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Correlating Measles Cases and Vaccination Rates in the United States and Abroad

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Abstract

Introduction: Measles is a highly contagious and vaccine-preventable viral respiratory infection that continues to affect children and adults in the United States (U.S.) and abroad. *Objective:* This study aims to correlate vaccination rates and measles cases in the U.S. to countries worldwide during 1995 to 2000 and 2013 to 2018. *Methods:* Two datasets, measles reported cases and percent single dose measles-containing-vaccine coverage in 1-year old infants, were obtained from World Health Observatory Data portal for 165 countries. Third dataset, population dynamics, was utilized from World Bank portal to convert reported measles cases to measles case rates for selected 165 countries. A Spearman Rank analysis and paired t-test was performed to determine if rates of vaccination and measles cases differ between the two

outlined time periods. *Results:* N=165, a Spearman Rank analysis showed a negative correlation ($r = -0.270$, $p<0.0001$) between the rate of measles cases and vaccination rate between the two time periods. The mean change in rate of measles cases between the two time intervals was approximately 29.34 cases per 100,000 population ($p<0.0001$), while the mean change in MCV-1 vaccination between the two time intervals was approximately -7.98 percent ($p<0.0001$). *Conclusion:* There was a statistically significant negative correlation between the rate of MCV-1 vaccination and rate of measles cases from 1995 to 2000 and 2013 to 2018. There was a statistically significant decrease rate of measles cases and increase in vaccination from 1995-2000 to 2015-2018. Overall, our study reiterates the relationship between vaccination and measles cases and how robust vaccination programs protect communities worldwide from deadly outbreaks.

Key Words: measles, vaccination, United States, global health, World Health Organization, Centers for Disease Control and Prevention

Introduction

Measles is a highly contagious and vaccine-preventable viral respiratory infection that continues to affect children and adults in the United States (U.S.) and abroad. World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) declared measles eradicated from the U.S. in 2000[1]. This public health achievement was the result of intensive vaccination, causing an incidence of 300 cases per 100,000 population in the 1960s to drop to approximately 1.3 cases per 100,000 population in the 1980s.[2] In the early 1990s, measles resurged in the U.S., which led to vaccine improvement for better coverage.[2] Finally, a second dose of the vaccine was introduced in the 1990s, which reduced the incidence to less than 1 case per 1 million population by the end of the century.[2] However, recent measles outbreaks and declining vaccination rates threaten this elimination status in the U.S. The rise of anti-vaccination theories, especially within the U.S., criminalizes the measles, mumps, and rubella (MMR) vaccine as an autism-causing agent.[3] These beliefs stem from a fraudulent, and now discredited Lancet study performed in 1998, where researcher Andrew Wakefield claimed the MMR vaccine caused autism in those children that received the vaccine.[3] Religious, spiritual, and personal beliefs have also been cited as reasons to refuse vaccinations, consequently causing an increase in non-medical exemptions over the past two decades.[2]

In 2018, WHO reported 82,500 measles cases within the European Region, triple the number of cases from the previous year.[3] A similar upward trend of measles cases was also observed within the U.S. As of October of 2019, there are measles cases reported in at least 31 states, which the CDC attributes to foreign travelers and unvaccinated communities.[4] As outbreaks continue to occur, many studies illustrate the connection between declining vaccination rates and increasing measles cases. A 2016 study reports that vaccine-exempted,

unvaccinated children were 35 times more likely to have measles compared to their vaccinated counterparts.[2] A 2018 study reiterates a similar point. This study used a simulated program to predict measles cases within Texas using 2018 state school vaccination rates, and projected measles cases over a nine month period.[5] This study found that lower vaccination rates in a large unvaccinated school population resulted in a larger potential measles outbreak.[5]

As the U.S. did in the 1980s and 1990s, robust vaccination campaigns have helped fight against measles outbreaks worldwide.[6] In 2012, the Global Vaccine Action Plan (GVAP) with the support of the WHO pledged to eliminate measles in five of the six WHO regions by 2020[7]. During 2000-2012, there was an increase in measles-containing-vaccine (MCV) coverage globally, causing a 77% decrease in worldwide reported measles incidence and 78% decrease in annual measles deaths.[8] Currently, the global coverage with a single dose of MCV is approximately 85 percent, and 67 percent for the second dose.[6] Nonetheless, these efforts still are inadequate in eradicating measles worldwide. WHO reported an increase in measles cases in 2017 with 110,000 estimated deaths, a majority of which were in 5 year old children.[3] These deaths were a result of not receiving a single dose of the measles-containing-vaccine (MCV) in approximately 20.8 million children in underdeveloped and developing countries.[3] In fact, one study reported that children in Democratic Republic of Congo, Ethiopia, India, Indonesia, Nigeria, and Pakistan comprise greater than 50 percent of all unvaccinated children worldwide.[9] As of April 2019, WHO reports measles cases continue to rise with a global 300% increase in reported cases from the previous year within the African, European, Eastern Mediterranean, Southeast Asia, and Western Pacific regions.[6]

This study aims to correlate measles cases and vaccination rates in the U.S. and worldwide over two 5-year intervals, 1995 to 2000 and 2013 to 2018. Examining these two time

intervals specifically helps to understand and confirm the benefits of intensive vaccination programs in the U.S. and abroad as illustrated in previous research studies. Moreover, there are limited studies correlating vaccination and measles cases rates between the U.S. and other countries worldwide, especially within the current decade. Finally, this study hopes to observe if global trends in vaccination and measle cases rates are meeting the goals as outlined by the GVAP in 2012.

Research Question

How does the U.S. vaccination and measles rates between 1995-2000 and 2013-2018 correlate to other countries worldwide?

To explore this research question fully, we also asked: (1) What is the difference in rate of measles cases between 2000 and 2018 for the U.S. and other countries worldwide? What is the difference in average rate of vaccination between 2000 and 2018 for the U.S. and other countries worldwide? (2) How is the rate of measles cases and average rate of vaccination between 2000 and 2018 correlated for the U.S. and other countries worldwide? (3) Is there a statistically significant change in the rate of measles cases between the two time periods for the U.S. and other countries worldwide? Is there a statistically significant change in the rate of vaccination between the two time periods for the U.S. and other countries worldwide?

Methods

Context/Protocol

We used the data available on the WHO Global Health Observatory portal (https://www.who.int/uat-portal/). We utilized two global datasets, *measles-number of reported cases* and *measles-containing-vaccine first dose (MCV1) immunization coverage among 1-year*

olds (%)[10,11]. We filtered each dataset by year and country prior to analysis, providing raw data on 194 countries from 1980 to 2018. We used population data available on The World Bank portal (http://wdi.worldbank.org/table). We obtained population data for years 2000 and 2018 from *table 2.1 population dynamics*[12]. This population data allowed us to correct reported measles cases to rates of measles cases per 100,000 population for more accurate analysis.

Data Collection

The first dataset, *measles-number of reported cases*, is organized by country and years (1974 to 2018). These values are nationally reported measles cases, which are confirmed clinically, epidemiologically, or by laboratory investigation. These cases are from surveillance data; therefore, statistically unadjusted and not corrected for population differences among the countries[10].

The second dataset, *measles-containing-vaccine first dose (MCV1) immunization coverage among 1-year olds (%)*, is organized by country and years (1980 to 2018). These values are nationally reported percentages of children under the age of one year that have at least one dose of the MCV and survive the first year of life. These percentages are weighted sums of WHO and UNICEF estimates of national coverage from the United Nations Population Division's World Population Prospects[11].

The third dataset, *table 2.1 population dynamics*, is organized as follows: country, population by millions in years 2000 and 2018, average annual percent population growth rate from 2000 to 2018, population age composition in 2018, dependency ratio in 2018, crude birth rate per 1,000 population in 2017, and crude death rate per 1,000 population in 2017. For our analysis, we extrapolated data in the population by millions column for each country listed only.

The population data are midyear estimates and include all the population residing in the country regardless of legal status or citizenship[12].

Data Analysis

The WHO and World Bank datasets include a wide range of datapoints. There were several considerations when determining which data points would be included in final analysis. The original WHO dataset included data from 194 countries. However, if countries did not have at least four reported measles cases and four MCV-1 percent vaccinated during 1995 to 2000 and 2013 to 2018, then these countries were excluded. In addition, if corresponding countries in the World Bank dataset reported zero population in 2000 or 2018, then these countries were also excluded. Using this exclusion criteria, 29 countries were excluded from final analysis.

This study analyzes 165 paired data points (reported measles cases and percent MCV1 vaccinated) from 165 countries over two intervals (1995 to 2000 and 2013 to 2018). Firstly, we calculated the average reported measles cases and average vaccination rate from 1995 to 2000 and 2013 to 2018 for each country. We converted each country's average reported measles cases for each time interval into rates of measles cases per 100,000 population using corresponding population values for years 2000 and 2018. The rate of measles cases from 1995-2000 and 2013-2018 were labeled as *measles_per 100,000_2000* and *measles_per 100,000_2018* respectively. We calculated the difference in the measles case rate between 2018 and 2000 and labeled this value as *measles rate change.* We calculated the difference in the average vaccination rate between 2018 and 2000 and labeled this value as *vaccine change.* Subsequently, the *measles rate change* and *vaccine change* values were correlated using a Speakman Rank analysis. We performed a two paired t-test analysis to determine if the change in measles case rate and

vaccination rate between the two time periods were statistically significant. All analysis were completed using SPSS software.

Results

Data from 165 countries met the inclusion criteria and were analyzed. A Spearman Rank analysis showed a negative correlation ($r = -0.270$, $p<0.0001$) between *measles rate change* and *vaccine change.* To better visualize the correlation between measles cases and vaccination, two socioeconomically different countries (U.S. and India) were chosen to create scatter plots with a trendline (Figure 1 and Figure 2 respectively). Figure 1 illustrates the U.S.' percent MCV-1 vaccination versus reported measles cases using all data points from 1980 to 2018. Figure 2 illustrates India's percent MCV-1 vaccination versus reported measles cases using all data points from 1980 to 2018. Two additional figures were created to illustrate the vaccination trends (Figure 3) and reported measles case trends (Figure 4) from 1980 to 2018 in the U.S. and India to highlight the dissimilarity between the two socioeconomically different countries.

A paired t-test was performed between the rate of measles cases in 1995-2000 and 2013-2018, as well as again between the average vaccination rate in 1995-2000 and 2013-2018. The results of this two paired t-test are listed in Table 1. The mean rate of measles cases was approximately 43.81 and 14.43 from 1995 to 2000 and 2013 to 2018 respectively (Table 1). The mean change in rates of measles cases between the two time intervals was approximately 29.34 cases per 100,000 ($p<0.0001$) (Table 1). The mean MCV-1 vaccination was approximately 80.27% and 88.25% from 1995 to 2000 and 2013 to 2018 respectively (Table 1). The mean change in MCV-1 vaccination between the two time intervals was approximately -7.98 percent ($p<0.0001$) (Table 1).

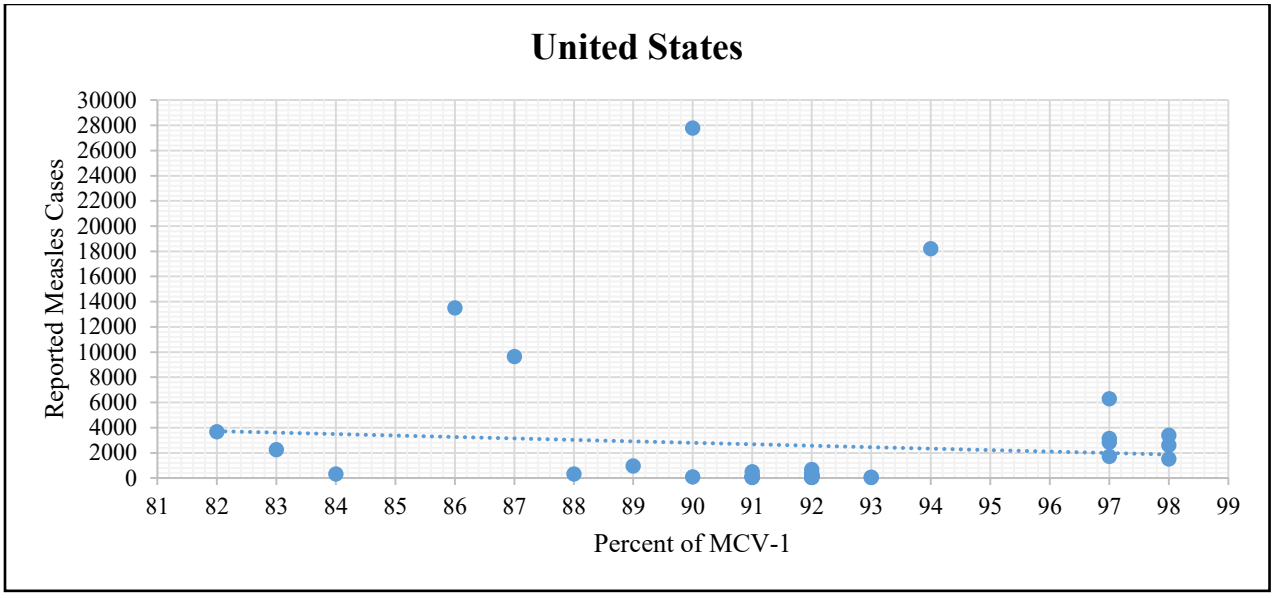

Figure 1. Scatter plot with trendline of U.S. percent MCV-1 vaccination versus reported measles cases from 1980-2018.

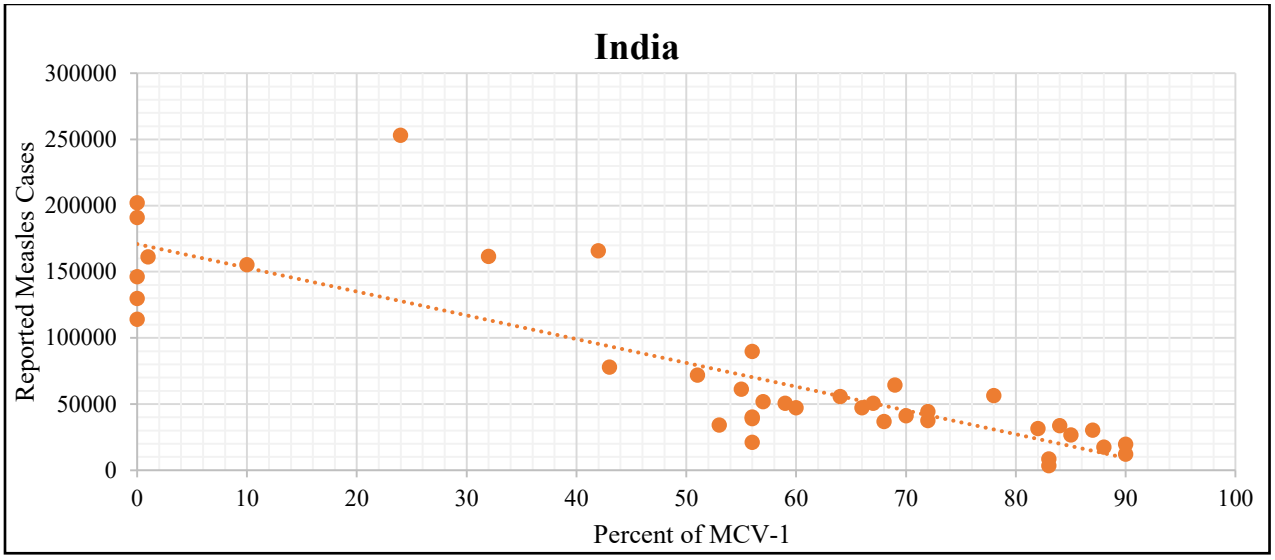

Figure 2. Scatter plot with trendline of India percent MCV-1 vaccination versus reported measles cases from 1980-2018.

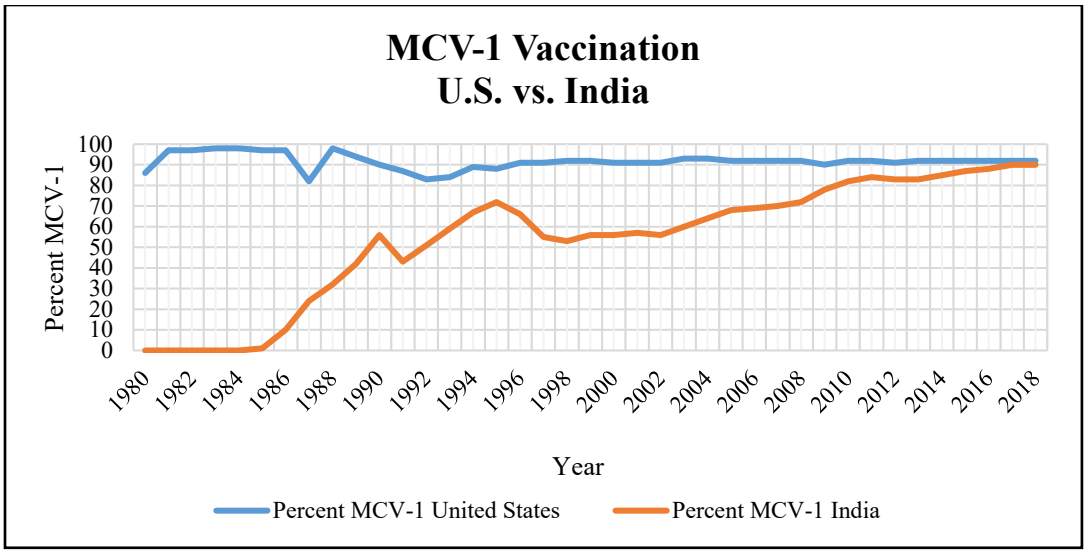

Figure 3. Line graph with percent MCV-1 vaccination in U.S. versus India from 1980 to 2018.

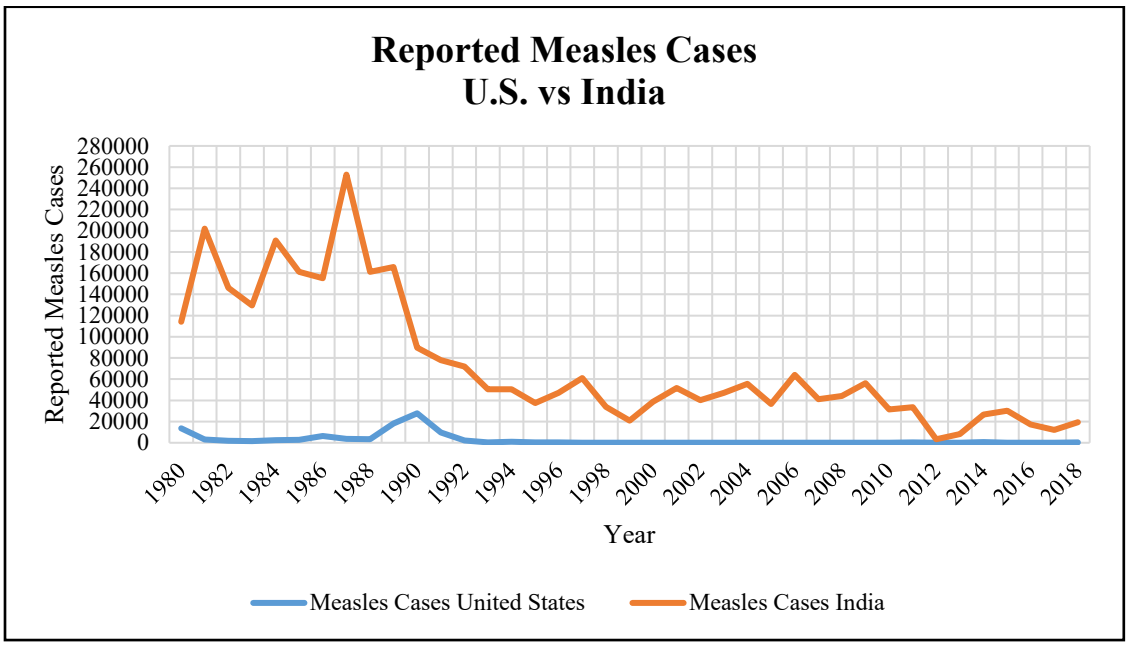

Figure 4. Line graph with reported measles cases in U.S. versus India from 1980 to 2018.

Paired t-test N = 165	Mean	Mean	Standard Deviation	95% Confidence Interval, t value	p value
Rate of measles cases 1995-2000	43.8104	29.37985	69.48474	(18.69885, 40.06086), 5.431	<0.0001
Rate of measles cases 2013-2018	14.4305				
1st dose MCV 1995-2000	80.2657	-7.98788	12.86334	(-9.96520, -6.01056), -7.977	<0.0001
1st dose MCV 2013-2018	88.2535				

Table 1. Difference in measles case rate and vaccination rate between 1995-2000 and 2013-2018.

Discussion

Overall, our study provides valuable insight on how the U.S. correlates to other countries worldwide over two decades. In this study, there was a statistically significant negative correlation between the rate of MCV-1 vaccination and rate of measles cases from 1995 to 2000 and 2013 to 2018. Moreover, there was a statistically significant decrease in rate of measles cases and increase in vaccination from 1995-2000 to 2015-2018. This relationship between vaccination and measles cases reiterates that robust vaccination programs protect communities worldwide from deadly outbreaks.

Figures 1 through 4 further highlight this relationship while focusing on two socioeconomically and developmentally different countries – the U.S. and India. A 2020 CDC's morbidity and mortality report (MMR) studied the global rates of measles cases and measles vaccination in a similar design as this study[13]. The results from this study support several findings in CDC's MMR, which are illustrated best through the figures of this study. The figures for India impressively demonstrate the effects of vaccination on reported measles cases in this developing country from 1980 to 2018. A thorough examination of the data for countries like India allude to the milestone work that these countries and global organizations like WHO have

done in attempting to eradicate measles[13]. Although the figures representing the U.S. are not as striking, the U.S. data does illustrate a steady rate of MCV-1 vaccination and lower reported measles cases. Our study estimated the steady MCV-1 vaccination rate for the U.S to be approximately 88% by 2018, which supports the plateau of 85% MCV-1 vaccination in the U.S. since 2010 mentioned in the CDC's MMR[13].

While this study exemplifies the valuable work of WHO and GVAP to create a measles free world, it also emphasizes the continued need for rigorous vaccination to decrease measles cases. The annual incidence of measles cases rapidly decreased from 145 cases per million population in 2000 to 18 cases per million population in 2016, reportedly the closest the world was to the goals outlined by WHO and GVAP[14]. Unfortunately, the incidence sharply rose to 120 cases per million population the following year in 2019, partially reversing the work done over decades[14]. In the U.S., specifically, there were 1,249 measles cases with 22 outbreaks in 2019[15]. This U.S. report documents the most number of cases in a single year since 1992 and second highest number of outbreaks since measles elimination in the U.S. in 2000[15]. Moreover, 89% of these cases occurred in unvaccinated patients or people with unknown vaccination status[15]. Although the U.S. continues to maintain its elimination status, recent rises in measles cases and outbreaks with declining vaccination status continues to threaten this enormous public health achievement. For example, the WHO Region of the Americas lost measles elimination status in 2018 after two short years of obtaining it in 2016[16].

Conclusion

There were several limitations in this study and its design. Firstly, this study attempted to sort and analyze a vast amount of public data, which is challenging and cumbersome to do efficiently and accurately. The analysis done in this study was limited with only a few tests

performed and interpreted. Secondly, we had to manually convert reported measles cases to rates of measles using a different dataset than WHO, which undoubtedly introduces a degree of error. Lastly, this study reported dissimilarities between the U.S. and one other socioeconomically and developmentally different country.

The strength of using public datasets is that they can be analyzed and interpreted in various ways. Future research can utilize the same datasets as this study and more thoroughly correlate the countries to one another by performing different statistical analysis like multiple linear regressions and z-scores. Furthermore, the data used in this study clearly illustrates a fluctuance in measles cases and vaccination rates among all WHO regions over the past two decades. Future research should explore etiologies causing these differences in cases and vaccination, such as social determinants health, health equity, cultural beliefs and traditions, health policy, and governmental politics, which affect all countries different. Finally, the same datasets may be used in future research to investigate if goals outlined in the Measles and Rubella Initiative's 2021-2030 campaign for "a world free of measles and rubella" are being met appropriately[16]. Like several other studies over the past two decades, this study supports the notion that strategic, equitable, and robust vaccination is the best solution to minimize measles outbreaks and preventable deaths.

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