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Tracking Childhood Vaccination Trends by Race: Analyzing MMR-Only, DTaP-Only, and Varicella-Only Vaccine Coverage Rates from 2016-2022

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by Victoria L. Gallagher

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ABSTRACT

Declining vaccination rates due to factors like hesitancy and access issues during the coronavirus disease 2019 (COVID-19) pandemic, have spurred outbreaks of preventable diseases like measles and pertussis. This capstone analyzes vaccination coverage for MMR-only, DTaP-only, and Varicella-only shots among children from 2016 to 2022, focusing on racial disparities. Data from the National Immunization Surveys (NIS) informed the analysis, encompassing 118,323 children. Odds ratios from a multivariable logistic regression were used to perform this analysis, and statistical significance was determined using a 95% confidence interval (CI). Black children had lower odds of MMR and Varicella vaccination compared to White children (OR: 0.81 and 0.84), while children of Other + Multiple race showed similar trends (OR: 0.94 for both vaccines). For DTaP, Black children had lower odds (OR: 0.84), whereas no significant difference was found for Other + Multiple race children (OR: 0.98). Yearly analysis showed a 3% increase in odds for MMR and Varicella vaccination but there was a 7% decrease in the odds of receiving a DTaP vaccine. DTaP coverage fluctuated across racial groups. Overall, while MMR and Varicella coverage remained stable or increased, DTaP rates varied among White, Black and Other + Multiple race children.

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Author’s Statement Page

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1 Introduction:

1.1 Summary

Vaccination programs are one of the most successful and cost-effective public health interventions ever developed in the history of medicine, allowing for the primary prevention of serious infectious diseases (Filia et al., 2019). Although, there is currently an increasing proportion of vaccine-hesitant individuals who refuse or delay vaccination for their children which creates challenges for communities aiming to prevent and reduce the burden of vaccine-preventable diseases (Gravagna et al., 2020). These declining vaccination rates due to hesitancy amongst other problems such as access issues due to the coronavirus disease 2019 (COVID-19) pandemic over the past years have led to numerous outbreaks of vaccine-preventable diseases in both high-burden and low-burden settings, including outbreaks of deadly diseases such as measles and pertussis. Due to this, three crucial vaccines MMR, DTaP, and Varicella amongst children were analyzed.

The MMR vaccine, consisting of measles, mumps, and rubella, offers protection against highly contagious diseases. Despite concerns about adverse effects, maintaining high vaccination coverage, especially with two doses, is crucial to achieving herd immunity and preventing outbreaks, given the significant morbidity and mortality associated with these diseases. The DTaP vaccine, administered in five doses at 2 months, 4 months, 6 months, 15–18 months, and 4–6 years is recommended by the Advisory Committee on Immunization Practices (ACIP). It provides protection against diphtheria, tetanus (lockjaw), and pertussis (whooping cough). Addressing missed vaccination opportunities can substantially enhance coverage, thereby reducing the risk of severe complications and transmission, particularly among vulnerable children. Varicella immunization, typically administered as a single dose but has now been increased to two doses, has led to a remarkable decrease in varicella-related incidents, including hospitalizations, ambulatory care visits, and deaths among young children.

Racial disparities play a role in vaccination presence among children aged 19-35 months, as evidenced by findings in existing literature. These disparities contribute to a gap, leaving certain children more vulnerable to diseases. Previous research has identified factors contributing to these disparities, particularly within the African American population, such as limited access to preventive healthcare, mistrust in the healthcare system, and a lack of understanding about the risks and benefits of vaccinations (Kulkarni et al., 2021). Addressing and researching these disparities is crucial to future implications of vaccination coverage. By identifying potential determinants of vaccination presence, like race, interventions and policies can be tailored to ensure equitable access to immunization services.

1.2 Purpose

The purpose of this capstone is to analyze race, vaccination presence, and trends across six years amongst children aged 19-35 months. Focused on the vaccination coverage of three vaccines MMR, DTaP, and Varicella—the research aims to show any racial disparities. As the prevalence of combination vaccines may phase out vaccines that only contain MMR, Varicella, and DTaP-only shots, this capstone is particularly significant. By utilizing the vaccination records from the National Immunization Survey, children classified as White only, Black only, and Other + Multiple race, this capstone seeks to differentiate which specific racial groups have exhibited the highest and lowest vaccination coverage over the span of seven years. Additionally, this capstone stands to make a contribution to the ongoing discourse surrounding childhood immunization especially when looking at three vaccines that contain only MMR, DTaP and Varicella.

2 LITERATURE REVIEW

2.1 MMR (Measles, Mumps & Rubella)

The MMR vaccine, containing measles, mumps, and rubella protection, has substantially reduced infectious disease admissions. One dose of the MMR vaccine is 95% effective at preventing measles and 92% effective at preventing the spread of measles to household contacts (Di Pietrantonj et al., 2021). If the vaccine is given at 9 months, 85% of children develop immunity. If the vaccine is given at 12 months or older, 95% of children develop immunity. If a second dose is added, more than 99% of children develop immunity. If measles infection is successfully cleared, lifelong immunity to measles is gained because of the creation of memory cells; a person cannot become infected again if they maintain immunocompetence. Measles is a highly communicable viral infection with serious complications. There have been continued outbreaks of measles in countries in which measles is considered to be eliminated, such as the United States and the Netherlands. Transmission of measles is dependent on person-to-person spread through respiratory droplets or direct contact. The measles virus triggers an aggressive immune response, involving both the humoral and cellular immune systems. About 30% to 40% of patients with measles will develop 1 or more complications, which are generally worse in very young patients. Respiratory tract complications include pneumonia, which is the leading cause of measles-associated death, and otitis media, which can cause hearing loss. The current US public health policy regarding measles vaccine booster doses began in response to the widespread measles outbreak in the United States from 1989 to 1991. Cases occurred more commonly in unvaccinated children and in young adults who had received only 1 dose of vaccine. Today, the policy in areas where measles has been controlled is to vaccinate between 12 and 15 months of age and to boost with a second dose before starting kindergarten. In outbreak situations, the first dose should be given at 6 months of age, with a repeat dose at 12 to 15 months of age and the usual booster before starting kindergarten (Porter & Goldfarb, 2019).

Mumps is an acute viral illness that presents classically with unilateral or bilateral inflammation of the parotid and other salivary glands (Lam et al., 2020). Mumps typically present as a mild illness of puffy cheeks and swollen jaw from parotitis; however, complications such as orchitis, oophoritis, pancreatitis, hearing loss, meningitis, and encephalitis can occur. Transmission of the mumps virus from persons is primarily through respiratory droplets. Furthermore, transmission also occurs from persons with asymptomatic infections, highlighting the challenges in preventing virus transmission. Although mumps can be administered as a monovalent vaccine, it is typically given as a part of the trivalent MMR vaccine (Almansour, 2020). Certain factors contributing to outbreaks among vaccinated populations is failure to vaccinate with the two recommended doses of the MMR vaccine, the limitations of existing diagnostic tests for mumps, densely populated environments with prolonged face-to-face contact, and delayed recognition, and reporting of mumps cases. Another reason for re-emerging mumps cases is waning immunity which has been recognized as a major contributor to recent outbreaks.

For decades, Rubella, also known as the “German measles,” was considered a mild viral infection of childhood manifesting with fevers, rash, and lymphadenopathy. Rubella is an acute illness caused by rubella virus and characterized by fever and rash. Rubella and congenital rubella syndrome can be prevented by rubella-containing vaccines, which are commonly administered in combination with measles vaccine. Despite rubella's elimination from the US in 2004, maintaining vaccination remains crucial for preventing imported cases (Di Pietrantonj et al., 2021). Rubella elimination is defined as the absence of continuous disease transmission for 12 months or more in a specific geographic area. Rubella is no longer constantly present in the

United States however, rubella remains a problem in other parts of the world. Today, less than 10 people in the United States are reported as having rubella each year. Since 2012, all rubella cases had evidence that they were infected when they were living or traveling outside the United States. To maintain rubella elimination, it is important that children are vaccinated against rubella. Although rubella and measles surveillance are most often integrated, surveillance is less likely to detect rubella, which is generally a milder disease with subclinical infections in 30–50% of the cases (Zhang et al., 2022).

2.2 DTaP

Since the 1990s, the introduction of diphtheria, tetanus toxoids, and acellular-cell pertussis vaccines has led to a dramatic decline in pertussis incidence across the United States. Pertussis, also known as whooping cough, caused by the highly contagious bacterium Bordetella pertussis, poses severe risks, particularly for children under 1 year old, with 50% of cases resulting in hospitalization and potential respiratory and neurological complications (Gabutti et al., 2022). Tetanus is a life-threatening but almost completely vaccine-preventable disease, caused by a potent neurotoxin produced by Clostridium tetani. This neurotoxin produces C. tetani spores that enter the body through breaches in the skin or mucous membranes. Respiratory diphtheria is an acute, communicable infectious illness caused by toxigenic strains of Corynebacterium diphtheriae. Toxin-producing strains of C. diphtheriae can cause disease in susceptible persons by multiplying and producing diphtheria toxin in either nasopharyngeal or skin lesions (Havers et al., 2020). Current DTaP-containing vaccines in the US demonstrate high effectiveness, with an estimated 97.7% effectiveness among children receiving ≥4 doses (Loiacono et al., 2021). But, little research has been done on vaccines that only contain DTaP. Disparities exist in vaccination rates, particularly among children that are non-White or of lower socioeconomic status, leading to higher pertussis incidence among those aged 2 to 5 years with fewer than four doses in their second year of life. Waning immunity from DTaP vaccination is recognized as a key driver of pertussis resurgence in high-coverage countries, with longer intervals between doses or missed immunizations increasing pertussis risk and potential for sustained transmission and outbreaks (Rane et al., 2021). Given the serious consequences of diphtheria, tetanus, and pertussis infections, children require a series of five DTaP shots, administered at specific ages (2 months, 4 months, 6 months,15–18 months and 4-6 years). Reducing missed vaccination opportunities is essential for increasing coverage and improving public health outcomes.

2.3 Varicella

Varicella also known as chickenpox is a highly infectious disease predominant in childhood. Varicella is generally a self-limiting, mild disease in childhood. Before the introduction of routine vaccination, varicella contributed significantly to the burden of childhood disease in the United States, with approximately 4 million cases, 10,500–13, 500 hospitalizations, and 100–150 deaths occurring annually; >90% of cases and the majority of severe complications occurred among children (Elam-Evans et al., 2022). The effectiveness of the varicella vaccine against any severity of varicella after two doses in children aged 11 to 22 months has been documented at an impressive 95%. Initially, the Food and Drug Administration (FDA) in 1995, stated the United States became the first country to recommend universal immunization with a single dose of the vaccine for susceptible children aged 12 months to 13 years (Papaloukas et al., 2014). But, in response to ongoing varicella outbreaks, the Centers for Disease Control and Prevention (CDC) added a second dose of varicella vaccine to the routine immunization schedule for children in June 2006. Subsequent studies have also demonstrated excellent effectiveness of two doses in the first 24 months after the recommendation of a routine second dose, with odds of developing varicella reduced by 95% for children who received two doses compared to one (Shapiro et al., 2011).

2.4 Importance of Childhood Vaccines

Maintaining public confidence and acceptance of vaccines has become increasingly important as timely vaccination is a major defense against emerging disease outbreaks. Especially childhood vaccines, that save an estimated 2–3 million lives worldwide every year (Nandi & Shet, 2020). Persistent or recurrent infections in early life can lead to poor growth and stunting, which in turn can adversely affect adult health. State-mandated school entry immunization requirements in the United States play an important role in achieving high vaccine coverage, but variations in vaccine exemption policies result in a patchwork of vaccine coverage across the country. Childhood vaccination rates tend to be lower in states with more permissive exemption policies, and, in states allowing personal belief exemptions, higher levels of exemptions are associated with lower levels of measles, mumps, and rubella (MMR) vaccination amongst many more (Garnier et al., 2020). Some of these impacts on vaccination rates may be limited because children may enter school without being fully vaccinated through other means such as the coronavirus disease 2019 (COVID-19) pandemic. In response to the pandemic, routine healthcare services, including delivery of vaccinations, were disrupted in many countries, while in some cases vaccination appointments were missed because of fear of attending healthcare facilities (Maltezou et al., 2022).

2.5 Racial disparities in vaccination coverage

There has been a longstanding disparity between the levels of vaccine coverage among white children compared with that among children in racial minority populations in the United

States (Hutchins et al., 2004). The Centers for Disease Control and Prevention (CDC) most recently stated that in 2016 overall vaccination coverage was lower among black children than among white children. Compared with white children, black children had lower coverage with ≥3 and ≥4 doses of DTaP (Hill et al., 2023). Another example, in 2017, Black and American Indian/Alaska Native infants were 7% and 10% less likely to be fully immunized, respectively, than White infants (Brumbaugh et al., 2024). Vaccination coverage remained high and relatively stable between 2007 and 2019; however, there were differences across racial groups (Brumbaugh et al., 2024). Despite decades of efforts to address inequities, disparities in childhood vaccination persist; federal-level interventions such as the Vaccine for Children (VFC) program and the Affordable Care Act, enacted in 1994 and 2010, respectively, have improved routine childhood vaccination coverage; however, improvements are inconsistent across race.

2.6 National Immunization Survey

The National Immunization Survey (NIS) was started by the CDC in 1994. NIS has been used to evaluate vaccination coverage among children 19–35 months in the United States according to the immunization schedule recommended by ACIP. The NIS collects immunization information through telephone surveys of households and mail surveys of immunization providers.The NIS has been collecting immunization data for young children by a variety of socio-demographic characteristics, so that immunization workers can assess the vaccination coverage by those domains, identify groups at risk of low vaccination coverage, and help the people in those groups to raise vaccination coverage (Zhao et al., 2017). The target population for the NIS is children who are or will be 19-35 months within a few weeks of being selected to participate in the survey and living in the United States. Data are used to monitor vaccination coverage among children at the national, state, selected local levels, and some in U.S. territories.

NIS maintains dedication to the quality of the survey data throughout all of its phases, including sample design, questionnaire development, data collection, data processing, derivation of weights and estimates, data delivery, and dissemination.

3 METHODS AND PROCEDURES

3.1 Summary

This section outlines the methodologies and procedures employed in the statistical analysis of race, year and its association with vaccination presence, focusing on MMR (Measles, Mumps, and Rubella), Varicella, and DTaP (Diphtheria, Tetanus, and Pertussis) vaccines. Georgia State University Institutional Review Board (IRB) approval is not required to use this public dataset since it is in the list of datasets pre-approved for such analysis by GSU.

3.2 Study Design

The data was collected from The National Immunization Survey (NIS), which is a group of phone surveys used to monitor vaccination coverage among children 19–35 months. The surveys are sponsored and conducted by the National Center for Immunization and Respiratory Diseases (NCIRD) of the Centers for Disease Control and Prevention (CDC) and authorized by the Public Health Service Act. The NIS uses two phases of data collection to obtain vaccination information for a large national probability sample of young children: an RDD (random digit dialing) telephone survey designed to identify households with children 19 through 35 months of age, followed by the Provider Record Check, a mailed survey dual identifiers were stored and used in the analysis. Respondents are asked to provide contact information for all providers who administered vaccines to their children. With parental consent, a survey is mailed to each identified provider, requesting the child's vaccination history. Multiple responses for an individual child are synthesized into a comprehensive vaccination history which is used to estimate vaccination coverage. At the end of the household interview, consent to contact the child's vaccination provider(s) is requested from the parent/guardian. When oral consent is obtained, each provider is mailed an immunization history questionnaire. This mail survey portion of the NIS is the Provider Record Check (PRC). The data from the questionnaires are edited, entered, cleaned, and merged with the household information from the RDD survey to produce a child-level record (Smith et al., 2001).

3.3 Search Engine Used

Two main search engines, Google Scholar and PubMed, were used alongside the Centers for Disease Control and Prevention (CDC) website. The CDC website provided both the dataset and served as a reference for understanding policies and guidelines regarding Measles, Mumps, Rubella (MMR), Diphtheria, Tetanus, and Acellular Pertussis (DTaP), and Varicella vaccinations. Google Scholar offered peer-reviewed articles and academic publications, while PubMed provided access to biomedical literature, enhancing the analysis with focused information on the biological aspects of vaccination. Overall, these resources ensured the inclusion of reliable, up-to-date data aligned with official public health guidelines.

3.4 Statistical Analysis

The statistical analysis of vaccine coverage rates involved several steps. Initially, summary and descriptive statistics were computed, as well as to identify missing data and explore variable distributions of race within the dataset. Using SAS v9.4, vaccine coverage rates were calculated, and trends over time were visualized using line graphs. In order to analyze the relationship between race, year and vaccination presence, multiple logistic regression analysis was performed. To perform such an analysis for a selected vaccine a new binary variable "Vaccination Presence" was created, categorizing children into two groups: those who received 0 shots and those who received at least 1 or more shots. Furthermore, “Year” variable was incorporated as a predictor variable into the multiple logistic regression model to account for temporal effects. To calculate vaccine coverage rates for each year, the mean was utilized, and line graphs were produced to visualize trends over time. Odds ratio (OR) and 95% confidence intervals were calculated using logistic regression for each predictor and used to evaluate the effect of predictors on the response.

4 RESULTS

4.1 Data Exploration

The MMR vaccination allowed for a maximum of 4 shots by 36 months, DTaP for 5 shots, and Varicella for 3 shots. Race categories were coded as follows: 1 for White Only, 2 for Black Only, and 3 for Other + Multiple race. The "Vaccination Presence" variable was created for each vaccine, MMR-only, Varicella-only and DTaP-only, to classify diseases as 0 for not vaccinated and more than 1 for vaccinated. There were 109,656 missing data for MMR, DTaP, and Varicella, while no missing data were observed for race. The dataset comprised a total of 227,979 children but after controlling for missing observations, the dataset had 118,323 children. In the 2016 dataset there were 28,296 children , in 2017 there were 28,465, in 2018 there were 28,971, in 2019 there were 33,799, in 2020 there were 36,750, in 2021 there were 35,995 and in 2022 there were a total of 35,703.

4.2 Statistical Summaries

Results are presented in both tables and figures. Table 1 presents a total 118,323 children that received an MMR-only shot by 36 months. 80.06% or 94,730 children had received at least 1 or more shots while 19.94% or 23,593 children had not received their MMR only shot. Table 2 showed a total of 118,323 children received a DTAP-only shot by 36 months. The majority of children, 66.91% or 62,719 children had at least 1 or more shots while approximately 33.09% or 39,149 children had not received their first shot by 36 months. Table 3 shows the summary of the Varicella vaccine in total 118,323 children received varicella only shots by 36 months. The majority of children, 79.04% or 93,531 children had received at least 1 or more shots.

In Table 4 and Figure 1, the racial distribution of children in the dataset is depicted, highlighting the predominance of White children, who accounted for 74.04% of the sample. Black children constituted 9.10% of the sample, while 16.86% identified as Other + Multiple race. More specifically, the sample included 87,604 White children, 10,765 Black children, and 19,954 children who identified as Other + Multiple race.

4.3 Race, Year and Vaccination Presence: Multiple Logistic Regression

Multiple logistic regression models the probability of the occurrence of a binary outcome variable based on the values of multiple predictor variables. In particular, in this analysis it models the probability of a child's vaccination presence given their race and the year. The outcome variable is the vaccination presence and it is being predicted or explained by the independent variables, including race and year.

The results of multiple logistic regression analysis is shown in Table 5 for the MMR vaccine. The odds ratio estimate 0.81, suggests that the odds of being vaccinated with MMR for Black children are estimated to be 0.81 times that of White children, with a 95% CI [0.77, 0.85]. The odds ratio of 0.94 suggests that the odds of being vaccinated with MMR for children of Other + Multiple races are estimated to be 0.941 times that of White children, with a 95% confidence interval of [0.91, 0.98]. While the odds ratio is slightly closer to 1 compared to Black children, it still suggests that children of Other + Multiple races are less likely to receive the MMR vaccine compared to White children. For each one-unit increase in Year, there is a positive association observed with MMR vaccination presence, where the log-odds of being vaccinated with MMR increase by approximately 0.03. The odds ratio of 1.03 suggests that with each passing year, the odds of being vaccinated with MMR is estimated to increase by approximately 3%, with a 95% confidence interval of [1.02, 1.03].

Table 6 presents the multiple logistic regression analysis for the Varicella vaccine. The odds ratio of 0.84 suggests that Black children are estimated to have approximately 0.84 times the odds of receiving the MMR vaccine compared to White children, with a 95% confidence interval of [0.80, 0.88]. The odds ratio of 0.94 suggests that children classified as Other + Multiple race are estimated to have approximately 0.94 times the odds of receiving the varicella vaccine compared to White children, with a 95% confidence interval of [0.90, 0.97]. For each one-unit increase in the year, the log-odds of being vaccinated with varicella is estimated to increase by approximately 0.03. The odds ratio was estimated to be 1.03, with a 95% CI [1.02, 1.03]. This shows that for each additional year, the odds of varicella vaccination is estimated to increase by approximately 3% when compared to the odds in the previous year.

Table 7 presents the results of multiple logistic regression analysis for the DTaP vaccine, examining the association between race, year and the odds of experiencing DTaP. Black children were estimated to have approximately 0.84 times the odds of receiving the DTaP vaccine compared to White children, with a 95% confidence interval of [0.81, 0.88]. Children classified as Other + Multiple race were estimated to have approximately 0.98 times the odds of receiving the DTaP vaccine compared to White children, with a 95% confidence interval of [0.95, 1.01]. The inclusion of the null value of 1 in the confidence interval indicates that there is no statistically significant difference between children classified as Other + Multiple race and White children concerning their odds of receiving the DTaP vaccine. The odds ratio associated with

Year was estimated to be 0.93, with a 95% CI [0.93, 0.94]. This suggests that for each additional year, the odds of having a DTaP vaccination decrease by approximately 7% when compared to the odds in the previous year. This suggests a negative association between the Year and the odds of having a DTaP vaccination.

4.4 Changes in Vaccination Coverage Rates from 2016 to 2022

Table 8 presents unvaccinated and vaccinated counts of vaccine presence by Race. The vaccination presence for MMR found that among White children, 17,056 were unvaccinated while 70,548 were vaccinated. For Black children, 2,470 were unvaccinated, with 8,295 vaccinated. For those of Other and Multiple races, along with unknown races, 4,067 were unvaccinated, and 15,887 were vaccinated. Overall, a total of 23,593 children were unvaccinated, while 94,730 children received at least one shot of the MMR vaccine. Varicella vaccination presence presented for White children, 17,974 were unvaccinated, while 69,630 were vaccinated. For Black children, 2,521 were unvaccinated, and 8,244 were vaccinated. For children of Other + Multiple race, 4,297 were unvaccinated, with 15,657 vaccinated. In total, 24,792 children were unvaccinated, while 93,531 children received at least one shot of the Varicella vaccine. The vaccination presence for DTaP showed that among White children, 28,592 were unvaccinated, while 59,012 were vaccinated. For Black children, 3,929 were unvaccinated, with 6,836 vaccinated. For those of Other and Multiple races, 6,628 were unvaccinated, and 13,326 were vaccinated. In total, 39,149 children were unvaccinated, while 79,174 children received at least one shot of the DTaP vaccine.

In Table 9, the coverage rates for MMR, DTaP, and Varicella vaccines presented coverage for White, Black and Other + Multiple race children from 2016 to 2022. Across all races, MMR coverage rates generally remained high throughout the years, with slight fluctuations. White children consistently exhibited the highest MMR coverage rates compared to other racial groups. Varicella coverage exhibited slightly lower MMR coverage rates for all racial groups. However, there was a decrease in Varicella coverage from 2019 to 2022 across all races. DTaP coverage rates were lower compared to MMR and Varicella coverage rates across all years and races. It's important to note that Black children consistently had the lowest DTaP coverage rates. While there were disparities in vaccination coverage rates between races, particularly for DTaP, there were instances where these gaps narrowed over time. For instance, the coverage gap between White and Black children for MMR and Varicella vaccines decreased in some years such as in 2016 there was a 1.29% difference between Varicella coverage for Black and White children.

In Figure 2, the total vaccination rates for MMR, DTaP, and Varicella vaccines from 2016 to 2022 illustrated. A trend emerges, revealing a significant decline in the proportion of children receiving DTaP vaccinations over the years, while there has been a notable increase in those receiving MMR and Varicella vaccines. The MMR and Varicella vaccines exhibit similar trendlines, suggesting a degree of correlation or shared influencing factors in their vaccination rates. MMR consistently achieves a slightly higher vaccination coverage rate throughout the 7-year period compared to Varicella.

Vaccination coverage rates for White children from 2016 to 2022, focusing on DTaP, MMR, and Varicella vaccines are presented in Figure 3. DTaP exhibited the lowest vaccination coverage rate in 2021, at 63.52%, while its highest coverage rate was observed in 2017, 72.36%. The period from 2017 to 2021 witnessed the sharpest decline in DTaP vaccination coverage among the three vaccines, amounting to 8.52%. In contrast, MMR displayed its highest vaccination coverage rate in 2022, reaching 82.50%, with its lowest rate occurring in 2018 at 78.30%. MMR experienced a spike in vaccination coverage between 2019 and 2022, reflecting an increase of 3.56%. Similarly, Varicella demonstrated its highest vaccination coverage rate in 2022, at 81.92%, while its lowest rate was observed in 2018, at 77.42%. There is a consistent trend observed in Varicella and MMR vaccination coverage rates, unlike the declining trend observed in DTaP vaccination rates.

Figure 4 showcases the vaccination coverage rates for Black children. DTaP vaccination displayed its highest coverage rate in 2016, reaching 69.46%, followed by a gradual decline to its lowest coverage rate of 59.75% in 2020. However, after 2019, vaccination coverage rates saw a modest increase of 0.92%, suggesting a potential improvement in coverage. In contrast, both MMR and Varicella vaccinations exhibited similar trends over the years, with their highest coverage rates recorded in 2022, reaching 78.48%. MMR experienced its lowest coverage rate in 2017, at 75.83%, while Varicella had its lowest coverage rate in 2020, at 75.21%. The vaccination coverage trends for MMR and Varicella were closely aligned, leading to an overlapping or converging trend line in 2021 and 2022.

Vaccination Coverage Rate of children classified as Other + Multiple race is presented in Figure 5. DTaP exhibited its highest vaccination coverage in 2016, at 72.74%, while experiencing a gradual decrease to its lowest coverage rate in 2019, at 61.83%. This decline amounted to a gradual decrease of 6.88% in total from 2016 to 2022. In contrast, both MMR and Varicella displayed very similar trendlines, with MMR slightly "outperforming" Varicella in terms of vaccination coverage rates. MMR experienced its lowest coverage rate in 2019, at 78.03%, and its highest in 2022, at 80.81%. Similarly, Varicella had its lowest coverage rate in 2019, at 76.81%, and its highest in 2022, at 80.37%.

5 DISCUSSION AND CONCLUSION

5.1 Study Limitations

Potential study limitations of the National Immunization Survey include sampling bias, response bias and incomplete vaccination records amongst many more. The NIS relies on a complex sampling design to obtain a representative sample of the U.S. population. Despite efforts to ensure representativeness, there may still be biases in the sampling process. Certain demographic groups may be underrepresented or overrepresented in the sample. Also, participation in the NIS is voluntary, and survey respondents may differ systematically from non-respondents. This could lead to response bias if certain groups are more or less likely to participate in the survey, which may affect the generalizability of the findings. This is apparent in the sample used due to the large number of White children sampled compared to Black and Other + Multiple race children.

Given this capstone focuses solely on vaccines containing MMR, DTaP, and Varicella, there were certain variables intentionally omitted, such as the 7 series vaccine. This vaccine includes immunization against DTAP, poliovirus, measles, mumps, rubella, hepatitis B, HIB, varicella, and pneumococcal infections. Another example is that for DTaP, the NIS dataset has a total of 5 variables that contain DTaP shots, 4 of them are combo containing at least one other vaccine. Similarly, there are 10 variables that contain some iteration of measles, mumps, or rubella. These variables were not used and could potentially show a higher vaccine coverage rate because they not only contain MMR, DTaP or varicella but many more.

5.2 Discussion

The distribution of the population children aged 19-35 months was shown in Figure 1, it shows an underrepresentation of Black, 9.10%, and Other + Multiple race children, 16.86%, compared to white children, 74.04%. MMR vaccination coverage rates showed an increasing trend across all racial groups, with White children reaching their highest coverage rate in 2022, 82.42%. Black and children of Other + Multiple race also demonstrated increasing coverage rates, with the highest rates recorded in 2022, 78.48% for Black children and 80.81% for children classified as Other + Multiple race. Varicella vaccination coverage rates followed a similar pattern to MMR, with all racial groups reaching their highest coverage rates in 2022 (White: 81.82%, Black: 78.48%, Other + Multiple race: 80.37%). MMR "slightly outperformed" Varicella in terms of coverage rates throughout the study period.

Future research efforts could include analyzing vaccination trends over a longer time period beyond the seven years examined in this capstone. However, changes in survey methodology, population demographics, immunization policies, and other factors over time can complicate the interpretation of trends and comparisons between survey cycles. National public health authorities should strengthen vaccination strategies and ensure the continuity of vaccination services, making this a critical public health priority. Nonetheless, more initiatives are needed to re-establish past vaccination coverage rates and to achieve higher rates over the next decade (Maltezou et al., 2022). To address these problems, continued efforts are needed to ensure equitable access to immunization services and address barriers to vaccination uptake such as the maintenance of Vaccines for Children Program and Affordable Act Program; which involves expanding access to healthcare services in underserved communities, enhancing public awareness and education about the importance of vaccination, and strengthening partnerships between healthcare providers, community organizations, and policymakers.

5.3 Conclusions

In conclusion, there has been a slight increase of vaccination coverage rates from 2016 to 2022 for MMR and Varicella while DTaP had a decrease. Since the only variables used contained DTaP-only, Varicella-Only and MMR-only, there could be a discrepancy when looking at total vaccination count and coverage rate, as there are multiple variables within the National Immunization Survey dataset that contain MMR, DTaP and varicella; this includes combination vaccines. When examining vaccination coverage rates by race, there were observed disparities, with White children consistently showing higher rates compared to Black and Other + Multiple race children. However, it's important to note the potential for sample size bias, particularly given the larger sample size of White children in the dataset. Future studies may benefit from stratified sampling techniques or using weighted frequencies to ensure more equitable representation across racial groups. When looking at and researching literature review of racial disparities in vaccination coverage, non-White children have significantly lower vaccination rates which is accurate in the results of the statistical analysis. Furthermore, the similarity between MMR and Varicella coverage rates suggests potential interactions in vaccination promotion strategies for these two vaccines. The observed fluctuations in DTaP coverage rates highlight the dynamic nature of vaccination uptake and the need for ongoing monitoring and adaptation of immunization programs. These fluctuations may be influenced by various factors, including changes in vaccine recommendations, public perceptions of vaccine efficacy, and equitable access to healthcare services. To conclude, the analysis portrays the importance of ongoing monitoring and adaptation of immunization programs to address disparities in vaccination coverage rates. By acknowledging the potential for sample size bias and applying insights from the literature on racial disparities in vaccination, we can inform targeted interventions to promote equitable access to immunization services.

Appendix A: Tables

Table 1. Total Number of MMR-only shots by 36 months of age determined from provider info, excluding any vaccinations after the HH interview date.		
Variable		
Vaccination	**Frequency**	**Percent**
0	23593	19.94
1	94730	80.06
Total	118323	100.00

Table 2. Total Number of DTaP-only shots by 36 months of age determined from provider info, excluding any vaccinations after the HH interview date.		
Variable		
Vaccination Presence DTaP	**Frequency**	**Percent (%)**
0	39149	33.09
1	79174	66.91
Total	118323	100.00

Table 3. Total Number of Varicella-only shots by 36 months of age determined from provider info, excluding any vaccinations after the HH interview date.		
Variable		
Vaccination Presence Varicella	**Frequency**	**Percent (%)**
0	24792	20.95
1	93531	79.05
Total	118323	100.00

Table 4. Race of Child		
Variable		
Race	**Frequency**	**Percent (%)**
WHITE ONLY	87604	74.04
BLACK ONLY	10765	9.10
OTHER + MULTIPLE RACE	19954	16.86
Total	118323	100.00

Table 5. Multiple Logistic Regression MMR Analysis						
Parameter	**Estimate**	**Standard Error**	**Wald Chi-Square**	**Odds Ratio (vs WHITE ONLY)**	**Lower Bound**	**Upper Bound**
Intercept	-51.69	7.42	48.57			
RACE: BLACK ONLY	-0.12	0.02	51.94	0.81	0.77	0.85
RACE: OTHER + MULTIPLE RACE	0.03	0.01	4.33	0.94	0.91	0.98
YEAR	0.03	<0.01	51.09	1.03	1.02	1.03

Table 6. Multiple Logistic Regression Varicella Analysis						
Parameter	**Estimate**	**Standard Error**	**Wald Chi-Square**	**Odds Ratio (vs WHITE ONLY)**	**Lower Bound**	**Upper Bound**
Intercept	-57.57	7.28	62.48			
RACE: BLACK ONLY	-0.09	0.02	31.50	0.84	0.80	0.88

RACE: OTHER + MULTIPLE RACE	0.01	0.01	0.97	0.94	0.90	0.97
YEAR	0.03	<0.01	65.29	1.03	1.02	1.04

Table 7. Multiple Logistic Regression DTaP Analysis						
Parameter	**Estimate**	**Standard Error**	**Wald Chi-Square**	**Odds Ratio (vs White Only)**	**Lower Bound**	**Upper Bound**
Intercept	143.40	63.54	509.42			
RACE: BLACK ONLY	-0.11	0.01	53.43	0.85	0.81	0.88
RACE: OTHER + MULTIPLE RACE	0.04	0.01	12.82	0.98	0.95	1.02
YEAR	-0.07	<0.01	504.77	0.93	0.93	0.94

Table 8. Total Number of MMR-only, Varicella–only and DTaP-only shots by 36 months of age from 2016 to 2022 by Race				
Vaccination Presence MMR	**Race**			
	White	**Black**	**Other + Multiple Race**	**Total**
0	17056	2470	4067	23593
1	70548	8295	15887	94730
Vaccination Presence Varicella				
0	17974	2521	4297	24792
1	69630	8244	15657	93531

Vaccination Presence DTaP				
0	28592	3929	6628	39149
1	59012	6836	13326	79174

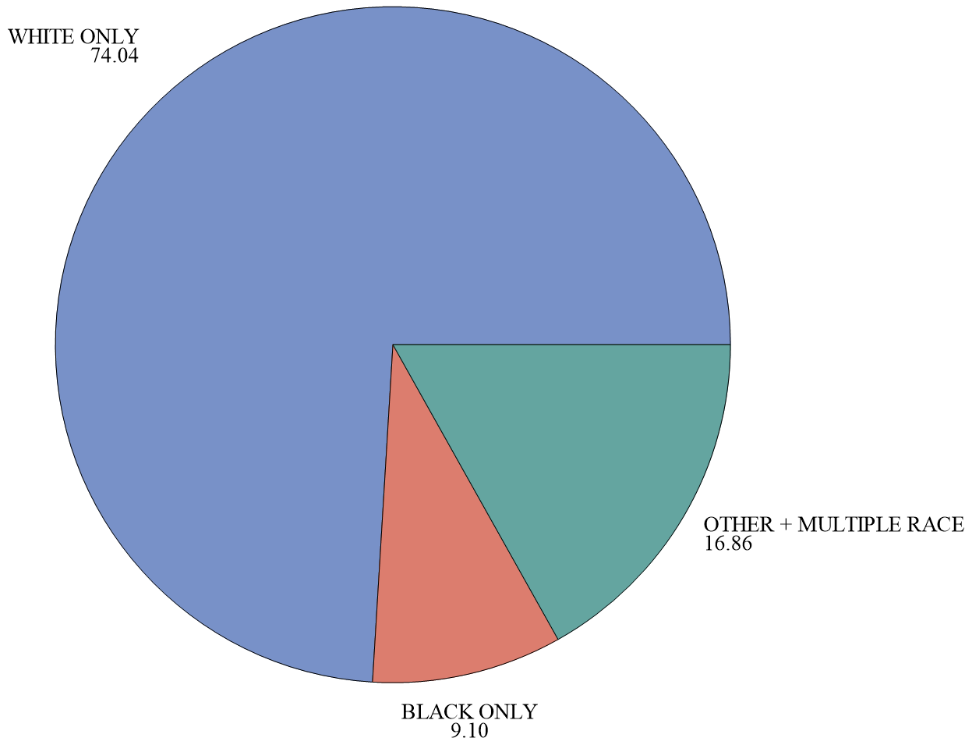
Table 9. Vaccinated Children Coverage Rates for MMR, Varicella and DTaP from 2016 to 2022				
YEAR	**Race**	**MMR Coverage (%)**	**Varicella Coverage (%)**	**DTaP Coverage (%)**
2016	**White**	80.18	78.87	72.04
	Black	77.65	77.58	69.46
	Other + Multiple Race	79.77	79.03	72.74
2017	**White**	79.92	78.65	72.36
	Black	75.83	74.67	68.42
	Other + Multiple Race	79.60	78.32	71.26
2018	**White**	78.42	77.52	69.58
	Black	77.07	75.55	65.46
	Other + Multiple Race	78.40	76.99	69.18
2019	**White**	78.86	77.96	66.27
	Black	76.51	75.72	62.93
	Other + Multiple Race	78.03	76.80	61.84
2020	**White**	81.79	80.55	64.63
	Black	76.09	75.21	59.75
	Other + Multiple Race	80.42	78.82	64.13
2021	**White**	81.66	80.53	63.52
	Black	77.37	77.26	60.00
	Other + Multiple Race	79.68	78.31	64.39

2022	**White**	82.42	81.82	64.81
	Black	78.53	78.53	60.71
	Other + Multiple Race	80.81	80.37	65.86

Appendix B. Figures

Figure 1. Percentage of Race

SUM of Percent of Total Frequency by RACE OF CHILD (RECODE)



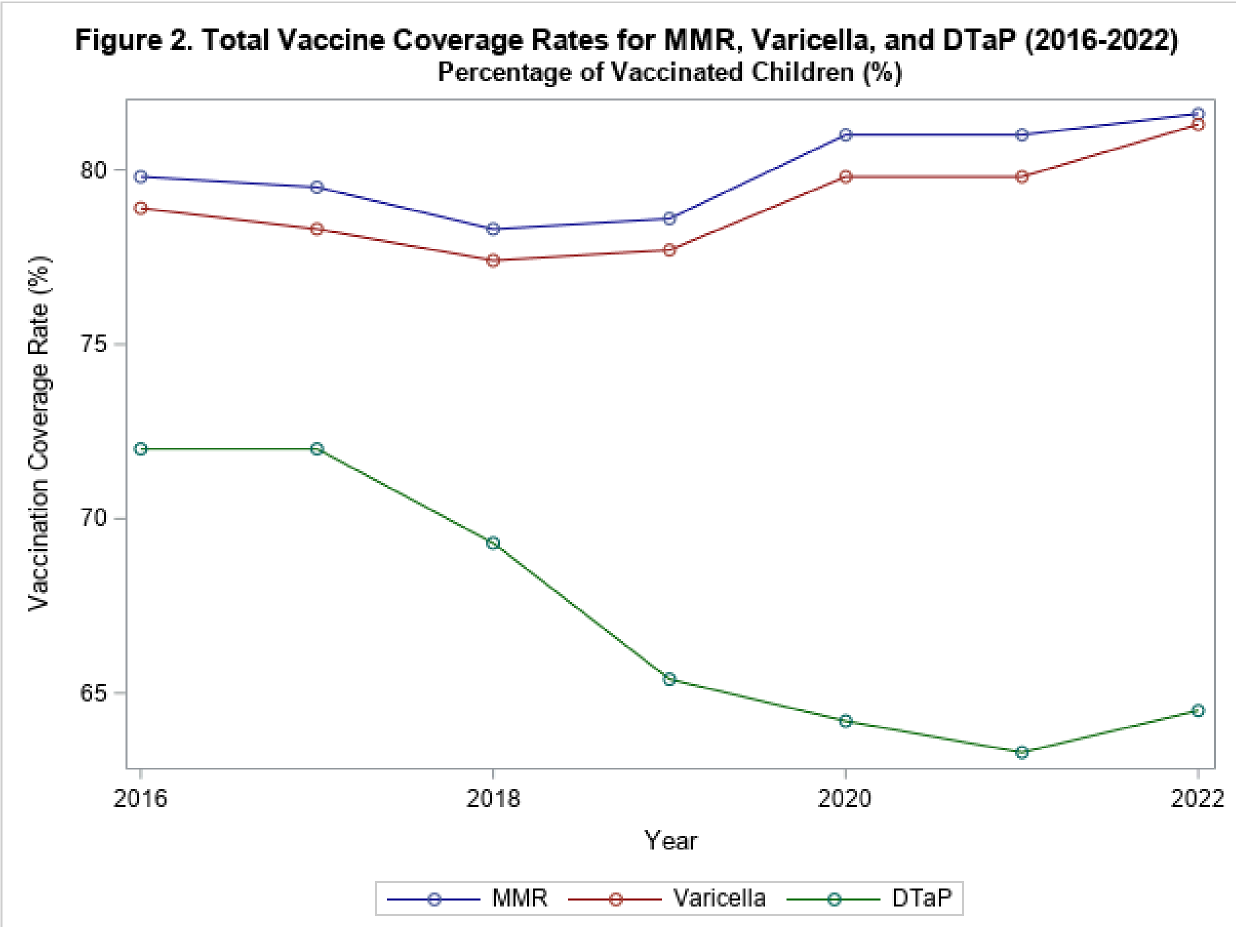


Figure 2. Total Vaccine Coverage Rates for MMR, Varicella, and DTaP (2016-2022)
Percentage of Vaccinated Children (%)
Vaccination Coverage Rate (%)
80
75
70
65
2016
2018
2020
2022
Year
MMR
Varicella
DTaP

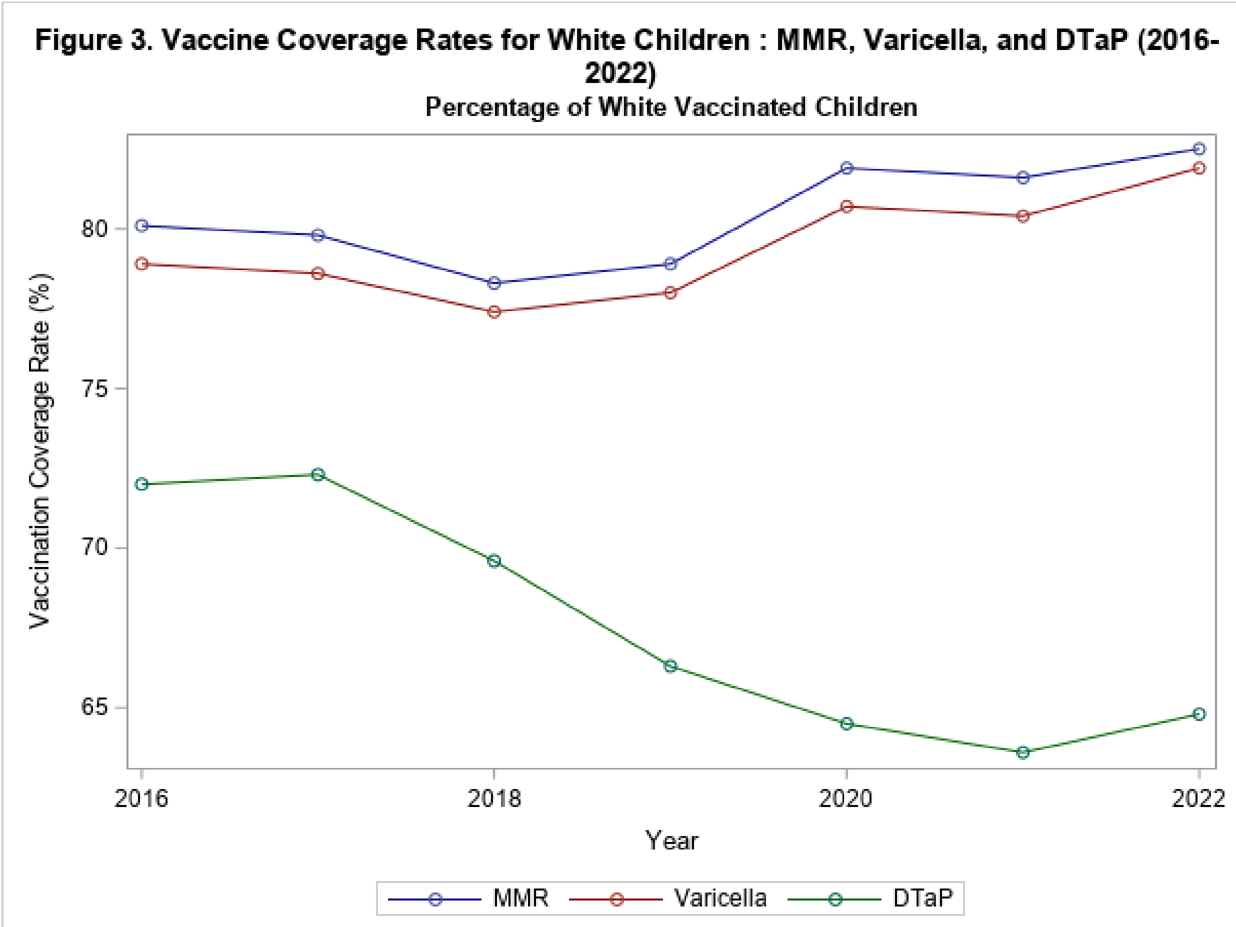
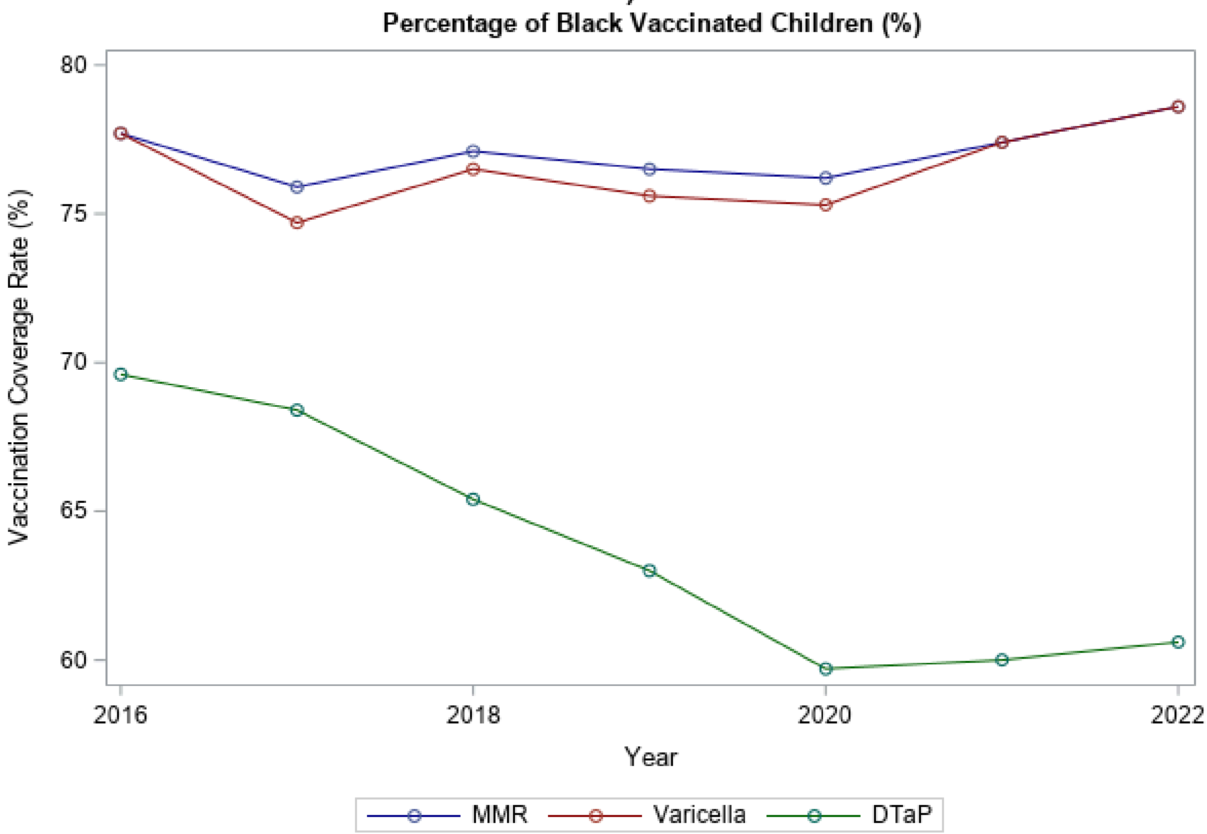


Figure 3. Vaccine Coverage Rates for White Children : MMR, Varicella, and DTaP (2016-2022)
Percentage of White Vaccinated Children
Vaccination Coverage Rate (%)
80
75
70
65
2016
2018
2020
2022
Year
MMR
Varicella
DTaP

Figure 4. Vaccine Coverage Rates for Black Children : MMR, Varicella, and DTaP (2016-2022)



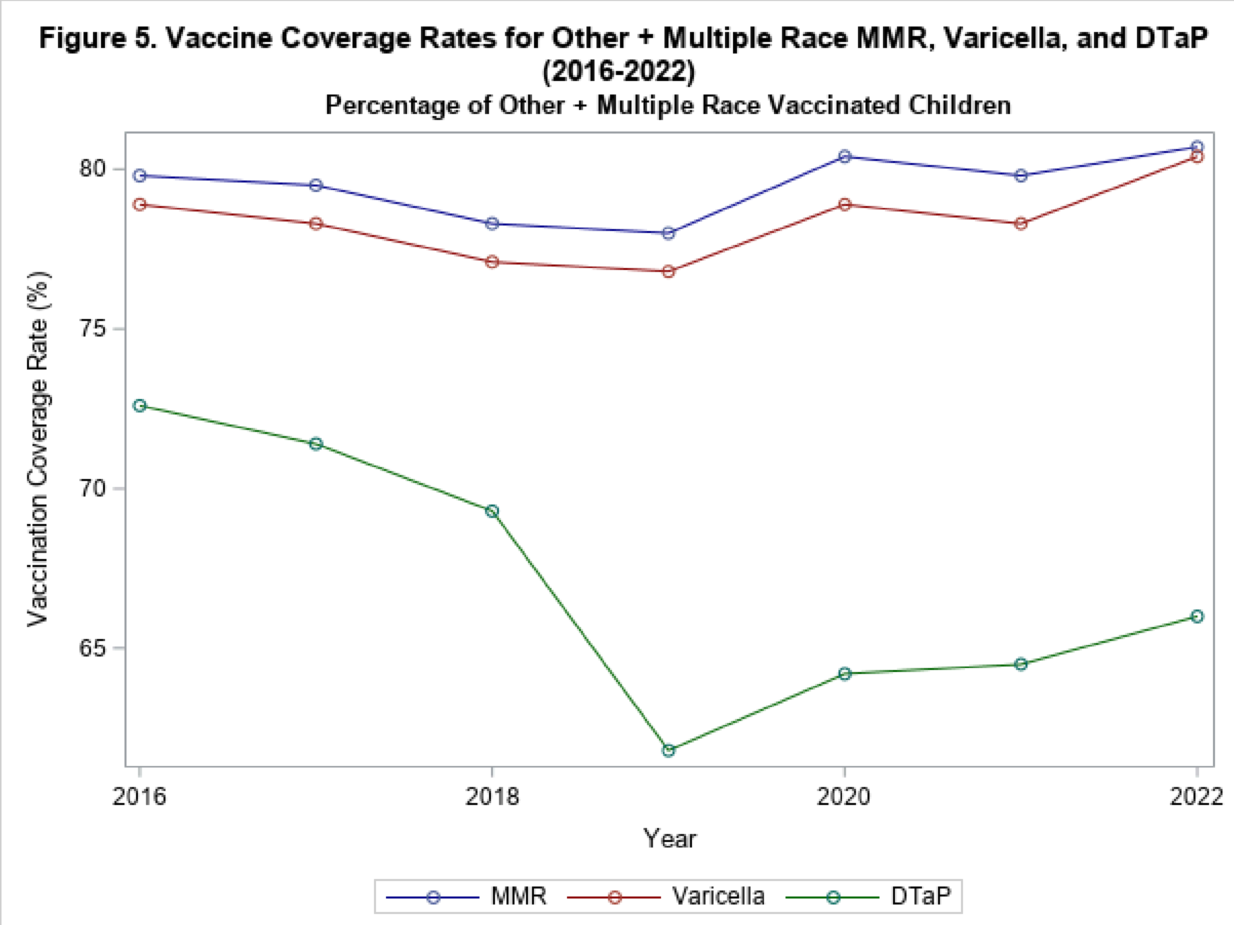


Figure 5. Vaccine Coverage Rates for Other + Multiple Race MMR, Varicella, and DTaP (2016-2022)
Percentage of Other + Multiple Race Vaccinated Children
Vaccination Coverage Rate (%)
80
75
70
65
2016
2018
2020
2022
Year
MMR
Varicella
DTaP

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