

Title Page

Title: Trends and Patterns of Human Papillomavirus Vaccination Rates on Long Island, 2012-2023: An Evaluation of Disparities in Vaccine Uptake

Abbreviated Title: Trends and Patterns of Human Papillomavirus Vaccination Study on Long Island, 2012-2023

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Abstract

Introduction: The Advisory Committee on Immunization Practices (ACIP) advised vaccinating young adults against Human Papillomavirus (HPV) in 2006, aiming to prevent HPV-related cancers and genital warts. As these preventive measures have spread rapidly, understanding vaccination patterns is essential for informing targeted public health interventions. This study aimed to explore the demographic disparities, temporal trends, and geographical patterns of HPV vaccine administration by analyzing large-scale immunization registry vaccine data for Long Island (LI) (Nassau and Suffolk Counties), New York (NY).

Methods: The vaccine registration data retrieved from the New York State Immunization Information System (NYSIIS) was used to assess the HPV vaccine administration rate from 2012 to 2023. Patients' demographic information and regional variations were evaluated to identify the disparities between different subgroups. The analysis was conducted between 2023 and 2024.

Results: The HPV vaccination rate among LI children ages 9 to 13 demonstrates a growth of 284.43% from 2012 to 2019 and a slight decrease of 5.04% around 2020. Around 68.07% of individuals received their first dose before their 15th birthday and 24.95% of them followed the recommended routine to receive 2 doses in half a year. Spatially, eastern LI consistently holds a higher HPV vaccination rate than northwestern LI.

Conclusions: The rising trend in HPV vaccination coverage on LI with a modest drop around 2020 indicates the likely impact of COVID-19 pandemic. Additional attention is called to be paid to the regions with the lower uptake rates given the uneven distribution of the vaccine coverage to prevent HPV-related cancers.

Keywords

Human Papillomavirus (HPV) Vaccine, Vaccine Rate Trends, Vaccine Rate Spatial Patterns, Child Immunization, Vaccine Uptake.

Introduction

Human Papillomavirus (HPV) infection, which is the most common sexually transmitted infection, causes approximately 33700 cases of cancer every year in the United States.¹⁻³ The HPV vaccine was designed to prevent infection by certain types of HPV, which can lead to six types of cancer (anal, cervical, oropharyngeal, vulvar, vaginal, and penile) and genital warts. It is one of the most effective ways to prevent HPV-related diseases.^{4,5} The vaccine is typically administered through a series of injections. In the United States, the HPV vaccine is widely available and recommended for adolescents and young adults.⁶ Various campaigns and initiatives have been launched to increase awareness and uptake of the vaccine.^{4,7} In 2022, 38.6% of children ages 9 to 17 had received one or more HPV vaccine doses.⁸ Additionally, school-based vaccination programs and community efforts have been utilized to reach adolescents globally and are standard in many countries.^{9,10}

The HPV immunization schedule followed a recommended protocol maximizing long-term protection against HPV-related diseases. Guidelines established by NYSDOH supported the 'Start at 9' initiative by the National Human Papillomavirus Vaccination Roundtable, promoting the recommendation for routine HPV vaccination to commence ages 11 to 12 starting as early as age 9.^{4,11} When the HPV vaccine is given to individuals before their 15th birthdays, only two doses, separated by a minimum of 6 months, are required to complete the vaccination series. However, for those who initiate the HPV vaccination series at age 15 or older, or

individuals age 9 to 26 with a weakened immune system, three doses are necessary for full protection. In the case of three doses, the second dose should be administered 1 to 2 months after the first, and the third dose should be given at least 6 months after the initial dose.¹² The minimum interval between the second and third doses is 12 weeks, and between the first and third doses is 5 months. Vaccination schedules may be used by healthcare providers give parents and patients recommendation about the importance of completing the full series for maximum benefit.^{13,14}

In New York, like in many other states, efforts have been made to ensure accessibility to the vaccine through healthcare providers, clinics, and public health programs. The New York State (NYS) government provided various measures to cover the expenses of HPV vaccination to promote its uptake among young people.¹⁵ Both women's and men's HPV vaccination coverage in NYS is higher than the average HPV vaccination rate nationally according to the official report released by NYSDOH in 2020.¹⁶

The purpose of this study is to better understand the HPV vaccination trends and patterns on Long Island (LI) by using data analytics and statistical tools. LI holds a diverse population with varying socio-economic backgrounds, cultural norms, and healthcare access, which can profoundly influence vaccination rates.¹⁶ The Bureau of Immunization within the NYSDOH is dedicated to enhancing the well-being of children in New York State by minimizing or eradicating vaccine-preventable diseases that impact the state's youth.^{18,19} This helps epidemiologic researchers and health providers understand how interventions and demographics affect vaccine uptake and lets them tailor public health efforts to LI's specific needs. Additionally, analyzing geographic patterns of vaccination may help identify the impact of socioeconomic differences, cultural norms, and healthcare access on HPV vaccination rates.

Therefore, focusing on HPV vaccination patterns on Long Island enables a comprehensive understanding of regional dynamics and facilitates targeted public health strategies to improve vaccine uptake and reduce the burden of HPV-related cancer on Long Island.

Methods

Study Sample

This study utilized patient vaccination data from NYSIIS (New York State Immunization System), managed by NYSDOH, collecting immunization records for individuals from 2008 to prevent vaccine-preventable diseases among children in the state.¹⁸ To protect patient privacy, the NYSDOH data presents case counts associated with zip codes rather than individual addresses.^{Error! Reference source not found.} Our research is centered on zip codes belonging to Long Island (LI) (Nassau and Suffolk Counties).²¹

We filtered data using “Gardasil” to identify patient visits for the HPV dose. Due to experimental requirements, we also gathered Tdap (Tetanus, Diphtheria, and Pertussis) vaccine-relevant data. Only people who received either HPV and/or Tdap vaccinations were included in our analysis. In total, 2173576 patients’ visit records, and 1120113 unique patients (473995 HPV vaccinated patients) were included in our analysis. We also utilized patient-level information, including demographics, vaccination months and years, provider information, and the patient’s zip code.

In New York State, children enrolled in daycare as well as those in pre-K through 12th grade are obligated to receive all necessary vaccines including Tdap doses according to the recommended timetable to be eligible for school attendance.²² In our study, we used the number of school-aged children who got the Tdap vaccination as the reference value to calculate the

HPV vaccination rate. We used the number of children aged 9-13 years who received the HPV vaccination as the numerator, and the number of children aged 9-13 years who either received the HPV and/or Tdap vaccinations as the denominator.

Statistical Analysis

a) Patients Demographic Analysis

The patient information was aggregated by the unique client ID and sorted by the vaccination year and month. Only initial visits are counted if a patient has multiple visits. In our study, we utilize patient-level data from 2008 to 2023. Our target group consisted of children aged 9 to 13. To include all the Tdap vaccine data in this timeframe, we needed to exclude the year range 2008 to 2011 as there were missing Tdap records before NYSIIS was established. Including these years might have caused an inaccurate denominator when calculating the rate. A comprehensive analysis was conducted to analyze gender, race, and ethnic disparities among those vaccinated patients.

b) Temporal Analysis over 2012 to 2023

All the patient-level data were aggregated by the vaccine year and month from those time-series data to visualize the trend and seasonality. In this section, if a person received multiple doses, only the initialized time was used in the temporal analysis. The number of children from 9 to 13 who either received Tdap and/or HPV vaccines in a specific year were counted as the denominator and the numerator was the number of children from 9-13 who received the HPV vaccination. The results included HPV vaccination rates for LI as well as individual county rates for Suffolk and Nassau Counties.

c) Geographical Spatial Analysis

We visualized the zip code level spatial distribution of HPV vaccination rate calculated by the formula provided in previous sections using geographical maps. The shade of color in each block represents the rate of HPV vaccination. All maps were generated using ArcGIS Desktop 10.5 (Esri, Redlands CA).

Approval was obtained from the NYSDOH and a Stony Brook University IRB before dataset acquisition and analysis (838962_MODCR008). As the data were obtained from an administrative database maintained by NYS, no informed consent was needed for study participation. All study analyses were completed between 2023 and 2024.

Results

HPV Vaccination Patients Demographic Overview

Table A provides an overview of patient demographics, including various groups categorized by demographics. Each row in the table represents a distinct demographic category, while columns display the number of HPV-vaccinated patients in that group ($p < 0.0005$). The table indicates that there is a slightly lower number of female patients compared to male patients. In our database, the largest group as defined by race is white, followed by Black and Asian (all $p < 0.0005$).

Figure 1 illustrates the age distributions of different groups of patients receiving the HPV vaccination. The histogram reveals that most patients receive their first dose between 10 and 14 years of age. There is a slight variation between genders, with females (year 10-11) initiating vaccination slightly earlier than males (year 11 to 12). Hispanic individuals tend to start their HPV vaccination series sooner than non-Hispanic individuals.

Temporal Trend and Doses Series Completeness Analysis

Figure 2 indicates the HPV vaccine initiation rate on Long Island among children aged 9-13 years from 2012 to 2023. The overall rate went up by 284.43% from 2012 to 2019 and is followed by a slight decline (5.04%) in 2020 and 2021. This may have been caused by the Covid-19 pandemic: the rate rose smoothly from 2021 to 2023, when the acute phase of the pandemic ended. This trend was evaluated via ordinary least squares (OLS) regression and emphasizes the significance of the linear trend ($p < 0.0005$).

In Figure 2, subfigure A, both males and females experienced a similar trend but the starting point for boys is slightly lower than girls. The U.S. Food and Drug Administration (FDA) approval of HPV vaccination for girls began in 2006, while it was recommended for boys until 2011.^{5,23} This discrepancy may have led to boys initiating the vaccination later than girls. In Figure 2, subfigures B and C, Nassau and Suffolk counties show similar trends from 2012 to 2023 ($p > 0.05$). Both have a statistically significant correlation to all gender rates over the years. Disparities among different racial and ethnic groups are shown in subfigure D: non-Hispanic and white people's HPV vaccination rates are consistently lower than people who identified themselves as Black and Hispanic among those children aged 9-13 years. Efforts to improve vaccination awareness and access are crucial for all racial and ethnic groups. Figure 2 also indicates HPV vaccinations are mostly offered to children in the summer as public and private schools in New York state require vaccination at the entry of school in fall.²² This can be helpful for the health provider and researcher to gain more attention in this period.

Regarding the completeness of the whole vaccination series, the nested pie chart A in Figure 3 represents the dose schedule among all the HPV vaccinated patients in our database. According to the CDC's HPV immunization schedule guideline, we divided all the patients by the age at the first HPV vaccine dose. Initial age < 15 and initial vaccination after the 15th

birthday was represented by the red and blue parts in the figure. Approximately 45.1% of the first group patients completed the recommended doses in 12 months and 37% of the second group finished their whole 3 doses series. Adolescents receiving their first dose before age 15 were more likely to finish than teens starting later, with over 82.58% of the under-15 group completing the series compared to about 45.75% of the over-15 group. Figure 3, Subfigures B and C illustrate the initiation rate and completion rate disparities among gender, race, and ethnicity groups. The number on the bars represents the portion of people who completed the HPV vaccine series compared to those who initiated the HPV vaccination schedule. Of those who started the vaccine, about 70.82% of them completed the full vaccination sequence. Girls finished the vaccine series slightly more often than boys and Asians had the highest completion rate at nearly 75%.

Geographic Patterns in Zip code Level

We chose 8 typical years of geographical maps in Figure 4 to represent the spatial distribution of HPV vaccination administration rate on Long Island (LI) among adolescents aged 9-13 years. In the significant test, OLS regression was utilized to verify the linear trend and over 82% of the zip code area rate has a $p < 0.05$ and the linear trend has been proved. For the overall difference, we use F-test ($p > 0.05$) which means we cannot reject the hypotheses that are not the same among those zip code areas. The HPV vaccination rate on the eastern side of LI consistently exceeds that on the western side. Especially the western LI. Riverhead (zip code 11901) became the highest HPV vaccination rate area on LI. This can be caused by various factors such as socioeconomic status, healthcare access and awareness, culture and social norms, and media influence. There is also a densely populated area in the eastern region, near the north shore; however, significant disparities exist. This information can raise awareness among

healthcare providers and researchers, prompting them to monitor and address the spread and popularity of HPV vaccination in areas where rates are low. A collaborative effort involving healthcare professionals, policymakers, educators, and the community is essential for successful HPV vaccine promotion on Long Island.

Discussion

This research fills the knowledge gaps related to HPV vaccination trends and patterns on Long Island (LI) by applying epidemiological and data analytics techniques to assess the geographic, temporal, and personal demographics of HPV-vaccinated individuals. The HPV vaccination rate across LI has gradually increased over the past decade with a slight drop during the COVID-19 pandemic. This trend aligns with national increases in HPV vaccination rates, as reported by the New York State Department of Health and the Centers for Disease Control and Prevention among children.^{8,16,24} The child vaccination rate rose each year until 2019, which had the highest rate at about 44.99%. However, when COVID-19 hit in early 2020, the vaccination rate dropped slightly (a 5.04% decrease from 2019 to 2021) in the HPV vaccination rate. Since then, the vaccination rate has gradually recovered but hasn't reached 2019's maximum rate yet. Another finding is that there are disparities in the HPV vaccination rates among different racial and ethnic groups. For example, Hispanic people had a consistently higher vaccination rate than other ethnicities. Segmenting by zip code, eastern Long Island is doing better than western Long Island with 82% of the ZIP codes testing the linear trend by the OLS regression. These findings support the continued encouragement of early vaccination and call for special efforts on western LI's north shore where fewer school-aged adolescents are getting vaccinated.

Our study adds to what we know from other recent studies in the past decade. The New York State Department of Health releases cancer-related statistics including HPV-related cancer

and HPV vaccination every five years, helping us track medium and long-term relationships between HPV vaccination and disease incidence rates.^{16,24,25} In 2016, Nadja A. Vielot and her team found that older boys and adolescents living in rural areas didn't get the HPV vaccine as much as other vaccines like Tdap or MenACWY.²⁶ Our findings are similar: boys' and especially older children's HPV vaccination rates are both quite lower than girls. Erika and her team focused on college students and emphasized that work is needed to increase women's HPV vaccination rates within the said demographic.²⁷ This aligns with our finding that older teens' HPV vaccination completion rate is vitally lower than that of younger children. Szu-Ta Chen and his team utilized the commercial insurance database in the US and indicated that HPV vaccination coverage among insured children still needs more efforts to improve.^{28,29} This is like what we saw with different places in Long Island—some areas and some groups required more effort to spread the HPV vaccination. Lastly, Kalyani et al. found that the primary reason for patients not initiating the HPV vaccination is the safety concern.³⁰ We need to put increasing effort into the intervention of unvaccinated teens and also work to correct the false information spreading on social media that greatly influences public opinion.³¹

Limitations of this study

One limitation of our study pertains to the calculation of HPV vaccination rates among individuals aged 9 to 13 years old. Our analysis relies on using the number of patients who have received the HPV and/or Tdap vaccination as the denominator for calculating HPV vaccination rates within this age group. However, it's important to note that this denominator may not accurately represent the total population within the 9 to 13 age range. Additionally, there is a possibility that patients may have received the Tdap vaccine in other states but received the HPV vaccine in New York State, leading to potential discrepancies in our calculations. These factors

introduce bias and limitations to our study's findings, highlighting the need for cautious interpretation and consideration of alternative methodologies for accurately assessing HPV vaccination rates among adolescents.

Another limitation of our study is the potential impact of population migration between the years 2012 and 2023, which falls outside the scope of our control in this experiment. Population migration, whether internal or external, can influence the composition and characteristics of the population under study. Individuals may relocate to different regions or countries for various reasons, such as job opportunities, economic factors, or personal circumstances, leading to changes in the demographics of the population. This demographic shift can introduce bias and confound the interpretation of our findings, particularly when assessing long-term trends in HPV vaccination rates. Moreover, migration patterns may vary across different demographic groups, potentially affecting the representation and generalizability of our study results. Therefore, while our study provides valuable insights into HPV vaccination patterns within a specific timeframe, it is essential to acknowledge the limitations imposed by population migration and consider its potential impact on the validity and reliability of our findings.

Conclusion

In conclusion, our study provides valuable insights into the HPV vaccination patterns and trends among adolescents aged 9 to 13 years old on Long Island, New York State. We provided several aspects to reveal the user profiles of the HPV vaccination patients and exhibit the yearly trend of the HPV vaccination rate from 2012 to 2023. Ultimately, our study contributes to the ongoing efforts to promote public health and advance our understanding of HPV vaccination practices among adolescents.

In future research, analysis of HPV vaccination trends and patterns could be analyzed in smaller geographic units, such as at the census tract level. This could help us learn more about what is happening in specific communities. We can also enlarge our research scale to the whole of New York States. This way, we could obtain a better understanding of how many people are getting vaccinated in both cities and rural areas. Our methodology provides a great opportunity to assist researchers, health providers, and clinic physicians in understanding the HPV vaccination utilization among various geographic regions and diverse population groups. Such investigation would inform adaptive strategies for policymakers and healthcare providers to address the need for HPV vaccine promotion and to better understand the pandemic's repercussions on HPV-related health outcomes.

Conflict of Interest Disclosures

The authors disclose no conflicts of interest.

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Fusheng Wang: Conceptualization, Resources, Supervision. **Zihan Ding:** Formal analysis, Methodology, Data curation, Visualization, Writing - Original Draft. **Jianyuan Deng:** Formal analysis, Investigation. **Linda Mermelstein:** Conceptualization, Methodology, Supervision, Writing - Review & Editing. **Barbara Nemesure:** Conceptualization,

295 Methodology, Supervision, Writing - Review & Editing **Tyler Osborne:** Writing - Review &
296 Editing

297 **Dissemination to participants and related patient and public communities:**

298 There are no plans to disseminate the results of the research to study participants or the
299 relevant patient community.

300

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Figure Legends

Figure 1. Age distributions of patients who received one or more doses of HPV vaccine by gender, race, and ethnicity.

Figure 2. HPV vaccine initiation rate among 9- to 13-year-old children in Nassau and Suffolk Counties, New York. The rate here was calculated by the number of children who already initialized the HPV vaccination divided by the number of children either receive the HPV vaccination or Tdap vaccination.

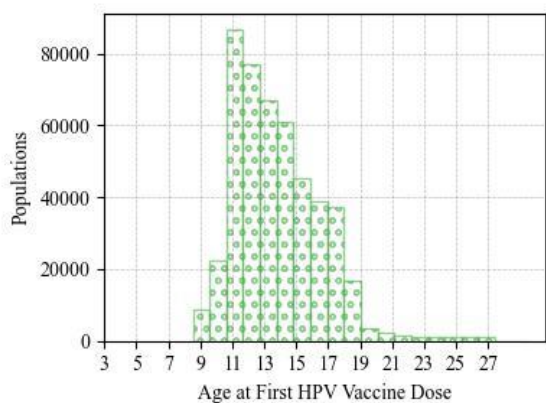
Figure 3. The completeness of the HPV vaccinated individuals on the Long Island, New York State, 2012-2023. The figures are generated according to the CDC HPV vaccination guidelines.

Figure 4. Geographical maps of HPV vaccination rates on Long Island, New York (Nassau and Suffolk Counties) among children ages 9-13 by zip code. The rate was calculated by the number of children receiving one or more HPV vaccine dose divided by the number of children who received HPV, Tdap or both vaccines.

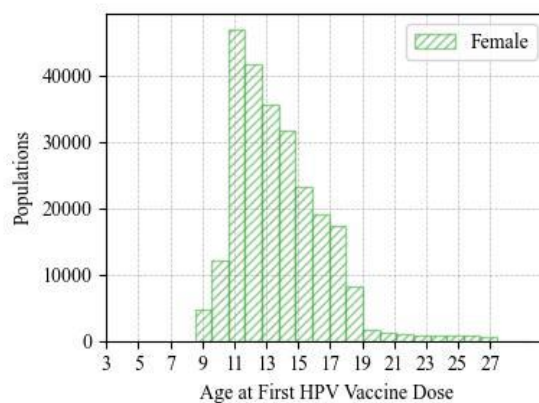
Table A. Summary of Aggregation Information of HPV Vaccination Patients on the Long Island. (The patients from the entire NYSIIS database) ¹														P value ⁵	
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Linear	Overall
Gender	Male	20574	38493	56711	77367	99946	120951	142650	163788	179135	193555	209654	225007	<0.0005	<0.0005
	Female	55221	70823	86802	106035	126958	146873	166948	187044	202339	216664	232859	248334	<0.0005	<0.0005
Age	9-13 ²	16458	23004	28215	36383	44374	49557	54729	58983	56735	52808	51848	51522	<0.0005	<0.0005
	14-25	59331	86296	115183	146644	181202	214563	246876	277885	302238	322171	338127	348376	<0.0005	<0.0005
	>=26 ³	162	239	410	725	1728	4148(1) ⁴	8468	14473(3)	23030(1)	25799(3)	53149(3)	74101(6)	<0.0005	<0.0005
Race and Ethnic	White	32635	49774	66838	86873	109218	130939	152995	174070	190051	203714	218956	233244	<0.0005	<0.0005
	Black	6643	9529	12635	16727	21117	25031	28954	32860	35569	38436	41532	44677	<0.0005	<0.0005
	Asian	3990	5803	7830	10642	13637	16675	20017	23285	25957	28451	31613	34801	<0.0005	<0.0005
	Hispanic	14329	21043	29631	39846	51594	61855	72568	84262	92393	101611	112155	122192	<0.0005	<0.0005
	Non-Hispanic	38598	58515	78026	101732	127471	152483	177657	201188	219371	234853	252642	269436	<0.0005	<0.0005
Total		75954	109540	143808	183751	227304	268268	310072	351339	381998	410773	443121	473995	<0.0005	<0.0005

1. The absolute numbers here represent the number of individuals in the specific group with one or more HPV vaccine doses.
2. Children ages 9- to 13-year-old are the targeted population studied in this paper.
3. HPV vaccination is not recommended for everyone older than age 26 years.
4. The numbers in the parentheses show the newly added patients who initiated the HPV vaccination during that year.
5. The OLS regression was used to test the P-value of each yearly trend.

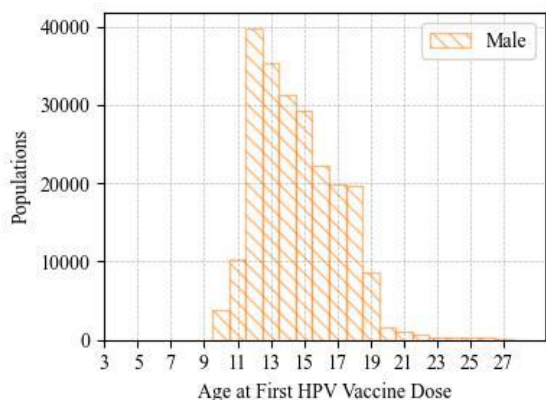
Figure 1. Age distributions of patients who received one or more doses of HPV vaccine by gender, race, and ethnicity.



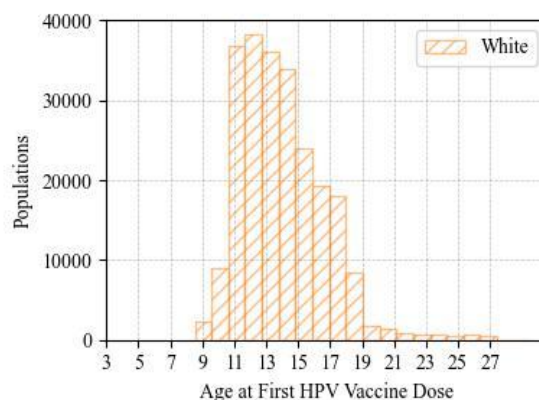
(A) All patients with one or more HPV Vaccine doses



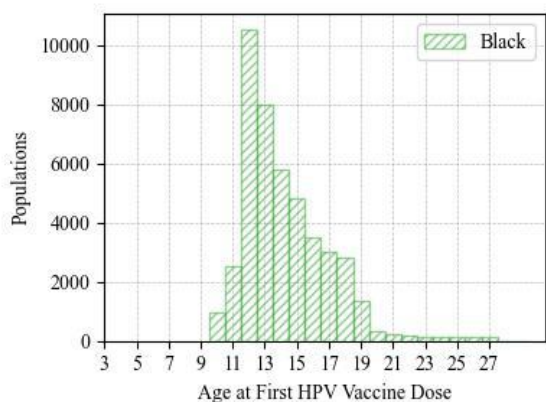
(B) Female patients with one or more HPV Vaccine doses.



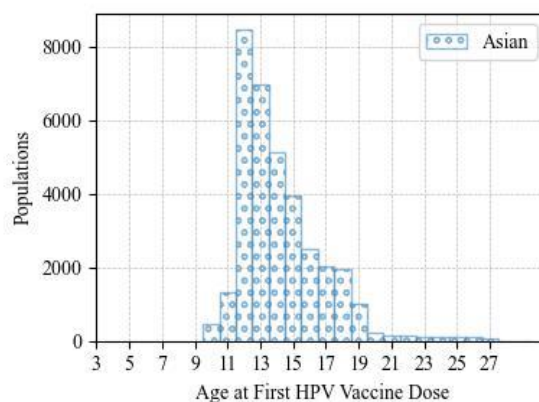
(C) Male patients with one or more HPV Vaccine doses.



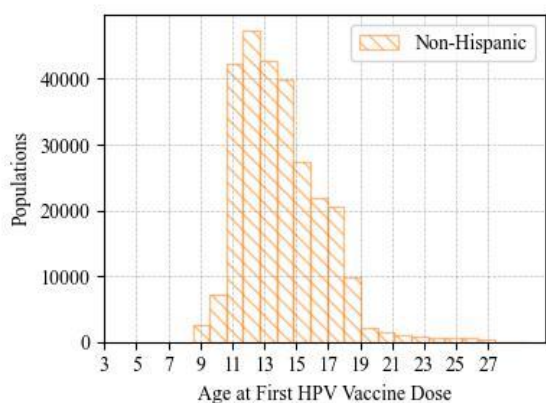
(D) White people with one or more HPV Vaccine doses.



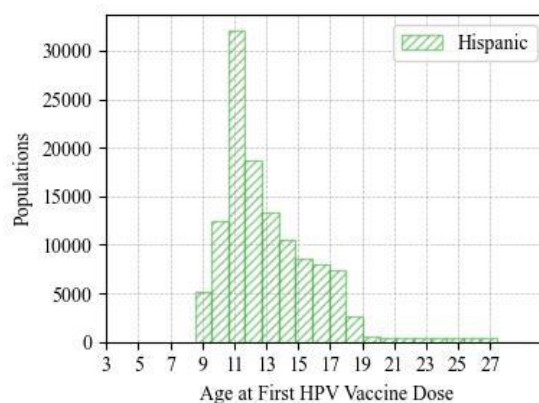
(E) Black people with one or more HPV Vaccine doses.



(F) Asian people with one or more HPV Vaccine doses.

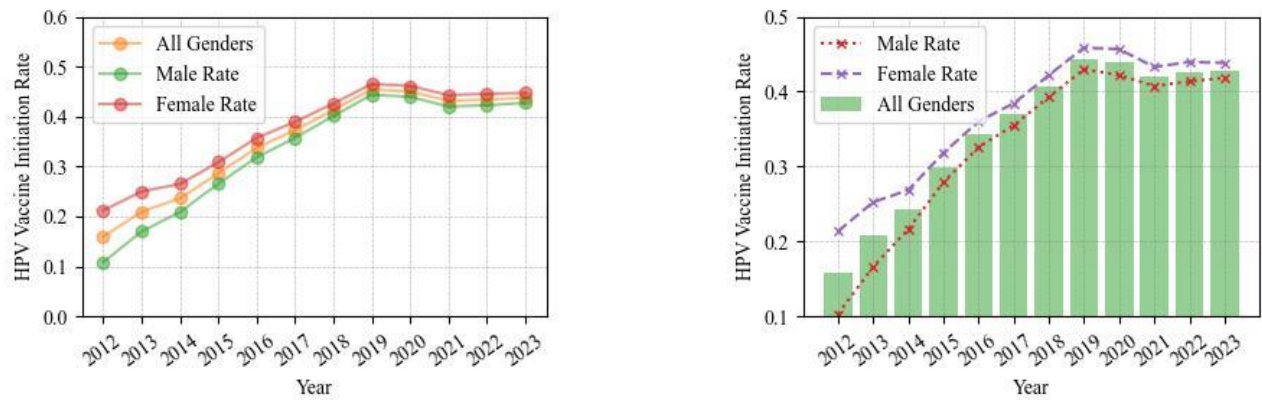


(G) Non-Hispanic people with one or more HPV Vaccine doses.

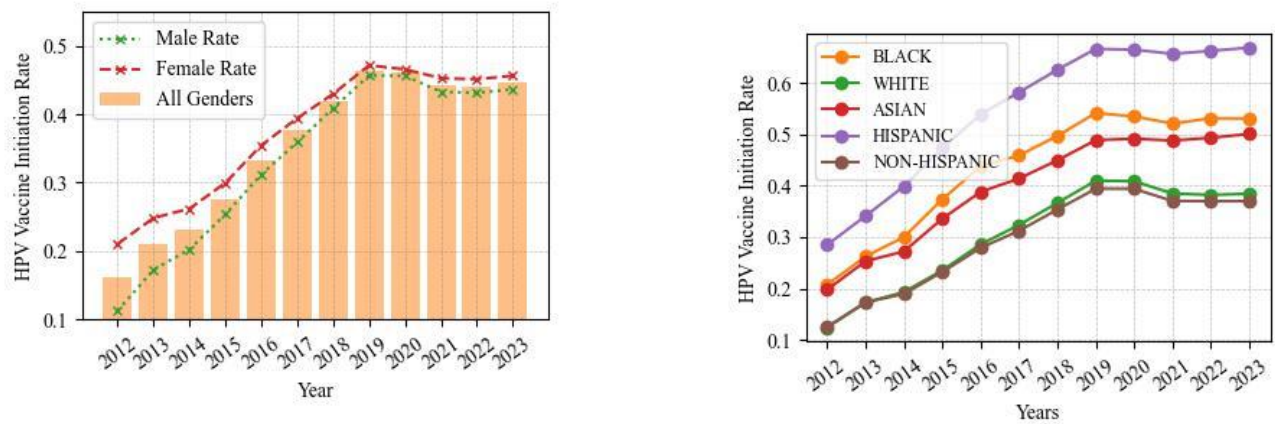


(H) Hispanic people with one or more HPV Vaccine doses.

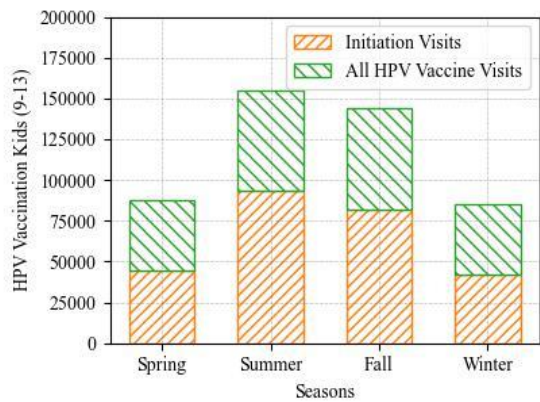
Figure 2. HPV vaccine initiation rate among 9- to 13-year-old children in Nassau and Suffolk Counties, New York. The rate here was calculated by the number of children who already initialized the HPV vaccination divided by the number of children either receive the HPV vaccination or Tdap vaccination, or both.



(A) HPV vaccine initiation rate for LI children ages 9-13 by gender. (B) HPV vaccine initiation rate for Nassau children ages 9-13 by gender.

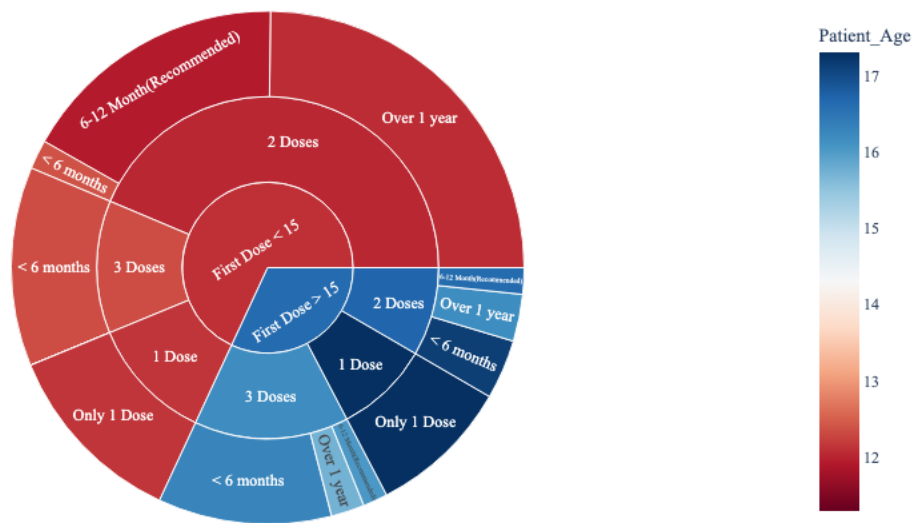


(C) HPV vaccine initiation rate for Suffolk children ages 9-13 by gender. (D) HPV vaccine initiation rate for LI children ages 9-13 by race and ethnicity.

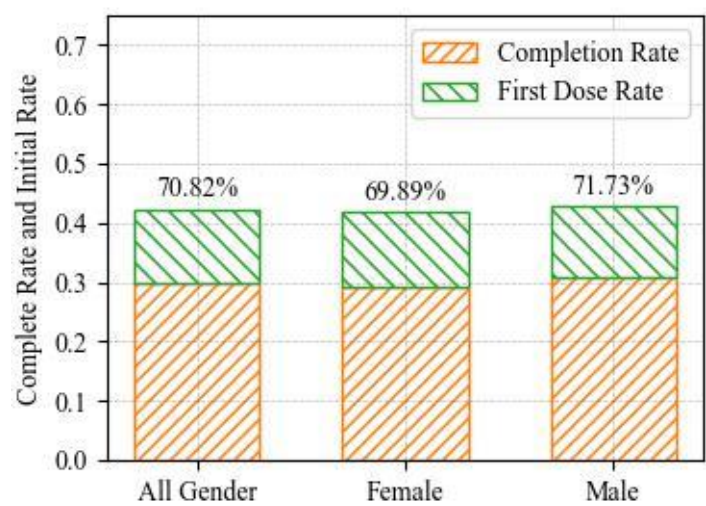


(E) HPV Vaccinated LI children ages 9-13 by Season

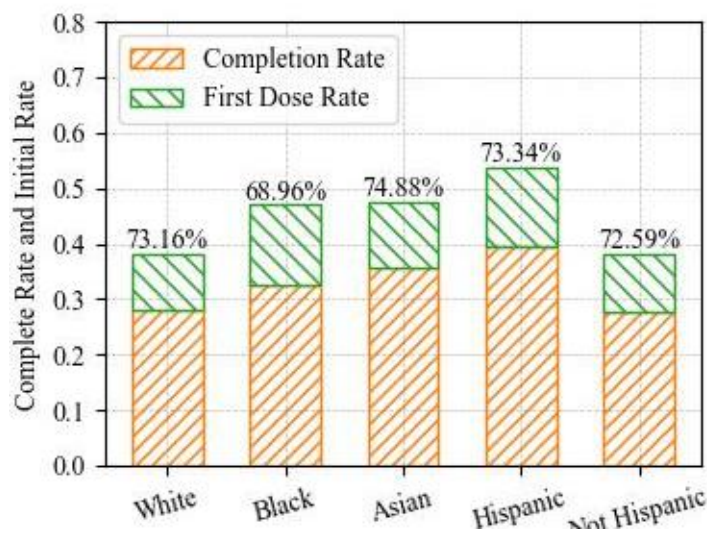
Figure 3. The completeness of the HPV vaccinated individuals on the Long Island, New York State, 2012-2023. The figures are generated according to the CDC HPV vaccination guidelines.



(A) The Nested Pie Chart shows the HPV Vaccination Patient Doses Schedule and Completeness Proportion.



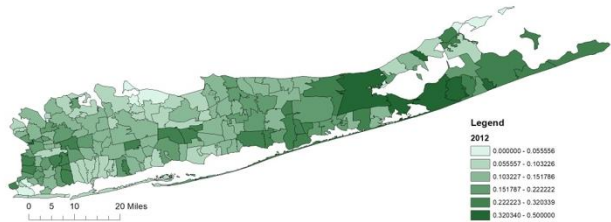
(B) HPV Vaccine Series Completion by Gender¹



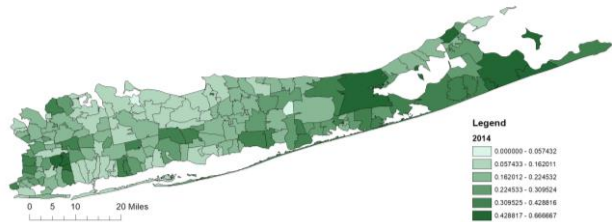
(C) HPV Vaccine Series Completion by Race and Ethnicity

¹The percentage on each bar represent the portion of patients who complete the HPV vaccine series towards the patients who initiate the HPV vaccine.

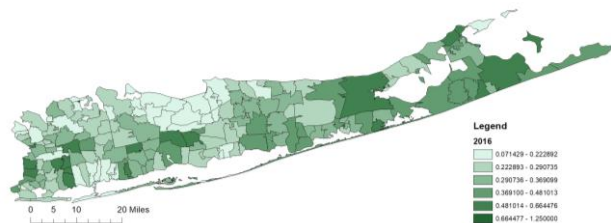
Figure 4. Geographical maps of HPV vaccination rates on Long Island, New York (Nassau and Suffolk Counties) among children ages 9-13 by zip code. The rate was calculated by the number of children receiving one or more HPV vaccine dose divided by the number of children who received HPV, Tdap or both vaccines.



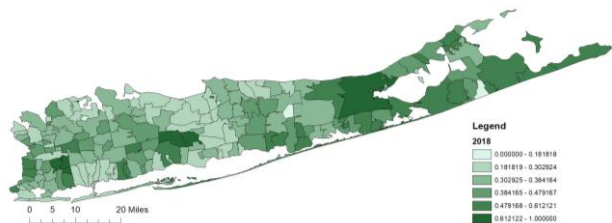
(A) (2012) Geographic Map of Long Island HPV Vaccination Rate by Zip.



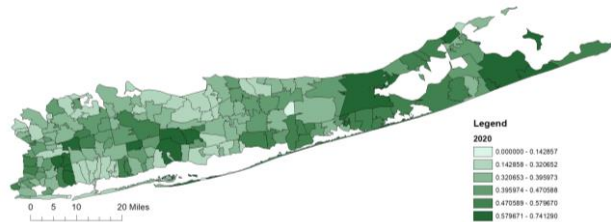
(B) (2014) Geographic Map of Long Island HPV Vaccination Rate by Zip Code



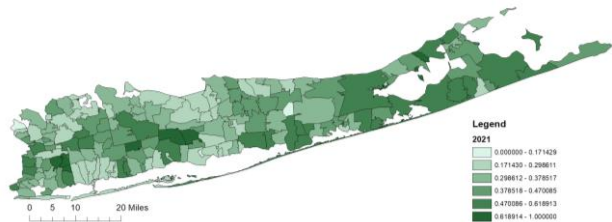
(C) (2016) Geographic Map of Long Island HPV Vaccination Rate by Zip Code



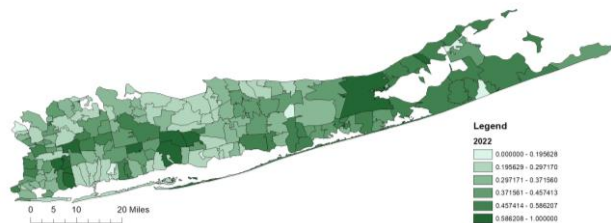
(D) (2018) Geographic Map of Long Island HPV Vaccination Rate by Zip Code



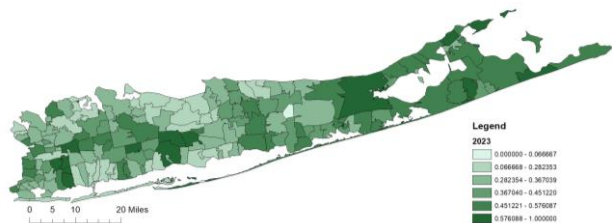
(E) (2020) Geographic Map of Long Island HPV Vaccination Rate by Zip Code



(F) (2021) Geographic Map of Long Island HPV Vaccination Rate by Zip Code



(G) (2022) Geographic Map of Long Island HPV Vaccination Rate by Zip Code



(H) (2023) Geographic Map of Long Island HPV Vaccination Rate by Zip Code

