School Opening Dates Predict Pandemic Influenza A(H1N1) Outbreaks in the United States

Dennis L. Chao,1 M. Elizabeth Halloran,2 and Ira M. Longini, Jr2
1Center for Statistics and Quantitative Infectious Diseases, Vaccine and Infectious Diseases Division, Fred Hutchinson Cancer Research Center and the University of Washington, and 2Department of Biostatistics, School of Public Health, University of Washington, Seattle, Washington

The opening of schools in the late summer of 2009 may have triggered the fall wave of pandemic influenza A(H1N1) in the United States. We found that an elevated percentage of outpatient visits for influenza-like illness occurred an average of 14 days after schools opened in the fall of 2009. The timing of these events was highly correlated (Spearman correlation coefficient, 0.62; P < .001). This result provides evidence that transmission in schools catalyzes community-wide transmission. School opening dates can be useful for future pandemic planning, and influenza mitigation strategies should be targeted at school populations before the influenza season.

Fall school openings have been consistently associated with an increase in the transmission of respiratory agents, including occasionally influenza [1]. It is difficult to measure the contribution of schools to influenza transmission in a community. School holidays and other closures have been used to estimate the impact of school closings on the reduction of seasonal influenza transmission [2]. Such studies may provide the best insight into the role played by schools in community-wide transmission, but these natural experiments generally occur in the midst of widespread transmission. With the recent outbreak of pandemic influenza A(H1N1) (pandemic H1N1) in the United States, we have the unique opportunity to observe the effect of school openings at the beginning of an epidemic.

We hypothesize that the opening of schools in the fall of 2009 led to regional surges in pandemic H1N1 in the United States. Pandemic H1N1 arrived in the United States in the spring of 2009 and continued to circulate beyond the influenza season [3]. Out-of-season outbreaks occurred in summer camps and other settings. Because the United States was heavily seeded with cases through the summer, some researchers had predicted an early peak (October) for pandemic H1N1, as was the case for Asian influenza A(H2N2) in 1957–1958 [4, 5]. The opening of schools might have been sufficient to trigger the observed statewide outbreaks. Typically, influenza season in the temperate Northern hemisphere is between November and March, well after schools are open, so the effect of school openings at the onset of an influenza outbreak is seldom observed. Here, we study the temporal relationship between the opening of public schools in the United States and the observed increase of influenza-like illness.

Methods. Influenza activity in each state can be monitored by the percentage of outpatient visits for influenza-like illness (ILI), as reported by the US Outpatient Influenza-like Illness Surveillance Network (ILINet) each week [6]. ILI is defined as “fever and a cough or a sore throat in the absence of a known cause other than influenza.” The Centers for Disease Control and Prevention (CDC) reports ILI data both as a national average [7] and by multistate US Department of Health and Human Services regions [8].

We defined the onset of elevated ILI activity to be the first date on which the percentage of outpatient visits for ILI exceeded baseline levels. Because of regional differences in ILI activity, the CDC defined independent baselines for the 10 multistate regions in the United States [6]. The CDC defines the baseline level of ILI activity to be “the mean percentage of patient visits for ILI during noninfluenza weeks for the previous 3 seasons plus 2 standard deviations.”

Because the CDC reports ILI trends by large geographic regions only, we used Google Flu Trends for ILI activity at the state level [9]. Google Flu Trends provides up-to-date estimates of ILI activity in the United States at the state and national levels [10]. In our analyses, we used the appropriate regional baseline as the baseline level for each state.

Opening dates for public schools in 19 states and the District of Columbia were available from their respective departments of education. States report these dates either by district or by individual school. For the remaining 29 states in the continental United States, we obtained opening dates from 25 randomly sampled school districts per state. We defined a state’s school...
opening date to be the median of the first day of classes in its school districts (or individual schools). Results were not appreciably different when the first or third quartiles of the opening dates were used instead. Although the districts can vary greatly in size, the use of random sampling should produce an unbiased estimate of the median. The median opening dates for each state were between 6 August and 9 September 2009. The average variance of school or district openings within a state was 18 days (range, 0–114 days). The mean standard deviation was 3.8 days (range, 0.0–10.7 days).

The public school opening date for each Department of Health and Human Services region was estimated by randomly sampling with replacement 10,000 opening dates from the appropriate states’ data (described above), with the sampling weight proportional to the state’s population estimate in 2009 [11].

To quantify the relationship between school opening dates and elevated ILI activity, we used linear regression and the Spearman correlation test. We computed the 95% confidence envelope using the predict function of R software (version 2.9.2; R Development). The percentage of cases of ILI is reported weekly, so linear interpolation was used to estimate the day on which the number of cases of ILI first crossed the regional baseline in the summer or fall of 2009. Analyses were performed using the R statistical software package [12].

**Results.** Up until late summer 2009, the number of cases of ILI for each state was below the corresponding regional baseline established by the CDC. Between 9 August and 24 September, the number of cases of ILI for each state surpassed the regional baselines (Figure 1A). Most of the elevated ILI activity in the fall of 2009 in the United States can be attributed to pandemic H1N1 because most subtyped influenza A isolates have been pandemic H1N1 [5].

We found that the number of cases of ILI in each state did not exceed regional baselines until after schools opened, with the exception of 1 state (Minnesota) (Figure 1B). This increase in ILI occurred 1–32 days after the median school opening date in each state (mean, 14 days), except for Minnesota, where the regional baseline was surpassed 5 days before its median school opening date. The beginning of elevated influenza activity was

---

**Figure 1.** A, Weekly percentage of cases of influenza-like illness (ILI), by state. The regional baselines for the 2009–2010 influenza season are shown as horizontal dashed lines. The regional baselines and weekly percentage of ILI activity by state are color-coded by influenza surveillance region, as shown in the legend. B, ILI data relative to the states’ school opening dates. The x axis represents the number of days relative to a state’s median school opening day, and the y axis represents the ILI activity of a state minus the appropriate regional baseline.

**Figure 2.** Beginning of elevated influenza-like illness (ILI) activity vs school opening date, by state. The date on which the percentage of cases of ILI in a state exceeds its regional baseline is shown on the y axis. Each point represents a state, the solid line represents the linear regression fit ($y = 0.69x + 20.33$), and the dashed lines represent the 95% confidence envelope.
highly correlated with the median school opening date (Spearman correlation coefficient, 0.62; *P* < .001) (Figure 2). The expected increase in influenza activity would be ∼19 days after the beginning of the first school openings (6 August 2009) or only 9 days after the beginning of the latest school openings (9 September 2009).

Using ILI data from the CDC, which is aggregated by multistate region, elevated ILI activity and median school opening dates did not have a statistically significant relationship (result not shown). However, the slope of the regression line was not statistically different than the slope from the state-level analysis. The small number of data points (10 regions) and the large size of the regions made it difficult to discern the relationship between elevated ILI activity and school opening dates by region.

**Discussion.** Detectable widespread transmission of pandemic H1N1 appears to occur 2 weeks after the opening of schools in a state. This information should be useful for future pandemic planning and control. When there is a pandemic influenza threat, vaccines and other control measures should be in place at least 2 weeks before schools open [5, 13]. For seasonal influenza, school-based vaccination should be performed before or shortly after schools open.

The results of this study could be refined with data at finer spatial and temporal resolutions. The CDC ILI data were aggregated by multistate region, which makes it difficult to determine the timing of outbreaks on the school district level. In addition, the regional ILI baseline values we used may not have captured the variation in baselines that could exist within a region. We therefore used Google Flu Trends’ state-level data, which could not be validated against actual ILI data by state but had been validated against data provided by the state of Utah, as reported elsewhere [9]. ILI data are reported weekly, so we used linear interpolation to estimate daily values. Ideally, a consistent definition of community-wide transmission at a fine geographic resolution should be used.

The lag between median school opening date and elevated cases of ILI shrank from August to September, from 19 to 9 days. Our analyses assumed that the transmissibility was constant from late summer to early fall. Many factors that are believed to affect influenza transmission, such as weather, may have changed during this time [14]. In addition, transmission from adjacent states with earlier influenza outbreaks could have led to earlier outbreaks in states with late school start dates.

Computer simulations can be used to explore the interactions between school closures and other mitigation strategies [15, 16]. Epidemic simulations and models require a variety of data for calibration, and observations of the dynamics of pandemic H1N1 complement the available data. Including school opening dates in models might be sufficient to reproduce the differences in regional peaks of influenza activity that were observed during the 2009–2010 influenza season in the United States and possibly other countries in the Northern hemisphere.

Our findings are unique in that they suggest that a delay in the opening of schools could delay the onset of an impending epidemic. This effect probably depends on the relatively high prevalence of the virus before the beginning of the school year.

There are no strict guidelines on the strategic use of school closures for mitigation or prevention of influenza outbreaks. Although closures can be used for short periods of time to stop outbreaks in schools [17], widespread transmission may resume once schools are reopened. Currently, the CDC does not generally recommend reactive dismissals [18]. School dismissals may protect the staff and children at high risk but are not likely to reduce community transmission. They may be used in conjunction with other mitigation strategies, such as vaccination.

The cost of closing schools is high and might not be the most cost-effective option [19]. However, community mitigation measures may be the only way to gain enough time to produce a vaccine tailored to the virus strain or to increase hospital capacity to accommodate cases of severe illness [20].

**Acknowledgments**

We thank Valerie Obenchain from the Fred Hutchinson Cancer Research Center, Robin Webb and Diane Wagener from RTI International, and Karen Lane from the Indiana Department of Education for assistance in gathering school opening data.

**References**


