR: 92.6-99.9) reduction compared to the baseline scenario.
- In a pre-print modelling study using worldwide data, Brauner et al. estimated that school closures would lead to a mean reduction in R_0 by 50% (95% credible interval [CrI]: 39-59).[32] School closure was more effective in reducing R_0 than closing non-essential businesses (34%), closing high-risk businesses (26%), limiting gatherings (≤10 people = 28%, ≤100 people = 17%, ≤1,000 people = 16%) and issuing stay-at-home orders (14%).
- In examining COVID-19 deaths across the United States (US), Yehya et al. reported that in 37 states with >10 deaths at a 28-day follow-up, delayed school closure led to more deaths (adjusted mortality rate ratio: 1.05, 95% CI: 1.01-1.09, p=0.008).[33]
- In a pre-print modelling study of interventions in China, Zhang et al. report that school closures can reduce the mean daily peak incidence of cases by 42% to 64% (under different scenarios and a baseline R_0=2.5).[34] The authors state “school-based closure policies are not sufficient to entirely prevent a COVID-19 outbreak, but they can affect disease dynamics and hence hospital surge capacity.”
- Banholzer et al. (pre-print), modelling NPIs worldwide, reported that school closures resulted in an 8% reduction in the number of new cases (95% CrI: 0-23%).[35] In comparison, other NPIs were more effective, such as venue closures (36%), ban on gatherings (34%) and ban on non-essential businesses (31%).

Two modelling studies suggest school closures may negatively impact the healthcare workforce with negative impacts on ICU capacity and mortality:

- In a modelling study, Bayham and Fenichel found that during US school closures, 15.0% (95% CI: 14.8-15.2) of healthcare workers will require childcare.[36] The model estimates that if COVID-19 mortality rate increases from 2.0% to 2.4%, with a 15.0% reduction in healthcare workforce, school closures could lead to a greater number of deaths than they would prevent.

- In a pre-print modelling study of the impact of school closures in the US, Chin et al. estimates that healthcare worker households at the national level will have 7.5-8.6% unmet childcare needs; the estimated reduction in ICU beds at peak demand range from 3.2% (R_0=4) to 7.2% (R_0=2).[37] At the county level, the model estimates that healthcare worker households will have 1.9-18.3% unmet childcare needs; the estimated reduction in fewer ICU beds at peak demand range from 5.7-8.8% (R_o=2). The authors suggest childcare subsidies should be in place to balance negative impacts of school closures.

Effectiveness of School Closures for Other Infectious Diseases

The benefits and adverse impacts of school closures for the mitigation of infectious diseases is well demonstrated in the literature, especially for pandemic influenza A (H1N1), and has been reviewed.[38-43] While school closures are effective in reducing influenza transmission, many reports have noted that there is a need to maintain social distancing when children are not in school,[38,40] which may have implications for less than full-time school delivery during the COVID-19 pandemic. It is important to note that pandemic influenza A (H1N1) had a much shorter timeline from pandemic onset to vaccine, compared to what we anticipate for COVID-19.

Please see **Appendix B** for synthesis of literature concerning the effectiveness of school closures on reducing influenza transmission.

Negative Impacts of School Closures on Children and Families

PHO conducted a rapid review of the Negative Impacts of Community-based Public Health Measures during a Pandemic (e.g., COVID-19) on Children and Families.[28] During the COVID-19 pandemic, school closures have resulted in various challenges and negative impacts; including substantial disruption of routines, unreported child abuse and adverse mental health outcomes. Childhood is a period for developing physical, social, emotional and cognitive abilities that will set the stage for healthy behaviours and outcomes throughout the life course. Quality relationships, optimal nutrition, a safe home environment and physical health support positive outcomes in learning, behaviour and health.[44] The disruption due to the closure of childcare centres, schools, recreational facilities and playgrounds may have consequences for both physical and mental health. Routines and structured days,[45] often established in a school environment, are vital particularly for children with physical and/or cognitive delays.

SCHOOL CLOSURES DURING COVID-19

Five studies and one review were identified that examined the effects of public health measures, including both school closures and stay at home orders/'lockdowns', on school-aged children and families during the COVID-19 pandemic.[46-51] The negative outcomes were movement behaviours (i.e. decreased physical activity, increased screen time and sedentary behaviour), poor nutrition, poor mental health and wellbeing, and risk of child abuse and neglect.

Movement behaviours and nutrition:

- Children had decreased time spent being physically active, sleep time increased and screen time related to non-school activities increased.[47,50] Orgilés et al. found children spent significantly more time daily using screens, less time being physically active, and tended to sleep more.[48] Pietrobelli et al. found the number of meals eaten per day increased significantly and there was an increased intake of potato chips, red meat and sugary drinks.[47] In another study, 21.9% of parents reported their children ate more compared to before the quarantine/lockdown period.[48]

Mental health and wellbeing:

- Three studies were published during the COVID-19 pandemic from Italy, Spain and China that examined mental health outcomes in children. In China, 22.6% of students reported having depressive symptoms, and 18.9% had anxiety symptoms.[49] In another study from Spain, the most common symptoms reported during 'lockdown' were difficulty concentrating (77%), boredom (52%), irritability (39%), restlessness (39%), nervousness (38%) and worrying (30%).[48] In Italy, Di Giorgio et al. reported families' difficulties following routines, and children had self-control difficulties during the lockdown.[51]

Child abuse and neglect:

- A review of the effects of pandemics on children in the care of Canada's child welfare system determined there is increased risk of physical and emotional maltreatment, gender-based violence, separation from caregivers, and social exclusion. There was also a likelihood of decreased access to in-home child welfare services.[46]

All these negative health impacts are in addition to the potential financial stressors, such as unemployment and loss of income in families due to the COVID-19 pandemic.

SCHOOL CLOSURES DURING 2009 H1N1 PANDEMIC

The literature search retrieved six studies that described the negative impacts of school closures on children predominantly during the 2009 H1N1 pandemic.[1,52-56] Of these, one was a systematic review,[1] and five were cross-sectional surveys.[52-56] The duration of school closures in the studies ranged from three days to two weeks.

No studies were identified that examined the effects of school closures independently from other public health measures during COVID-19. The COVID-19 school closures have been largely proactive closures in the absence of cases or outbreaks in schools, implemented as an approach to physical distancing in communities to flatten the epidemic curve, in addition to other public health measures. Thus, it is likely that the negative impacts identified by the studies reviewed may be more pronounced during COVID-19 given the current duration of school closures.

Please see **Appendix C** for synthesis of literature concerning the negative impacts of school closures during the 2009 H1N1 pandemic.

Impacts on COVID-19 Transmission for School Reopening during the Pandemic

While students have been exposed to infectious individuals in the school setting, there are studies that indicate that widespread COVID-19 transmission has not occurred in schools. Currently, there is limited published data on the potential impacts with the reopening of schools (i.e., school-based or community-based outbreaks).[14,27,57] However, multiple outbreak investigations summarized below suggest a low risk of transmission from children in school settings. Compiling the data from four studies of school exposures, a combined 28 child and teacher index cases exposed 2,093 contacts to COVID-19 with only 2 transmissions (0.01% attack rate).[58-61]

Several pre-print modelling studies have predicted a resurgence of COVID-19 upon reopening of schools; however, they assert that impacts can be mitigated by implementing additional NPIs in schools and society (e.g., reduced class sizes, testing symptomatic people, contact tracing).[62,63]

This section does not address guidance for reopening schools.

- In Ireland, Heavey et al. reported on three children (all 10-15 years old) and three adults with COVID-19 who had exposed 924 children and 101 adults in school settings (primary and secondary) when all but one child were symptomatic.[58] There were no COVID-19 specific infection prevention and control practices in place at time of exposures. Among school contacts, there were no secondary COVID-19 cases; and the only transmission identified was from an adult case to two adults outside the school setting. However, only symptomatic contacts were tested.

- In New South Wales, Australia, the National Centre for Immunisation Research and Surveillance reported on 18 people (9 children and 9 adults) with COVID-19; 8 students and 4 staff in 10 high schools, and 1 student and 5 staff in 5 primary schools.[61] 735 students and 128 staff were considered close contacts of the 18 cases and underwent monitoring and testing; however, only one student in a secondary school and one student in a primary school were found to have COVID-19 infection where transmission was likely to have occurred in school.

- In Singapore, Yung et al. screened children after there was identification of 3 COVID-19 seeding incidents in school settings (child in a secondary school, child in a preschool, staff in a preschool).[59] Two schools implemented terminal cleaning, suspension of extracurricular and sport activities, and staggered recess breaks. One pre-school closed for 14 days due to an increasing number of staff members with COVID-19. All symptomatic and asymptomatic child contacts in the three schools (n=119) were tested and all were negative for COVID-19. In the preschool with the staff member case, there were 16 additional staff member cases.

- Early during the pandemic in France, Danis et al. reported on a cluster of COVID-19 cases.[60] Within this cluster, there was a 9-year-old child with COVID-19 that attended three schools with infection prevention and control measures in place. The child had 86 contacts, of which 55 developed symptoms but none tested positive for COVID-19.

- In a study of a symptomatic COVID-19 teacher in the US, Brown et al. reported that of the 5 students exposed to the teacher in a classroom setting with serological testing, only one child showed serological evidence of prior infection, and another child had an indeterminate result.[64]

- In Stockholm, Sweden where there was no closure of schools for children <16 years old, Hildenwall et al. found 63 pediatric admissions for children (0-18 years) from March 13 to May 14, 2020.[65] Children with COVID-19 represented 0.7% (30/4,347) of all hospital admissions in the region, demonstrating low severity among school-attending children during the first two months of the pandemic.

- Sugishita et al. (pre-print) modelled school closure effectiveness (before, during and after school closure) in Japan.[66] The authors estimated that R_0 before school closure was 2.0 (range: 1.9-2.1), during closure R_0=1.1 (range: 0.98-1.3) and R_0 after schools reopened was 3.1 (range: 2.5-3.7).

- In France, Fontanet et al. (pre-print) investigated COVID-19 serology on primary school students (6-11 years old), teachers, staff and student relatives.[67] Prior to school closure, 3 students with COVID-19 infection were identified, during which no infection prevention and control measures were in place. Four weeks after school closure, parents (11.9%, 76/641) and relatives (11.8%, 14/119) had the highest seropositivity, whereas students had (8.8%, 45/510), followed by teachers (7.1%, 3/42) and staff (3.6%, 1/28). There was no evidence of onward transmission from the 3 children in the school setting. In a similar study in a secondary school setting with 2 cases per month prior to serology testing, Fontanet et al. (pre-print) showed that seropositivity by group was students 38.3% (92/240), staff (59.3%, 16/27), teachers (43.4%, 23/53), parents (11.4%, 24/211) and siblings of students (10.2%, 13/127). 68.4% of participants reported symptoms at some point in the approximately 3 months prior to testing.[68]

- In a school outbreak in March in Chile, Torres et al. reported on antibody testing of 1,009 students and 235 staff.[69] Antibody positivity rates were 9.9% for students and 16.6% for staff. The authors of this study suggest that most child cases were from parents in the home or teachers, and most staff infections were from fellow staff. The results should be interpreted cautiously as the antibody test used has uncertain validity.

- In a press release from Germany, in May and June, a COVID-19 antibody test was performed on 1,500 students aged 14-18 years old and 500 teachers from 13 schools, and only 12 total (0.6%) tested positive.[70] The authors suggest this provides some reassurance on the low risk of school transmission in the context of low community rates. This study has not been published.

- In a modelling study of NPIs against COVID-19, Davies et al. showed that lifting of interventions (i.e., school closures, physical distancing, shielding of older people, self-isolation of symptomatic individuals), even if R_0<1 during intervention period, led to rapid increase in transmission.[29]

Strengths and Limitations

Strengths of this review include the search of both peer-reviewed and grey literature for relevant records using multiple search strings. The questions explored in this review are timely and contribute to better understanding of the impacts of school closures and the reopening of schools that can inform our response during the COVID-19 pandemic. Additionally, the framework we provided for a systematic approach to analyzing the findings.

Due to time and resource constraints, it is likely that relevant literature may have been missed in this rapid review; however, its generalizability to the current context may be limited. Additionally, we recognize that the data and research during the COVID-19 pandemic are rapidly evolving and emerging,

and new relevant records may now be available. The records included were examined by one reviewer and were not assessed for methodological quality using a quality appraisal tool.

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Appendix A. Example Search Strategy

MEDLINE

Ovid MEDLINE(R) ALL <1946 to July 10, 2020>

#	Searches	Results	Concept
1	*Pandemics/ or (Pandemics/ and (Disaster Planning/ or *Influenza, Human/ or Quarantine/)) or (pandemic*.kf,kw,ti. not medline.st.)	15144	Pandemics
2	COVID-19.ps,px,rs,rx. or ("2019 corona virus" or "2019 coronavirus" or "2019 ncov" or "corona virus 19" or "corona virus 2019" or "corona virus 2019" or "corona virus disease 19" or "corona virus disease 2019" or "corona virus epidemic*" or "corona virus outbreak*" or "corona virus pandemic*" or "coronavirus 19" or "coronavirus 2019" or "coronavirus 2019" or "coronavirus disease 19" or "coronavirus disease 2019" or "coronavirus epidemic*" or "coronavirus outbreak*" or "coronavirus pandemic*" or "covid 19" or "covid 2019" or "new corona virus" or "new coronavirus" or "novel corona virus" or "novel coronavirus" or "novel human coronavirus" or "sars coronavirus 2" or "sars cov 2" or "sars cov2" or "sars like coronavirus" or "severe acute respiratory syndrome corona virus 2" or "severe acute respiratory syndrome coronavirus 2" or "severe specific contagious pneumonia" or "wuhan corona virus" or "wuhan coronavirus" or 2019ncov or covid19 or covid2019 or ncov or sarscov2 or "coronavirus response" or "corona virus response").kf,kw,ti. or ((novel or Wuhan or China or Chinese or "seafood market" or "2019" or outbreak* or epidemic* or pandemic*) adj5 (coronavirus* or "corona virus*" or betacoronavirus* or "beta coronavirus*" or "beta corona virus*" or pneumonia* or SARS or "severe acute respiratory syndrome")).kf,kw,ti. or ((coronavirus* or "corona virus*" or betacoronavirus* or "beta coronavirus*" or "beta corona virus*" or SARS or "severe acute respiratory syndrome") adj5 pneumonia*).kf,kw,ti.	33474	COVID-19
3	limit 2 to yr="2020 -Current"	31299	
4	1 or 3	37200	
5	Schools/ or Students/ or (school* or class or classes or classroom* or (education* adj3 setting?) or kindergarten* or teacher* or instructor* or student* or pupil or pupils).ab,kf,kw,ti.	1058819	Schools
6	("grade* 1" or "grade* one" or "first grade*" or "1st grade*" or "grade* 2" or "grade* two" or "second grade*" or "2nd grade*" or "grade* 3" or "grade* three" or "third grade*" or "3rd grade*" or "grade* 4" or "grade* four*" or "fourth grade*" or "4th grade*" or "grade* 5" or "grade* five*" or "fifth grade*" or "5th grade*" or "grade* 6" or "grade* six*" or "sixth grade*" or "6th grade*" or "grade* 7" or "grade* seven" or "seventh grade*" or "7th grade*" or "grade* 8" or "grade* eight" or "eighth grade*" or "8th grade*" or "grade* 9" or "grade* nine" or "ninth grade*" or "9th grade*" or	105540	

#	Searches	Results	Concept
	"grade* 10" or "grade* ten" or "tenth grade*" or "10th grade*" or "grade* 11" or "grade* eleven" or "eleventh grade*" or "11th grade*" or "grade* 12" or "grade* twelve" or "twelfth grade*" or "12th grade*").ab,kf,kw,ti.		
7	5 or 6	1140994	
8	(open* or reopen* or "re-open*" or restart* or "re-start*" or resume* or resuming or "re-establish*" or reestablish* or "re-instat*" or reinstat* or return* or restor* or "go* back" or closur* or close* or closing or suspend* or suspension* or "stay* home" or shutdown* or "shut down*" or "back to?" or recover*).kf,kw,ti.	371851	Closure/ reopening
9	((school* or class or classes or classroom* or (education* adj3 (setting? or institution?)) or kindergarten* or teacher* or instructor* or student* or pupil or pupils) adj5 (open* or reopen* or "re-open*" or restart* or "re-start*" or resume* or resuming or "re-establish*" or reestablish* or "re-instat*" or reinstat* or return* or restor* or "go* back" or closur* or close* or closing or suspend* or suspension* or "stay* home" or shutdown* or "shut down*" or "back to?" or recover*)).ab,kf,kw,ti.	14491	
10	((ease* or easing or lift* or loosen* or end or ends or ended or ending or cancel* or remov* or relax* or reduc* or "scal* back" or "scal* down" or "roll* back" or gradual* or phase or phases or phased or phasing or "next step*" or timeline* or "time line*" or timeframe* or "time frame*") adj5 (restrict* or ban or bans or banned or banning or measure or measures or rule or rules or quarantin* or law or laws or constraint* or order or orders or lockdown* or "lock down*" or isolat* or (stay adj3 home) or ((nonpharmeceutical or non-pharmaceutical) adj3 intervention*) or ((mitigat* or exit) adj2 (plan or plans or planned or planning or strategy or strategies)) or "social distanc*" or "physical distanc*")).kf,kw,ti.	7700	
11	((school* or class or classes or classroom* or (education* adj3 (setting? or institution?)) or kindergarten* or teacher* or instructor* or student* or pupil or pupils) adj15 (ease* or easing or lift* or loosen* or end or ends or ended or ending or cancel* or remov* or relax* or reduc* or "scal* back" or "scal* down" or "roll* back" or gradual* or phase or phases or phased or phasing or "next step*" or timeline* or "time line*" or timeframe* or "time frame*") adj5 (restrict* or ban or bans or banned or banning or measure or measures or rule or rules or quarantin* or law or laws or constraint* or order or orders or lockdown* or "lock down*" or isolat* or (stay adj3 home) or ((nonpharmeceutical or non-pharmaceutical) adj3 intervention*) or ((mitigat* or exit) adj2 (plan or plans or planned or planning or strategy or strategies)) or "social distanc*" or "physical distanc*")).ab,kf,kw,ti.	1713	
12	(home* adj3 school*).ab,kf,kw,ti.	3767	
13	8 or 9 or 10 or 11 or 12	394567	

#	Searches	Results	Concept
14	Air Microbiology/ or Air Pollution, Indoor/ or Biofouling/ or Bodily Secretions/ or Body Fluids/ or Communicable Disease Control/ or Communicable Diseases/pc or Community-Acquired Infections/ or Cough/ or Cross Infection/ or Decontamination/ or Disease Outbreaks/ or Disease Reservoirs/ or Disease Transmission, Infectious/ or Disinfection/ or Epidemics/ or Equipment Contamination/ or Equipment Reuse/ or Exhalation/ or exp Hand Hygiene/ or Fomites/ or Hygiene/ or Infection Control/ or Infection/pc or Inhalation Exposure/ or Sneezing/ or Sterilization/ or tm.fs. or Universal Precautions/ or Ventilation/ or Virus Shedding/	455516	Transmisson
15	(transmi* or "bio foul*" or "cross infect*" or (infect* adj3 route*) or biofoul* or cluster* or communicability or epidemic* or excret* or infectivity or outbreak* or reinfect* or "re infect*" or shed* or spread* or droplet* or ((body or bodies or lung* or mouth* or nose*) adj3 (fluid* or secretion* or secrete or discharge*)) or cough* or sneez* or ((room* or classroom* or school* or HVAC or vent or vents or "ventilation system*" or duct*) adj3 circulat*) or ((new* or increas* or decreas* or up or down or rise* or rising or fall* or higher* or lower*) adj5 cases) or ((infect* or disease*) adj3 (prevent* or control*)) or fomite* or cleaning or contaminat* or decontaminat* or disinfect* or ((hand or hands) adj3 (hygiene or wash* or clean* or disinfect* or rub* or scrub*)) or handwash* or hygiene or IPAC or reservoir* or sanitis* or sanitiz* or sterilis* or steriliz* or "universal precautions").kf,kw,ti.	547613	
16	((acquir* or acquisition* or get* or become or contact* or circulat* or airborne or HVAC or vent or vents or "ventilation system*" or duct*) adj5 (infect* or disease* or virus* or coronavirus* or "corona virus*" or COVID* or nCoV* or SARS or "severe acute respiratory syndrome*")).kf,kw,ti.	21616	
17	((clean* or colonis* or coloniz* or contamina* or decay* or decontaminat* or detect* or disinfect* or distribut* or expos* or grow* or harbor* or harbour* or inactivat* or persist* or sanit* or stabilit* or surviv* or viab*) adj15 (bathroom* or carpet* or chair* or classroom* or cloth* or computer* or desk* or "door handle*" or "door knob*" or doorknob* or environment* or equipment* or fabric* or faucet* or fixture* or floor* or furnish* or furniture* or handrail* or "hand rail*" or keyboard* or keypad* or "key pad*" or "light switch*" or material* or plastic* or railing or railings or room or rooms or sink* or supplies or surface or surfaces or textile* or tile* or toilet* or "touch screen*" or upholster* or wall* or washroom*)).kf,kw,ti.	66163	
18	14 or 15 or 16 or 17	918619	
19	4 and 7 and (13 or 18)	533	
20	limit 19 to English	500	
21	remove duplicates from 20	488	

Appendix B. Effectiveness of School Closures for Other Infectious Diseases

School closures for COVID-19 have been noted to reduce the incidence of other viral infectious diseases, representing an indirect benefit of school closures.[4,71,72] This section does not address cost-effectiveness for various public health measures for mitigating seasonal and pandemic influenza.

Most studies investigating the effectiveness of school closures on influenza transmission concentrated on reduction of cases, delaying peaks in activity and reducing the magnitude of peak activity:

- In Alberta, Canada, Earn et al. used mathematical models to estimate that school closures reduced pandemic influenza A (H1N1) transmission among children by more than 50%.[73]
- Copeland et al. investigated the effectiveness of school closures on pandemic H1N1 transmission in the intervention community [IC] of Dallas/Fort Worth, Texas, US (compared to surrounding districts with no school closure, control community [CC]).[74] The increase in acute respiratory illness [ARI] rates was 45% lower in the IC (0.6% before closure vs. 1.2% during closure) than in the CC (0.4% before vs. 1.5% during) ([$RRR_{During/Before}$]: 0.55, p=0.001; adjusted OR [$aOR_{During/Before}$]: 0.49, p<0.03). The relative increase of total emergency department flu visits in the IC was 27% lower (2.8% before vs. 4.4% during) compared with the CC (2.9% before vs. 6.2% during).
- In Hong Kong during pandemic H1N1, Wu et al. estimated that the effective reproductive number (R_e) was 1.7 before school closures for children <13 years of age, decreasing initially to R_e=1.5 soon after closure and finally down to R_e=1.1 during the summer vacation.[75]
- Using data from the 1957 influenza pandemic in the United Kingdom (UK), Vynnycky and Edmunds estimated that early school closure during a future epidemic could reduce the epidemic size by <10% if R_0 is high (2.5-3.5) and by 22% if R_0 is low (1.8).[76]
    - The authors noted that school closure effectiveness varied if contact patterns of children changed while outside of the school setting. For example, if contact between children is reduced 75%, then epidemic size will decrease by 22%; if contact is reduced by 25%, then epidemic size is reduced by 6% (using an R_0=1.8 and disease rate = 50/100,000).
- A US modelling study of pandemic H1N1 found that school closures can delay the epidemic peak by 4-6 days for each additional week of closure (assuming surveillance correctly diagnose 5-10% of symptomatic individuals).[77]
    - The authors acknowledge that modelling contact rates among children during school closures is difficult, as there is little data on contacts outside the home. In their models, the incidence of new influenza cases remained the same when best case (i.e., contact rates involving children in households are unchanged and child-related contacts outside the home are reduced by 50%) and worst case (contact rates involving children in households are doubled and child-related contacts outside the home are reduced by 30%) scenarios are compared.

Multiple studies indicated that school closures could effectively decrease influenza attack rates and contacts for children:

- Ciavarella et al., using data from Italy, modelled the effectiveness of gradual school closures (i.e., strategies involving closing classes first, then grades or the entire school) on reducing impacts of pandemic H1N1.[78] The authors estimated that gradual school closure strategies could lead to attack rate reduction up to 20-25%, with a peak weekly incidence reduction up to 50-55%.

- Cauchemez et al. reported in a modelling study that prolonged school closure during an influenza pandemic could reduce the cumulative number of influenza cases by 13-17% (18-23% in children) and peak attack rates by up to 39-45% (47-52% in children).[79]

    - The authors note that the effectiveness of school closures is reduced if low contact rates among children outside of the school setting are not maintained.

- In modelling pandemic H1N1 (with R_0=1.5), Fumanelli et al. reported that without intervention, the average attack rate was 19.5% (95% CI: 19.4-19.5), the mean peak incidence was 6.8 (95% CI: 5.8–7.1) cases per 1,000 individuals and the peak incidence occurred on average 13.8 weeks (95% CI: 12.1-17.2) after the first national case.[80] Using different school closure interventions (i.e., reactive, gradual, county and national), attack rates were decreased by 0-45%, peak incidence reduction was -10 to 80% with a peak delay of -2 to 18 weeks ($p<0.0001$ for each strategy).

- Using a simulation model for pandemic H1N1, Halder et al. reported if schools closed for eight weeks, then attack rates were reduced from 33% to 19% (14% reduction in overall attack rate) (with 30 daily diagnosed cases and R_0=1.5). As R_0 is increased, school closure becomes less effective.[81]

- Martinez et al., using a modelling approach, noted that school closures could reduce influenza attack rates from 33-50% to below 10%.[82]

- Jackson et al. estimated that school closures during pandemic H1N1 in the UK led to a 65% reduction in the mean total number of contacts for each student.[83]

- In a modelling study of seasonal influenza in Russia, Litvinova et al. reported that school closures led to a reduction in the number of contacts made by students (14.2 [pre-closure] vs. 6.5 [post-closure] contacts per day) and workers (11.2 vs. 8.7 contacts per day).[84] The authors estimate that school closures resulted in a 33% reduction in influenza attack rates.

- Davis et al. investigated the impact of school closures on pandemic H1N1 in Michigan, US and concluded that school closures at the district level were not effective in reducing influenza-like illness (ILI).[85] The authors stated “We observed that school closures were reactive, and there was no statistically significant difference between ILI rates over the study period. There was an elevated rate ratio for ILI at 51%-100% closure, and a reduction in the rate ratio at the 1%-50% compared to the 0% closure level."

- In simulations of pandemic influenza, Haber et al. concluded that school closures (1-3 weeks in duration) would not have a substantial effect on pandemic-related outcomes, at least in the absence of measures to reduce contacts of children outside of the school setting.[86]

- In a review of SARS, Viner et al. reported that school closures in China, Hong Kong and Singapore did not contribute to control of the outbreak; however, modelling studies had conflicting results.[87]

- Fung et al. modelled the effectiveness of school closures on a potential influenza pandemic. The authors estimated that for every week of school closure, the peak in influenza activity would be delayed by approximately five days (at day 5 of introduction and a 30% clinical attack rate).[88] The delay in peak activity increased as the attack rate was decreased in the model.

    - The authors state that the estimated impact of school closure decreased since there was an increase in household and community contacts among children.

- In modelling an influenza pandemic, Jackson et al. estimated that school closures were more effective if they led to large reduction in contacts, if $R_0<2$, and if attack rates were higher in children than in adults.[41]

Appendix C. Negative Impacts of School Closures on Children and Families (Non-COVID-19 Literature)

School closures affected parental income/employment and additional childcare expenses,[55] poor nutrition due to missed school-provided meals,[1,53,55] loss of education,[52] loss of school-based healthcare services[53] and mental health and emotional well-being.[54]

Parental loss of income/employment, childcare expenses:

- Childcare responsibilities resulting from school closures may impose extra financial burden on families due to lost work hours as parents stay home to take care of their children. Basurto-Davila et al. reported the majority of respondents who reported economic problems as a major concern were from lower income families.[52]

Poor nutrition:

- School-based nutrition programs provide free or low-cost meals during the school day and support adequate nutrition for children, especially those from economically vulnerable families. Epson et al. and Steelfisher et al. reported 3% and 19% of the respondents, respectively, faced challenges because their children missed the school-based subsidized meal.[53,55]

Loss of education:

- While online learning platforms provide an alternative to support the educational needs of children during the COVID-19 pandemic, access to reliable internet service, or material hardware such as laptops/computers, printers etc. may be a barrier for some families. Basurto-Davila et al. reported that the main concern of 229 parents during a school closure due to the H1N1 pandemic was the negative impact on education of their children.[52]

Access to school-based healthcare services:

- Health services provided in schools are often important initial health assessments to children in many communities. Steelfisher et al. examined 523 US households affected by school closure (up to three days) due to the H1N1 pandemic, found only 1% of the respondents reported lack of access to school-based health services as a risk for their child's health.[53] However, this was likely due to the short duration of the closure.

Mental health and wellbeing:

- Effler et al. surveyed 233 households with school-aged children from three schools in Perth, Australia during the 2009 H1N1 pandemic and found that 90% of parents reported minimal or no anxiety in their child due to the one-week school closure, but 55% reported that school closure caused moderate or severe disruption to their family routines.[54]

School closures lasting for a couple of days to weeks without stay at home orders were described during the 2009 H1N1 pandemic and provide a different context than the current COVID-19 pandemic. COVID-19 stay at home orders as well as school closures suggests a proportion of parents are at home with their children (working remotely or have become unemployed). Therefore, some of the outcomes

reported in the H1N1 school closure data, such as cost of alternative childcare arrangements, are less relevant in the present situation.

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