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Lack of Vaccination Risks

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Abstract

This paper is a study regarding how vaccination rates are related to the number of measles cases that occur in a particular state. First, I will review the history of vaccines and the motivations for the refusals of this medical procedure. In addition, I will examine the various regulations regarding vaccinations and which states allow non-medical exemptions for religious or personal reasons. Within my analysis, I will provide examples of recent outbreaks to represent the extent of this current dilemma. Furthermore, I will offer potential solutions to mitigate measles outbreaks and the science regarding Herd Immunity Thresholds (HIT) to limit the spread of communicable diseases. To show the relationship between vaccination rates and the number of measles cases in a particular state, I will perform regression and correlation analysis on these statistics.

Keywords: vaccination, measles, exemptions, autism, immunity, regression, correlation

Lack of Vaccination Risks

Introduction

Large outbreaks of disease have plagued the world for many years, causing havoc in communities and sometimes even spreading worldwide. To combat these outbreaks, early civilizations began their own self vaccinations by exposing themselves to the disease. As society progressed, more legitimate methods were established and vaccine use spread. Soon, it became standardized to become vaccinated and disease outbreaks thinned. Yet, there were skeptics who doubted the safety and necessity of vaccines, causing further outbreaks due to low vaccination rates. Others refused vaccinations for philosophical or religious reasons, decreasing the population's immunity to these diseases. Even with the evidence surrounding the overwhelming success of vaccines against disease prevention, groups throughout history doubt their use and the same cycle appears. Luckily, there may be some solutions to help prevent this phenomenon and keep preventable diseases at bay.

History

The use of vaccines started as early as 1000 CE, when the Chinese used smallpox inoculation, a process that involves "grinding up smallpox scabs and blowing the matter into the nostril" or "scratching matter from a smallpox sore into the skin" ("All Timelines," n.d.). This practice was also done in India, Africa, and Turkey before spreading to Europe and the Americas ("All Timelines," n.d.). Then, in 1796, Edward Jenner decided to test the idea that exposure to cowpox could boost an individual's immunity to smallpox ("All Timelines," n.d.). He inoculated an eight-year-old boy named James Phipps, who fell ill but recovered in a few days ("All Timelines," n.d.). Later on, when James was exposed to smallpox, the boy remained healthy and was not affected by the disease ("All Timelines," n.d.). This event helped show that vaccines were a true possibility and was one of the first steps toward the widespread use of these medical procedures. Very shortly after the Phipps event, Massachusetts became the first state to publicly endorse the use of vaccines and death rates began to decrease drastically ("All Timelines," n.d.). Some places, such as the United Kingdom, even imposed fines or imprisonment if individuals didn't comply with vaccination guidelines ("All Timelines," n.d.). Furthermore, schools began mandating vaccination requirements for smallpox before a child could attend ("All Timelines," n.d.). As confidence in vaccines spread, anti-vaccination groups also emerged, such as the Anti-Vaccination League of America. This group claimed smallpox was spread by filth, not contagion ("All Timelines," n.d.). Due to this pushback and others, outbreaks started to occur. For example, low vaccination rates in Muncie, Indiana lead to a smallpox outbreak that infected 140 people and killed 20 in 1893 ("All Timelines," n.d.). As history progressed, more diseases emerged and researchers worked diligently to find vaccines to prevent future outbreaks. Even with vaccination success, groups were still skeptical about the need or safety of this process.

Current Issues

Current pushback against vaccines is largely due to a skewed study performed in 1998 by Andrew Wakefield (DeNoon, 2011). In this study of only twelve patients, Wakefield claimed that vaccines, specifically the measles-mumps-rubella (MMR) vaccine, causes autism (DeNoon, 2011). Many frightened parents stopped vaccinating their children and pushback against vaccines increased. Later, many flaws were found in the study, including the fact that the children were all "recruited through an anti-MMR-vaccine campaigners" (DeNoon, 2011). Furthermore, differences could be seen between the published case results and the original medical and parent records (DeNoon, 2011). Even though the study was proven to be skewed, some parents continue to believe this false rhetoric that vaccines cause autism. This may be because "children often exhibit the first unmistakable signs of autism when they are toddlers – an age at which they are receive their childhood vaccination series" (DeNoon, 2011). Even so, some parents that already believed vaccines caused autism were only encouraged by Wakefield's fake study, further pushing his ideals and causing panic (DeNoon, 2011). According to the Centers for Disease Control and Prevention (CDC), vaccines are very safe and do not cause autism ("Vaccine Safety," 2015). In fact, a study in 2011 of eight vaccines found that vaccines are very safe and only cause complication in rare cases ("Vaccine Safety," 2015). Another study in 2013 compared antigen levels from vaccines in a child's first two years of life ("Vaccine Safety," 2015). Antigens are "substances in vaccines that cause the body's immune system to produce disease-fighting antibodies" ("Vaccine Safety," 2015). Results showed that children with Autism Spectrum Disorder (ASD) received the same number of antigens as children without ASD ("Vaccine Safety," 2015). While there are still possible side effects for vaccines just like any other medication, these side effects are usually minor and subside in a few days

("For Parents," 2018). Additionally, the U.S. Food and Drug Administration (FDA) studies the effectiveness and safety of vaccines before approving them for use, further ensuring the safety of consumers ("For Parents," 2018). Even with the risks, Dr. Andrew Bernstein, who is a clinical assistant professor of pediatrics at Northwestern University Feinberg School of Medicine and a spokesperson for the American Academy of Pediatrics, summed up the comparison of risk to reward perfectly. Bernstein points out, "If there is, in theory, 1 in 10 million people that don't do well with the vaccine, well, that's awful. It's a terrible thing and we have to try to figure out what is causing that and prevent it. But if you're talking a 1 in 10 million risk versus a 1 in 1,000 risk of dying if you get the disease, that's not a good exchange" (Campbell, 2019).

Other than the fear of causing autism, consumers elect to refuse vaccinations for other reasons as well. One of these is religion. In these cases, parents are following their core religious beliefs and usually refuse all vaccines (Mckee & Bohannon, 2016). The cause of this refusal is usually due to animal-derived gelatin or human fetus tissue components found in some vaccines (Mckee et al., 2016). Similarly, some individuals refuse vaccination for personal beliefs. These parents believe exposure to diseases without protection will naturally boost a child's immune system and benefit the child in the long run (Mckee et al., 2016). In fact, Kentucky Governor Matt Bevin revealed that he purposefully exposed his nine children to chickenpox so they would not contract the disease later in life (Bosman, 2019). This practice was not uncommon before the chickenpox vaccine was available in 1995 (Bosman, 2019). Parents who held these "chickenpox parties" believed that contracting this disease at a young age was safer than allowing their children to contract it as adults (Bosman, 2019). The CDC has urged against parents to not participate or host these parties because chickenpox "can be serious and can lead to severe complications and death, even in healthy children" ("Chickenpox," 2018). In addition, many don't see preventable diseases as life-threatening, making vaccination unnecessary (Mckee et al., 2016). Some parents feel they don't know enough about vaccines and just need more information to be confident that the benefits outweigh the risks (Mckee et al., 2016).

Reasons aside, history has shown that opposition and lack of vaccinations has huge consequences. While there are many preventable disease outbreaks that occur every year, this paper focuses on measles outbreaks and the measles, mumps, rubella (MMR) vaccine. Even though measles was said to be eradicated in the United States in 2000, lack of vaccinations has led to outbreaks in the past 18 years (“Measles | History,” 2018).

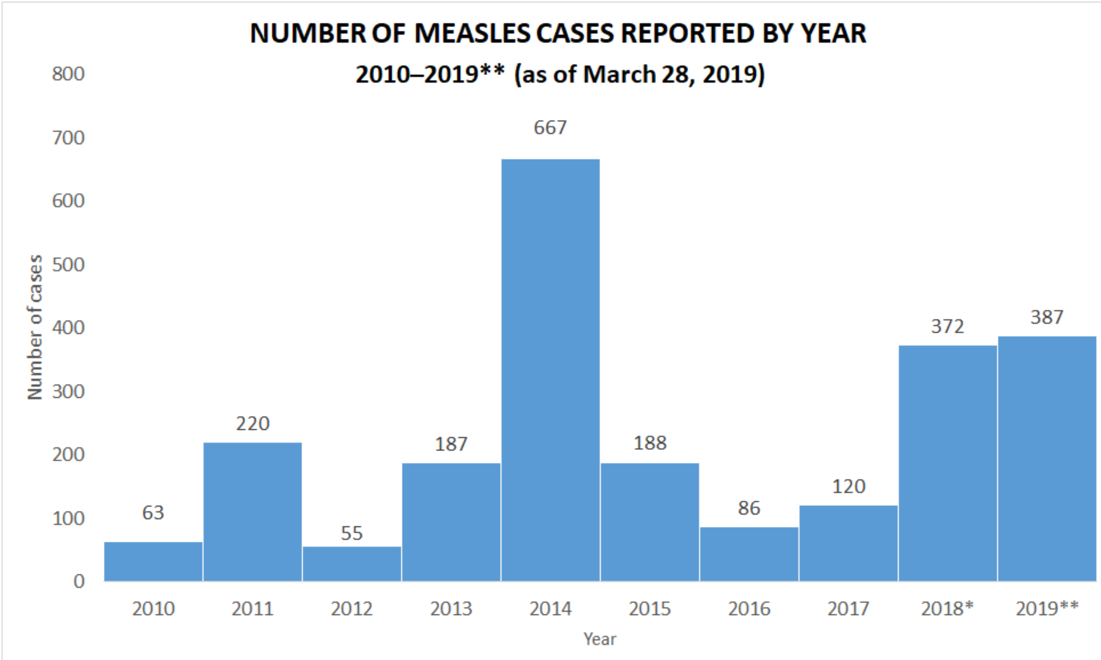


Figure 1. Number of Measles Cases from 2010-2019 in the United States. Reposted from the Centers for Disease Control and Prevention at https://www.cdc.gov/measles/cases-outbreaks.html

According the Figure 1, the highest number of cases occurred in 2014 where 667 individuals contracted measles. This year alone, 387 cases have been reported as of March 28 and this number will probably continue to rise throughout 2019. A list of some relevant measles outbreaks in the past few years are as follows:

- In 2011, nearly 15,000 people were infected with measles due to lack of vaccinations (Doucleff, 2014).
- Then, “in 2012 the U.K. reported more than 2,000 measles cases, the largest number since 1994” (Doucleff, 2014).
- A 2013 outbreak in New York City occurred resulting in 58 cases of measles, with 78% of individuals unvaccinated from refusal or intentional delay (Rosen, 2018). This outbreak took 10,052 hours to control and cost the Department of Health and Mental Hygiene $394,448 (Rosen, 2018).

- In 2014, 383 Amish individuals in Ohio were infected with measles due to low vaccination rates (Keneally & Orsini, 2019). Specifically, 89% were unvaccinated and this community accounted for 99% of cases in the outbreak (Gastañaduy et al., 2016).
- Minnesota experienced a measles outbreak in 2017 involving mostly Somali-American children where more than 80% of children were unvaccinated (Belluz, 2017). Overall, 79 cases were reported (Belluz, 2017).
- In 2019, a large outbreak in New York City occurred within under-vaccinated Orthodox Jewish communities (Tanne, 2019). Overall, 182 cases were reported and vaccination rates were as low as 50% in these communities (Tanne, 2019).
- Another outbreak in 2019 occurred in Clark County in southeastern Washington, where kindergarten vaccination rates were only at 76.5% (Keneally & Orsini, 2019). In this county, 7.9% of kindergarteners had non-medical exemptions for personal reasons (Keneally & Orsini, 2019).
- New York also experienced an outbreak this year in Rockland County. In this case, 158 individuals were infected with the disease, with 82.8% of these individuals having zero doses of the measles, mumps, rubella vaccine ("Measles Information," n.d.).

Overall, "the CDC said that the percentage of unvaccinated children has quadrupled since 2001, as over 100,000 US infants and toddlers had received no vaccines and millions more had received only some crucial shots" (Tanne, 2019). In addition, these cases point out various groups that may be at higher risk of outbreaks due to low vaccination rates. This includes some religious groups and immigrant communities. In fact, researchers from the CDC found that "children with at least one foreign-born parent were 25% less likely to be current on their vaccination at 36 months than were children born to two U.S.-born parents, after adjusting for maternal race, age, and educational attainment" (Belluz, 2017). Although it is still possible to contract measles even with the vaccine, these cases are normally rare. Specifically, the CDC estimates that three out of every 100 individuals can contract measles even with the vaccine, but these individuals will contract a much milder form of the disease (Shiffer, 2019). If vaccination rates continue to drop, numerous accounts of preventable disease outbreaks will continue to occur if solutions are not implemented.

Potential Solutions

One possible solution regarding lack of vaccinations involves the idea of herd immunity. Herd immunity "is a form of immunity that occurs when the vaccination of a significant portion of a population (or herd) provides a measure of protection for individuals who have not developed immunity" ("What is," 2017). This means that if most of the population is vaccinated, those who are infected will be less likely to spread the disease, especially to those more vulnerable. In particular, children too young to be vaccinated, individuals who are already ill, and those with compromised immune systems are more susceptible to getting infected ("What is," 2017).

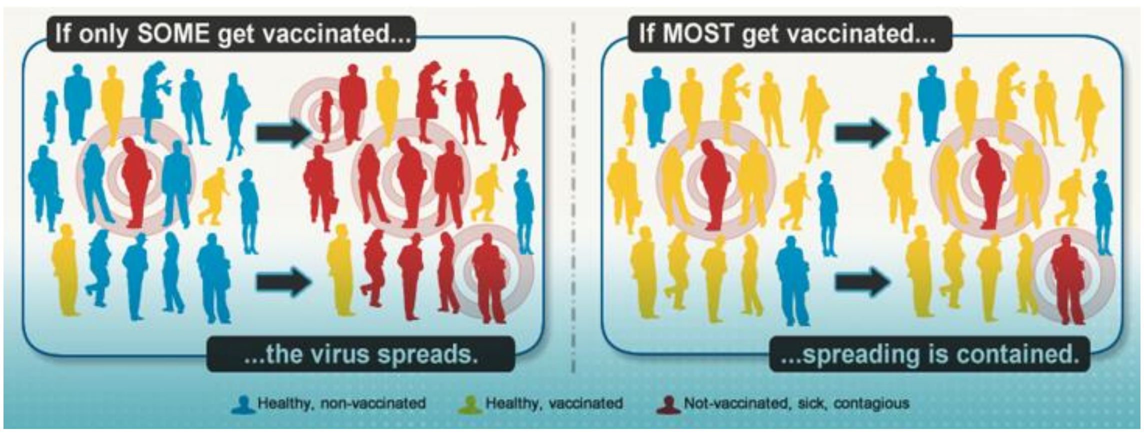


Figure 2. The idea of herd immunity. Reposted from the Centers for Disease Control and Prevention at https://www.cdc.gov/vaccines/vac-gen/whatifstop.htm.

Figure 2 is a visual representation of herd immunity, showing how spreadable diseases can be contained if most of the population is vaccinated. For herd immunity to work properly, a certain percentage of the population has to be vaccinated, called the herd immunity threshold (HIT) (Vanderslott & Roser, 2018).

Disease	Transmission	Basic reproduction number	Herd Immunity Threshold
Measles	Airborne	12–18	92–95%
Pertussis	Airborne droplet	12–17	92–94%
Diphtheria	Saliva	6–7	83–86%
Rubella	Airborne droplet	6–7	83–86%
Smallpox	Airborne droplet	5–7	80–86%
Polio	Fecal-oral route	5–7	80–86%
Mumps	Airborne droplet	4–7	75–86%
SARS	Airborne droplet	2–5	50–80%
Ebola	Bodily fluids	1.5–2.5	33–60%
Influenza	Airborne droplet	1.5–1.8	33–44%

Figure 3. Herd Immunity Thresholds of vaccine-preventable diseases. Reprinted from Our World in Data at https://ourworldindata.org/vaccination

For diseases that are highly contagious, such as measles and pertussis, a larger percentage of the population needs to be vaccinated in order for the disease to not exist in the population (Vanderslott et al., 2018). Figure 3 indicates the highest HIT needed for vaccine-preventable-diseases is measles at 92-95%, while influenza only needs 33-44% of the population vaccinated in order to have protection (Vanderslott et al., 2018). Herd immunity thresholds are calculated by epidemiologists based on a value called the basic reproduction number or RO (Helft & Willingham, 2014). The basic reproduction number "represents how many people in an unprotected population one infected person could pass the disease along to" (Helft & Willingham, 2014). Highly contagious diseases like measles have a higher RO, meaning a higher percentage of the population must be vaccinated in order for herd immunity to take effect (Helft & Willingham, 2014). Other factors are considered as well, such as the effectiveness of the vaccine, how long the vaccine provides immunity to the disease, and which populations are more susceptible to the disease that provide links in its transmission (Helft & Willingham, 2014). Knowing this variability exists, the most cautious route towards herd immunity would involve mass vaccination. Some countries already require compulsory vaccination, such as France and Italy (Vanderslott et al., 2018). The United States has mandated vaccination before a child can enter school or daycare as a way to protect crowded classrooms of students (Vanderslott et al., 2018). Unfortunately, these mandates are not foolproof due to the allowance of religious and philosophical reasons, which can lead to outbreaks where large groups of these individuals exist.

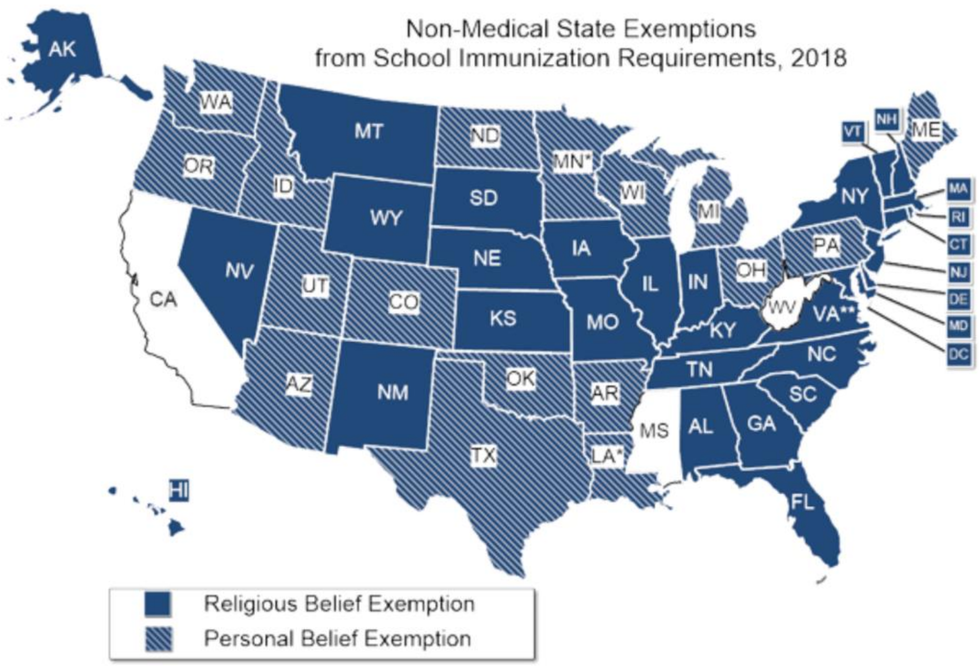
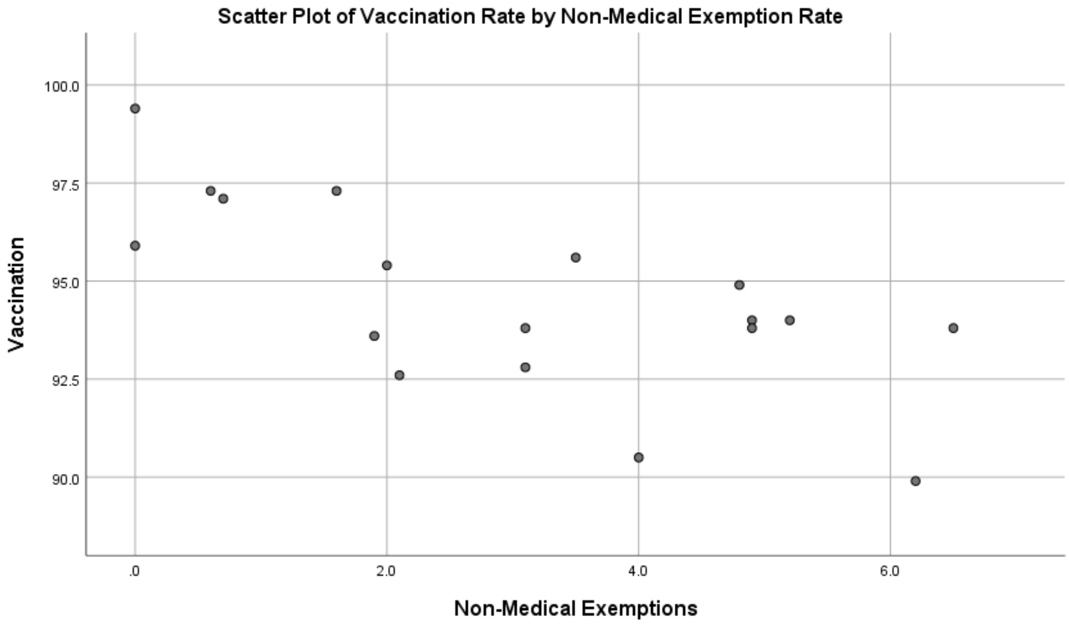


Figure 4. Non-Medical State Exemptions from School Immunization Requirements in 2018. Reposted from the National Conference of State Legislatures at http://www.ncsl.org/research/health/school-immunization-exemption-state-laws.aspx

Currently, almost all states allow religious exemptions with California, Mississippi, and West Virginia as the exceptions ("States With," 2019). According to Figure 4, 17 states allow exemptions for philosophical beliefs which can include personal, moral, or other beliefs ("States With," 2019). These non-medical exemptions can have a real impact on vaccination rates overall, allowing greater opportunity for outbreaks. To show this, I performed a linear regression between non-medical exemptions and vaccination rates of some key states. Before performing the regression, five assumptions must be met.

Assumption 1: there is a linear relationship between the variables

To show there is in fact a linear relationship between these variables, I performed a simple scatter plot between vaccination rates and non-medical exemption rates.



This plot shows us there is likely a linear relationship between vaccination rates and non-medical exemption rates in that state.

Assumption 2: no significant outliers

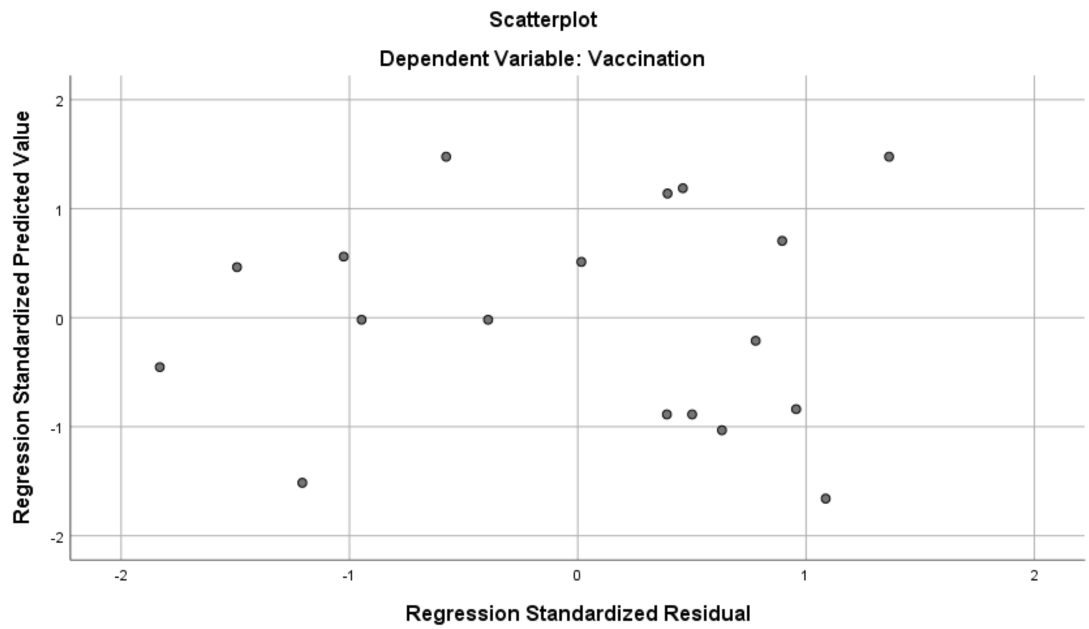
Originally, I had Colorado's data in the study but it had to be removed as to not throw our regression off. Colorado had a low vaccination rate of 87.3% and a non-medical exemption rate of 3.4%. With this in mind, I decided to focus on states with a vaccination rate higher than 89%.

Assumption 3: independence of observations – is there autocorrelation between the residuals?

In our case, autocorrelation between the residuals does not apply because our data is not in a time order. Therefore, we do not need to worry about this assumption.

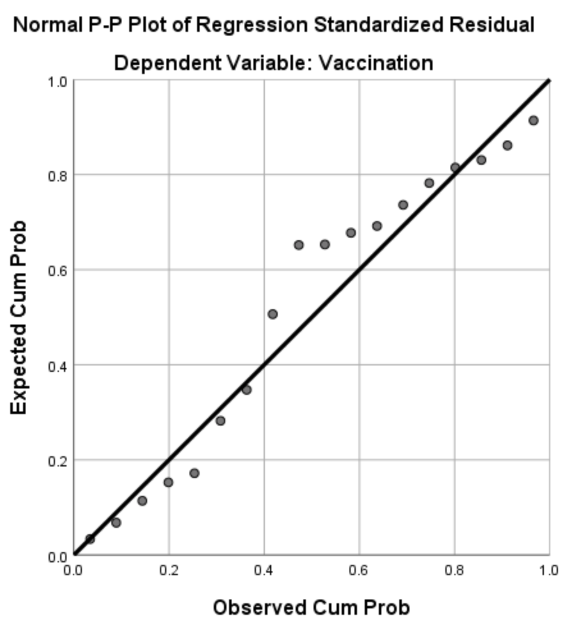
Assumption 4: no homoscedasticity

Simply, we would like to see constant variance of our residuals and the plot below represents this well. If our observations were more cone shaped, this assumption would be violated.

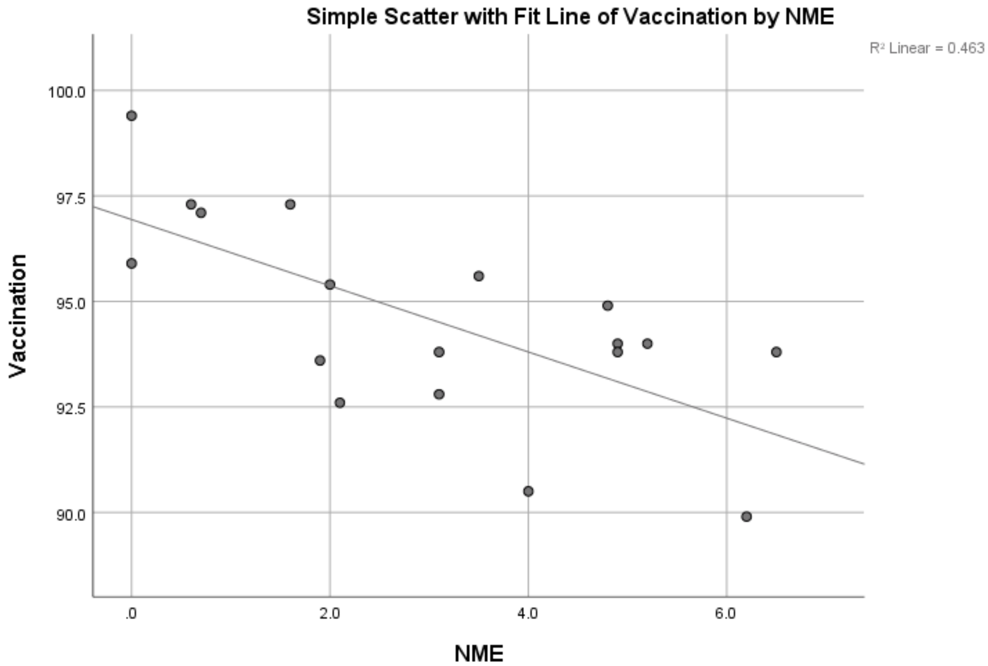


Assumption 5: residuals are approximately normally distributed

Looking at the plot below, our observations do not stray far from the regression standardized residual line, meaning that this last assumption is satisfied.



With our assumptions satisfied, we can now perform our linear regression.



Above is our linear regression between vaccination rates and non-medical exemption rates in some key states. As you can see, as non-medical exemption rates increase, vaccination rates decrease. Our r-squared is 46.3% meaning that 46.3% of the variation in vaccination rates can be explained by non-medical exemption rates in that state. While this value isn't as high as I had hoped, it still gives us some insight that non-medical exemptions may influence vaccination rates and the allowance of more non-medical exemptions could contribute to lower vaccination rates. Again, lower vaccination rates decrease herd immunity, meaning that states or areas with lower vaccination rate are more susceptible to large outbreaks.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	44.936	1	44.936	13.808	.002[b]
	Residual	52.067	16	3.254		
	Total	97.003	17			

a. Dependent Variable: Vaccination

b. Predictors: (Constant), NME

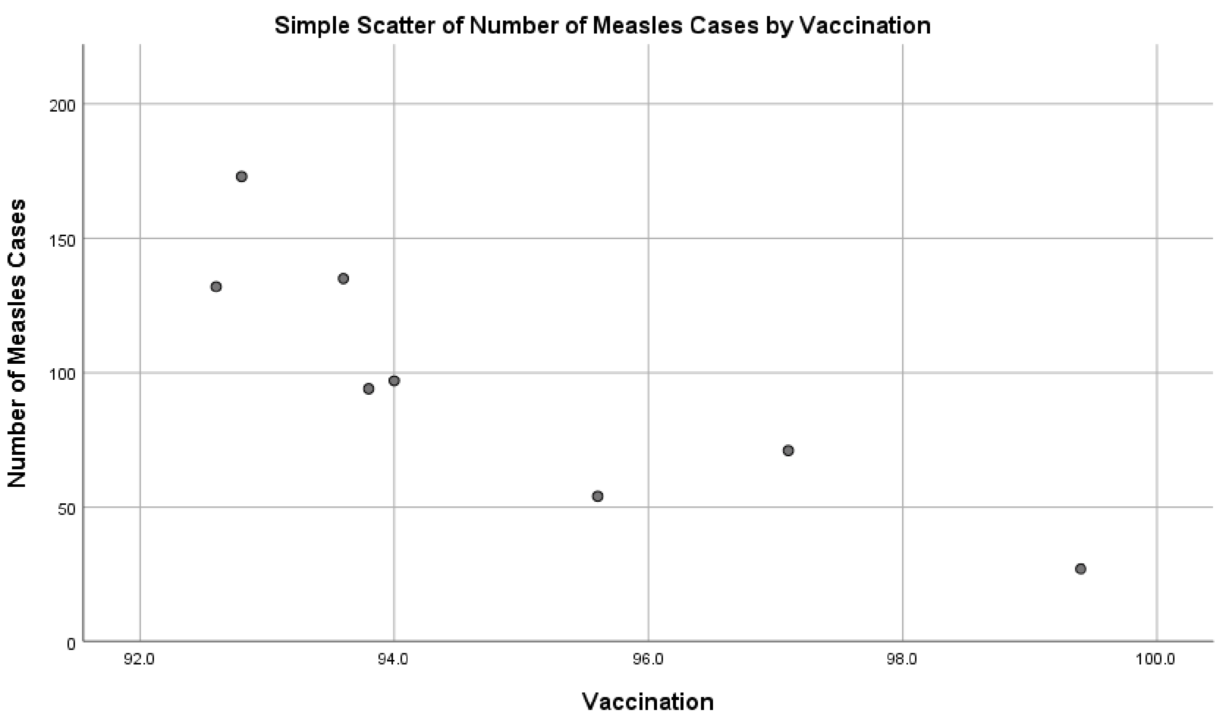
Our ANOVA table above shows that our model is significant with a value of .002.

In places where voluntary vaccination exists, other mechanisms could help convince individuals to support this process. For one, educating the public on the importance of vaccinations will allow parents to feel more confident in allowing their child(ren) to be vaccinated. In addition, researchers should try to offer alternatives to ingredients in vaccinations opposed by religious groups. If an outbreak occurs, isolating those infected and following other procedures to stop the spread of disease is crucial. Allowing the disease to spread further will exponentiate the problem.

Now that we know that the allowance of non-medical exemptions may influence vaccination rates, I will try to connect how vaccination rates in some states lead to more outbreaks in that state. First, we need to satisfy some assumptions.

Assumption 1: there is a linear relationship between the variables

To show there is in fact a linear relationship between these variables, I performed a simple scatter plot between vaccination rates and number of measles cases in some key states. This plot is shown below. Unfortunately, only 8 states were included due to limited data available on measles outbreaks by state. This is a sub-population of the previous analysis regarding non-medical exemption and vaccination rates.



The plot on the previous page shows us there is likely a linear relationship between number of measles cases in a particular state and vaccination rates in that state. The states included in this plot are Louisiana, Michigan, Minnesota, Mississippi, Ohio, Oregon, Pennsylvania, and Wisconsin.

Assumption 2: no significant outliers

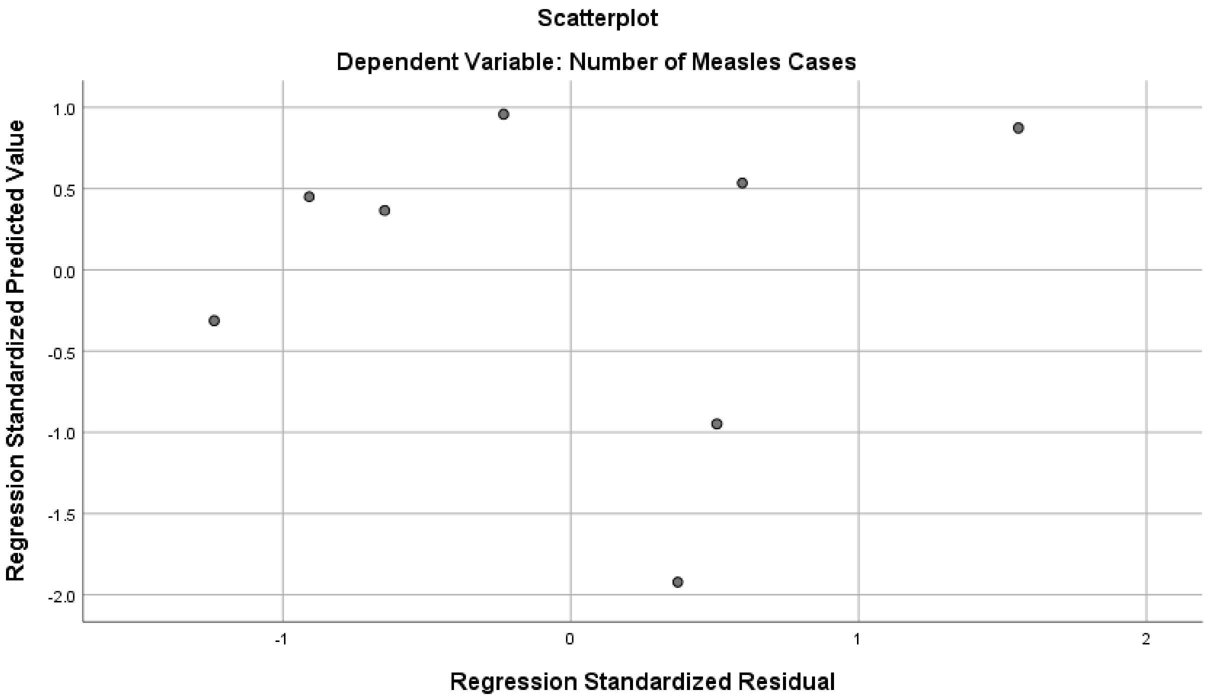
Originally, I had Colorado's data in the study but it had to be removed as to not throw our regression off. Colorado had a low vaccination rate of 87.3% and also had a high number of measles cases at 102 cases. In addition, Arkansas had a vaccination rate of 91.9% and experienced 2,953 measles cases. Another removal was Missouri with a vaccination rate of 95.4% with 771 cases. Furthermore, Washington experienced 934 cases of measles and had a vaccination rate of 90.5%. Overall, some of these numbers were so high that you could not see the rest of the data points. I attempted to include these cases with various methods such as a log transformation, but unfortunately, these efforts did not work. To fix this dilemma, I focused on states with vaccination rates between 92%-99% in which many states had a reasonable number of outbreaks to compare. Even with these removals, you can see that states with much lower vaccination rates overall had a significantly higher number of measles cases.

Assumption 3: independence of observations – is there autocorrelation between the residuals?

In our case, autocorrelation between the residuals does not apply because our data is not in a time order. Therefore, we do not need to worry about this assumption.

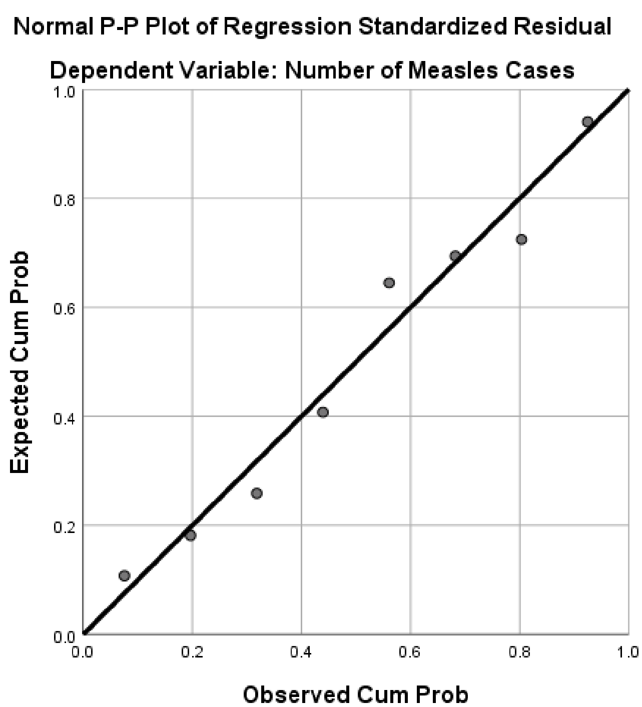
Assumption 4: no homoscedasticity

Simply, we would like to see constant variance of our residuals and the plot on the next page satisfies this assumption.

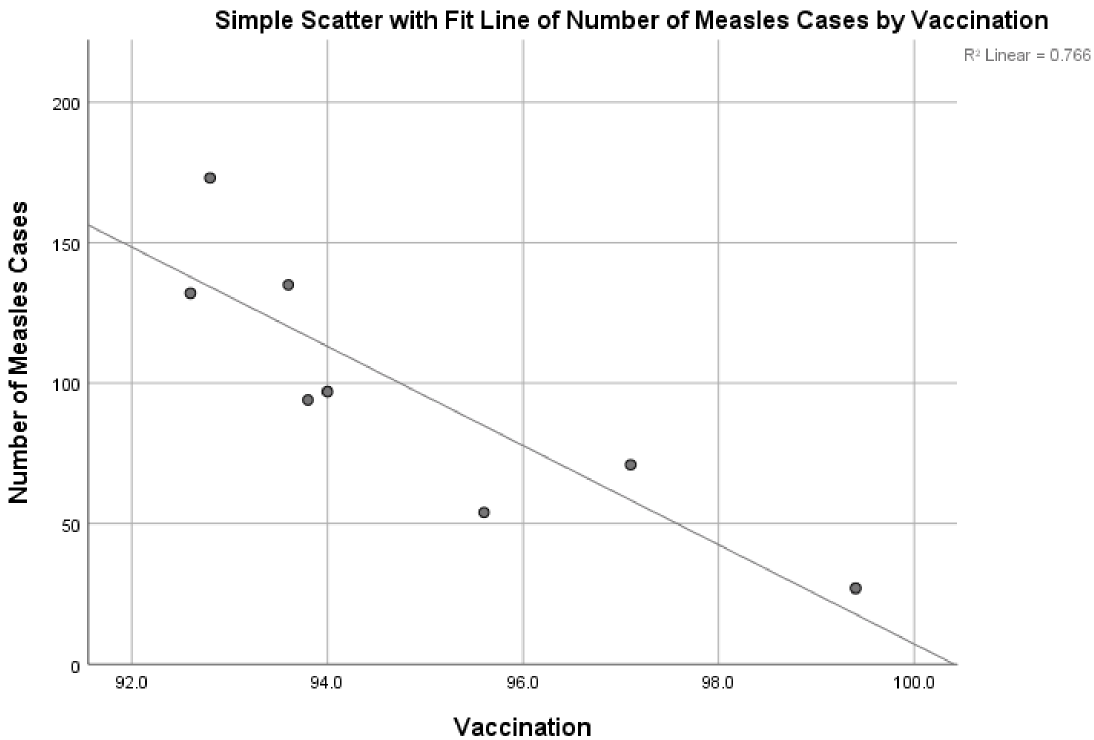


Assumption 5: residuals are approximately normally distributed

Looking at the plot below, our observations do not stray far from the regression standardized residual line, meaning that this last assumption is satisfied.



The chart below is our overall regression model of vaccination percentage in a particular state by number of measles cases in that state.



As you can see, our R squared value is 76.6% meaning that 76.6% of the variation in number of measles cases by state is explained by the overall vaccination percentage in that state. This shows that there may be a relationship between these variables and that less vaccination coverage can lead to greater outbreaks in these states.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12152.028	1	12152.028	19.596	.004[b]
	Residual	3720.847	6	620.141		
	Total	15872.875	7			

a. Dependent Variable: Outbreaks

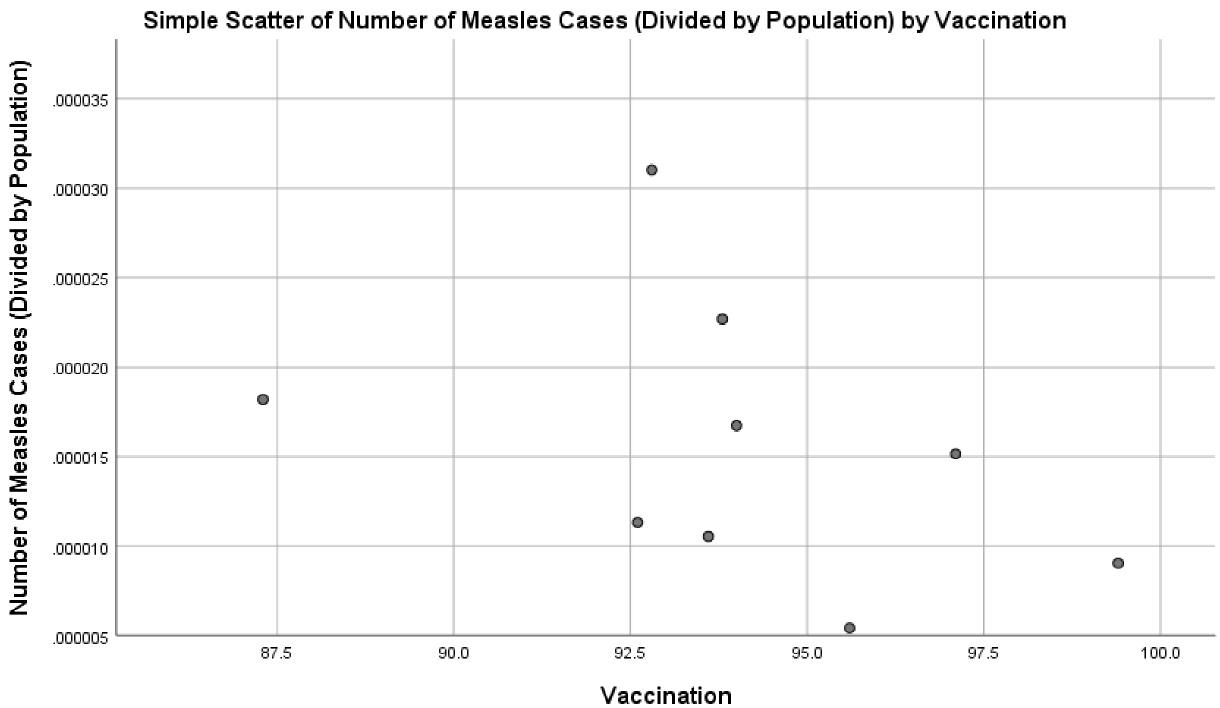
b. Predictors: (Constant), Vaccination

Our ANOVA table above further shows that our model is significant with a p-value of .004.

A difference in population may also affect the number of measles cases in a particular state. In other words, states with a higher population may experience more outbreaks simply due to more individuals being exposed to the disease. To investigate this, I performed a regression on the same eight states in the previous analysis, but divided the number of cases by the population in that particular state. Once again, our five assumptions must be met.

Assumption 1: there is a linear relationship between the variables

In the plot below, there doesn't seem to be as strong of a linear relationship between the variables but we will continue along to compare this scenario to our previous analysis.



Assumption 2: no significant outliers

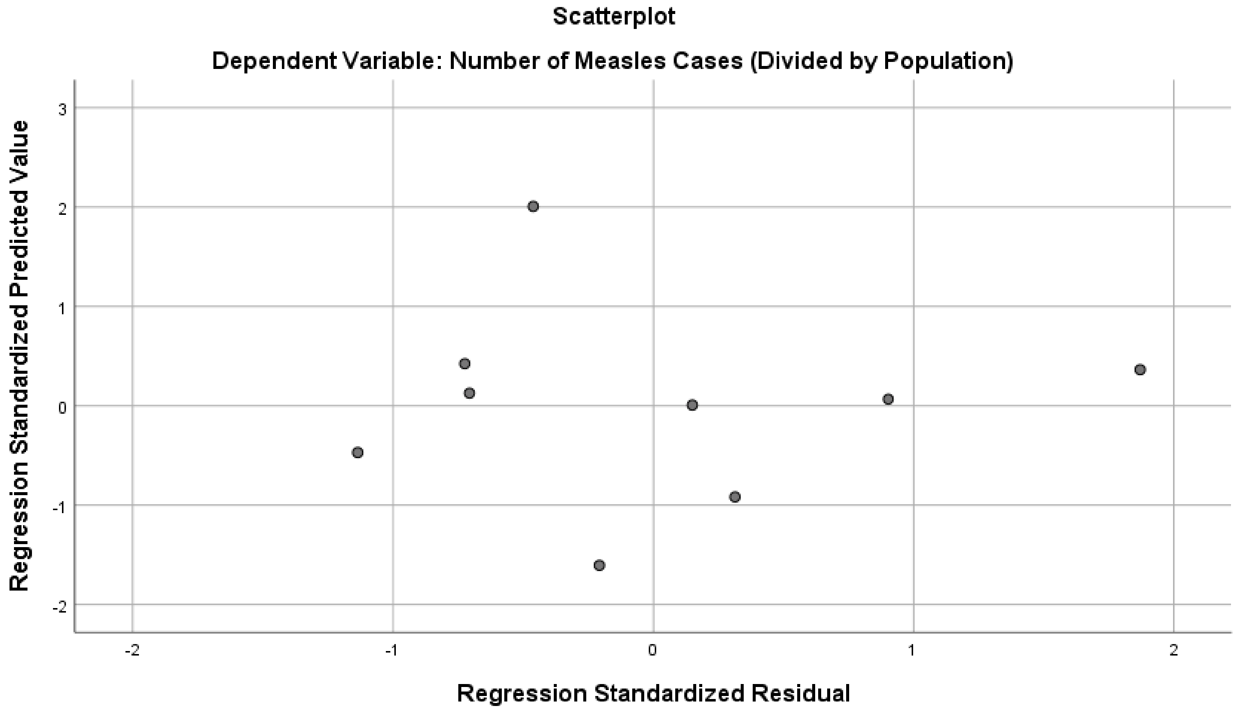
This time, I decided to include Colorado's data because it wasn't as much of an outlier.

Assumption 3: independence of observations – is there autocorrelation between the residuals?

In our case, autocorrelation between the residuals does not apply because our data is not in a time order. Therefore, we do not need to worry about this assumption.

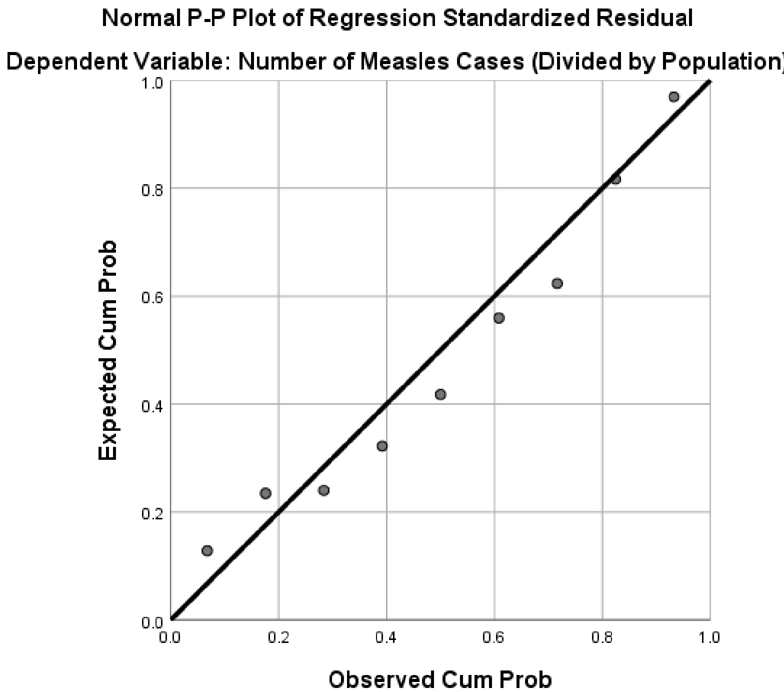
Assumption 4: no homoscedasticity

Simply, we would like to see constant variance of our residuals and the plot below satisfies this assumption.

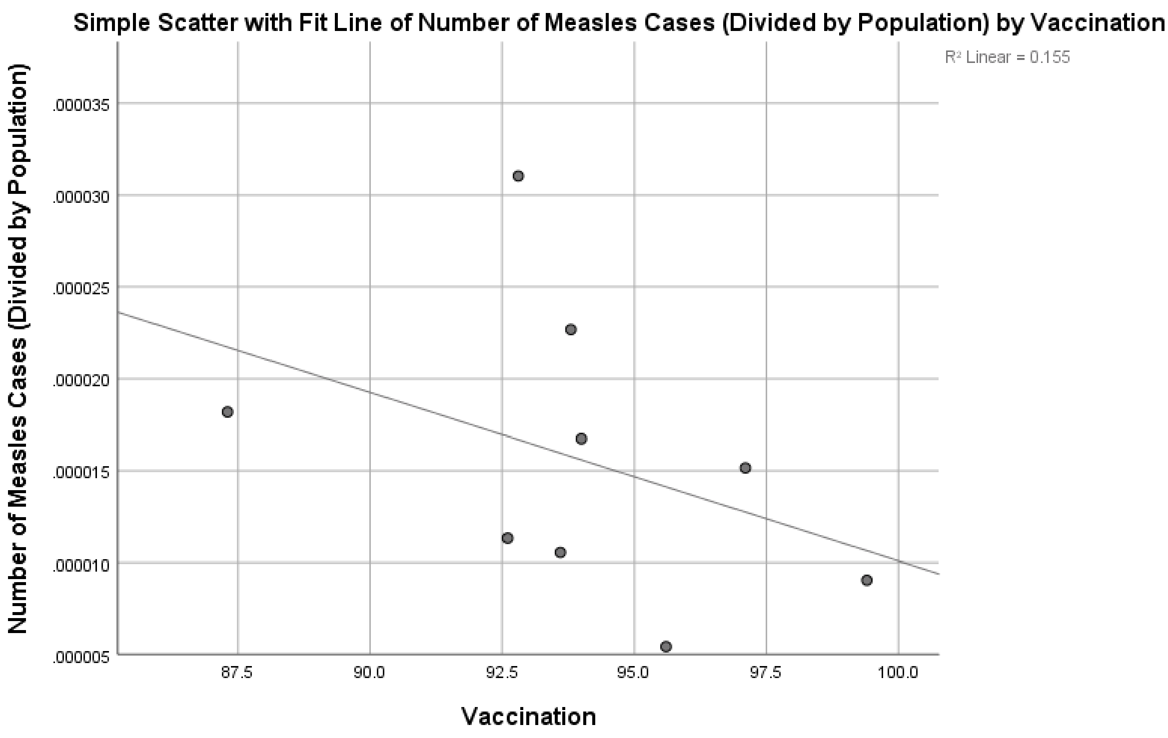


Assumption 5: residuals are approximately normally distributed

Looking at the plot on the next page, our observations do not stray far from the regression standardized residual line, meaning that this last assumption is satisfied.



Some of our assumptions were violated, but the regression analysis is still shown below.



Our r-squared value is only 15.5%, which is not very significant. Without Colorado's data in the study our value may have been higher, but I wanted to include as many data points as possible.

The ANOVA table below further shows us our regression is not significant.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	1.284	.295[b]
	Residual	.000	7	.000		
	Total	.000	8			

a. Dependent Variable: Outbreaks (Divided by Population)

b. Predictors: (Constant), Vaccination

While the number of measles cases and vaccination rates by state seemed significant, evaluating the number of measles cases in relation to the population was not. This may seem alarming, but recall earlier that many measles outbreaks occurred in specific unvaccinated communities. Therefore, the overall population may not be as much of a factor in these outbreaks, and our focus is still on overall vaccination rates and how they affect the number of measles cases in that state.

To include the outliers in our study, I performed a correlation between vaccination rates and number of measles cases in a particular state. The states included in this analysis are Louisiana, Michigan, Minnesota, Mississippi, Ohio, Oregon, Pennsylvania, Wisconsin, Colorado, Arkansas, Missouri, and Washington.

Correlations

			Vaccination	Number of Measles Cases
Spearman's rho	Vaccination	Correlation Coefficient	1.000	-.692*
		Sig. (2-tailed)	.	.013
		N	12	12
	Number of Measles Cases	Correlation Coefficient	-.692*	1.000
		Sig. (2-tailed)	.013	.
		N	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

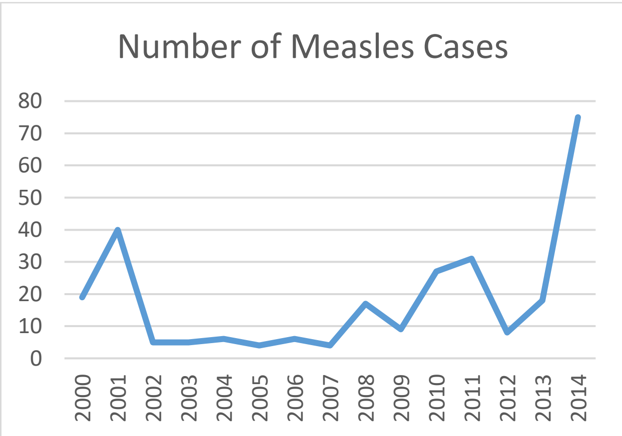
The correlation between these variables is -69.2%. This means that vaccination rates and number of measles cases have an inverse relationship. Unfortunately, correlation has some limitations. While we know these variables have an inverse relationship, we cannot conclude if one variable causes the other. Luckily, our significance level of .013 shows this correlation is significant.

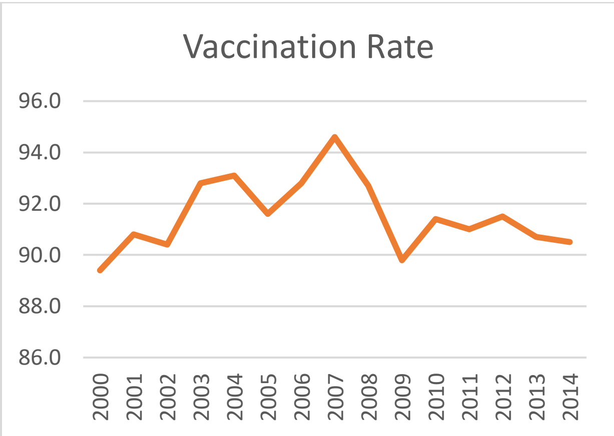
Correlations

			Vaccination	Number of Measles Cases (Divided by Population)
Spearman's rho	Vaccination	Correlation Coefficient	1.000	-.559
		Sig. (2-tailed)	.	.059
		N	12	12
	Number of Measles Cases (Divided by Population)	Correlation Coefficient	-.559	1.000
		Sig. (2-tailed)	.059	.
		N	12	12

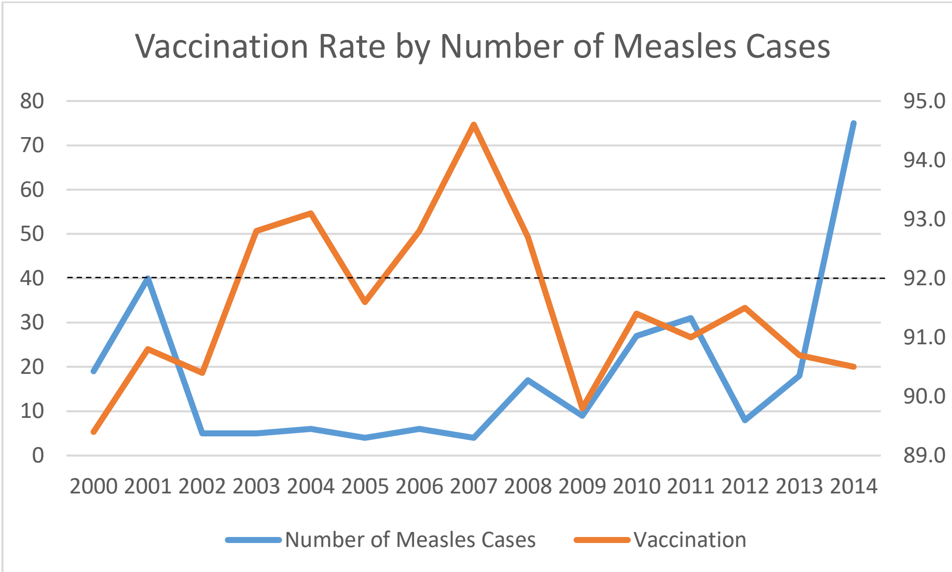
The correlation table above represents the vaccination rate and the number of measles cases relative to the population in a particular state. The correlation between these variables is -55.9% and also signifies an inverse relationship. Looking at the significance level of .059, the correlation between vaccination rate and the number of measles cases relative to the population in a particular state is not significant.

To further show the relationship between number of measles cases and vaccination percentage, I graphed the number of measles cases in California as well as the vaccination percentage of the MMR vaccine. This data is from 2000 to 2014.





A graph that combines both the number of measles cases and vaccination rates is shown below.



As you can see, the years vaccination rates were at their highest from 2003 to 2007, California experienced the least number of measles outbreaks (Harriman, 2015). Most of these years, vaccination rates were higher than the required HIIT threshold needed for herd immunity of 92%. Looking at 2010 to 2014, you can see an inverse relationship between vaccination rates and number of measles cases. As vaccination rates dropped from 2010 to 2011, measles cases increased (Harriman, 2015). Similarly, as vaccination rates increased from 2011 to 2012, measles cases dramatically dropped from 31 to 8 respectively (Harriman, 2015). Once again, when vaccination rates continued to drop from 2012 to 2014, measles cases spiked up to 18 in 2013 and 75 in 2014 (Harriman, 2015). From 2010 to 2014, a correlation of -70.3% exists between vaccination rates and number of outbreaks. This inverse correlation may show that there is a relationship between these variables.

Conclusion/Projections

In conclusion, our analysis showed promising evidence that low vaccination rates may contribute to higher measles outbreaks. It is important to keep in mind that limited data available restricted this analysis to only a few states, keeping our sample size small. Hopefully, as measles outbreaks continue to occur, more data is collected and further analysis will be possible. It would be quite interesting to analyze specific populations where huge deficits in vaccination occur, but many more examples of these outbreaks would need to be available in the coming years to practically do statistical analysis regarding these communities.

Overall, vaccination success and pushback will probably continue for many years. As more vaccines are established, new diseases emerge, and scientists are always battling the clock to find a solution to these deadly pathogens. Luckily, if most of the population is vaccinated, the disease can be contained and it won't have an exponential effect. While some groups may resist vaccines, education on the benefits of vaccines may help alleviate some concerns. As consumers gain more confidence in vaccines, outbreaks could decrease or have fewer reaching effects. Other solutions may involve more government control on the allowance of non-medical exemptions, therefore decreasing the risk of low vaccination. For now, it is up to individuals to choose whether the benefit of immunity outweighs the risks.

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