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Impact of Kentucky Vaccination Exemption Laws on Pertussis Incidence

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Katherine Blain, Student

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Linda Alexander, EdD, Director of Graduate Studies

Impact of Kentucky Vaccination Exemption Laws on Pertussis Incidence

by

Katie Blain
Bachelors of Science in Human Nutrition
Biology Minor

Final Examination:
April 6, 2015

A capstone submitted in partial fulfillment
of the requirements for the
Degree of Masters of Public Health
in Health Behavior

Capstone Committee:

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Introduction

Vaccinations are the greatest achievement in public health, helping to shift mortality rates in developed nations from communicable disease to chronic disease. However, in the United States (U.S.), approximately 42,000 adults and 300 children still die annually from vaccine-preventable diseases.¹

Cases of pertussis in the U.S. decreased dramatically after the vaccine was developed in the 1940s; however, since the 1980s, the number of reported cases has been gradually increasing. In 2010, more cases were reported than any year since 1959.² In 2012, the Centers for Disease Control and Prevention (CDC) recorded a record 48,277 cases of pertussis in America.³ Approximately half of infants who contract pertussis will be hospitalized, and 1% of those will die, often from a secondary bacterial pneumonia.³ Economic burden from childhood pertussis includes lost work days by parents, visits to healthcare providers, antibiotic medications, and often costs of hospitalization. A retrospective study in Monroe County, New York estimated that on average, \$3561 of indirect and direct costs resulted per individual case of pertussis in 1997.⁴ This cost estimate does not take into consideration the perverse inflation in American healthcare costs over the past 15 years, nor the associated public health costs of outbreak surveillance and containment.

It is well known that vaccination has majorly decreased the incidence of pertussis and pertussis related deaths among Americans over the past few decades; however, in the past 5 years, diagnoses of pertussis have begun to increase. When pertussis incidence is stratified by age, it has been found that the rise is most prominent in adolescents aged 11-18 and adults greater than 19 years of age.⁵ Adolescents and

adults often carry a subclinical form of the disease, which means they may be less likely to seek medical treatment, and the number of reported cases might be falsely low.⁶

These infected adults can then transmit pertussis to infants, where the bacteria cause a much more virulent and sometimes deadly infection.

The cause for increased incidence of pertussis is thought to be multifactorial, but has not been extensively studied. One possible reason is that the efficacy of Tdap and DTap vaccines is not as high as other vaccinations. Acellular pertussis vaccines (Tdap) replaced whole cell vaccines (DTwP) for adults and teenagers in 2005.⁵ Therefore, there are very limited data on Tdap vaccination long-term efficacy and efficacy at reducing transmission to infants. The childhood acellular vaccine (DTaP) has an efficacy of 88.7-97% immediately after completion of the immunization sequence.^{7,8} However, evidence is growing that the DTaP vaccine produces a waning immunity to pertussis.⁹

Another possible explanation is that due to increased attention to pertussis rates, physicians have become more diligent in testing sick children for the disease. Reasons a practitioner may not conduct a pertussis diagnostic test are delay in obtaining test results, inconvenience of collecting samples, lack of testing supplies, lack of familiarity with testing protocols, and cost.¹⁰ Growing pressure from the media and concerned parents may be motivation for providers to overcome barriers to testing.

The focus of this study is to evaluate the possible role parental acceptance of vaccination plays in pertussis incidence. If fewer children are vaccinated, it is logical that pertussis incidence would increase. Several studies have attempted to identify factors that influence parents' decisions to vaccinate adolescents with Tdap. The factor

commonly associated with an increased likelihood to vaccinate was provider recommendation, while low perceived risk of getting pertussis was the most common barrier to vaccination.^{11,12} Another barrier was that adolescents are less likely than young children and infants to see a healthcare provider on a regular basis.¹³

Requiring vaccination in school-aged children has had tremendous impact on controlling preventable disease outbreaks. In 1977, a CDC study concluded that states requiring vaccination before school entry experienced measles incidence rates 40-50% lower than states that did not.¹⁴ In Kentucky, vaccination is required to attend public and private school. Despite the overwhelming evidence that vaccines are safe and effective, every state has vaccination exemption laws. All 50 states allow vaccination exemption for medical reasons. Children with compromised immune systems and those with previous allergic reactions or adverse effects associated with vaccination would fall into this category. In these children, vaccination may be unsafe. Several states also allow religious exemptions, and others allow religious and philosophical exemptions. The process for obtaining exemptions also varies by state.

The recent measles outbreak at Disneyland¹⁵ has called into question the stringency of vaccination exemption laws. Although it seems logical to assume a correlation, published literature linking vaccination exemption obtainment with disease incidence is sparse. One study of New York state schoolchildren found that counties with higher rates of exemption also experienced increased incidence of pertussis among both vaccinated and unvaccinated children when compared to counties with low exemption rates.¹⁶ It is hypothesized that the same correlation would be observed in Kentucky, because like New York, the law allows both medical and religious

exemptions. The process for obtaining a religious exemption is also similar between the two states, requiring the parents to sign a document saying they understand the risks but object to vaccination for religious reasons.^{17,18} In Kentucky, this form must be signed by a healthcare provider, pharmacist, local health department or other licensed healthcare facility.¹⁸ In New York, the form must also be notarized.¹⁷

The primary objective of this study was to determine if a county-level association existed between vaccination exemptions among school-aged children and pertussis incidence during the years 2004-2012. Secondly, a regional analysis was conducted to determine if Appalachian counties reported higher rates of exemption than non-Appalachian counties. The Appalachian area has many health disparities in maternal and child health, including lack of access to care, low socioeconomic status, and low educational attainment.

Research on the health impact of legal vaccination exemptions provides valuable information for use when lobbying for vaccination initiatives in the legislature. If statistically significant associations are found, further research regarding the public health outcomes of parents' decisions to vaccinate or seek exemption is highly warranted. This glimpse into vaccination exemptions in Kentucky could be a starting point for legislative reform in Kentucky.

Methods

Institutional Review Board Exemption

Because the data do not contain protected health information, the study received IRB exemption from both the University of Kentucky and Kentucky Cabinet for Health and Family Services (CHFS) Institutional Review Boards.

Data Source

This study investigated the correlation between vaccination exemption in kindergarten and sixth grade and pertussis incidence in all 120 Kentucky counties between 2004 and 2012. Kentucky schools are required to submit a Commonwealth of Kentucky School/Facility Annual Immunization Survey to their county health department.¹⁹ The county health department then sends a report to the epidemiologists at the Immunization Program at Kentucky CHFS. This study used the epidemiological reports for all kindergarten and sixth grade immunizations along with statewide Communicable Disease Case Reports submitted to CHFS from 2004-2012.

Study Design

This study retrospectively analyzed data from 120 Kentucky counties from 2004-2012. If <50% of schools within a county submitted Immunization Surveys in a given year, the county was excluded from analysis. Study design closely mirrored a similar study published in 2013 with data from New York State.¹⁶ Annual county exemption rates were calculated as the percent of exemption certificates out of the total number of kindergarten and sixth grade students per county, as reported in the Annual Immunization Survey. This served as the independent variable. Overall annual exemption rates for the state were also calculated in this manner. The correlation

between exemptions and pertussis for the years 2004 through 2012 was tested using non-parametric Spearman analysis because data were not normally distributed. Changes in vaccination exemption rates and pertussis incidence over time from 2004 to 2012 were analyzed using Friedman tests, the non-parametric analog to repeated measures analysis of variance (ANOVA).

The total number of pertussis cases reported in each county over all age groups per year was used as the dependent variable because age-specific data were not available. US Census Bureau 2010 total county populations were used to calculate the incidence rate per 100,000.

In addition, counties were categorized via a median split into two groups representing those with higher versus lower exemption rates: Above Median Group (AMG) and Below Median Group (BMG). A non-parametric Mann-Whitney U test was performed to test for a statistically significant difference in pertussis incidence between the two groups.

Finally differences in pertussis incidence and exemptions between Appalachian and non-Appalachian counties were also analyzed using non-parametric Mann-Whitney U tests.

All analyses were conducted using SPSS (Version 22) software and all statistical tests were two-tailed with alpha set at 0.05.

Results

Descriptive Statistics

Of 1080 total reported cases (i.e. county in a given year), 937 were included for analysis and 143 were excluded. The mean exemption rate was 0.5058 ± 0.656 exemptions per 100 students. The median exemption rate was 0.3656 per 100 students. The distribution of exemptions was skewed to the right and therefore non-parametric tests were used to test for significant associations. Descriptive statistics are summarized in Tables 1 and 2.

Correlation Analysis

A non-parametric Spearman test showed a statistically significant correlation between overall vaccination exemptions and pertussis incidence ($\rho=0.176$, $p<0.001$).

Time Analysis

Non-parametric Friedman tests were used to analyze difference over time in the rates of vaccination exemption and pertussis in the 120 counties. There was a statistically significant difference in vaccination exemption rates over the nine year period, $X^2(8) = 119.576$, $p<0.001$. There was also a statistically significant difference in pertussis incidence over the nine-year period, $X^2(8) = 192.867$, $p<0.001$. Both vaccination exemption rates and pertussis incidence rates tended to increase over time. The attached maps provide a visual representation of change in vaccination exemptions in Kentucky counties in 2004 as compared to 2012 (Figures 1 and 2).

Median Split Analysis

The Below-Median Group (BMG) was defined as all cases with an exemption rate <0.3656 per 100 students ($n=468$). The Above-Median Group (AMG) was defined

as all cases with an exemption rate ≥ 0.3656 per 100 students ($n=469$). The BMG mean pertussis incidence was 0.0044 ± 0.019 per 100 people, compared to the AMG mean of 0.0066 ± 0.014 per 100 people. Median pertussis incidence in groups BMG and AMG were 0.00015 and 0.000 per 100 people; the distributions in the two groups differed significantly (Mann-Whitney $U=93595$). Figure 3 illustrates the distribution of exemption rate frequencies in both groups, in which the AMG distribution is shifted slightly to the right compared to the BMG distribution.

Appalachian Analysis

The average pertussis incidence in Appalachian cases was 0.00531 ± 0.021 per 100 people ($n=416$). The average pertussis incidence in non-Appalachian cases was 0.00568 ± 0.013 per 100 people ($n=521$). Median incidence in both groups was 0.000 ; however, the distributions in the two groups differed significantly (Mann-Whitney $U = 96867$, $P=0.001$). The attached histogram illustrates the distribution of pertussis rates in the two groups (Figure 4), in which the proportion of non-zero incidence was higher in non-Appalachian counties.

The average vaccination exemption rate in Appalachian counties was 0.4464 ± 0.622 per 100 students. The average vaccination exemption rate in non-Appalachian counties was 0.5533 ± 0.677 . Median exemption rates in Appalachian and non-Appalachian groups were 0.2834 and 0.4189 respectively. The distributions in the two groups differed significantly (Mann-Whitney $U= 92481$, $P<0.05$). The attached histogram illustrates the distribution of vaccination exemptions in the two groups (Figure 5), in which the proportion of cases with non-zero exemption rates was higher in non-Appalachian counties.

Discussion

Vaccinations are a controversial political and social topic. This study found that in counties with higher rates of vaccination exemptions in school-aged children, significantly higher pertussis incidence rates were observed. This finding mirrors the results found in New York in 2000-2011.¹⁵ Research such as this is important as public health advocates argue for more stringent childhood vaccination laws.

Additional analyses revealed that non-Appalachian counties reported higher rates of vaccination exemption and also slightly higher rates of pertussis incidence than non-Appalachian counties. This result supports the theory that more exemptions are filed in high-income areas. This is a refreshing contrast to most published literature on health in Appalachian areas and shows that although health disparities exist in the area, pertussis incidence is not disproportionately higher in Appalachian counties.

Strengths of this study include a large sample size spanning several years of collection. Also, exemption data were a census of schools for the given time period, not a random sample. However, study limitations should be considered. Due to inconsistencies in county-level reporting of data and state-level maintenance of records, one case was defined as one county during one year of data collection. Therefore, the same county population was used to calculate 9 different pertussis incidence rates, even though countywide immunity would change from year to year as vaccination trends changed. Data were structured in this way in order to maximize the sample size and streamline statistical analyses. Future research using more complex longitudinal

analyses with an accumulation of exemptions over time may yield more accurate statistical results.

For future research, the data set compiled from the Commonwealth of Kentucky School/Facility Annual Immunization Survey could yield a wealth of information about Kentucky vaccinations. For example, the same study could be repeated using rate of reported Tdap/Dtap vaccination as the independent variable instead of filed vaccine exemption. This would factor in students who were not vaccinated or who did not receive the entire vaccine series, but whose parents did not take the steps to file for exemption. In theory, these students would be required to complete the vaccine series in order to attend school. However, that is often not the case. This topic would especially be interesting to study in Appalachian counties because it may better address barriers to vaccination.

This research serves as a valuable stepping-stone for behavioral research regarding parental decisions to abstain from vaccination. Such research is pivotal when developing health initiatives and programs promoting vaccination of Kentucky children. The current findings also provide ammunition for reform of vaccination exemption laws in Kentucky. Changing the law to only allow for medical exemptions and/or to increase the complexity of applying for a religious exemption could potentially increase vaccination rates in Kentucky schoolchildren.

Many factors may influence a parent's decision to vaccinate his or her child. Although the current study did not examine parental decisions, results suggest that higher rates of exemption sought by parents have an epidemiological impact on the health of our state. It is in the best interest of our Commonwealth that public health

officials and healthcare providers continue to stress the importance of vaccinations in order to keep preventable communicable diseases, such as pertussis, at bay.

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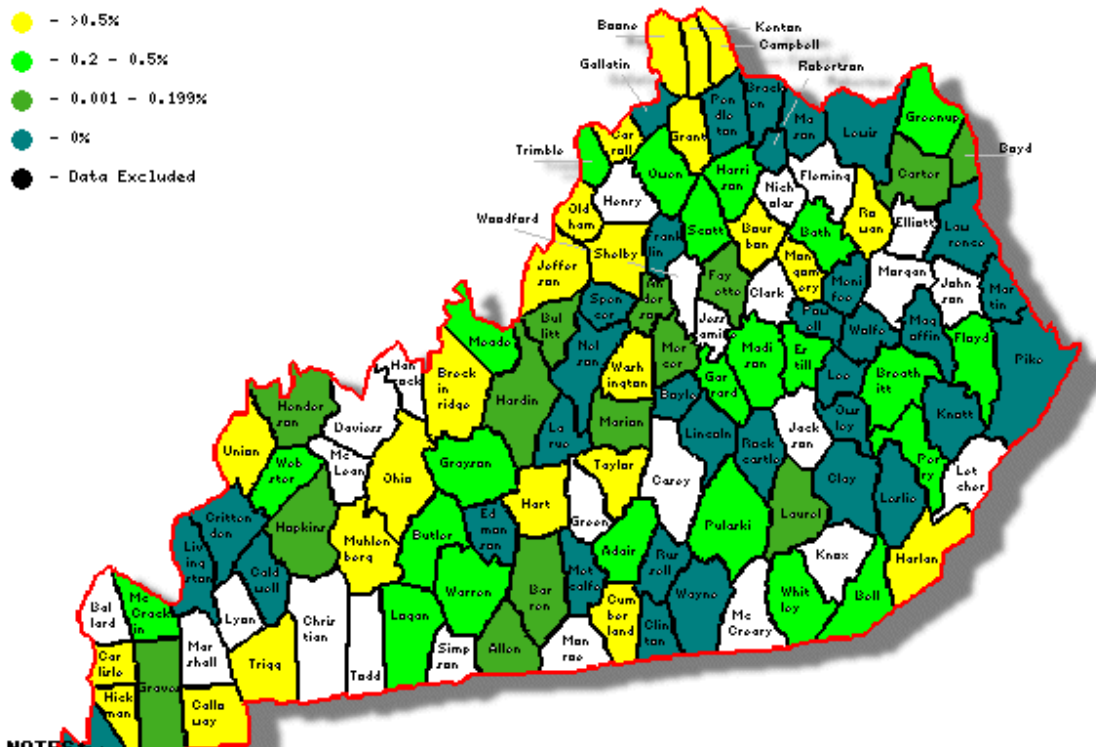
Table 1: Descriptive Statistics of Vaccination Exemptions and Pertussis Incidence in Kentucky Counties, 2004-2012			
	Overall	Above- Median Group ^a	Below- Median Group ^b
Total Cases	937	469	468
Mean Exemption Rate (per 100 students)	0.508 \pm 0.656	0.8907 \pm 0.738	0.1202 \pm 0.133
Median Exemption Rate (per 100 students)	0.3656	0.6977	0.0502
Range of Exemption Rates (per 100 students)	0.0000 – 5.672	0.3656 – 5.672	0.0000 – 0.3636
Mean Pertussis Rate (per 100 people)	0.0055 \pm 0.0174	0.0066 \pm 0.0147	0.0044 \pm 0.0197
Median Pertussis Rate (per 100 people)	0.00	0.00	0.00
Range of Pertussis Rates (per 100 people)	0.0 – 0.3680	0.0 – 0.1587	0.0 – 0.3680
^a Above-Median Group refers to cases with vaccination exemption rates greater than or equal to the overall median of 0.3656 per 100 students. ^b Below-Median Group refers to cases with vaccination exemption rates less than the overall median of 0.3656 per 100 students.			

Table 2: Descriptive Statistics of Vaccination Exemptions and Pertussis Incidence in Appalachian versus Non-Appalachian Counties in Kentucky, 2004-2012			
	Overall	Appalachian	Non-Appalachian
Total Cases	937	416	521
Mean Exemption Rate (per 100 students)	0.508 \pm 0.656	0.4464 \pm 0.622	0.5532 \pm 0.678
Median Exemption Rate (per 100 students)	0.3656	0.2834	0.4190
Range of Exemption Rates (per 100 students)	1.0000 – 5.672	0.0000 – 5.10	00000 – 5.67
Mean Pertussis Rate (per 100 people)	0.0055 \pm 0.0174	0.0053 \pm 0.0214	0.0057 \pm 0.0134
Median Pertussis Rate (per 100 people)	0.00	0.00	0.00
Range of Pertussis Rates (per 100 people)	0.0 – 0.3680	0.0 – 0.3680	0.0 – 0.1587

Figure 1: 2004 County-Level Vaccination Exemption Rates in Kentucky

2004 Vaccination Exemption Rates (%)

- - >0.5%
- - 0.2 - 0.5%
- - 0.001 - 0.199%
- - 0%
- - Data Excluded



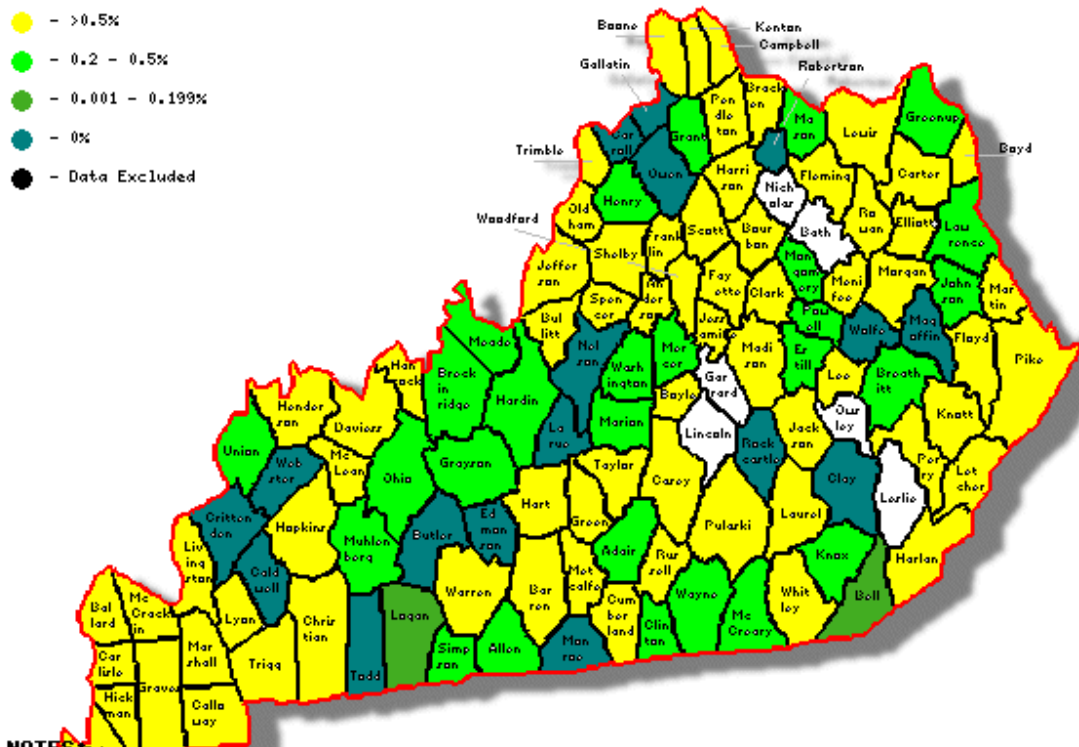
NOTES: Counties were excluded if <50% of schools reported to the CHFS Childhood Vaccination Survey

Source: diymaps.net (c)

Figure 2: 2012 County-Level Vaccination Exemption Rates in Kentucky

2012 Vaccination Exemption Rates (%)

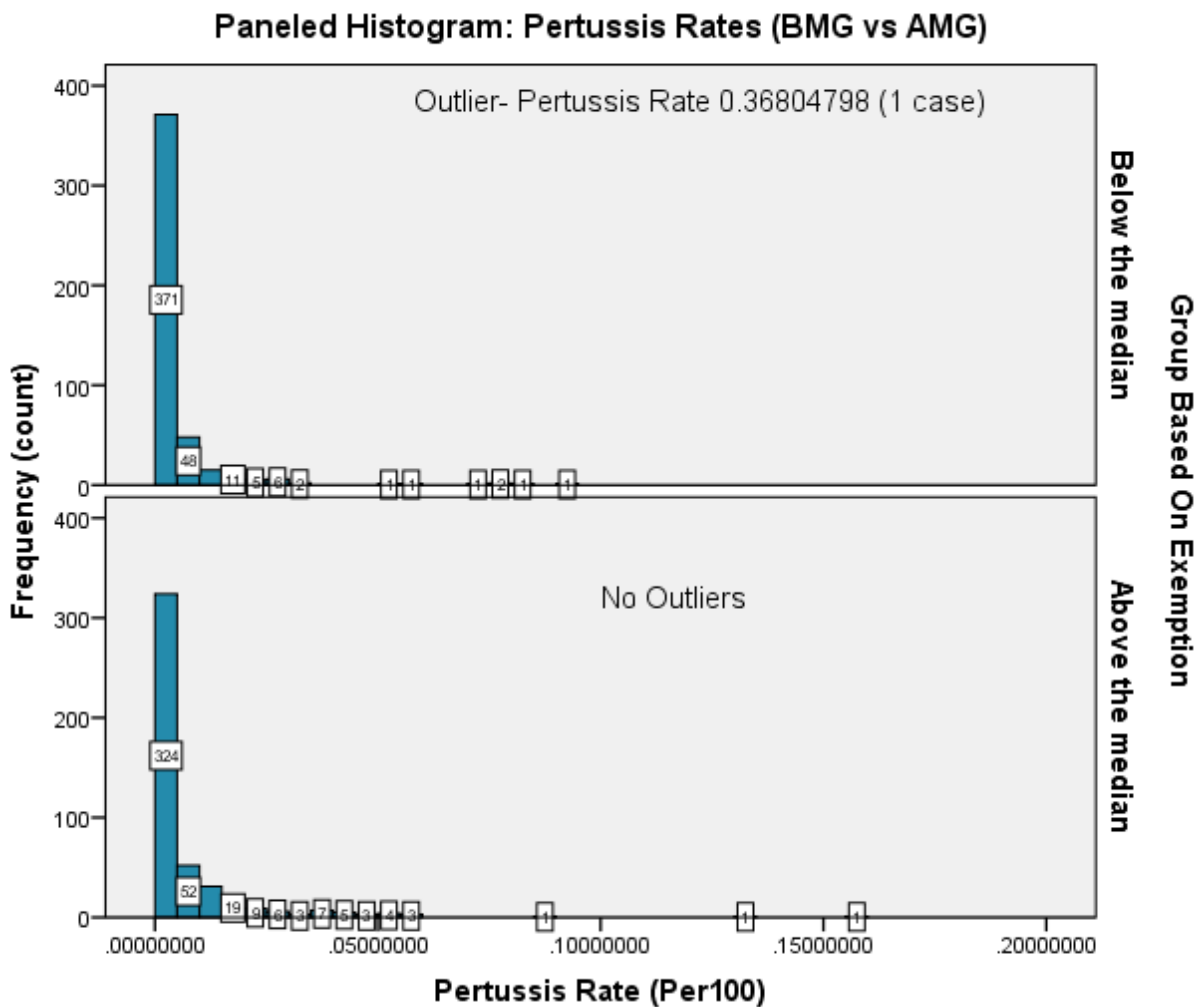
- - >0.5%
- - 0.2 - 0.5%
- - 0.001 - 0.199%
- - 0%
- - Data Excluded



NOTES: Counties were excluded if <50% of schools reported to the CHFS Childhood Vaccination Survey

Source: diymaps.net (c)

Figure 3:



Note: Below the Median refers to the Below-Median Group (BMG), including cases with vaccination exemption rates less than the overall median of 0.3656 per 100 students. Above the median refers to the Above-Median Group (AMG), including cases with vaccination exemption rates greater than or equal to the overall median of 0.3656 per 100 people.

Figure 4:

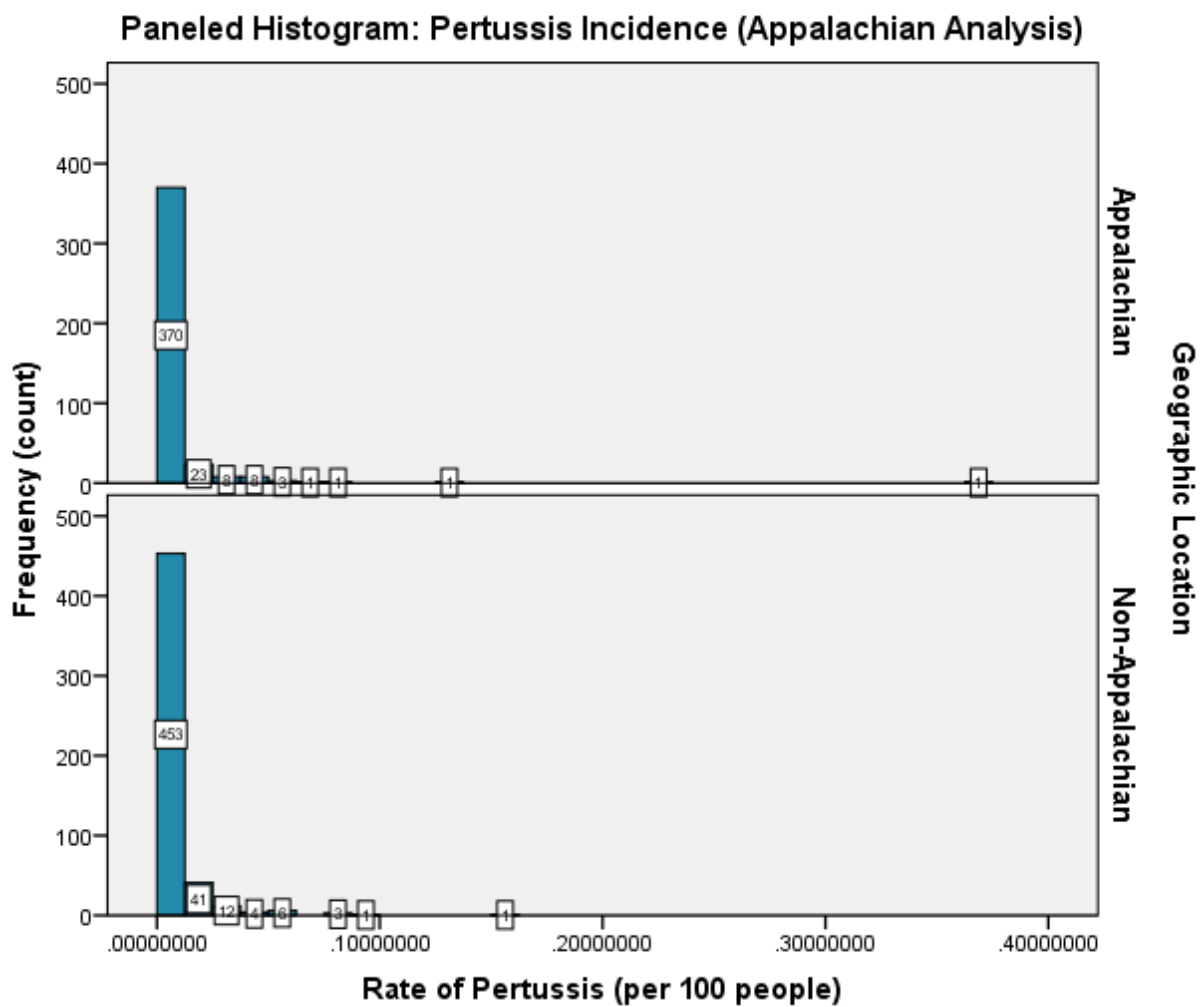


Figure 5:

