

# School closures were over-weighted against the mitigation of COVID-19 transmission

## A literature review on the impact of school closures in the United States

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### Abstract

**Background:** The pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread wildly across the world. In March of 2020, almost all kindergarten through 12th grade (K-12) schools were closed in the United States in an urgent attempt to curb the pandemic in the absence of effective therapeutics or vaccination. Thirteen months since then, schools remain partially closed. Accumulated evidence suggests that children and adolescents are not the primary facilitators of transmission, limiting the restrictive effects of school closures on disease transmission. The negative effects of school closures on K-12 students need to be systematically reviewed.

**Methods:** Following the guideline of Preferred Reporting Items for Systematic Reviews and Meta-analyses, a comprehensive literature search from PubMed, EMBASE, Cochrane Library, Scopus, and Web of Science regarding school closures and its impact on K-12 students was conducted. The primary outcomes included the impact of school closures on the mitigation of the pandemic and the resulting public health concerns of K-12 students.

**Results:** Prolonged school closures possessed negative effects on K-12 students' physical, mental, and social well-being and reduced the number of health and social workers, hindering the reopening of the country.

**Conclusions:** School closures were over-weighted against the mitigation of coronavirus disease 2019 (COVID-19) transmission. A safe reopening of all K-12 schools in the United States should be of top priority.

**Abbreviations:** COVID-19 = coronavirus disease 2019, K-12 = kindergarten through 12th grade, SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.

**Keywords:** children, coronavirus disease 2019, impact, kindergarten through 12th grade, mitigation, pandemic, school closure

## 1. Introduction

On January 10th, 2020, the first case of coronavirus disease 2019 (COVID-19) was officially detected in Wuhan, China. Eleven days later, the first case confirmed via serological test in the United States was detected on January 21st, 2020.<sup>[1]</sup> In the

following 7 weeks, the virus infected more than a thousand Americans.<sup>[2]</sup> On March 13th, 2020, the United States declared a national state of emergency to control the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19.<sup>[3]</sup> Thirteen months later, as of April 25th, 2021, during the revision of this literature review, there were 146,721,545 confirmed cases of SARS-CoV-2 and 3,103,555 deaths from the infections globally. 32,072,187 confirmed cases and 572,186 deaths were reported in the United States.<sup>[4]</sup>

School children were anticipated to contribute significantly to the community transmission of SARS-CoV-2 due to their daily social contacts with peers and household members, leading to severe community morbidity and mortality.<sup>[5]</sup> This presumption was based on experience with influenza and other respiratory diseases,<sup>[6–9]</sup> where children and adolescents were typically at the greatest risk of infection. They transmit the virus to each other and their family members at considerable speed, leading to severe outcomes.<sup>[10,11]</sup> Presumably, they play an important role in the transmission of SARS-CoV-2 as many affected children were asymptomatic and prolonged fecal viral shedding makes it very difficult for school nurses and health officials to diagnose, trace, and prevent the spread of the virus.<sup>[12,13]</sup> Therefore, school-aged children and adolescents have been suggested as the drivers of SARS-CoV-2 transmission. Data on viral load suggested that they may have similar COVID-19 viral loads as adults.<sup>[14]</sup> In addition, life-threatening multisystemic hyperinflammatory syndrome and

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toxic shock syndrome-like conditions in children following SARS-CoV-2 infections had been observed in pediatric patients.<sup>[15,16]</sup>

Amidst the lack of effective therapeutics or vaccination, in response to the pandemic, 191 countries implemented school closures worldwide.<sup>[17]</sup> As a result, about 1.6 billion (90.2%) students were out of face-to-face elementary, secondary, and tertiary education in order to slow the transmission of SARS-CoV-2.<sup>[18,19]</sup> Strict public health interventions, such as social distancing, stay-at-home orders, and mandated shutdown had also been introduced to the United States. Kindergarten through 12th grade (K-12) schools in all 50 states and Washington District of Columbia (D.C.) closed in March 2020 in an attempt to curb the pandemic.<sup>[20]</sup> With the pandemic unabated and vaccines unapproved, most schools remained closed for the first half of the 2020 to 2021 academic year, indicating that about 40 million prekindergarten through 8th-grade children were unable to enter or return to their classrooms during the first semester. Among them, about 27 million students are pre-K through 5th graders.<sup>[21]</sup> Unable to go to school physically, many of them have lost out and will continue to lose out on essential education, health care, and other social resources, which may have long-term negative effects on their development.<sup>[22–24]</sup> To date, online instruction has been incorporated into the curriculum of most students in the United States for more than 13 months.

Fortunately, as the knowledge on COVID-19 has accumulated, clinical and epidemiological evidence showed that most children or adolescents had asymptomatic infections or mild illnesses from COVID-19 and had better prognosis than adults.<sup>[25–27]</sup> In addition, students aged 6 to 11 years were less likely to transmit the virus compared to high-school-aged children, who could transmit the virus as efficiently as adults.<sup>[28]</sup> Although it is possible for children to develop multisystem inflammatory syndrome after a SARS-CoV-2 infection, it was very rare and its prognosis was good upon early diagnosis and treatment.<sup>[21,29]</sup> As of August 31st, 2020, school-aged children and adolescents accounted for under 7% of COVID-19 cases and less than 0.1% of COVID-19-related deaths in the United States. Their morbidity and mortality rates were much lower than those of adults.<sup>[5,30]</sup> Therefore, it is of great importance to re-evaluate the impact of school closures. A safe reopening of schools should be of top priority for policymakers.<sup>[31]</sup>

Following the guideline of Preferred Reporting Items for Systematic Reviews and Meta-analyses, a comprehensive literature search from PubMed, EMBASE, Cochrane Library, Scopus, and Web of Science regarding school closures and its impact on K-12 students was conducted. The primary outcomes of this study included the impact of school closures on the mitigation of pandemic, mental health, physical well-being, child maltreatment, healthcare and social services, education, and other pertinent public health concerns of K-12 students.

In this literature review, no research subjects' information or other sensitive information was collected and/or disclosed. All of the references that have been cited by this paper were published in international peer-reviewed journals with proper review from corresponding ethics committees if necessary. Therefore, an ethical review for this study is not necessary.

## 2. Impact on the mitigation of pandemic

School closures, one of the primary social distancing measures, was implemented to mitigate transmission of SARS-CoV-2.<sup>[32]</sup> Its

effectiveness has become a major concern due to its negative effect on children and adolescents.<sup>[33]</sup> To date, there have only been sporadic cases providing limited evidence of school-based transmission of SARS-CoV-2.<sup>[34]</sup> While many field investigations and modeling studies have been published, their results have been inconsistent and their conclusions remain controversial.

A study involving 10 high schools and 5 primary schools in New South Wales traced the close contacts of 18 infected students and staff. The results showed that there may have been 2 secondary cases and no evidence of children infecting faculty members.<sup>[12]</sup> In contrast, when Israeli schools fully reopened on May 17th, 2020 after a two-month hiatus, there was a major outbreak in a high school that led to 153 students (13.2%) and 25 staff members (16.6%) testing positive for COVID-19. One month later, 87 additional confirmed COVID-19 cases had occurred among close contacts of the first school's cases. These included siblings attending other schools, participants in extracurricular activities, and parents and relatives of students and staff members.<sup>[35]</sup>

Researchers have also obtained contradictory results from modeling studies regarding the effectiveness of school closure on the mitigation of COVID-19. In the United Kingdom, some results indicated that delaying school reopening by 2 weeks could halve risks to children.<sup>[36,37]</sup> In the United States, researchers found that between March 9, 2020 and May 7, 2020, school closures were temporally associated with a significant decline in the incidence and mortality of COVID-19. It was estimated that the adjusted relative change per week of incidence and mortality could decrease by 62% and 58% respectively. When cumulative incidence of COVID-19 was low, the earlier schools closed, the larger the relative reduction in incidence and mortality.<sup>[38]</sup> Based on this study, school closures in the United States were associated with 128.7 fewer cases per 100 000 population over 26 days and with 1.5 fewer deaths per 100 000 population over 16 days. Using an individual-based stochastic model, researchers from the University of California, Berkeley simulated COVID-19 transmission dynamics based on social-contact data of school-aged children from the Bay Area in California. Assuming children younger than 10 years old were half as susceptible to SARS-CoV-2 infection as older children and adults, from March 17th to June 1st, 2020, school closures could avert 13,842 cases infections (95% confidence interval: 6290–23,040), with similar effect as workplace closures and social distancing. The results also suggested that the effect of school closures was driven by middle and high school students and faculty.<sup>[7]</sup>

Researchers from the United Kingdom estimated the effects of a range and combinations of different social distancing measures. Using data from the general population and schools of the United Kingdom together with data on transmission dynamics reported from the COVID-19 outbreak in Wuhan, they found that when all schools and 25% of universities were closed, there was a 50% increase in non-school social contacts for families with children and a 25% increase in community contacts during the closures.<sup>[39]</sup> As an isolated measure, school closures were predicted to reduce total deaths by 2% to 4% during a COVID-19 outbreak in the United Kingdom, which was not as effective as case isolation. A combination of measures would be the most effective. Since children are not the key drivers of transmission, school closures alone is relatively insufficient in mitigating the COVID-19 pandemic, compared to seasonal influenza epidemics.<sup>[39]</sup>

A network-based modeling study to simulate realistic scenarios of social interventions in Michigan, United States was conducted.

This model allowed researchers to individually manipulate transmission dynamics with school and workplace closures and social distancing efforts. The results demonstrated that delaying school reopening only delayed and could not reduce the magnitude of the second peak in COVID-19 cases. Meanwhile, decreasing contact between co-workers was identified as a significant factor in delaying and reducing the magnitude of the second wave.<sup>[40]</sup> Another modeling study on the effectiveness of different social distancing measures obtained similar results. Researchers from the United States evaluated the impact of different measures, including shelter-in-place orders, bans on large-scale social gatherings, school closures, and closures of entertainment venues, gyms, bars, and restaurant dining areas on the growth rate of confirmed COVID-19 cases across United States counties between March 1st, 2020 and April 27th, 2020. Results showed that adoption of social distancing measures reduced the daily growth rate of confirmed COVID-19 cases significantly. There would have been ten times greater spread of COVID-19 by April 27th without shelter-in-place orders (10 million cases) and more than 35 times greater spread without any of the 4 measures (35 million cases). However, no evidence proved that school closures had a statistically significant impact on the growth rate in confirmed COVID-19 cases, but the 95% confidence intervals meant that reductions of up to 4 to 5 percentage points could not be ruled out.<sup>[41]</sup>

Whether school closures can specifically mitigate the transmission of COVID-19 remains controversial as results of modeling studies were highly dependent on some uncertain parameters, such as the relative susceptibility and infectiousness of children and the extent of community transmission.<sup>[7]</sup> Nonetheless, it appears that there is greater evidence supporting the meager impact of school closures. Furthermore, the negative societal side-effects of school closures cannot be ignored. School closures have affected the battle against the pandemic negatively through reductions in the healthcare workforce available to care for patients. In January 2020, there were about 3.1 million healthcare workers across 1.3 million households in the United States. About 29% of them needed to provide care for 3 to 12 years old children.<sup>[42]</sup> Even if they could receive help from non-working family members, 15% of healthcare workers would still need childcare during school closures. Based on the results of a modeling study, during the COVID-19 pandemic, a 15% healthcare workforce reduction would increase cumulative mortality by 17.6%, compared to the baseline mortality rate of 2%.<sup>[42]</sup> Additionally, school closures burden the economy. Costs have been estimated to be as high as 3% of the gross domestic product for an 8-week closures in United States studies and have raised the United States unemployment rate from 3.5% in February 2020 to 14.7% in April 2020.<sup>[43]</sup> These are indicators of a global economic crisis that could be as severe as the 2008 recession.<sup>[44]</sup> A society cannot not fully reopen without reopening schools first. Thus, it is also very necessary for policymakers to carefully weigh the potential contagion prevention from school closures against the potential increase in mortality due to the loss of available healthcare workers.

### 3. Impact on mental health

The COVID-19 pandemic has created substantial stress in many families due to the widespread changes in financial situations, health concerns, and uncertainty about the future. These changes have led to reductions in social contacts, consequently increasing

feelings of loneliness that are associated with increased risks of anxiety, depression, and suicidal behavior among children.<sup>[44]</sup> A cross-sectional study conducted in Brazil showed that social distancing without parents and more persons living together at home had caused about 20% of Brazilian children to suffer from anxiety, which may affect the development and mental health of children and adolescents.<sup>[45,46]</sup>

Children and adolescents are active during and after the regular school day. Their normal social life can help them learn from classmates and friends, which is very helpful for them to develop personality traits and a sense of identity.<sup>[47]</sup> Due to the pandemic, many schools have been closed for more than half a year, leaving children confined to their homes. In the United States, children were more likely to perform physical activity at home during the early COVID-19 period rather than play on neighborhood streets as they had done before the pandemic. About a third of children used remote/streaming services for activity classes and lessons during the early-COVID-19 period.<sup>[48]</sup> Removed from their usual schedules and unable to engage in their normal social life, children may have experienced irregular sleeping patterns, lack of interaction with friends or classmates, limited outdoor activities, longer screen time, and changes in family members' health and emotional states. These risk factors can be as grave as a traumatic experience and trigger a vicious circle of psychological and physical repercussions.<sup>[49-51]</sup>

Sleep is crucial for children and adolescents' mental health and well-being. In the pandemic context, one of the significant benefits of sound sleep is support to the immune system.<sup>[52]</sup> Worsened sleep due to stress may also result in increased susceptibility to mood and anxiety problems and lead to greater attentional difficulties and oppositionality for some adolescents, resulting in behavior that resembles attention-deficit/hyperactivity disorder.<sup>[53]</sup> Research showed that during the pandemic, children's attention-deficit/hyperactivity disorder symptoms were significantly worse than during normal times, which may negatively impact a wide range of aspects including learning ability, interpersonal relationships, self-esteem, and emotions.<sup>[54]</sup>

Under the stress of the pandemic, children of different ages may exhibit different responses as they may not understand the situation well, perceiving it to be confusing and frightening.<sup>[55]</sup> Mild responses to stress may have little effect on daily life. Moderate response may affect emotional, physical, and cognitive functions for several hours.<sup>[56]</sup> Younger children may be more nervous and scared, pestering their parents about the situation of the pandemic and asking for their permission to play with peers. Adolescents may have worries, develop irritability, and throw tantrums as they may spend a lot of time following news about the pandemic.<sup>[57]</sup> A severe stress response due to isolation, quarantine, and even losing a close relative from the pandemic may seriously affect the lives and learning abilities of children, potentially leading to a severe mental health crisis.<sup>[58]</sup> The disruption of peer-to-peer relationships has been associated with depression, guilt, and anger in children. Adolescents may be particularly vulnerable to the effects of social distancing and isolation as they are required to physically distance from peers while simultaneously experience significantly longer time with caregivers.<sup>[59]</sup> It is reported that post-traumatic stress disorder during pandemics events than those whose movements were not restricted.<sup>[59]</sup>

Parents or guardians are the primary supporters for children with mental stress.<sup>[60]</sup> Nevertheless, in the United States, 40% of

families have school-aged children and in more than 90% of these households, at least 1 parent is employed outside of the home.<sup>[61]</sup> Many working parents have struggled to earn a living and maintain their employment during this economic recession, and thus may not have enough time or energy to alleviate their child/children's mental stress.<sup>[62]</sup> Those fortunate enough to be able to work from home have to supervise their children's education and daily life simultaneously. This makes it very easy for them to transmit negative emotions, such as frustration and fear, to their children, increasing family conflict.<sup>[63]</sup> A systematic review of the United Kingdom discovered that among children, family conflict is one of the major precipitants of suicidal acts, and childhood abuse and neglect are also associated with attempts of suicide. Out of those seeking treatment for self-harm, there is a high prevalence of domestic violence victimization.<sup>[44,64,65]</sup>

There have also been other tangible negative impacts on families. Families with moderate to severe food insecurity increased from 6% before March 2020 to 8% after, employer-sponsored insurance coverage for children decreased from 63% to 60%, and 24% of surveyed parents reported loss of regular child-care.<sup>[66]</sup> The results of a national survey showed that since March 2020, 27% of parents reported worsening mental health and 14% reported worsening behavioral health for their children. Worsening mental health for parents occurred alongside worsening behavioral health for children in nearly 1 in 10 families, among whom 48% reported loss of regular child-care, 16% reported change in insurance status, and 11% reported worsening food security.<sup>[66]</sup>

Many schools have also failed to deliver the necessary mental health services to students due to a lack of guidelines. In this situation, children must learn how to cope with mental stress on their own; the difficulty of this task should not be underestimated.<sup>[67]</sup> Whether prolonged school closures will cause long-term and/or irreversible mental health problems requires further investigation.<sup>[68]</sup>

#### 4. Impact on physical well-being

Movement behavior, including sufficient physical activity, limited sedentary behavior, and adequate sleep, is important to the healthy development of children and adolescents.<sup>[69]</sup> They are recommended to participate in at least 1 hour moderate-intensity to vigorous-intensity physical activity, engage in at most 2 hours of sedentary recreational screen time, and have 9 to 11 hours of high-quality sleep each day.<sup>[70]</sup> When schools were open, providing physical education classes, athletic training, and unstructured free time, it has been estimated that 75% of American students between the ages of 6 and 15 did not meet the national guidelines for physical activity and have excessively high screen time.<sup>[71,72]</sup> According to results from a study of Singapore, virtual learning may lead to changes in behavior that are conducive for the onset and progression of myopia. Even if school closures are terminated soon, these behavioral changes, such as increased use of digital devices, increased screen time, and reduced time participating in outdoor activities can lead to long-run increases in prevalence of myopia.<sup>[73]</sup> While increased screen time is inevitable and confers some benefits, excessive screen time is also associated with risk factors for cardiovascular problems including obesity, high blood pressure, and insulin resistance.<sup>[74]</sup>

The level of physical activity has been negatively impacted by school closures.<sup>[70]</sup> During prolonged school closures, many students have been left without sufficient and appropriate spaces

for physical activity and have very little structure and guidance. About 90% of the children were engaged in free play or other unstructured activity while about 50% of the children simply went for a walk.<sup>[48]</sup> Some children have turned to workout videos posted on various social media websites. Aside from their effectiveness, underprivileged students are once again at a disadvantage for they may not have the same access to such online content.<sup>[75,76]</sup>

In-person schooling, extracurricular activities, and socialization with peers have had to take place via electronic-based platforms. The loss of in-person activities and related peer relationships have contributed to reduced physical activity and increased sedentary screen time and sleeping.<sup>[70]</sup> A survey conducted in the United States representing 35 states and Washington D.C., including 211 children with an average age of 8.73 years, showed that children engaged in about 1.5 hours of school-related sitting and more than 8 hours of leisure-related sedentary activities each day. The decrease in physical activity and increase in sedentary behavior in older children (ages 9–13) was greater than that in younger children (ages 5–8) since the pandemic.<sup>[48]</sup> Similarly, in Canada, after the outbreak of the COVID-19, only 4.8% of children and 0.6% of youth met the combined movement behavior guidelines during COVID-19 restrictions. Children and youth had lower physical activity levels, less outside time, higher sedentary behavior, and more sleep during the outbreak.<sup>[69]</sup> This is quite similar to patterns observed during summer vacations. As a result, prolonged school closures may have disastrous and long-term effects on the health of students all across the United States.<sup>[48]</sup>

Obesity is one of the adverse effects directly or jointly caused by changes of movement behavior, positive energy balance, and other risk factors. In the United States, among 2 to 19-year-olds, the prevalence of obesity from 2011 to 2014 was 17.0% and extreme obesity was 5.8%. In particular, the prevalence of obesity in school-aged children (6–11 years) and adolescents (12–19 years) was much higher than in preschool-aged children, reaching 17.5% and 20.5%, respectively. The same pattern was seen in both sexes.<sup>[77,78]</sup> Physical inactivity among children is one of the major behavioral risk factors for childhood obesity.<sup>[79]</sup> It has been reported that during summer breaks, the rate of obesity among children in the United States could increase by 0.85 percentage points per month (95% confidence interval: 0.58–1.12).<sup>[80]</sup> At this average rate, there should have been a 5.1% increase after 6 months of school closures. However, the results of a microsimulation modeling study have only suggested an increase of 2.373% in childhood obesity prevalence in 1 year of school closures due to the COVID-19 pandemic in the United States. The average body mass index could increase by up to 0.198, and the impact was modestly greater among boys, and non-Hispanic blacks and Hispanics, respectively.<sup>[81]</sup> The discrepancy between the results of different modeling studies may be attributed to the different algorithms of the different models and the parameters incorporated. In addition, some families have adopted new hobbies or accessed new physical activity resources, which may partially account for the lower projected increase. Yet, they both support the conclusion that school closures during the pandemic possess the potential to increase the prevalence of childhood obesity.<sup>[69]</sup> Childhood obesity is associated with chronic diseases including hypertension, type 2 diabetes, heart disease, stroke, and even some types of cancer.<sup>[82]</sup> Extended school closures not only increase the risk of childhood obesity and other chronic diseases due to a positive energy balance but

also deprive children of the physical and mental-health-enriching benefits of physical activities.<sup>[81]</sup> A meta-analysis of 22 studies representing 143,603 children also reveals the heightened prevalence of depression among obese children. Compared to normal-weight children, obese children were 1.32 times more likely to be depressed, and obese girls specifically were found to be 1.44 times more likely to be depressed compared to their normal-weight female counterparts. As the risks for girls also persist into adulthood, clinicians should also consider screening obese girls for symptoms of depression.<sup>[83]</sup>

## 5. Impact on child maltreatment

Studies have shown that stress is a risk factor in child maltreatment potential.<sup>[84]</sup> Nearly 40% of children experienced maltreatment by adulthood,<sup>[85]</sup> correlating with lower education attainment, lower income, and social problems, such as an increased likelihood to commit crime and attempt suicide in prison.<sup>[86,87]</sup> Therefore, it is integral that stress is reduced and cases of maltreatment are brought up by children to trusted adults, such as teachers and psychology workers in schools.<sup>[88]</sup>

The COVID-19 pandemic has brought about an unprecedented range of stressors for parents and children alike, impacting their health, safety, and economic well-being, whether families have or have not been directly exposed to the virus.<sup>[89,90]</sup> In an attempt to maintain social distancing, elementary and secondary schools have canceled in-person classes and shifted instruction online for about a year. Partially as a result, many parents and guardians have been laid off or have had to quit their jobs to take care of their children full-time.<sup>[17]</sup> Those who retain their jobs may see their work time and pay reduced, find it difficult to simultaneously work and assist with schoolwork, or have physical difficulty looking at screens for long periods of time during teleworking.<sup>[62]</sup> As a result, financial, mental, and physical stress for parents are expected. Child maltreatment is a very likely outcome of the accumulation of these risk factors.<sup>[91,92]</sup> This is a highly prevalent issue, as rates of childhood maltreatment are between 29% and 68%.<sup>[87]</sup> Literature also revealed that child maltreatment occurred from stressors that result from economic hardship, low education, single parenthood, a large number of dependent children, or extended periods of close contact during stressful times.<sup>[49,93]</sup> All of these risk factors are applicable or exacerbated by the COVID-19 pandemic.

While more cases of child maltreatment during the COVID-19 pandemic are expected, research results have indicated reduced reports of them. A study of children in Florida, United States between March and April 2020 uncovered that, when adjusted for seasonal fluctuation and secular trends, the total number of reported allegations of child maltreatment was more than 27% lower than what had been expected; this reduction can largely be attributed to the closing of in-person education. Nationally, it is estimated that 215,000 cases of maltreatment went unreported during March and April 2020.<sup>[11]</sup> Many children struggle to report cases of maltreatment and receive treatment for mental illnesses with instruction online. Without the involvement of school-based counselors, these concerns may not be investigated and the long-lasting negative impacts will fester.<sup>[88,93]</sup>

## 6. Impact on healthcare and social services

Schools are vital to students across the United States, providing numerous important services in a low-cost and supportive

environment. They include basic needs like physical protection, heating, cooling, sanitation, and nutritional support in the form of reduced-price or free breakfast and lunch. Schools also fulfill students' secondary needs, such as medical care, mental health and psychosocial support, and specific education including driver's education, sexual health education, special education, and advanced academic programs.<sup>[94]</sup> Daily, 35 million children in American schools and childcare facilities depend on numerous nutritional programs as a vital safety net against food insecurity.<sup>[95]</sup> At least 20 million children rely on schools for breakfast and lunch,<sup>[88]</sup> which provide roughly half of children's daily caloric intake.<sup>[96]</sup> Surveys indicate that 20% of children under the age of 12 go hungry and about 14% of households with children suffered from food insecurity.<sup>[88]</sup> Among families with children, food insecurity rates may have doubled since school closures associated with the pandemic, owing in no small part to the lack of school meals.<sup>[96]</sup> Roughly 2.5% of America's public-school students do not have a permanent residence.<sup>[20]</sup> Therefore, an unintended side effect of school closures to mitigate the spread of COVID-19 has been the deprivation of these potentially life-saving resources for dozens of millions of American children, who need them even more during this period of remote instruction, economic crisis, social isolation, and high burden on health services.<sup>[95]</sup> These negative impacts unfortunately affect underprivileged children the most, as they may have to rely exclusively on health services through schools and their parents may struggle to find and/or pay for the services that their children desperately need.<sup>[21,61]</sup> According to clinicians working at school-based health centers in New York City, since March 2020, underprivileged patients have faced growing psychological distress and compounded trauma, and school closures have also prevented them from receiving most of their healthcare.<sup>[97]</sup> While there have been efforts to provide essential services, such as nutritional support, to underprivileged children, estimates indicate that less than 1 out of 7 children qualify for the Summer Food Service Program, due to numerous difficulties in delivering the services.<sup>[96]</sup> School-based health center clinicians have been helping New York City's underprivileged, but the communities they service may nevertheless be more prone to developing clinical disorders due to social isolation and related stressors.<sup>[97]</sup> Safe and widespread school reopening is integral for parents to return to their workplaces, perform their jobs to their maximum efficiency, and thus provide as much support for their children as possible. Research further indicated that the lack of these crucial resources during these troubling times also affected learning significantly.<sup>[20]</sup>

## 7. Impact on education

Schools and teachers have placed great emphasis on ensuring the quality and quantity of academic instruction. However, due to some insurmountable difficulties, virtual instruction, while expedient, cannot replace face-to-face instruction. On the other hand, there is emerging evidence regarding the adverse impact of school closures on the education and intellectual development of children and adolescents.<sup>[57,98]</sup>

By the end of the 2019 to 2020 school year in June 2020, millions of American children have missed months of in-class instruction and vital learning opportunities. Worldwide, about 1.6 billion, more than 90% of the world's students have been affected due to school closures.<sup>[19]</sup> During those months, underprivileged students may have lacked access to the proper

technology necessary to have the best remote learning experience possible.<sup>[99]</sup> With summer vacation immediately following the months-long hiatus of in-person learning, many of America's children face serious risk of falling behind the normal academic curve by 9 to 12 months.<sup>[47,88,100]</sup> Additionally, the lack of in-person education has prevented children from fully engaging in meaningful and much needed social-emotional experiences, such as playing with classmates, resolving problems and conflicts, learning to help 1 another, and forming and maintaining relationships with peers and adults.<sup>[21]</sup>

Online education is challenging for students, especially younger ones. Many are at the stage where they are developing crucial fine motor skills and hand-eye-coordination with projects and activities that cannot be properly conducted through a computer screen. The difficulties of remote instruction are further compounded by the possible lack of parental guidance due to work or other obligations. This is particularly detrimental to young students, most of whom have not properly disciplined themselves to pay attention and learn without an authority figure in their vicinity.<sup>[47,94]</sup> Nonetheless, a survey indicates that 31% of parents in the United States would still prefer to keep their children at home for the fall semester, if given the choice.<sup>[101]</sup> Hence, the negative impact of school closure on education is significant.

Many schools have considered returning portions of students to classrooms in a gradual process, frequently beginning with younger students and students with special education needs, for the same aforementioned reasons.<sup>[102]</sup> Nevertheless, this brings about its own unique educational challenges. It is difficult for teachers to ensure social distancing, proper sanitation, and educational quality in the classroom while simultaneously interacting with students receiving education remotely.<sup>[94]</sup> Young children in classrooms will not be able to resist the urge to interact with each other after months of separation, leading to breaches of social distancing rules and the possibility of physical contact that may spread the virus.<sup>[12]</sup> As a result, certain schools have laid out independent learning plans. Nevertheless, not only are many students not able to rigidly follow them, but education is best conducted in groups in a social manner.<sup>[21]</sup>

## 8. Impact on other public health issues

Adolescence, referring to the period between the ages of 10 and 19 years, is a critical period of growth leading to physical, psychological, and sexual maturation, during which adolescents tend to explore and develop sexual relationships. Positive and healthy relationships are strongly linked to the sexual and reproductive health as well as overall well-being of adolescents.<sup>[103]</sup> Therefore, sexual and reproductive health of adolescents should definitely not be ignored in the midst of COVID-19.

In particular, prolonged school closures may contribute to unintended teenage pregnancy, which may lead to termination of education, reduced job and career prospects, and increased vulnerability to poverty and exclusion. In addition, complications during pregnancy and delivery of teenage pregnancy are the leading causes of death for 15 to 19 years old girls globally.<sup>[104]</sup> In some areas, during prolonged school closures, adolescent girls are at a higher risk of dropping out of school and being forced into childhood marriages. They may also experience sexual exploitation and/or violence.<sup>[105]</sup> Although the prevalence of teenage pregnancy in most states has been decreasing over the past score years, teenage pregnancy is still one of the most important public

health issues in the United States.<sup>[106–108]</sup> It is worth noting, however, that the decreasing trend was not observed across all ethnic groups and socioeconomic classes. For example, from 1991 to 2014, the birth rate among teens aged 15 to 19 years old in the United States declined 61%, from 61.8 to 24.2 births per 1000. However, in 2014, the teen birth rate remained approximately twice as high for Hispanic and non-Hispanic black teens compared to non-Hispanic white teens.<sup>[106–109]</sup>

During stay-at-home and social-distancing mandates and other COVID-19-related events, the pornographic website Pornhub has noted a worldwide increase in pornography use. When Pornhub made its premium services free, more substantial increases were observed in the United States and some European countries.<sup>[110]</sup> It is difficult to determine the exact age groups of the users. However, it is reasonable to assume that when adults view such pornographic content, adolescents may have unintentionally seen it, or adolescents may have viewed pornography secretly when their parents/guardians were not present to satisfy their curiosity and/or cope with loneliness and/or anxiety.<sup>[111]</sup> In addition, other internet addictions, including internet gaming disorder, online gambling, problematic substance use, and excessive use of social media and communication sites have led to impairment or distress in school-aged children and adolescents.<sup>[112–115]</sup>

Suicide is a leading cause of death in the United States. Its prevalence has steadily risen over the past 2 decades by 30%.<sup>[116]</sup> Between 2005 and 2017, suicide was the third-leading cause of death for Americans aged between 10 and 24 years old. In particular, for adolescents between 15 and 19 years old, the annual percentage change of suicide rates increased by 3.1% from 2007 to 2014, followed by a sharp increase of 10.0% from 2014 to 2017.<sup>[117]</sup> Suicide is an extreme consequence of the psychological burden most likely caused by multiple reasons. Therefore, the reasons for the change in suicide prevalence are very complicated.<sup>[118]</sup> Previous studies have suggested that anxiety caused by disease and/or social isolation, mental health problems, alcohol and other substance misuse, unemployment and financial loss, relationship problems and loss, access to lethal means, and even TikTok addiction can lead to suicide.<sup>[119–121]</sup> Therefore, it is reasonable to assume that suicide could be an extreme consequence driven by the psychological burden caused by the measures to mitigate the pandemic of COVID-19. However, it is also logical to presume that school closures may have reduced suicide rates by reducing academic and social pressure, as well as peer conflict and bullying in school.<sup>[122]</sup>

A few studies on suicide rates among children and adolescents during the pandemic and school closures have been published.<sup>[123,124]</sup> In Japan, the suicide rate did not change significantly during the first 3 months (from March to May 2020) of school closures as compared to the same period in 2018 and 2019.<sup>[125]</sup> In another study, following a monthly decline in suicide rates by 14%, it increased by 16% during the second wave (July to October 2020) in Japan with a 49% increase among children and adolescents. The changes in suicide rates for children and adolescents may be attributed to school closures and the reopening of schools.<sup>[118]</sup> Current literature discussing the impact of school closures due to COVID-19 on rates of suicides among K-12 students in the United States is scant. One investigation carried out in Michigan revealed that in the emergency department, the proportion of patients under 18 years old encountered suicide-related behavior less than 18 to 65-year-olds following the onset of the COVID-19 pandemic.<sup>[126]</sup> School

closures may have decreased academic pressure and the opportunities for suicide-related behavior or access to means of death when the adolescents and their parents/guardians spend more time together in close contact.<sup>[126]</sup>

The studies above have demonstrated that school closures were associated with sexual health, suicide, and various internet-mediated problematic behaviors. The adverse impacts of the COVID-19 pandemic and school closures may remain in the long term even with schools fully reopening in the near future. Before more robust investigations are conducted and more reliable data is published, it may be too early to draw definitive conclusions currently. However, it is never too early to take effective preventative measures against vulnerable populations.

## 9. Conclusions

School closures, as an effort to curb the spread of COVID-19, may have been marginally effective during the early parts of the pandemic. Nonetheless, as time has passed, more problems have surfaced as a result of prolonged school closures that make them a poor tradeoff. The absence of in-person instruction significantly reduces physical activity, negatively affects students' mental health, excludes many from a myriad of health services, potentially leads to a series of significant health problems, impedes the provision of social and emotional support, increases the exposure to conflict at home, and causes significant retardation in academic progress. With students at home, many parents are forced to stay at home to care for them as well, creating financial troubles and burdening communities economically, socially, and health-wise. According to the evidence, it appears that the role children play in transmitting COVID-19 has been overestimated, and hence the positive effect of school closures. Not only does reopening schools in a staged fashion not solve the problems at their root, they may also raise additional issues. The longer lockdowns continue, the greater the risks to children's well-being. It is hoped that as vaccines and other non-pharmaceutical preventative measures proliferate the United States and other countries, schools can fully reopen their doors to students earlier, allowing these problems to be fundamentally alleviated.

## Author contributions

**Conceptualization:** Wanli Tan.

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