Measuring the benefits of school closure interventions to mitigate influenza

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Gerardo Chowell

Author for correspondence:
Division of Epidemiology and Population Studies, Fogarty International Center, National Institutes of Health, Bethesda, MD, USA
and
School of Human Evolution and Social Change, Arizona State University, Tempe, AZ, USA
Tel.: +1 480 965 4730
Fax: +1 480 965 7671
gchowell@asu.edu

Cécile Viboud

Division of Epidemiology and Population Studies, Fogarty International Center, National Institutes of Health, Bethesda, MD, USA

Lone Simonsen

Division of Epidemiology and Population Studies, Fogarty International Center, National Institutes of Health, Bethesda, MD, USA
and
Department of Global Health, School of Public Health and Health Services, George Washington University, Washington DC, USA

Mark A Miller

Division of Epidemiology and Population Studies, Fogarty International Center, National Institutes of Health, Bethesda, MD, USA

EXPERT REVIEWS

"…social distancing may reduce infectious disease transmission by limiting contact of infectious and noninfectious persons within populations."

In the absence of an effective vaccine, public health interventions that provide social distancing may reduce infectious disease transmission by limiting contact of infectious and noninfectious persons within populations. These measures include school closures, the cancellation of large public gatherings and the use of facemasks. Such drastic interventions can be socially disruptive, costly or ethically unappealing. Hence it is critical that early public health efforts focus on estimating epidemic severity and transmission potential to guide the implementation of social distancing measures.

"School closure has been proposed as a potentially effective measure to mitigate influenza transmission."

Studies on the effectiveness of population-based social distancing measures are limited compared with the large evidence base regarding the individual-level effectiveness of vaccines, antivirals and other biomedical interventions. Here we briefly discuss observational studies that provide estimates of the impact of school closures on mitigating influenza spread.

School closure has been proposed as a potentially effective measure to mitigate influenza transmission [1]. The CDC has recommended prompt school closure in the event of a severe pandemic [2]. The theory behind the mitigating effect of school closings is that school age children have high contact rates, tend to be more susceptible to influenza infection than other age groups and have increased viral shedding [1]. Thus, reducing influenza transmission in school children may reduce the attack rates in all age groups.

Quantifying the effectiveness of school closure interventions

The effectiveness of school closures are typically estimated as the effective change in the reproduction number over time, based on the evolution of daily or weekly disease incidence. The effective reproduction number (R[t]) is a function of dynamic variables associated with the pathogen, type of population, mixing patterns and prior immunity. R(t) measures the average number of secondary cases generated by a primary infectious individual at time(t) in the population [3]. When R(t) >1, an epidemic is successfully spreading in the population whilst R(t) <1 implies that the epidemic is waning or that the pathogen cannot cause an epidemic. Hence, estimates of R(t) early in the outbreak provide information about the intensity of the interventions necessary to achieve epidemic control. Once the outbreak is under way, a reduction in R(t) can be attributed to effective public health interventions, changes in population behavior or seasonal transmission, depletion of susceptible hosts, or a combination of these. A relative reduction in the R(t) associated with school closure (compared with settings without such intervention) suggests the effectiveness of this intervention.

Keywords: influenza • mathematical model • reproduction number • school closure interventions • transmission rate

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In practice, it is extremely difficult to control for all factors that could potentially affect the reproduction number during an epidemic. In general, the effectiveness of school closures will depend on their starting time, relative to the outbreak onset, duration and intensity, and on any pre-existing immunity in school children. These interventions are expected to have a greater effect on transmission when put in place early and for prolonged periods of time, and when immunity in children is lowest.

Time-dependent changes in the age distribution of cases can be the result of changes in population mixing structure. In particular, for the 2009 A/H1N1 influenza pandemic, the proportion of influenza cases occurring in school-age children was higher when schools were in session [4]. Likewise, a decline in this age ratio concomitant with the school closure period is indicative of the effectiveness of school-based interventions on reducing influenza transmission. However, monitoring age-specific influenza cases does not in itself provide a quantitative estimate of the effectiveness of school closures.

School closure & seasonal influenza

Public health authorities may implement school closure in the advent of severe seasonal influenza epidemics. In Hong Kong, public health authorities suspended educational activities in kindergartens and primary schools for 2 weeks in winter of 2008 after two pediatric influenza deaths had been identified [5]. However, the authors were not able to detect a significant effect of the school closure on the transmission patterns, probably because school closure was implemented after the epidemic peak.

School activities have been linked with increased seasonal influenza transmission rates [6]. Hence, school holidays and schoolteacher strikes can offer an opportunity to explore the impact of school terms in boosting influenza transmission. Cauchemez *et al.* took advantage of the geographic variability of the school calendar in France to quantify their effect of school holidays on influenza transmission [7]. They found a 16–18% reduction in influenza-like illness incidence associated with the 2-week school winter break periods, based on the analysis of 21 years of surveillance data. Similarly, a European study of variation in contact rate patterns suggested a 13–40% reduction in the basic R(t) associated with school holiday periods in Belgium, Great Britain and The Netherlands [8]. Another study found a reduction of 43% in weekly rates of respiratory disease associated with a 12-day teacher strike in Israel in the winter of 1999 [9].

School closure & pandemic influenza

School closures as a mitigation tool for influenza can be traced back at least to the 1918 A/H1N1 influenza pandemic. Several studies have reported significant effects of school closings and other social distancing measures in reducing pandemic transmission in the USA [10,11]. During the subsequent 1957–1958 A/H2N2 influenza pandemic in the USA, there was no large-scale policy in place to close schools in the autumn of 1957, although some schools and student activities had to close owing to a large proportion of sick individuals [12]. Moreover, the fall pandemic onset in the USA coincided with the reconvening of schools starting in Louisiana in August 1957 [12].

Experience with school closure during the 2009 A/H1N1 pandemic

Following the emergence of the 2009 pandemic in March–April in Mexico, early containment efforts relied, in part, on the implementation of school closure interventions owing to limited availability of antivirals and the absence of an effective vaccine. Given the uncertainty regarding the severity of the pandemic, educational activities in Mexico City were cancelled on 24 April and these measures were expanded to the rest of the country on 27 April, as a result of reports of elevated numbers of severe cases among young adults in Mexico. Additional social distancing interventions were implemented in Mexico City, including the cancellation of large public gatherings. Schools reopened on 11 May and remained in session until the scheduled summer vacation period, which began in July 2009. These actions provided an opportunity to measure the effect of school closing on transmission: the R(t) was reduced by 29–37% during the intervention period in central Mexico; and the proportion of school-age children among influenza cases was low during the summer vacations and increased sharply following the start of school activities in August.

> "…reducing influenza transmission in school children may reduce the attack rates in all age groups."

Japan quickly implemented school closures on 16 May 2009 for a week across all schools in Osaka and Hyogo after initial A/H1N1 influenza outbreaks among school-age children. The reproduction number declined significantly following the implementation of school closures, suggesting that the intervention yielded substantial transmission reductions [13].

In Hong Kong, Wu *et al.* estimated approximately 25% reduction in pandemic A/H1N1 influenza transmission following secondary schools closures from 11 June to 10 July 2009 [14], and Jackson *et al.* found a 65% reduction in the total mean number of contacts per student by conducting a questionnaire survey 2 weeks after a secondary school closure in the UK in mid-June 2009 [15].

In Peru, public health authorities started the national winter school vacation 2 weeks early in July 2009 in an attempt to mitigate the impact of the pandemic [16]. The fact that the winter school vacation period coincided with the waning phase of the pandemic in Peru makes the quantification of the effectiveness of school closure challenging. However, the school closure period was shown to be associated with a significant decline in the ratio of school-age to other cases, a pattern that suggests mitigation was achieved [16].

Observational studies tend to evaluate temporary effects of school closures, but do not consider what may happen once schools eventually reopen with the resurgence of pandemic influenza [17,18]. Mitigation may just delay pandemic burden or distribute it over longer time periods; the delay gained by mitigation may buy enough time for vaccines and antivirals to become available, and alleviate pressure on the healthcare system. Indeed, large-scale modeling studies of school closure interventions have found reductions of attack rates by up to 40% during the peak of a pandemic [19]. Any susceptible individuals spared in the first pandemic wave by school closure interventions could become infected during subsequent waves, leading to a prolonged pandemic with a reduced peak incidence, which could relieve disease burden in hospitals. Overall, further modeling work is needed to consider the total public health benefits or school closure both during and after the mitigation period has ended. This can be critical in the context of pandemic periods characterized by multiple waves, especially if successive waves differ in disease severity [17,18,20].

Conclusion

Recent observational studies support the implementation of school closure interventions to achieve reductions in influenza transmission rates. In the context of a pandemic, this can be particularly useful to gain time until biomedical measures (vaccines or antivirals) become available, and to relieve the burden on healthcare institutions due to a reduced surge of influenza patients. However, in the context of multiple pandemic waves occurring over several months or years, the proportion of cases averted by these social distancing measures remains uncertain. More empirical studies and methodological approaches are needed to fully elucidate the effects of school closure interventions on seasonal and pandemic influenza. In particular, a systematic multicountry comparison of the 2009 pandemic experience would be useful to shed light on the effectiveness of school-based intervention policies under different epidemiological, behavioral and demographic situations.

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