Predicting virologically-confirmed influenza using school absences during the 2007-2015 seasons in Allegheny County, PA

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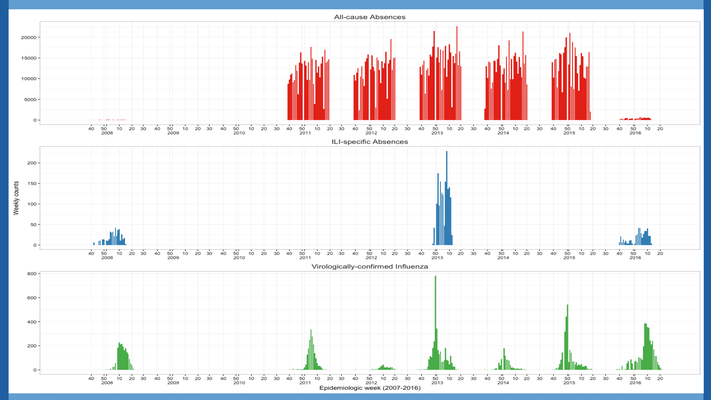
BACKGROUND

- School-based surveillance has been considered for real-time flu monitoring, as 5-17 year olds play an important role in community-level transmission.
- We studied if all-cause and cause-specific school absences improved predictions of virologically-confirmed influenza in the community.

FIGURE 1. ALL-CAUSE ABSENCES, ILI-SPECIFIC ABSENCES & REPORTED CONFIRMED FLUE CASES OVER FIVE INFLUENZA SEASONS



Weekly counts of reported all-cause absences (9 school districts (SD), 2010-2015, a subset of schools in 3 districts 2007-2008, 2015-2016) (top panel). ILI-specific absences for 3 SDs (2007-2008, 2012-2013 and 2015-2016) (middle panel) and virologically-confirmed influenza all of Allegheny county from 2007 and 2010-2016 (bottom panel).

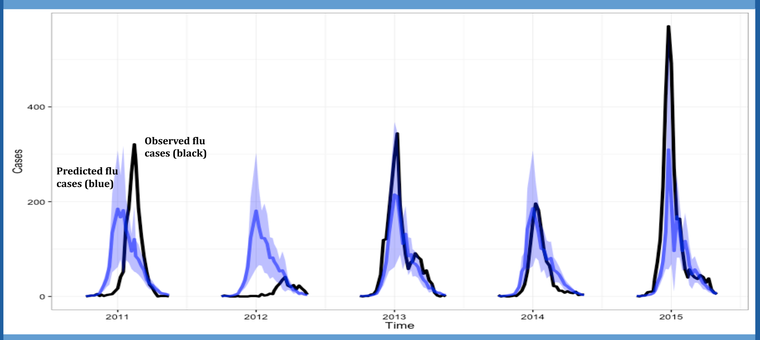
DATA & METHODS

- Virologically-confirmed flu cases (all ages) collected from all county emergency departments & outpatient providers (2007 and 2010-2016) provided by Allegheny County Department of Health
- Reported all-cause school absence rates from 9 Allegheny County school districts for 2010-2015
- Six school districts provided influenza-like illness (ILI)-specific absences collected using a standard protocol
  - 10 K-5 schools in 1 school district (2007-2008)
  - 9 K-12 schools in 2 school districts (2012-2013)
  - 9 K-12 schools from 3 school districts (2015-2016)
- We used negative binomial regressions to predict weekly county-level flu cases in Allegheny County, Pennsylvania during the 2010-2015 seasons.
- Candidate model covariates:
  - All-cause school absence rates of different weekly (1-3) lags & administrative levels (county, school type, & grade) (assessed separately)
  - Week and month of the year (assessed separately)
  - Average weekly temperature & relative humidity (assessed separately)
- Separately, for 3 districts for which ILI-specific and all-cause absences were available, we predicted weekly county-level influenza cases using all-cause and ILI -specific absences with all previously stated covariates.
- We used several cross-validation approaches to assess models including leave 20% of weeks out, leave 20% of schools out, and leave 52-weeks out.

RESULTS

- Overall, in Allegheny county, there were:
  - 2,184,220 reported all-cause absences from 9 school districts (2010-2015)
  - 19,577 reported all-cause and 3,012 ILI-related absences from 3 school districts (2007, 2012 and 2015)
  - 11,946 reported virologically-confirmed influenza cases (2007, 2010-2015)
- Including 1-wk lagged absence rates in multivariate models improved model fits & predictions of influenza cases over models using week of year and weekly average temperature (ΔAIC=-4).
- All-cause absences from lower grades explained data best
  - Kindergarten absences explained 22.1% of model deviance compared to 0.43% using 12th grade absences in validation.
- Multivariate models of week-lagged kindergarten absences, week of year, & weekly average temperature had the best fits over other grade-specific multivariate models (ΔAIC=-6 comparing K to 12th grade)
- ILI-specific absences perform marginally better than total absences in two years, adjusting for other covariates, but markedly worse in one year. However, these results were based on a small number of observations.
- Increased length of absence from school also improved predictions

FIGURE 2. OBSERVED & PREDICTED CASES USING WEEKLY COUNTY ALL-CAUSE ABSENCES



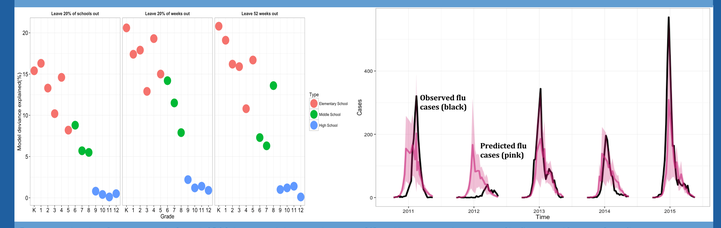
Weekly observed virologically-confirmed (black line) and predicted (blue line) influenza cases over five influenza seasons (2010-2015) in Allegheny County . Predictions used a negative binomial regression accounting for 1-week lagged county absences, week of the year, and average temperature. Blue shading represents the uncertainty bounds. Predictions shown here use 20% of schools left out validation.

Table 2. Performance of models including week-lagged kindergarten absences to predict virologically-confirmed influenza in Allegheny County, PA.

Validation	Model	R^2
Leave 20% of data out	Absence	58.1%
Leave 20% of data out	Temperature & week	35.9%
Leave 20% of data out	Absence, temperature & week	65.4%
Leave 52 weeks out	Absence	19.2%
Leave 52 weeks out	Temperature & week	49.9%
Leave 52 weeks out	Absence, temperature & week	42.8%
Leave 20% of schools out	Absence	19.1%
Leave 20% of schools out	Temperature & week	40.6%
Leave 20% of schools out	Absence, temperature & week	58.6%

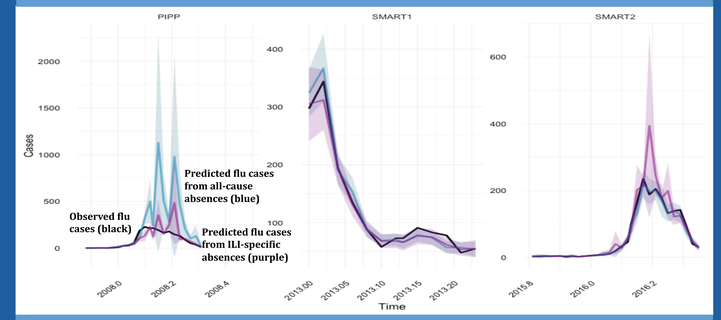
Negative binomial model included various lagged weekly absence rates, and splines of week of the year, and average temperature. Model validation withheld 20% of data. Deviance is the in-sample deviance explained by the model. R^2 was obtained by linearly regressing the observed cases against the predicted cases using the out-of-sample data. Mean absolute error is the mean absolute prediction error over the time-series.

FIGURE 3. GRADE-SPECIFIC MODEL DEVIANCE AND PREDICTIONS USING KINDERGARTEN ABSENCES



In-sample deviance explained (%) by weekly grade-specific all-cause absences (left panel) ranging from kindergarten to 12th grade, & observed & predicted cases from kindergarten absences (right panel) using negative binomial regression models of virologically-confirmed influenza in Allegheny County from 2010-2015. Colors in left panel represent different school types: red for elementary school grades, green for middle school grades, and blue for high school grades. Pink line & shading represent the predicted cases and 95% uncertainty bounds using a negative binomial regression of absences, wk & temp, & leave 20% of schools out validation.

FIGURE 4. OBSERVED & PREDICTED FLU USING ALL-CAUSE VS ILI-SPECIFIC ABSENCES



Weekly virologically-confirmed observed (black) and predicted (blue line refers to all-cause absence model and purple line refers to ILI-specific absence model) influenza cases during 3 seasons (2007-2008, 2012-2013, & 2015-2016). Shading represents uncertainty bounds. model included weekly-lagged absence rates from the previous week, week of the year, and average temperature. SMART[1] models included weekly-lagged absence rates and week of the year. Cross-validation used leave 20% of schools out.

Table 3. All-cause and cause-specific model performance using three school-based cohort data for three influenza seasons

Influenza Season	Cohort	Absence-type model	R^2
2007-2008	PIPP	All-cause absence	44.3%
		ILI-specific absence	49.0%
2012-2013	SMART[1]	All-cause absence	99.9%
		ILI-specific absence	99.9%
2015-2016	SMART[2]	All-cause absence	99.0%
		ILI-specific absence	84.0%
Pooled analysis	PIPP, SMART[1], SMART[2]	All-cause absence	35.0%
		ILI-specific absence	31.0%

Each negative binomial model included weekly-lagged absence rates from the previous week, week of the year, and average temperature. SMART[1] models included weekly-lagged absence rates and week of the year. Cross-validation used leave 20% of schools out. R^2 was obtained by linearly regressing the observed cases against the predicted cases using the out-of-sample data

CONCLUSIONS

- Our findings suggest models including younger student absences improve predictions of virologically-confirmed influenza.
- We found ILI-specific absences performed similarly to all-cause absences, but more observations are needed to assess the relative performances of these two datasets.

Acknowledgements
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