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County-level assessment of United States kindergarten vaccination rates for measles mumps rubella (MMR) for the 2014–2015 school year

Sheryl A. Kluberg [a], Denise P. McGinnis [a], Yulin Hswen [a,b], Maimuna S. Majumder [a,c], Mauricio Santillana [a,d,e], John S. Brownstein [a,e,*]

[a] Computational Epidemiology Group, Children's Hospital Informatics Program, Division of Emergency Medicine, Boston Children's Hospital, MA, USA
[b] Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, Boston, MA, USA
[c] Engineering Systems Division, Massachusetts Institute of Technology, Cambridge, MA, USA
[d] School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA
[e] Department of Pediatrics, Harvard Medical School, Boston, MA, USA

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ABSTRACT

United States kindergarten measles-mumps-rubella (MMR) vaccination rates are typically reported at the state level by the Centers for Disease Control and Prevention (CDC). The lack of local MMR data prevents identification of areas with low vaccination rates that would be vulnerable to the spread of disease. We collected county-level vaccination rates for the 2014–2015 school year with the objective of identifying these regions.

We requested county-level kindergarten vaccination data from state health departments, and mapped these data to visualize geographic patterns in achievement of the 95% MMR vaccination target. We aggregated the county-level data to the state level for comparison against CDC state estimates. We also analyzed the relationship of MMR vaccination level with county-level and state-level poverty (using U.S. census data), using both a national mixed model with state as a random effect, and individual linear regression models by state.

We received county vaccination data from 43 states. The median kindergarten MMR vaccination rate was 96.0% (IQR 89–98) across all counties, however, we estimated that 48.4% of the represented counties had vaccination rates below 95%. Our state estimates closely reflected CDC values. Nationally, every 10% increase in under-18 county poverty was associated with a 0.24% increase in MMR vaccination rates (95% CI: −0.07%; 0.54%), but the direction of this relationship varied by state.

We found that county data can reveal vaccination trends that are unobservable from state-level data, but we also discovered that the current availability of county-level data is inadequate. Our findings can be used by state health departments to identify target areas for vaccination programs.

1. Introduction

Measles, a disease that was eliminated in the United States (U.S) nearly two decades ago, has seen an alarming rise in incidence in recent years. In 2014, a record 667 cases were reported from 27 states, a 256 percent increase from the 187 cases reported in 2013 [1]. One large outbreak within an unvaccinated Amish community in Ohio resulted in 383 cases [1], while a case of measles at California's Disneyland spread to 111 individuals in seven U.S. states, Canada, and Mexico [2]. Both of these events have been attributed to importation of the disease from the Philippines, and while imported cases of measles from abroad are not uncommon, it is unusual for these cases to initiate a large outbreak [1].

Measles is a highly infectious disease that continues to be one of the leading causes of death in young children globally despite the existence of an effective vaccine [3]. In 2014, the World Health Organization reported approximately 114,900 global measles deaths, the majority of which were among children under the age of five [3]. Two doses of the measles-mumps-rubella (MMR) vaccine is 97% effective in preventing measles while one dose of the vaccine is 93% effective [4]. In the U.S., the first dose of MMR vaccine is administered at 12–15 months and the second administered between 4 and 6 years of age [5]. Almost all U.S. states and the District of Columbia (D.C.) require two doses of measles-containing

* Corresponding author at: Computational Epidemiology Group, Children's Hospital Informatics Program, Division of Emergency Medicine, Children's Hospital Boston, 401 Park Drive, Boston, MA 02215, USA.
E-mail address: John.Brownstein@childrens.harvard.edu (J.S. Brownstein).

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vaccine for entrance to public school kindergartens, although many states allow exemptions for medical, religious, or personal reasons. The intent of this strict vaccine requirement is to achieve herd immunity, a concept described as the protection of a given community from disease when a sufficient portion of the population is immunized [6]. Because of its high level of transmissibility, the percent of immunized people needed to achieve herd immunity against measles in a given community has been estimated at 92–95% [6,7]. Despite states' strict immunization requirements, their permitting of exemptions compromises efforts to ensure herd immunity [8–11]. In a recent review by Phadke et al., vaccine refusal was associated with an increased risk for measles among people who refuse vaccines and among fully vaccinated individuals [12].

The U.S. Centers for Disease Control and Prevention (CDC) collects yearly immunization data from school surveys and state and local immunization programs to estimate kindergarten vaccination coverage at the state level [13]. They also sample individual-level vaccination data via phone survey to estimate regional vaccine coverage for children aged 19–35 months and detect associations between demographic characteristics and vaccination probability [14]. The CDC's state-level analysis of kindergarten MMR vaccination rates for the 2014–2015 school year found that the median state-level coverage was 94.0%, 32 states did not meet the 95% 2-dose MMR target, and seven states had <90% 2-dose MMR coverage [13]. While these are important findings, this analysis did not identify within- or cross-state pockets where MMR vaccination rates are lower than the 95% target. Even states with high overall vaccination rates might have regions of low vaccination, putting them at greater risk of an outbreak.

Studies of childhood vaccination rates for other vaccines such as influenza and Human Papilloma Virus (HPV) have shown that nation-wide analysis can mask state- or community-level trends [15,16], but that each layer of analysis provides valuable insight for policy design. A national assessment paints a general picture of progress, while a state-level analysis can compare existing policies, a county-level analysis can identify local populations at risk for undervaccination, and an individual-level analysis can establish causal relationships between demographic factors, policies, and vaccination.

Research studies evaluating potential risk factors for MMR undervaccination have examined poverty (and affluence), race, geography, and parents' education [14,17–20]. Of the two studies conducted in the U.S., the national analysis found that poverty was associated with lower vaccination rates [14], while the California study found that affluence was associated with a reduced likelihood of vaccination [17]. This discrepancy suggests that heterogeneity exists in the association of socioeconomic status and MMR vaccination across the U.S.

We built upon the CDC's data by compiling county-level rates of MMR vaccination among kindergarteners for the 2014–2015 school year. We evaluated the accessibility of vaccination data, identified geographic clusters of under-vaccination that might be susceptible to an outbreak upon exposure to measles, and analyzed the county-level relationship between poverty and MMR vaccination rates. Our results can help target support for communities at greatest risk for measles outbreaks.

2. Methods

2.1. Data

To determine county level rates of immunization for MMR, we contacted state health departments via email or telephone to request kindergarten county-level vaccination data for the 2014–2015 school year. We requested a report of county-level percentage of kindergarten students vaccinated with two doses of MMR from school census data; if a complete school survey had not been performed, we accepted a state immunization registry query for children with birthdates of September 2008 through August 2009. Where data specific to two doses of MMR were not available, we also accepted reports on the percentage of students completing one MMR dose or the entire vaccination series.

We compare our results against the CDC's state-level estimated kindergarten MMR vaccination rates for the same year. The CDC collected only school data, but sampling methods varied. Of the 50 states and D.C., 29 programs used a complete school census, two used a voluntary response of schools, 10 used a type of sample (either two-stage cluster, one-stage cluster, or simple random sample), and 10 used a mix of methods [13]. The sampling methods were designed to produce a valid state-level estimate, but do not provide adequate data for estimation of local vaccination rates [13].

To study the relationship of vaccination rates and county poverty levels, we collected 2014 Census Bureau estimates of county-level proportion of under-18 year-old youths in poverty [21].

2.2. Analysis

For states with two-dose MMR data, we calculated the percent of kindergarten age children in the county, school district, or health district who had been fully vaccinated prior to the beginning of the school year. For states that only reported single-dose MMR coverage or completion of the entire vaccine series (not MMR-specific), we calculated county-level percentages for these values.

To establish validity of our estimates, we compared our state-level aggregated results against CDC estimates for state-level kindergarten MMR vaccination rates for the same school year. For states that provided county-level kindergarten enrollment numbers along with vaccination rates, we estimated state-level aggregated rates as population-weighted averages of county-level vaccination rates.

To assess the variability of vaccination rates across the country despite large differences between school survey and state registry data, we standardized each state's vaccination rates to have the same mean as estimated by the CDC. Counties and districts were then categorized as fulfilling or not fulfilling the 95% herd immunity vaccination threshold. We created a map of U.S. counties denoting achievement of the 95% vaccination target standardized to the CDC estimates.

We also assessed whether county poverty was associated with county MMR vaccination rates in our data. To evaluate the national trend, we ran a univariate linear mixed model with county-level under-18 poverty as our independent variable, county kindergarten two-dose MMR rates as our dependent variable (not standardized to CDC values), and state as a random variable to control for variability in state vaccination reporting methods. To evaluate state-level trends we ran the same linear regression separately for each state.

3. Results

3.1. Data received

We received data from 43 states. Six states did not have suitable data to provide (Alaska, Colorado, Delaware, Hawaii, New Mexico, Oklahoma) and one state did not respond (Georgia). Thirty-five states provided school census data, six states provided registry data, and two states provided state-level vaccination rate estimates without raw data (Table 1). The median kindergarten MMR vaccination rate was 96.0% (IQR 89–98) across all counties.