Spatial Analysis of Pertussis Outbreaks and Herd Immunity in the USA

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GEOG 596A
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Agenda

- Pertussis Overview
- Herd Immunity
- Objectives
- Data
- Other Health GIS Examples
- Methodology
- Limitations
- Timeline
Pertussis (Whooping Cough)

Respiratory disease caused by *Bordetella pertussis* bacteria
Transmitted via airborne droplets (coughing/sneezing)
Vaccine-preventable

Whooping cough is on the rise
- ~16 million cases & 195,000 deaths world-wide per year
- ~10k-40k cases & 10-20 deaths in USA per year
  Approximately 50% of children <1 y are hospitalized

Source: Centers for Disease Control and Prevention, http://www.cdc.gov/pertussis
San Diego County On Pace Toward Worst Year For ‘Whooping Cough’ Cases Since 2010

Doctors see increase in highly contagious Whooping Cough

The Press Democrat
Whooping cough outbreaks reported in Sonoma County (w/video)
Why Are We Seeing Increases?

- Improved diagnostic testing and better reporting (CDC 2012)
- Waning effectiveness of the vaccine itself (CDC 2012)
- Cyclical Outbreaks (CDC 2012)
- Decreased perception of disease danger and severity (Kennedy 2011)
- Increase of parents delaying or fore-going vaccination due to personal beliefs or apathy about vaccinations (Lundquist 2010)

Exemptions due to religious, philosophical and medical reasons 1991-2004

- Nonmedical exemptions rose from 0.98% to 1.48 in USA
- Religious exemptions remained around 1%
- Philosophical or personal belief exemptions increased from 0.99% to 2.54% in states allowing personal belief exemptions

(Omer et al., 2009)
Reported NNDSS pertussis cases: 1922-2013*

*2013 data are provisional.

SOURCE: CDC, National Notifiable Diseases Surveillance System and Supplemental Pertussis Surveillance System and 1922-1949, passive reports to the Public Health Service
Reported pertussis incidence by age group: 1990-2013*

*2013 data are provisional.

SOURCE: CDC, National Notifiable Diseases Surveillance System and Supplemental Pertussis Surveillance System
Herd Immunity

- Protect the population from disease
- Minimize outbreaks through high levels of immunity
- Different diseases have varying thresholds of herd immunity
Herd Immunity Thresholds for Vaccine Preventable Diseases

\( R_0 \) is the basic reproduction number, or the average number of secondary infectious cases that are produced by a single index case in a completely susceptible population.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Transmission</th>
<th>( R_0 )</th>
<th>Herd immunity threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumps</td>
<td>Airborne droplet</td>
<td>4–7</td>
<td>75–86%</td>
</tr>
<tr>
<td>Polio</td>
<td>Fecal-oral route</td>
<td>5–7</td>
<td>80–86%</td>
</tr>
<tr>
<td>Rubella</td>
<td>Airborne droplet</td>
<td>5–7</td>
<td>83–85%</td>
</tr>
<tr>
<td>Smallpox</td>
<td>Social contact</td>
<td>6–7</td>
<td>83–85%</td>
</tr>
<tr>
<td>Diphtheria</td>
<td>Saliva</td>
<td>6–7</td>
<td>85.00%</td>
</tr>
<tr>
<td>Measles</td>
<td>Airborne</td>
<td>12–18</td>
<td>83–94%</td>
</tr>
<tr>
<td>Pertussis</td>
<td>Airborne droplet</td>
<td>12–17</td>
<td>92–94%</td>
</tr>
</tbody>
</table>
Anti-Vaccination & Disease Rebound

Anti-vaccine movement is giving diseases a 2nd life

Similar to smallpox (now eliminated) in the 19th century, reduction in vaccinations led to resurgence of smallpox.

Smallpox fell between 1802 and 1840 through vaccination. Resurgence of smallpox in 1850’s vaccination decreased leading to disease outbreaks throughout the 1870’s.

1905 – Jacobson v. Massachusetts

(Omer et al 2009)

Smallpox % deaths in Berlin

Objectives

(1) Explore the spatial distribution of pertussis cases and exemptions throughout the USA
   - Areas with positive or negative trends

(2) Compare and contrast pertussis incidence over the past 5-10 years in 2 states.
   - Investigate the relationship between vaccination rates (i.e. herd immunity) and pertussis
   - Characterize demographic composition in these areas
Cases of Pertussis in the USA 1993-2012
All states allow medical exemptions for schoolchildren

48 states allow religious exemptions

17 states allow philosophical or person belief exemptions (PBE)

Varying degrees of difficulty to receive PBEs

PBEs:
WA, CA, ID, UT, CO, AZ, ND, MN, WI, MI, OH, TX, OK, AR LA, VT, ME

http://www.nvic.org/Vaccine-Laws/state-vaccine-requirements.aspx
2010
27,550 cases

2012
48,277 cases

Pertussis Incidence Over the Past 20 Years
California & Florida

California  - Averaged 1,960 cases / year
  - highest annual number of cases in the USA
  - Cyclical outbreaks in last 20 years
    with 1.5 – 19.3 cases/100,000 population
  - Current outbreaks in 2014

Florida  - Averaged 290 cases / year
  - Average number of cases annually in the USA
  - Stable number of cases in last 20 years
    with < 3 cases/100,000 population
Pertussis Cases in California (1947 – 2013) and Florida (1963 – 2012)

California

Florida

Source: Florida CHARTS, Florida Department of Health & California Department of Public Health
Pertussis Incidence by County – California & Florida

2010

2011

2012

2013

Florida

Pertussis
Incidence
Data
Published in
December

Source: FloridaCHARTS.com provided by the Florida Department of Health, Division of Public Health Statistics & Performance Management
California Department of Public Health
Variation exist across the states, within counties, and within school districts and communities.

Nevada County
Sonoma County

The Press Democrat
Whooping cough outbreaks reported in Sonoma County (w/video)
Measles Outbreak San Diego, 2008

1 infected child exposed 839 people to measles and caused 11 new cases (all in unvaccinated children)

Variables statistically evaluated using chi-square and regression testing

Higher exemption rates correlated to higher median income ($88k vs. $53k)

Source: Sugerman, 2010
Rotavirus in Berlin, Germany 2007-09

Spatial Bayesian regression models for statistics

Link found between hospitalization rates from Rotavirus and 1) Percent unemployment in the neighborhood & 2) Percentage of children attending day care

Methodology

Data:
- Number pertussis cases available at county level in Florida (2009-2012) and California (2010-2013)
- Number kindergarteners immunized and exempted by school district/city/county
- Number of kindergarteners by school district/city/county
- US Census Bureau demographic information from 2010 census

Ideally like to perform analysis at address level but may be unlikely. Instead analyze data at smallest scale possible.

Analysis:
Examine the correlation between immunization coverage and pertussis incidence.

Explore relationship between socioeconomic factors: unemployment, income, median age, population density WITH pertussis cases AND PBEs (simple & multivariate regression analysis). Test for significance using Chi-Square.
Limitations

Data:

Range of years available for data between FL and CA

Level of geographic detail for ideal analysis

Exemption and immunization data is for kindergarteners but pertussis cases by county/state is for the entire population

Analysis:

Cyclical nature of disease may cause statistically significant results one year but not another
Expected Outcomes

Identify critical areas with high pertussis numbers both by volume and cases per 100k population

Identify critical areas with little to no herd immunity

Find a correlation between exemption areas and pertussis outbreaks

Find a correlations between socioeconomic factors (education/income/ethnicity, etc.) and pertussis outbreaks

Suspect the rates are too low in Florida to drawn statistically significant results, but not the case in California
Timeline

May – July : Data collection and analysis
Aug – Oct : Analysis of data
Oct – Dec : Writing of capstone project

Presentation Venue: ESRI Health GIS Conference, Nov. 3-5 Colorado Springs, CO
Deadline to submit abstract is August 1, 2014

Paper outlet: International Journal of Health Geographics
Acknowledgments

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Sources

California Department of Public Health

Centers for Disease Control and Prevention

U.S. Census Bureau

Florida Department of Health


The National Institute of Allergy and Infectious Diseases

National Vaccine Information Center


Thank You!  

PROTECT

Protect yourself: get the vaccines you need, when you need them.

Question?