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Major article

Geospatial patterns in influenza vaccination: Evidence from uninsured and publicly insured children in North Carolina

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Background: The purpose of this study was to explore geospatial patterns in influenza vaccination.
Methods: We conducted an ecological analysis of publicly funded influenza vaccinations at the ZIP code tabulation area (ZCTA) level using secondary data for publicly funded influenza vaccinations among eligible school-aged children (age range, 5-17 years) for the 2010-2011 and 2011-2012 influenza seasons from the North Carolina Immunization Registry (NCIR). NCIR data were merged by ZCTA with other publicly available data. We tested for spatial autocorrelation in unadjusted influenza vaccination rates using choropleth maps and Moran's I. We estimated nonspatial and spatial negative binomial models with spatially correlated random effects adjusted for demographic, economic, and health care variables. The study was conducted at the University of North Carolina at Chapel Hill in the spring of 2014.
Results: The NCIR demonstrated spatial autocorrelation in publicly funded influenza vaccinations among uninsured and means-tested, publicly insured school-aged children; ZCTAs tended to have influenza vaccination rates that were similar to their neighbors. This result was partially explained by included ZCTA characteristics, but not wholly.
Conclusion: To the extent that the geospatial clustering of vaccination rates is the result of social influences, targeting interventions to increase influenza vaccination among school-aged children in one area could also lead to increases in neighboring areas.
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School-aged children are an important population for influenza vaccination policy. School-aged children experience high rates of influenza infection, absenteeism, hospitalization, and death.[1-3] In addition to the effects of influenza on children, they are also a major source for the transmission of influenza within families, schools, and communities because of high infection rates, prolonged viral shedding, and close contact with other classmates.[4-8] Therefore, from a policy perspective, increasing influenza vaccination rates in school-aged children can reduce influenza illness in the larger susceptible population[7,9] and can be a potentially cost-effective way to prevent influenza in the population as a whole.[10,11]

As a result, beginning with the 2008-2009 influenza season, the Advisory Committee on Immunization Practices recommends annual influenza vaccination for all children aged 6 months to 18 years.[12] This recommendation meant that uninsured and low-income children could receive influenza vaccinations at no cost through the Vaccines for Children (VFC) program, which provides Advisory Committee on Immunization Practices-recommended vaccines at no cost to children who might not otherwise be vaccinated because of inability to pay.[13] Despite the VFC program and other state programs to remove access and cost barriers, influenza vaccination rates among school-aged children remain low: median coverage across states was 41.2% during the 2009-2010 influenza season.[14]

Vaccination is of particular importance for under- and uninsured children, more so than school-aged children with private insurance. Because these students are from poor families without access to private insurance, they may lack many of the family and financial safety nets of their peers. Short, acute illnesses that can be shrugged off with a visit to the pediatrician's office and parents taking a few days off from work for relatively affluent children will be more problematic for the vulnerable population in our study. These children may not be able to receive proper, timely medical treatment. Absence from school results in lower test scores, and because students in poverty score lower, all else equal, each day of

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schooling missed is more costly, relative to their classmates.[15] In addition, because of parents' work schedule inflexibilities, they may be forced to return to school earlier than is ideal, inadvertently increasing the risk of transmitting the flu to their schoolmates.

Several simulation models of the geospatial spread of influenza suggest that spatial targeting of influenza vaccination could be an effective strategy to reduce the spread of pandemic influenza.[16,17] However, within the United States, regional estimates of influenza vaccination are rare and have not been studied in-depth using geospatial techniques.[18-20] Previous studies have focused on spatial patterns of influenza infections,[21,22] hospitalizations,[23,24] or deaths.[25] With the exception of Yousey-Hindes and Hadler,[24] we know of no other studies that have focused on influenza outcomes for children. Spatial patterns are important not only for targeting high-need areas, but also because if vaccination rates are causally related from one area to another (eg, through information networks), targeting interventions to increase influenza vaccination among school-aged children in one area could lead to positive spillover effects in neighboring areas.

This study explores geospatial patterns in publicly funded influenza vaccination among uninsured and means-tested, publicly insured school-aged children in North Carolina. North Carolina has one of the highest levels of intrastate variation in influenza vaccination coverage.[20] This study is one of the first to investigate geospatial patterns in influenza vaccination. Using vaccination registry data, we conducted an ecological analysis of publicly funded influenza vaccination rates to determine if vaccination rates tend to cluster geographically. The analysis tests the extent to which influenza vaccination rates cluster geographically because of similar demographic, economic, and health characteristics in nearby areas. The results of this study will inform efforts to increase vaccination rates among school-aged children and prevent transmission of influenza in the population by identifying correlates with low rates in certain areas and highlighting areas where interventions are needed.

DATA

We collected data for publicly funded influenza vaccinations among school-aged children (age range, 5-17 years) for the 2010-2011 and 2011-2012 influenza seasons from the North Carolina Immunization Registry (NCIR), provided by the North Carolina Department of Health and Human Services. The NCIR is a secure, Web-based clinical tool to provide official immunization information to the state.[26] This study is one of the first to use vaccination registry data. We are aware of only 3 other studies that used registry data, and they all focused on H1N1 vaccination in non-U.S. settings.[18,27,28] A major benefit of vaccination registries is that they are objectively reported by providers and avoid recall and reporting bias from self-reported measures in surveys.[28]

Providers receiving any state-supplied vaccine were required to report influenza vaccinations during the 2008-2009 and 2009-2010 influenza seasons. However, because of budget limitations, in the 2010-2011 and 2011-2012 influenza seasons included in this study, only influenza vaccination doses funded by the federal VFC program were required to be reported to the NCIR. To assess whether there were any changes in reporting patterns by providers, we analyzed data from the National Immunization Survey-Teen for North Carolina. Among 13-17 year olds in North Carolina with provider-confirmed influenza vaccinations for the 2010-2011 season ($n = 89$ teens), 72.0% of respondents' providers reported to the state registry, and another 19.4% had at least some of their providers report to the registry. This rate of registry reporting was comparable with the 2009-2010 season, during which reporting was required in North Carolina: 75.4% of teens had all providers report to the registry, and 18.6% had some but not all providers report to the registry. The rates of providers reporting to the registry in North Carolina were higher than the national average in both influenza seasons.

We aggregated the number of children vaccinated against influenza using public funds in each season by patient ZIP code, which we then cross-walked to the ZIP code tabulation area (ZCTA).[29] ZCTAs are generalized area representations of ZIP code service areas developed by the U.S. Census Bureau to overcome the difficulties in precisely defining the land area covered by each ZIP code. For our analysis, ZCTAs provide sufficient variation across geographic areas while also having data available for area-level characteristics. We collected geographic boundary and demographic characteristics for North Carolina ZCTAs from the U.S. Census Bureau: 2013 Topologically Integrated Geographic Encoding and Referencing shape files,[30] 2010 U.S. Census, and 2008-2012 (5-year) American Community Survey (ACS). Data at the ZCTA level were only available at 1 point in time, centered around 2010.

We measured the severity of the influenza season using county-level data on influenza-like illness (ILI) visits to the emergency department (ED) for the 2009-2012 seasons from the North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT). The NC DETECT receives data daily from 113 (of the 115) 24 h/d, 7 d/wk EDs in North Carolina. The NC DETECT definition of ILI includes any case with the term flu or influenza or at least 1 fever term and 1 influenza-related symptom.

We also collected county-level characteristics from the 2012-2013 Area Resource File (ARF). All variables at the county level, which cross ZCTA boundaries, were converted to ZCTAs using weighted averages of the county-level data. For count variables we used census calculations of the percentage of the total population of the 2010 county represented by the ZCTA or county overlap for the weights (eg, a ZCTA that accounted for 10% of the county population received 10% of the county's medical providers). For dichotomous variables, all counties touched by the ZCTA must have a positive indicator for the ZCTA to receive a positive value. For per-capita variables we used census calculations of the percentage of the total population of the 2010 ZCTA represented by the ZCTA or county overlap for the weights (eg, a ZCTA with 90% of its population in county A and 10% in county B will weight per capita variables from county A at 90% and per capita variables from county B at 10%). Data at the county level were available for each influenza season: 2010 for the 2010-2011 season, and 2011 for the 2011-2012 season.

VARIABLES

The dependent variable in the analysis was the number of school-aged children (age range, 5-17 years) vaccinated for influenza using public funds in each ZCTA in each influenza season. The explanatory variables included the following demographics: the population of uninsured and means-tested, publicly insured school-aged children (logged when used as exposure in count models, 2008-2012 ACS); percent women (2010 U.S. Census); percent Hispanic; percent non-Hispanic black; percent other or multirace or multiethnicity (non-Hispanic white omitted; 2010 U.S. Census); percent with less than high school diploma; and percent with at least some college (high school diploma omitted; 2008-2012 ACS). Based on previous literature,[31] we expected ZCTAs with more women, minorities, and higher levels of education to have higher influenza vaccination rates.

We adjusted for access to vaccinations using 2 economic variables: percent in poverty (2008-2012 ACS) and unemployment rate for ages ≥ 16 years (ARF). We hypothesized that higher rates of poverty and unemployment rates would be associated with lower

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