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Assessing Influencing Factors of HPV Vaccine Series Uptake in the United States Using the 2020 National Immunization Survey-Teen (NIS-Teen)

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By

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2021

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Abstract

Assessing Influencing Factors of HPV Vaccine Series Uptake in the United States Using the 2020 National Immunization Survey-Teen (NIS-Teen)

By Kelsey E. Fudge

Background/Intro: Human papillomavirus (HPV)-related cancers can be prevented through vaccination. HPV vaccination is recommended for all males and females from 9 to 26 years of age, with catch-up vaccination available to adults 27 to 45 years of age through a shared clinical decision-making recommendation. The vaccine series consists of two or three doses, depending on age of initiation. Little is known about sociodemographic influences on HPV vaccine series completion, incompletion, and non-initiation.

Methods: We conducted a secondary analysis of HPV vaccination data from the 2020 NIS-Teen using SAS (version 9.4, The SAS Institute, Cary, NC) procedures appropriate for complex survey data analysis, weighted according to the NIS-Teen Data User's Guide specifications, restricted to provider-verified immunization history data. Adolescents were classified into three categories of vaccination status—not initiated, initiated but not complete (partial), and complete. These classifications were compared by key sociodemographic characteristics using weighted proportions, prevalence ratios, and 95% confidence intervals for all estimates. Multivariable Poisson regression using methods for subset analysis of NIS-Teen data was used to estimate adjusted prevalence ratios and associated 95% confidence intervals.

Main Results: Overall, 58.6% of adolescents had completed the HPV vaccine series, with 16.5% partially vaccinated, and 24.9% unvaccinated. Only 45.6% of 13-year-olds completed the HPV vaccine series, in contrast with 17-year-olds (64.5%). Among each race/ethnicity category, the majority had completed the HPV vaccine series, ranging from 55.4% completion among White adolescents to 62.8% completion among Hispanic adolescents. There were relatively small differences in vaccine uptake among males versus females. With regard to poverty status, previously identified patterns in HPV vaccination for 13- to 17-year-olds remained consistent, as there were higher vaccination rates among adolescents living below the poverty line compared to adolescents living at or above the poverty line.

Conclusions/Public Health Recommendations: This study suggests that adolescents of racial and ethnic minorities living below poverty are significantly more likely to be either partially or completely vaccinated against HPV when compared to their less disparate counterparts. Utilizing the findings presented here, targeted interventions and policies can begin to be constructed towards specific groups whose vaccine coverage is lacking.

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CHAPTER 1: INTRODUCTION

Current Issue

Human papillomavirus, or more commonly known as HPV, is the most prevalent sexually transmitted infection (STI) in the United States (U.S.) (United Health Foundation, 2022). Approximately 85% of individuals will be impacted by HPV at some point in their lives, and it is attributable to nearly 32,000 cases of cancer each year (United Health Foundation, 2022). About 40 years ago, it was found that HPV is associated with cervical cancer, and due to that discovery, nearly 98% of all cervical cancer-related deaths have been attributable to high-risk HPV infections (Kombe et al., 2021). HPV infection can be prevented through vaccination, and it is recommended for all males and females from 9 to 26 years of age, however most physicians recommend children receive their first dose at 11 or 12 years of age (Meites et al., 2019). Adults from 27 to 45 years of age are still able to receive the HPV vaccine, but this recommendation is a "shared clinical decision-making" recommendation, rather than the routine vaccination recommendation for individuals aged 9 to 26 years (Meites et al., 2019).

Current Breadth of Knowledge

Despite the overwhelming recommendations for HPV vaccination and evidence of its efficacy, in 2020, 75.1% of adolescents in the United States had received at least one dose of the vaccine, and only 58.6% were up to date on their vaccination status (Pingali et al., 2021). This means that in 2020, 24.9% of United States adolescents were completely unvaccinated, facing an increased HPV infection risk. More specifically, 56% of males and 61.4% of females were up to date on their HPV vaccines, demonstrating a slight gap in coverage between sexes (Pingali et al., 2021; National Center for Immunization and Respiratory Diseases [NCIRD], 2021). Given that there remains a significant unvaccinated adolescent population in the United States, this thesis

will aim to analyze various sociodemographic factors that influence HPV vaccine series completion, compared to individuals who initiated but did not complete the HPV vaccine series and individuals who did not initiated the HPV vaccine series, among individuals aged 13 to 17 years in the United States in order to understand what can be done to increase national HPV vaccine uptake among adolescents.

Current Knowledge Gap

As referenced by recent studies, there is limited evidence and knowledge on sociodemographic influence of HPV vaccination. In a study conducted by Avni-Singer et al. (2020), a comprehensive search of population-level HPV vaccine data was performed. 4,139 studies were reviewed, and only twenty-three were found to report population-level data (Avni-Singer et al., 2020). Upon collection and assessment of those twenty-three studies, only 57% noted sociodemographic data (Avni-Singer et al., 2020). Of those, only 15% communicated results that were stratified by various sociodemographic factors, the most common being race, ethnicity, and income (Avni-Singer et al., 2020). In another study conducted by Maness and Thompson (2019), datasets from six different adolescent and young-adult surveys, with at least one indicator of HPV vaccination, were examined. The datasets were then reviewed for the five levels of the social determinants of health framework (Maness & Thompson, 2019). It was found that all datasets contained aspects of education, health/healthcare, and economic stability, but neighborhood/built environment and community context were only found in half (Maness & Thompson, 2019). In all datasets, even when each social determinant of health aspect was present, Maness and Thompson (2019) found gaps, as the measures were severely limited. Although this study yielded more comprehensive findings than that of Avni-Singer et al. in terms of sociodemographic data, there still proves to be significant gaps present.

Importance of Addressing Knowledge Gap

It is crucial that these aforementioned knowledge gaps are assessed. The lack of data surrounding such topics represents a significant demand for more knowledge and understanding. As more is discovered about the sociodemographic influence on HPV vaccine uptake, targeted interventions and policies can be constructed towards specific groups whose vaccine coverage is lacking. If attention can be focused on specific populations who have limited vaccine uptake, we can begin to assess why such disparities exist and, ultimately, work to rectify the contributory inequities and disparate vaccine coverage.

List of Abbreviations

AAP – American Academy of Pediatrics

ACIP – Advisory Committee on Immunization Practices

ACS – American Cancer Society

FDA – U.S. Food and Drug Administration

HHS – Health and Human Services

HIV – Human immunodeficiency virus

HPV – Human papillomavirus

HSV – Herpes Simplex Virus

MMWR – Morbidity and Mortality Weekly Report

MSM – Men who have sex with men

NIS-Teen – National Immunization Survey-Teen

NVAC – National Vaccine Advisory Committee

OIDP – Office of Infectious Disease and HIV/AIDS Prevention

SES – Socioeconomic Status

STI – Sexually Transmitted Infection

CHAPTER 2: REVIEW OF THE LITERATURE

Overview

Human papillomavirus, or more commonly referred to as HPV, is the most prevalent STI in the United States (Centers for Disease Control and Prevention [CDC], 2022). In 2018, there were over 40,000,000 HPV infections among older adolescents and those in their early twenties, indicating a high risk within this population (CDC, 2022). The virus is transmitted via oral, anal, and/or vaginal sex, requiring close skin-to-skin contact, and symptoms may not show up until years after initial infection (CDC, 2022; Cubie, 2013). Given this virus's prevalent asymptomatic nature, HPV surveillance can be difficult. However, there does exist a vaccine that reduces one's risk of becoming infected. The vaccine is recommended for all males and females aged 9 to 26 years; however, most physicians recommend children receive their first dose at ages 11 to 12 years (Meites et al., 2019). Adults from 27 to 45 years of age are still able to become vaccinated, but this is not a routine recommendation, rather a "shared clinical decision-making" recommendation, with patients encouraged to speak to their primary care physician prior to receiving the vaccination (Meites et al., 2019).

Despite the availability of this vaccine, however, many populations remain unvaccinated. In 2020, 75.1% of adolescents in the United States had received at least one dose of the vaccine, and only 58.6% were up to date on their vaccination status (Pingali et al., 2021). This means that in 2020, 24.9% of United States adolescents were completely unvaccinated (Pingali et al., 2021). The underlying causes of this lack of vaccine uptake can be attributable to a variety of different sociodemographic factors such as race/ethnicity, age, and socioeconomic status, to name a few (NCIRD, 2021).

The studies selected for this literature review aim to highlight the severity of HPV infection

and emphasize the importance of HPV vaccination, while also exploring the current literature surrounding sociodemographic influence on HPV vaccine uptake. Overall, the major sections of this literature review include HPV-associated diseases, the agencies involved in HPV vaccine research and uptake, HPV epidemiology, the HPV vaccine over time, and current vaccine coverage and factors of uptake.

Nature of the Problem

HPV-Associated Diseases

HPV usually manifests itself in skin lesions called papillomas or warts (Handisurya et al., 2009). Some of the different skin lesions are called verrucae plantae, Butcher's warts, Bowen's disease, plane warts, and EV-squamous cell carcinomas (Handisurya et al., 2009; Cubie, 2013). The virus can also manifest through mucosal lesions, some of which being Heck's disease, Buschke-Löwenstein tumor, and high-grade squamous intraepithelial neoplasia (Handisurya et al., 2009). Skin lesions usually occur on the hands, face, and feet, sometimes on the arms, legs, neck, and torso (Cubie, 2013). Mucosal legions can occur in the mouth and in the genital regions of the body (Cubie, 2013). HPV is also the cause of all cervical cancers, the majority of anal cancers, and a portion of penile, vaginal, vulvar, and oropharyngeal cancers (Handisurya et al., 2009). Cervical cancer, specifically, is the second most prevalent cancer and the third most common cancer in women globally (Kombe et al., 2021). Of these conditions, the HPV vaccine currently used in the United States protects against those that cause genital warts and are carcinogenic, meaning that the vaccine is extremely effective in reducing the incidence of HPV-related cancers (Senkomago, 2019; Yang, 2016). According to Senkomago (2019), between the years of 2012 to 2016, nearly 44,000 HPV-associated cancers were reported each year, and 79% of those were caused by HPV infection. Of that 79%, 92% were found to be caused by the types

of HPV prevented by the vaccine, meaning thousands of cancer cases between the years of 2012 to 2016 were preventable (Senkomago, 2019).

Agencies Involved in Vaccine Research and Uptake

The Office of Infectious Disease and HIV/AIDS Prevention, also known as the OIDP, manages the National Vaccine Advisory Committee, or NVAC (Office of Infectious Disease and HIV/AIDS Prevention [OIDP], 2021a). NVAC, specifically, is an agency that provides recommendations on communicable disease prevention through the development of vaccines and advisement on adverse vaccine reactions (OIDP, 2021b). NVAC also works to ensure that an adequate supply of vaccines is available in the United States, and they also provide recommendations on research topics to the Director of the National Vaccine Program to ensure the presence of safe and efficacious vaccines (OIDP, 2021b). The OIDP has assisted NVAC in their development of two separate HPV-focused reports, one released in 2018 and another in 2015 (OIDP, 2021a). The NVAC report released in 2018 is titled "Strengthening the Effectiveness of National, State, and Local Efforts to Improve HPV Vaccination Coverage in the United States: Recommendations from the National Vaccine Advisory Committee" and recommends four different ways to increase national HPV vaccine uptake (Smith, 2018). The first way is via the selection of additional national partnerships and the second is through the coalition of states/building of partnerships (Smith, 2018). The third recommendation involves operationalizing interoperable healthcare delivery systems, and the fourth focuses on acknowledging the needs of healthcare providers in rural settings (Smith, 2018). The OIDP is working with the Director of the National Vaccine Program to examine NVAC's aforementioned recommendations and determine a scope of implementation (OIDP, 2021a).

Another agency committed to HPV research and increasing national HPV vaccine uptake

is the American Cancer Society, or ACS. ACS heads a program called the HPV VACs Program, which focuses on increasing HPV vaccine uptake among adolescent populations throughout the United States (American Cancer Society [ACS], 2022). The VACs Program collaborates with various policy actors and healthcare partners as they aim to improve HPV vaccination rates via clinic-based interventions, healthcare provider education programs, network-wide procedural revisions, and comprehensive quality improvement, all for the purpose of improving the availability and uptake of the HPV vaccine (ACS, 2022). ACS also has an initiative called "Mission: HPV Cancer Free" with the goal of an HPV vaccination rate of 80% per year among 13-year-olds by the year 2026 (ACS, 2022). Ultimately, with this initiative, ACS aspires to eradicate vaccine-preventable HPV cancers as a public health concern (ACS, 2022).

HPV Epidemiology

Nearly, 40 years ago, it was discovered that multiple strains of HPV are associated with cervical cancer, and since then, nearly 98% of all cervical cancer-related deaths worldwide have been attributable to high-risk HPV infections (Kombe et al., 2021; College of Physicians of Philadelphia, 2023). In the U.S., specifically, HPV is the leading cause of incident STI cases; around 6 million incident HPV cases occur every year (Ault, 2006). In 2006, there were a total 20 million people living with HPV in the United States, and since then, that number has increased to 79 million (Ault, 2006; Office on Women's Health, 2022). The virus is transmitted via oral, anal, and/or vaginal sex, requiring close skin-to-skin contact (CDC, 2022). The population facing the highest risk of HPV infection, and who have the highest rates of infection, is women less than 25-years-old who are sexually active (Ault, 2006). Common HPV risk factors include having multiple sex partners and coinfections with either *Chlamydia trachomatis* or herpes simplex virus (HSV), both of which are common STIs among high-risk groups of HPV

(Ault, 2006). Though the majority of HPV infections are asymptomatic and resolve on their own, symptoms can appear and often require clinical intervention (Ault, 2006). In low-risk cases, symptoms include genital warts, and in high-risk cases, symptoms can consist of abnormal Pap smear test results, low- and high-grade squamous intraepithelial lesions, cervical cancer, and penile, anal, mouth, and throat cancers (Ault, 2006; College of Physicians of Philadelphia, 2023). These high-risk symptoms often yield high rates of morbidity and mortality, but can be prevented through routine vaccination (Ault, 2006).

The HPV Vaccine Over Time

The HPV vaccine has been recommended for nearly two decades, and use of the vaccine has been supported by evidence of its safety and efficacy. On June 8, 2006, the U.S. Food and Drug Administration (FDA) licensed the use of a quadrivalent HPV vaccine, and that same month, the Advisory Committee on Immunization Practices (ACIP) approved the recommendations for use of the vaccine (Markowitz et al., 2007). This vaccine protects against HPV types 6, 11, 16, and 18 (Markowitz). ACIP recommended routine vaccination with 3 doses of the quadrivalent vaccine among females aged 11 to 12 years, with initiation beginning as young as 9 years of age (Markowitz et al., 2007). They also recommended catch-up vaccination for females aged 13 to 26 years of age who were not previously vaccinated or had not completed the 3-part series in full (Markowitz et al., 2007). It was recommended that the second and third doses be administered 2 and 6 months after the first dose, respectively (Markowitz et al., 2007). These ACIP recommendations did not apply to females less than 9 or greater than 26 years of age, nor did they apply to males (Markowitz et al., 2007).

On October 16, 2009, the FDA licensed a bivalent HPV vaccine to be used among females aged 10 to 25 years, which protects against HPV types 16 and 18 (CDC, 2010a).

Following licensure, the ACIP recommended routine HPV vaccination for females 11 or 12 years of age, with either the bivalent or quadrivalent vaccine; the bivalent vaccine was also suitable for females as young as 9 years of age (CDC, 2010a). Much like the quadrivalent vaccine, the ACIP also recommended that the bivalent vaccine was suitable for catch-up vaccinations, also stating that remaining doses, after the first one, may be administered after 26 years of age (CDC, 2010a).

Also on October 16, 2009, the FDA licensed the quadrivalent HPV vaccine for use in males aged 9 to 26 years (CDC, 2010b). On October 25, 2011, the ACIP recommended routine use of this vaccine in males aged 11 to 12 years; they also recommended its use among males aged 13 to 21 years who were not previously vaccinated or had not completed the 3-part series in full (CDC 2011). The ACIP also said that males 22 to 26 years of age may also be vaccinated with the quadrivalent vaccine (CDC, 2011). In 2014, published reports further elaborated on the most recent ACIP recommendations, stating that the quadrivalent vaccine was also recommended for use among men who have sex with men (MSM), those living with human immunodeficiency virus (HIV), and other immunocompromised individuals, all through the age of 26 years (Markowitz et al., 2014).

On December 10, 2014, the 9-valent HPV vaccine was approved by the FDA, and in February of 2015, the ACIP recommended that vaccine as one of the three able to be used for routine vaccination against HPV in both males and females (Petrosky et al., 2015). Previous ACIP recommendations remained, and the age ranges from the bivalent and quadrivalent vaccine recommendations applied to the 9-valent vaccine as well (Petrosky et al., 2015). This new vaccine protects against HPV types 6, 11, 16, 18, 31, 33, 45, 52, and 58, and is also a 3-dose series (Petrosky et al., 2015).

In October of 2016, after much discussion and voting, the ACIP unanimously approved the recommendations that males and females aged 9 to 14 years be moved to a 2-dose HPV vaccine schedule, and those initiating the series at ages 15 to 26 years should remain on the 3-dose schedule, along with immunocompromised individuals (Meites et al., 2016). The previous recommendations surrounding routine and catch-up age groups remained the same (Meites et al., 2016). In June of 2019, the ACIP clarified their catch-up recommendations, saying that they applied to all individuals through the age of 26 years regardless of sex (Meites et al., 2019). The ACIP also newly recommended that adults from 27 to 45 years of age receive the HPV vaccine, but stated that it is a "shared clinical decision-making" recommendation, rather than the routine vaccination recommendation for individuals aged 9 to 26 years (Meites et al., 2019). They also stated that patients are encouraged to speak to their primary care physicians prior to receiving the vaccination (Meites et al., 2019). No other recommendations were amended, and the ACIP has not provided recommendation updates since.

Current HPV Vaccine Coverage and Factors of Uptake

Historically, with regard to HPV vaccine coverage, data surrounding partial vaccination has been presented as a category of individuals who received at least one dose, regardless of completion status. Rarely have we seen data presented in a way where partial vaccination represents those who received at least one dose but never completed the series, and there is a need to investigate those interrupted vaccine schedules. According to 2020 NIS-Teen Survey data, among adolescents who received at least one dose of the HPV vaccine but never completed the series, 53.2% were male, 29.3% were 13 years of age, 47.9% were White, 76.3% were living at or above poverty, 22.5% were living in HHS Region 4 (southeastern U.S.), 58.7% had one healthcare provider, and 47% had private health insurance (NCRID, 2021). Additionally, among

those who had only partially completed the series, 3.5% lived in HHS Region 1, suggesting better vaccine coverage in the northeastern U.S. (NCRID, 2021). Further uptake data demonstrate that, among adolescents who have mothers with less than 12 years of education, completion rates are around 64.1%, and among those whose mothers are not currently married, completion rates are around 59.2% (NCRID, 2021). These findings suggest that HPV vaccine coverage is not dependent on education or the status of parents' relationships.

As referenced by recent studies, there is limited evidence and knowledge on sociodemographic factors affecting HPV vaccine uptake. In a study conducted by Avni-Singer et al. (2020), a comprehensive search of population-level HPV vaccine data was performed. 4,139 studies were reviewed, and only twenty-three were found to report population-level data (Avni-Singer et al., 2020). Upon collection and assessment of those twenty-three studies, only 57% noted sociodemographic data (Avni-Singer et al., 2020). Of those, only 15% communicated results that were stratified by various sociodemographic factors, the most common being race, ethnicity, and income (Avni-Singer et al., 2020). In another study conducted by Maness and Thompson (2019), datasets from six different adolescent and young-adult surveys, with at least one indicator of HPV vaccination, were examined. The datasets were then reviewed for the five levels of the social determinants of health framework (Maness & Thompson, 2019). It was found that all datasets contained aspects of education, health/healthcare, and economic stability, but neighborhood/built environment and community context were only found in half (Maness & Thompson, 2019). In all datasets, even when each social determinant of health aspect was present, Maness and Thompson (2019) found gaps, as the measures were severely limited. Although this study yielded more comprehensive findings than that of Avni-Singer et al. in terms of sociodemographic data, there still proves to be significant gaps present. Historical patterns

surrounding the influence of the number of healthcare providers on HPV vaccine uptake demonstrate that individuals with multiple providers lack a "medical home" leading to inconsistent vaccination tracking and uptake (Elam-Evans et al., 2020). Additionally, it has been found that medically underserved populations with less access to routine care, especially racial and ethnic minorities, have higher rates of cervical cancer (Garner, 2003; American Cancer Society Cancer Action Network, 2018). As a result, maternal experiences with HPV-related disease have been associated with greater willingness to vaccinate daughters against HPV (Salz et al., 2010). Additional sociodemographic factors not mentioned here with the potential to influence HPV vaccine uptake are home ownership status and receipt of an 11- or 12-year-old well-child check-up (NCRID, 2021).

Summary/Conclusion

This literature review aims to highlight the severity of HPV infection and emphasize the importance of HPV vaccination. Through this literature review, it was discovered that there is a severe gap in knowledge and understanding surrounding sociodemographic influence on HPV vaccine uptake. As this thesis aims to analyze sociodemographic factors that influence HPV vaccine series completion, incompletion, or non-initiation among individuals aged 13 to 17 years in the United States, the information covered in this literature review may prove relevant to such populations. Building upon the literature reviewed, this thesis will aim to quantify the influence of various sociodemographic factors on HPV vaccine uptake, and subsequently provide potential policy recommendations to be considered as a way to rectify gaps in vaccine coverage across the United States.

CHAPTER 3: RESULTS/MANUSCRIPT

Title: Assessing Influencing Factors of HPV Vaccine Series Uptake in the United States Using the 2020 National Immunization Survey-Teen (NIS-Teen)

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Declaration of interests
Authors declare no competing interests.

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The views expressed are those of the authors alone and do not necessarily reflect the policies or recommendations of the institutions with whom they are affiliated. This also serves as a disclaimer that the analysis, interpretations, and conclusions reached are attributable to the authors (recipients of the data file) and not to NCIRD, which is responsible only for the initial data.

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Abstract

Assessing Influencing Factors of HPV Vaccine Series Uptake in the United States Using the 2020 National Immunization Survey-Teen (NIS-Teen)

By Kelsey E. Fudge

Background/Intro: Human papillomavirus (HPV)-related cancers can be prevented through vaccination. HPV vaccination is recommended for all males and females from 9 to 26 years of age, with catch-up vaccination available to adults 27 to 45 years of age through a shared clinical decision-making recommendation. The vaccine series consists of two or three doses, depending on age of initiation. Little is known about sociodemographic influences on HPV vaccine series completion, incompletion, and non-initiation.
Methods: We conducted a secondary analysis of HPV vaccination data from the 2020 NIS-Teen using SAS (version 9.4, The SAS Institute, Cary, NC) procedures appropriate for complex survey data analysis, weighted according to the NIS-Teen Data User's Guide specifications, restricted to provider-verified immunization history data. Adolescents were classified into three categories of vaccination status—not initiated, initiated but not complete (partial), and complete. These classifications were compared by key sociodemographic characteristics using weighted proportions, prevalence ratios, and 95% confidence intervals for all estimates. Multivariable Poisson regression using methods for subset analysis of NIS-Teen data was used to estimate adjusted prevalence ratios and associated 95% confidence intervals.
Main Results: Overall, 58.6% of adolescents had completed the HPV vaccine series, with 16.5% partially vaccinated, and 24.9% unvaccinated. Only 45.6% of 13-year-olds completed the HPV vaccine series, in contrast with 17-year-olds (64.5%). Among each race/ethnicity category, the majority had completed the HPV vaccine series, ranging from 55.4% completion among White adolescents to 62.8% completion among Hispanic adolescents. There were relatively small differences in vaccine uptake among males versus females. With regard to poverty status, previously identified patterns in HPV vaccination for 13- to 17-year-olds remained consistent, as there were higher vaccination rates among adolescents living below the poverty line compared to adolescents living at or above the poverty line.
Conclusions/Public Health Recommendations: This study suggests that adolescents of racial and ethnic minorities living below poverty are significantly more likely to be either partially or completely vaccinated against HPV when compared to their less disparate counterparts. Utilizing the findings presented here, targeted interventions and policies can begin to be constructed towards specific groups whose vaccine coverage is lacking.

Introduction

Human papillomavirus, or more commonly known as HPV, is the most prevalent STI in the United States (United Health Foundation, 2022). Approximately 85% of individuals will be impacted by HPV at some point in their lives, and it is attributable to nearly 32,000 cases of cancer each year (United Health Foundation, 2022). HPV infection can be prevented through vaccination, and it is recommended for all males and females from 9 to 26 years of age, however most physicians recommend children receive their first dose at 11 or 12 years of age (Meites et al., 2019).

Despite being recommended for nearly two decades and supported by evidence of its safety and efficacy, in 2020, only 75.1% of adolescents in the United States had received at least one dose of the vaccine, and only 58.6% were up to date on their vaccination status (Markowitz et al., 2007; CDC, 2010a; CDC, 2010b; CDC, 2011; Markowitz et al., 2014; Petrosky et al., 2015; Meites et al., 2016; Meites et al., 2019; Pingali et al., 2021). This means that in 2020, 24.9% of United States adolescents were completely unvaccinated, facing an increased risk of HPV infection. More specifically, 56% of males and 61.4% of females were up to date on their HPV vaccines, demonstrating a slight gap in coverage between sexes (Pingali et al., 2021; NCIRD, 2021).

Given that there remains a significant unvaccinated adolescent population in the United States, there is a need to analyze various sociodemographic factors that influence HPV vaccine series completion, compared to incomplete series vaccination or lack of initiation, among individuals aged 13 to 17 years in the United States in order to understand what can be done to increase national HPV vaccine uptake among adolescents. There is a lack of data surrounding such topics, and this represents a significant demand for more knowledge and understanding.

As more is discovered about the sociodemographic influence on HPV vaccine uptake, targeted interventions and policies can be constructed towards specific groups whose vaccine coverage is lacking. To address these gaps in our understanding of HPV vaccine uptake, we analyzed data from the 2020 National Immunization Survey-Teen (NIS-Teen) to understand sociodemographic influence on complete, incomplete, or non-initiated HPV vaccination.

Methods

We conducted a secondary analysis of HPV vaccination data from the 2020 NIS-Teen using SAS (version 9.4, The SAS Institute, Cary, NC) procedures appropriate for complex survey data analysis, weighted according to the NIS-Teen Data User's Guide specifications (NORC at the University of Chicago [NORC], 2021). Methods for the NIS-Teen have been previously described (NORC, 2021). Briefly, the NIS-Teen is a cellphone-based survey among parents of 13- to 17-year-olds residing in the United States, using a random digit dialing methodology (NORC, 2021). Parents who are completing this household survey are asked for permission from the survey team to contact their adolescent's health care provider(s) for vaccination history verification. This analysis was restricted to provider-verified immunization history data. At the time of this analysis initiation, the 2020 NIS-Teen public use file was the latest available for inclusion. Currently, the 2021 dataset is now published, but given the ongoing nature of this analysis, a choice was made to continue the use of the 2020 dataset. Additionally, given the recent recommendation of the 2-dose HPV vaccine for before 15 years of age, older NIS-Teen data was not used in this analysis.

Adolescents were classified into three different categories with regard to vaccination status—not initiated, initiated but not complete (hereafter, partial), and complete. The category of partial vaccination does not reflect the more standard category of those who received at least

one dose, regardless of completion status; rather this represents those who received at least one dose but never completed the series.

After classifying adolescents by their HPV vaccination status, the classifications were compared by key sociodemographic characteristics (i.e., age, race/ethnicity, sex, poverty status, number of healthcare providers, and HHS region), using population level proportions, weighted proportions, prevalence ratios, and 95% confidence intervals for all estimates. In terms of a combination metric of race/ethnicity and poverty, each race/ethnic group was combined with each level of poverty status and analyzed in a bivariate model; given the distribution of variables, a choice was made not to include this metric in the fully adjusted model. Multivariable regression was performed under a Poisson distribution, using methods for subset analysis of NIS-Teen data to estimate prevalence ratios and associated 95% confidence intervals (Hale et al., 2013).

This secondary analysis of previously collected, publicly available, deidentified data does not meet the definition of human subject research requiring Institutional Review Board review as defined in the federal regulations. Per the Emory University IRB's Non-Human Subject Research Determination Form, there was no IRB required, and the confidentiality of the information accessed and obtained will be protected.

Results

In the 2020 NIS-Teen, there were a total of 45,626 parents of 13- to 17-year-olds included, with 20,632 (45.2%) adolescents having provider-verified vaccination data available for analysis (NORC, 2021). The data file used for analysis, including data from all fifty U.S. states, the District of Columbia, and Puerto Rico, consisted of data for 45,008 13- to 17-year-olds, with 20,332 (45.2%) having provider-verified vaccination data (NORC, 2021). This

analysis was restricted to these 20,332 respondents.

Older adolescents were more likely to have completed the HPV vaccine series. Only 45.6% of 13-year-olds completed the HPV vaccine series, with completion proportions then ranging from 56% among 14-year-olds to 64.5% among 17-year-olds. In bivariate comparisons, compared to 13-year-olds, older aged adolescents (14 years through 17 years) were all less likely to be partially vaccinated, though the only statistically significant differences were observed for 14-year-olds (PR 0.85, 95% CI 0.73-0.98) and 16-year-olds (PR 0.78, 95% CI 0.66-0.92). In contrast, compared to 13-year-olds, older aged adolescents were consistently more likely to have completed the HPV vaccine series, ranging from 12% more likely among 14-year-olds (PR 1.12, 95% CI 1.04-1.20) to 26% more likely among 17-year-olds (PR 1.26, 95% CI 1.18-1.35). In multivariate analysis, adjusting for other sociodemographic factors, age-related patterns were similar to bivariate results for HPV vaccine series completion, but most age-related patterns for partial vaccination were attenuated (Tables 1 and 2).

Among each race/ethnicity category, the majority had completed the HPV vaccine series, ranging from 55.4% completion among White adolescents (95% CI 53.88-56.93) to 62.8% completion among Hispanic adolescents (95% CI 59.36-66.13). When compared to White adolescents, all racial and ethnic minorities were more likely to have partially completed the HPV vaccine series than not initiated the series, although these findings were only significant for Hispanic and Other/Multiple Race adolescents, and not for Black adolescents (adjusted prevalence ratios [aPR] for Hispanic: 1.19 (95% CI 1.03-1.37); Black: 1.16 (95% CI 0.99-1.37); Other/Multiple Race: 1.19 (95% CI 1.04-1.37)). Similarly, compared to White adolescents, all racial and ethnic minorities were significantly more likely to have completed the HPV vaccine

series, ranging from 12% more likely among Black adolescents (aPR 1.12, 95% CI 1.05-1.18) to 14% more likely among Hispanic adolescents (aPR 1.14, 95% CI 1.08-1.20). (Tables 1 and 2).

In 2020, 56% of males had completed the HPV vaccine series (95% CI 54.14-57.85) and 61.4% of females had completed the series (95% CI 59.48-63.28), though this difference was not statistically significant in multivariate modeling (aPR 0.96, 95% CI 0.87-1.06). However, males were less likely to have completed the HPV vaccine series when compared to females, with males being 8% less likely to have completed the HPV vaccine series after adjustment for other sociodemographics (aPR 0.92, 95% CI 0.89-0.95) (Tables 1 and 2).

With regard to poverty status, previously identified patterns in HPV vaccination for 13- to 17-year-olds remained consistent, as there were higher vaccination rates among adolescents living below the poverty line compared to adolescents living at or above the poverty line. Regardless of poverty status, the majority of adolescents were completely vaccinated against HPV (63.1% completion among adolescents living below poverty and 57.8% completion among adolescents living at or above poverty) or partially vaccinated (20.1% partial vaccination among adolescents living below poverty and 15.8% partial vaccination among adolescents living at or above poverty). Compared to those below poverty, adolescents living at or above poverty were statistically significantly less likely to be partially vaccinated (aPR 0.84, 95% CI 0.73-0.97) or to have completed the full HPV vaccine series (aPR 0.92, 95% CI 0.87-0.97) (Tables 1 and 2).

In 2020, among each group in a combination metric of race/ethnicity and poverty status, the majority had completed the HPV vaccine series, ranging from 54.5% completion among White adolescents below poverty (95% CI 49.51-59.55) to 69% completion among Hispanic adolescents below poverty (95% CI 63.32-74.6). For Hispanic and Multiple Race/Other Race adolescents, there was little difference in series completion between those living below poverty

compared to those living at or above poverty, whereas White and Black adolescents living below poverty were more likely to have completed the series than those living at or above poverty. For partial vaccination only, adolescents living below poverty consistently had higher partial vaccination rates than those living at or above poverty for each race/ethnicity group (Tables 1 and 2).

In 2020, most adolescents with healthcare providers had completed the HPV vaccine series, with completion rates from 49.5% among adolescents with three or more healthcare providers to 60.8% among adolescents with one healthcare provider. There was little different in partial vaccination rates by number of healthcare providers, though adolescents who had more than one provider were more likely to have not initiated the HPV vaccine series, and less likely to have completed the HPV vaccine series, with the greatest disparities noted for adolescents with three or more healthcare providers (Tables 1 and 2).

HPV vaccine series completion rates were over 50% in all HHS Regions in the United States, ranging from 52.8% among adolescents in Region 4 (southeastern U.S.) (95% CI 49.89-55.79) to 71% in Region 1 (northeastern U.S.) (95% CI 67.93-74.08). In multivariate regression analysis, compared to adolescents in Region 4 (southeastern U.S.), adolescents in all other HHS regions were more likely to have completed the HPV vaccine series, with all estimates reaching statistical significance with the exception of Region 6 (south-central U.S.) (estimates ranged from aPR of 1.03 (95% CI 0.96-1.12) for Region 6 (south-central U.S.) to 1.27 (95% CI 1.20-1.24) for Region 1 (northeastern U.S.)) (Tables 1 and 2). There were no statistically significant differences by HHS Region for partial vaccination.

Table 1.

Overall population proportions for each sociodemographic variable and percent coverage among each sociodemographic variable stratified by vaccination status and corresponding 95% confidence intervals.

		Not Initiated (0)		Initiated, NC (1)		Complete (2)	
	Overall Population %	%	95% CI	%	95% CI	%	95% CI
Age							
13	20.21%	30.55	27.82-33.29	23.86	21.31-26.41	45.58	42.65-48.52
14	20.06%	27.72	24.90-30.53	16.31	14.27-18.35	55.97	53-58.95
15	20.25%	22.39	20.13-24.65	15.76	13.43-18.08	61.85	58.99-64.72
16	20.59%	22.77	20.32-25.21	11.78	9.92-13.63	65.46	62.63-68.28
17	18.90%	21.01	18.50-23.51	14.48	12.30-16.66	64.51	61.53-67.50
Race/Ethnicity							
Hispanic	25.03%	20.01	17.20-22.83	17.24	14.68-19.80	62.75	59.36-66.13
NH, White	50.04%	28.87	27.46-30.28	15.73	14.57-16.88	55.41	53.88-56.93
NH, Black	13.13%	21.88	18.67-25.10	17.41	14.53-20.30	60.7	56.93-64.47
Other, MR	11.80%	22	18.81-25.20	16.73	14.07-19.39	61.27	57.51-65.02
Sex							
Male	51.04%	26.65	25.20-28.50	17.15	15.78-18.52	56	54.14-57.85
Female	48.96%	22.92	21.31-24.53	15.71	14.27-17.15	61.38	59.48-63.28
Mother's Edu							
< 12 years	12.39%	15.71	12.47-18.95	20.21	16.16-24.25	64.09	59.37-68.81
12 years	21.27%	27.42	24.39-30.44	17.56	15.25-19.86	55.03	51.80-58.25
> 12 years, NCG	24.05%	28.83	26.43-31.23	17.06	15.11-19	54.12	51.48-56.75
College grad	42.29%	24.15	22.67-25.63	14.44	13.20-15.67	61.41	59.70-63.13
Checkup @ 11/12							
Yes	48.84%	19.25	17.84-20.66	15.69	14.25-17.14	65.06	63.26-66.85
No	8.39%	35.95	31.58-40.31	22.02	18.46-25.58	42.03	37.29-46.78
DK	42.76%	29.25	27.29-31.20	16.21	14.73-17.69	54.55	52.43-56.67
Poverty Status							
Below poverty	19.63%	16.77	14.48-19.06	20.14	17.30-22.99	63.09	59.74-66.43
At/above poverty	80.37%	26.42	25.14-27.70	15.79	14.72-16.86	57.79	56.35-59.23
HHS Region							
1	4.13%	15.12	12.82-17.41	13.88	11.41-16.35	71.01	67.93-74.08
2	8.03%	22.89	19.67-26.12	11.82	9.43-14.2	65.29	61.63-68.96
3	8.88%	22.88	20.13-25.63	14.54	12.28-16.8	62.58	59.45-65.71
4	19.97%	28.66	26.01-31.31	18.50	16.23-20.77	52.84	49.89-55.79
5	16.13%	23.53	21.29-25.77	16.68	14.6-18.76	59.80	57.16-62.43
6	14.41%	27.52	24.32-30.72	17.98	15.12-20.84	54.50	50.86-58.14
7	4.47%	28.73	25.50-31.97	14.65	12.04-17.26	56.62	53.06-60.17
8	4.05%	23.83	20.71-26.95	17.88	14.82-20.94	58.29	54.62-61.96
9	15.69%	23.24	18.67-27.80	16.47	12.63-20.31	60.29	54.98-65.61
10	4.27%	24.80	21.21-28.39	16.34	13.39-19.29	58.86	54.83-62.9
Race/Poverty Interaction							
Hispanic, at/above	15.91%	23.38	19.73-27.04	16.36	13.23-19.48	60.26	56.05-64.47
Hispanic, below	8.66%	11.28	8.03-14.54	19.76	14.75-24.78	68.96	63.32-74.6
NH Black, at/above	9.19%	23.24	19.19-27.28	17.19	13.69-20.69	59.58	54.94-64.21
NH Black, below	3.98%	19.08	13.21-24.95	19.37	13.57-25.17	61.55	54.36-68.74
NH White, at/above	45.68%	28.88	27.37-30.38	15.43	14.20-16.65	55.7	54.08-57.33
NH White, below	4.89%	26.4	22.04-30.76	19.07	14.77-23.37	54.53	49.51-59.55
Other MR, at/above	9.60%	22.83	19.54-26.12	15.27	12.32-18.21	61.91	57.85-65.97
Other MR, below	2.10%	12.58	7.95-17.20	25.7	17.92-33.48	61.73	52.79-70.66
Mom's Marital Status							
Married	62.40%	26.14	24.71-27.56	15.55	14.36-16.74	58.32	56.70-59.94
Not currently married	37.60%	22.92	20.95-24.89	17.94	16.18-19.69	59.15	56.85-61.44
Home Ownership Status							
Owned/being bought	66.10%	26.46	25.11-27.82	15.42	14.32-16.52	58.12	56.62-59.62
Rented	30.93%	21.84	19.60-24.08	18.38	16.31-20.45	59.79	57.06-62.51
Number of providers							

1	61.67%	23.51	22.05-24.97	15.66	14.43-16.88	60.83	59.13-62.53
2	25.97%	24.74	22.57-26.90	17.17	15.13-19.21	58.09	55.57-60.62
3+	12.19%	31.36	27.74-34.99	19.13	16.15-22.12	49.5	45.75-53.26
Current Health Ins. Status							
Private only	52.99%	26.72	25.19-28.25	14.59	13.40-15.78	58.69	57.02-60.35
Any Medicaid	36.10%	20.63	18.65-22.60	18.27	16.40-20.15	61.1	58.66-63.55
Other insurance	6.71%	27.89	23.93-31.85	17.06	13.31-20.80	55.06	50.30-59.82
Uninsured	4.20%	34.46	27.63-41.29	23.14	17.09-29.18	42.4	35.03-49.77

Table 2.

Percent coverage among each sociodemographic variable stratified by outcome status and bivariate and multivariate predictors of HPV vaccination status and corresponding 95% confidence intervals.

	Complete %	Partial %	None %	Partial:None Bivariate Analysis PR (95% CI)	Partial:None Multivariate Analysis aPR (95% CI)	Complete:None Bivariate Analysis PR (95% CI)	Complete:None Multivariate Analysis aPR (95% CI)
Overall	58.63	16.45	24.92	N/A	N./A	N/A	N/A
Age				-	-	-	-
13	45.58	23.86	30.55	Referent	Referent	Referent	Referent
14	55.97	16.31	27.72	0.85 (0.73-0.98)	0.90 (0.78-1.03)	1.12 (1.04-1.20)	1.14 (1.07-1.22)
15	61.85	15.76	22.39	0.94 (0.81-1.09)	0.93 (0.81-1.07)	1.23 (1.15-1.31)	1.24 (1.16-1.32)
16	65.46	11.78	22.77	0.78 (0.66-0.92)	0.84 (0.72-0.98)	1.24 (1.16-1.33)	1.28 (1.20-1.36)
17	64.51	14.48	21.01	0.93 (0.80-1.09)	1.01 (0.86-1.17)	1.26 (1.18-1.35)	1.31 (1.23-1.39)
Race/Ethnicity							
Hispanic	62.75	17.24	20.01	1.31 (1.14-1.51)	1.19 (1.03-1.37)	1.15 (1.10-1.21)	1.14 (1.08-1.20)
NH, White	55.41	15.73	28.87	Referent	Referent	Referent	Referent
NH, Black	60.7	17.41	21.88	1.26 (1.08-1.46)	1.16 (0.99-1.37)	1.12 (1.06-1.18)	1.12 (1.05-1.18)
Other, MR	61.27	16.73	22	1.23 (1.06-1.42)	1.19 (1.04-1.37)	1.12 (1.06-1.18)	1.12 (1.06-1.18)
Sex							
Male	56	17.15	26.65	0.96 (0.87-1.06)	0.96 (0.87-1.06)	0.93 (0.89-0.97)	0.92 (0.89-0.95)
Female	61.38	15.71	22.92	Referent	Referent	Referent	Referent
Mother's Edu							
< 12 years	64.09	20.21	15.71	1.5 (1.29-1.76)	1.12 (0.94-1.35)	1.12 (1.06-1.18)	0.99 (0.92-1.06)
12 years	55.03	17.56	27.42	1.04 (0.91-1.20)	0.90 (0.78-1.04)	0.93 (0.88-0.99)	0.88 (0.83-0.93)
> 12 years, NCG	54.12	17.06	28.83	0.99 (0.88-1.12)	0.85 (0.75-0.97)	0.91 (0.87-0.95)	0.88 (0.84-0.93)
College grad	61.41	14.44	24.15	Referent	Referent	Referent	Referent
Checkup @ 11/12							
Yes	65.06	15.69	19.25	Referent	Referent	Referent	Referent
No	42.03	22.02	35.95	0.85 (0.72-0.99)	0.80 (0.68-0.94)	0.7 (0.63-0.77)	0.68 (0.62-0.74)
DK	54.55	16.21	29.25	0.79 (0.71-0.89)	0.74 (0.67-0.82)	0.84 (0.81-0.88)	0.83 (0.80-0.86)
Poverty Status							
Below poverty	63.09	20.14	16.77	Referent	Referent	Referent	Referent
At/above poverty	57.79	15.79	26.42	0.69 (0.61-0.77)	0.84 (0.73-0.97)	0.87 (0.83-0.91)	0.92 (0.87-0.97)
HHS Region							
1	71.01	13.88	15.12	1.22 (1.03-1.45)	1.15 (0.96-1.37)	1.27 (1.20-1.35)	1.27 (1.20-1.24)
2	65.29	11.82	22.89	0.87 (0.71-1.07)	0.84 (0.68-1.04)	1.14 (1.07-1.22)	1.12 (1.04-1.20)
3	62.58	14.54	22.88	0.99 (0.84-1.17)	0.96 (0.81-1.15)	1.13 (1.06-1.21)	1.13 (1.06-1.20)
4	52.84	18.50	28.66	Referent	Referent	Referent	Referent
5	59.80	16.68	23.53	1.06 (0.91-1.23)	1.08 (0.94-1.26)	1.11 (1.04-1.18)	1.13 (1.07-1.20)
6	54.50	17.98	27.52	1.01 (0.85-1.20)	1.01 (0.85-1.19)	1.03 (0.95-1.10)	1.03 (0.96-1.12)
7	56.62	14.65	28.73	0.86 (0.71-1.04)	0.94 (0.77-1.14)	1.02 (0.95-1.10)	1.11 (1.03-1.19)
8	58.29	17.88	23.83	1.09 (0.92-1.30)	1.16 (0.97-1.38)	1.1 (1.02-1.18)	1.16 (1.08-1.24)
9	60.29	16.47	23.24	1.06 (0.85-1.32)	1.06 (0.86-1.30)	1.11 (1.02-1.22)	1.13 (1.04-1.22)
10	58.86	16.34	24.80	1.01 (0.84-1.22)	1.01 (0.83-1.23)	1.09 (1.01-1.17)	1.13 (1.04-1.21)
Race/Poverty Interaction							
Hispanic, at/above	60.26	16.36	23.38	1.2 (1.01-1.43)	-	1.1 (1.03-1.17)	-
Hispanic, below	68.96	19.76	11.28	1.86 (1.58-2.19)	-	1.31 (1.24-1.38)	-
NH Black, at/above	59.58	17.19	23.24	1.24 (1.03-1.50)	-	1.1 (1.02-1.18)	-
NH Black, below	61.55	19.37	19.08	1.47 (1.15-1.88)	-	1.16 (1.06-1.28)	-
NH White, at/above	55.7	15.43	28.88	Referent	-	Referent	-
NH White, below	54.53	19.07	26.4	1.23 (1.00-1.49)	-	1.03 (0.95-1.11)	-
Other MR, at/above	61.91	15.27	22.83	1.17 (0.99-1.39)	-	1.11 (1.05-1.18)	-
Other MR, below	61.73	25.7	12.58	1.96 (1.65-2.33)	-	1.27 (1.17-1.37)	-
Mom's Marital Status							
Married	58.32	15.55	26.14	0.85 (0.77-0.94)	0.98 (0.87-1.10)	0.96 (0.92-1.00)	0.99 (0.95-1.04)
Not currently married	59.15	17.94	22.92	Referent	Referent	Referent	Referent
Home Ownership Status							
Owned/being bought	58.12	15.42	26.46	0.81 (0.72-0.90)	0.88 (0.78-0.99)	0.94 (0.90-0.98)	0.98 (0.93-1.03)
Rented	59.79	18.38	21.84	Referent	Referent	Referent	Referent
Number of providers							
1	60.83	15.66	23.51	Referent	Referent	Referent	Referent

2	58.09	17.17	24.74	1.03 (0.92-1.16)	1.03 (0.92-1.15)	0.98 (0.94-1.02)	0.96 (0.93-1.00)
3+	49.5	19.13	31.36	0.96 (0.82-1.12)	1.01 (0.87-1.18)	0.85 (0.79-0.92)	0.85 (0.79-0.91)
Current Health Ins. Status							
Private only	58.69	14.59	26.72	Referent	Referent	Referent	Referent
Any Medicaid	61.1	18.27	20.63	1.33 (1.19-1.48)	1.17 (1.02-1.35)	1.09 (1.05-1.13)	1.08 (1.03-1.15)
Other insurance	55.06	17.06	27.89	1.08 (0.89-1.30)	1.06 (0.88-1.28)	0.97 (0.90-1.04)	1.00 (0.92-1.07)
Uninsured	42.4	23.14	34.46	1.14 (0.90-1.44)	1.01 (0.80-1.28)	0.8 (0.69-0.94)	0.85 (0.74-0.98)

Discussion

Historically, with regard to HPV vaccine coverage, data surrounding partial vaccination has been presented as a category of individuals who received at least one dose, regardless of completion status. However, understanding the proportion of the adolescent population who are only partially vaccinated can assist with future tailored outreach efforts to increase full series vaccination. To date, this presentation of HPV vaccine uptake has not routinely been conducted, and these findings add to the literature to support efforts to improve HPV vaccination coverage in the US.

Age-related findings highlight gaps in HPV vaccine recommendations for young adolescents through documented low completion rates among those 13 years of age. Lower completion among 13-year-olds suggests that they need more time to catch up to their older-aged counterparts. Among all age ranges (13 to 17), the group with the lowest completion rate is 13-year-olds (45.6%), and this is concerning as ACIP recommendations indicate HPV vaccination should ideally be complete at that point (Meites et al., 2019). Older aged adolescents have had more time to complete the vaccine series, so seeing an increase in series completion makes sense, whereas it appears that older age is not consistently associated with partial HPV vaccination. Additionally, recent efforts have been taken by the American Cancer Society's (ACS) National HPV Vaccination Roundtable to support starting HPV vaccination at age 9 to maximize completion (ACS, 2021). The National HPV Vaccination Roundtable has implemented an initiative titled "Start at 9" that emphasizes the importance of initiating the HPV vaccine series as early as possible, ideally at age 9; this recommendation is also backed by the American Academy of Pediatrics (AAP) (ACS, 2021). The ACS's National HPV Vaccination Roundtable identifies several benefits to initiating the vaccine series at age 9, such as providing

more time to complete the series by age 13, increasing the likelihood of vaccination before first HPV exposure, and decreasing sexual promiscuity questions by parents and guardians of vaccine recipients (ACS, 2021).

The finding of lowest HPV vaccination among White adolescents at or above poverty needs further evaluation; this follows prior patterns identified in the CDC's Morbidity and Mortality Weekly Report (MMWR) that White, higher educated parents may be more hesitant to vaccinate their children against HPV (Pingali, 2021). This may be related to findings of increased refusal of all childhood vaccines among mothers who were white, were college educated, and had higher incomes (Smith et al., 2004). It is possible that HPV vaccination is more often refused by White adolescents at or above-poverty because of greater access to routine cervical screening, leading to a lowered perceived need for the HPV vaccine. These findings necessitate the need for outreach efforts in affluent areas populated by this demographic, as well as clinical interventions at healthcare facilities frequented by such individuals (Warner et al., 2017). It also may be worthwhile to provide training resources for clinicians in regard to improving the delivery of strong HPV vaccine recommendations (Warner et al., 2017).

We found that national estimates of HPV vaccine series completion demonstrate a consistent pattern of higher HPV vaccine uptake among adolescents below the federal poverty level, compared to those at or above the poverty level. This finding is comparable to historical patterns and is unique to the HPV vaccine; this pattern persisted across racial and ethnic categories. Due to the fact that parental permission is needed to vaccinate individuals under 18 years of age, parents living at or above poverty may have different views regarding the HPV vaccine than parents below poverty (Jeudin et al., 2014). There is a need for healthcare providers to improve their system of HPV vaccine recommendation to parents living at or above poverty, as it has

been documented that parental decisions to vaccinate are highly influenced by provider recommendations (Jeudin, 2014).

Compared to females, there is lower uptake among males, but not significant, for partial vaccination, but it is significant for complete vaccination, meaning that in general, boys are less likely to have either initiated but not completed the series, or completed the series compared to girls. However, these are relatively small differences, indicating that the sex gap in vaccine uptake is minimizing. Prior MMWR data demonstrate how this gap has been closing over the years. In 2016, 49.5% of females were up to date on their HPV vaccine status and 37.5% of males were up to date, a 12-percentage point difference in HPV vaccine coverage (Walker et al., 2018). In 2017, the sex gap had reduced to 8.8-percentage points, and in 2018, there was a 5-percentage point difference (Walker et al., 2018; Walker et al., 2019). In 2019, overall uptake increased from the year prior, but the percentage point difference remained the same (Elam-Evans et al., 2020). Given these data, is important that we focus on overall vaccine promotion with an emphasis on making sure males are returning for the remainder of their doses.

Historical patterns surrounding the influence of the number of healthcare providers on HPV vaccine uptake demonstrate that individuals with multiple providers lack a "medical home" leading to fragmented care and inconsistent vaccination tracking and uptake (Elam-Evans et al., 2020). Additionally, it has been found that medically underserved populations with less access to routine care, especially racial and ethnic minorities, have higher rates of cervical cancer (Garner, 2003; American Cancer Society Cancer Action Network, 2018). As a result, maternal experiences with HPV-related disease have been associated with greater willingness to vaccinate daughters against HPV (Salz et al., 2010). Compared to historical socioeconomic status (SES)

patterns that have been previously described, trends in HPV vaccination for 13- to 17-year-olds remained consistent, demonstrating that SES has an inverse relationship with vaccine status.

The finding of lowest HPV vaccination among adolescents in HHS Region 4 (southeastern U.S.) is consistent with historical discrepancies in the southeast regarding vaccination. The states in this Region – Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee – tend to have uninspiring vaccination rates, but this provides for an opportunity to bring key stakeholders together and find a solution to increase vaccine uptake in this Region.

This study is subject to some limitations. First, NIS-Teen has a relatively low response rate, and this could potentially limit the generalizability of the findings presented (NORC, 2021). Additionally, only approximately half of the parents gave permission for provider verification of vaccine status, which can bias the results toward higher vaccine coverage with the potential of additional parental engagement in healthcare among those giving this permission (NORC, 2021). There is also a lack of a SAS procedure for generalized linear models for complex survey data, and this necessitated the use of the PROC GENMOD procedure to evaluate bivariate and multivariate predictors of HPV vaccination status, using Poisson regression (Hale et al., 2013). Finally, this analysis is limited to 2020 data, as the 2021 NIS-Teen public use files were not available at the time this analysis began; after analysis initiation, a more recent dataset became available.

Overall, this study suggests that adolescents of racial and ethnic minorities living below poverty are significantly more likely to be either partially or completely vaccinated against HPV when compared to their counterparts who have not historically exhibited these types of health disparities. There are relatively small differences in vaccine uptake among males versus females,

indicating that the sex gap in vaccine uptake is minimizing. Utilizing the findings presented here, targeted interventions and policies can begin to be constructed towards specific groups whose vaccine coverage is lacking. If attention can be focused on the specific populations who have limited vaccine uptake, we can begin to assess why such disparities exist and, ultimately, work to rectify the contributory inequities and disparate vaccine coverage across the United States. Expanded use of detailed surveillance efforts to reach more granular subpopulations of adolescents and utilization of multiple years of data to evaluate consistent disparity patterns are needed to develop and implement interventions to address disparities in adolescent immunization coverage. More research on sociodemographic influence of HPV vaccine uptake is needed.

CHAPTER 4: CONCLUSIONS & PUBLIC HEALTH RECOMMENDATIONS

This study suggests that adolescents of racial and ethnic minorities living below poverty are significantly more likely to be either partially or completely vaccinated against HPV when compared to their counterparts who have not historically exhibited these types of health disparities. The national estimates of HPV vaccine series completion demonstrate a consistent pattern of higher HPV vaccine uptake among adolescents below the federal poverty level, compared to those at or above the poverty level. Overall, it was found that SES has an inverse relationship with vaccine status. The finding of lowest HPV vaccination among White adolescents at or above poverty needs further evaluation. This may be related to findings of increased refusal of all childhood vaccines among mothers with a higher SES (Smith et al., 2004). It is possible that HPV vaccination is more often refused by White adolescents at or above-poverty because of greater access to routine cervical screening, leading to a lowered perceived need for the HPV vaccine. There are relatively small differences in vaccine uptake among males versus females, indicating that the sex gap in vaccine uptake is minimizing.

Utilizing the findings presented here, targeted interventions and policies can begin to be constructed towards specific groups whose vaccine coverage is lacking. If attention can be focused on the specific populations who have limited vaccine uptake, we can begin to assess why such disparities exist and, ultimately, work to rectify the contributory inequities and disparate vaccine coverage across the United States.

Expanded use of detailed surveillance efforts to reach more granular subpopulations of adolescents and utilization of multiple years of data to evaluate consistent disparity patterns are needed to develop and implement interventions to address disparities in adolescent immunization coverage. More research on sociodemographic influence of HPV vaccine uptake is needed.

REFERENCES

American Cancer Society Cancer Action Network. (2018, October 17). *Cancer Disparities Chartbook*. American Cancer Society Cancer Action Network. Retrieved April 12, 2023, from https://www.fightcancer.org/policy-resources/cancer-disparities-chartbook

American Cancer Society. (2021). *HPV Vaccination Starts at Age 9*. American Cancer Society, National HPV Vaccination Roundtable. Retrieved April 17, 2023, from https://hpvroundtable.org/hpv-vaccination-starts-at-9/

American Cancer Society. (2022). *Our HPV Vaccination Initiatives*. American Cancer Society. Retrieved April 17, 2023, from https://www.cancer.org/health-care-professionals/hpv-vaccination-information-for-health-professionals/our-hpv-vaccination-initatives.html

Ault, K. A. (2006). Epidemiology and Natural History of Human Papillomavirus Infections in the Female Genital Tract. *Infectious Diseases in Obstetrics and Gynecology*, *2006*, 1–5. https://doi.org/10.1155/idog/2006/40470

Avni-Singer, L. R., Yakely, A., Sheth, S. S., Shapiro, E. D., Niccolai, L. M., & Oliveira, C. R. (2020). Assessing sociodemographic differences in human papillomavirus vaccine impact studies in the United States: A systematic review using narrative synthesis. *Public Health*, *178*, 137–150. https://doi.org/10.1016/j.puhe.2019.08.010

Centers for Disease Control and Prevention. (2010). FDA Licensure of Bivalent Human Papillomavirus Vaccine (HPV2, Cervarix) for Use in Females and Updated HPV Vaccination Recommendations from the Advisory Committee on Immunization Practices (ACIP). *MMWR Morbidity and Mortality Weekly Report*, *59*(20), 626–629.

Centers for Disease Control and Prevention. (2010). FDA Licensure of Quadrivalent Human Papillomavirus Vaccine (HPV4, Gardasil) for Use in Males and Guidance from the Advisory Committee on Immunization Practices (ACIP). *MMWR Morbidity and Mortality Weekly Report*, *59*(20), 630–632.

Centers for Disease Control and Prevention. (2011). Recommendations on the Use of Quadrivalent Human Papillomavirus Vaccine in Males — Advisory Committee on Immunization Practices (ACIP), 2011. *MMWR Morbidity and Mortality Weekly Report*, *60*(50), 1705–1708.

Centers for Disease Control and Prevention. (2022, April 12). *HPV Fact Sheet*. Centers for Disease Control and Prevention. Retrieved March 24, 2023, from https://www.cdc.gov/std/hpv/stdfact-hpv.htm

College of Physicians of Philadelphia. (2023). *Human Papillomavirus (HPV) Infection*. History of Vaccine. Retrieved April 12, 2023, from https://historyofvaccines.org/diseases/human-papillomavirus-hpv-infection

Cubie, H. A. (2013). Diseases associated with human papillomavirus infection. *Virology*, *445*(1-2), 21–34. https://doi.org/10.1016/j.virol.2013.06.007

Elam-Evans, L. D., Yankey, D., Singleton, J. A., Sterrett, N., Markowitz, L. E., Williams, C. L., Fredua, B., McNamara, L., & Stokley, S. (2020). National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years — United States, 2019. *MMWR Morbidity and Mortality Weekly Report*, *69*(33), 1109–1116. https://doi.org/10.15585/mmwr.mm6933a1

Garner E. I. (2003). Cervical cancer: disparities in screening, treatment, and survival. Cancer epidemiology, biomarkers & prevention : a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology, 12(3), 242s–247s.

Hale, J.J., Thompson, D.M., & Darden, P.M. (2013). Calculating Subset Weighted Analysis Using PROC SURVEYFREQ and GENMOD.

Handisurya, A., Schellenbacher, C., & Kirnbauer, R. (2009). Diseases caused by human papillomaviruses (HPV). *Journal Der Deutschen Dermatologischen Gesellschaft*, *7*(5), 453–466. https://doi.org/10.1111/j.1610-0387.2009.06988.x

Jeudin, P., Liveright, E., del Carmen, M. G., & Perkins, R. B. (2014). Race, Ethnicity, and Income Factors Impacting Human Papillomavirus Vaccination rates. *Clinical Therapeutics*, *36*(1), 24–37. https://doi.org/10.1016/j.clinthera.2013.11.001

Kombe, A. J., Li, B., Zahid, A., Mengist, H. M., Bounda, G.-A., Zhou, Y., & Jin, T. (2021). Epidemiology and Burden of Human Papillomavirus and Related Diseases, Molecular Pathogenesis, and Vaccine Evaluation. *Frontiers in Public Health*, *8*. https://doi.org/10.3389/fpubh.2020.552028

Maness, S. B., & Thompson, E. L. (2019). Social Determinants of Human Papillomavirus Vaccine Uptake: An Assessment of Publicly Available Data. *Public Health Reports*, *134*(3), 264–273. https://doi.org/10.1177/0033354919838219

Markowitz, L. E., Dunne, E. F., Saraiya, M., Lawson, H. W., Chesson, H., & Unger, E. R. (2007). Quadrivalent Human Papillomavirus Vaccine Recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Morbidity and Mortality Weekly Report*, *56*(2), 1–24.

Markowitz, L. E., Unger, E. R., Bocchini, J. A., Gee, J., Curtis, C. R., Chesson, H. W., Saraiya, M., & Dunne, E. F. (2014). Human Papillomavirus Vaccination: Recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Morbidity and Mortality Weekly Report*, *63*(5), 1–30.

Meites, E., Kempe, A., & Markowitz, L. E. (2016). Use of a 2-Dose Schedule for Human Papillomavirus Vaccination — Updated Recommendations of the Advisory Committee on

Immunization Practices. *MMWR Morbidity and Mortality Weekly Report*, *65*(49), 1405–1408. https://doi.org/10.15585/mmwr.mm6549a5

Meites, E., Szilagyi, P. G., Chesson, H. W., Unger, E. R., Romero, J. R., & Markowitz, L. E. (2019). Human Papillomavirus Vaccination for Adults: Updated Recommendations of the Advisory Committee on Immunization Practices. *MMWR Morbidity and Mortality Weekly Report*, *68*(32), 698–702. https://doi.org/10.15585/mmwr.mm6832a3

National Center for Immunization and Respiratory Diseases (NCIRD). (2021). The 2020 National Immunization Survey – Teen. U.S. Department of Health and Human Services.

NORC at the University of Chicago (NORC). (2021). National Immunization Survey-Teen: A User's Guide for the 2020 Public-Use Data File. Centers for Disease Control and Prevention. https://www.cdc.gov/vaccines/imz-managers/nis/downloads/NIS-TEEN-PUF20-DUG.pdf

Office of Infectious Disease and HIV/AIDS Policy (OIDP). (2021). *Featured Priority: HPV Vaccination*. HHS.gov. Retrieved March 24, 2023, from https://www.hhs.gov/vaccines/featured-priorities/hpv-vaccination/index.html

Office of Infectious Disease and HIV/AIDS Policy (OIDP). (2021). *National Vaccine Advisory Committee (NVAC)*. HHS.gov. Retrieved March 24, 2023, from https://www.hhs.gov/vaccines/nvac/index.html

Office on Women's Health. (2022, December 29). *Human papillomavirus*. OASH, Office on Women's Health. Retrieved April 12, 2023, from https://www.womenshealth.gov/a-z-topics/human-papillomavirus#:~:text=Genital%20HPV%20is%20the%20most,some%20point%20in%20their%20lifetime.

Petrosky, E., Bocchini, J. A., Hariri, S., Chesson, H., Curtis, C. R., Saraiya, M., Unger, E. R., & Markowitz, L. E. (2015). Use of 9-Valent Human Papillomavirus (HPV) Vaccine: Updated HPV Vaccination Recommendations of the Advisory Committee on Immunization Practices. *MMWR Morbidity and Mortality Weekly Report*, *64*(11), 300–304.

Pingali, C., Yankey, D., Elam-Evans, L. D., Markowitz, L. E., Williams, C. L., Fredua, B., McNamara, L. A., Stokley, S., & Singleton, J. A. (2021). National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years — United States, 2020. *MMWR Morbidity and Mortality Weekly Report*, *70*(35), 1183–1190. https://doi.org/10.15585/mmwr.mm7035a1

Salz, T., Gottlieb, S. L., Smith, J. S., & Brewer, N. T. (2010). The association between cervical abnormalities and attitudes toward cervical cancer prevention. *Journal of Women's Health*, *19*(11), 2011–2016. https://doi.org/10.1089/jwh.2009.1790

Senkomago, V., Henley, S. J., Thomas, C. C., Mix, J. M., Markowitz, L. E., & Saraiya, M. (2019). Human Papillomavirus–Attributable Cancers — United States, 2012–2016. *Morbidity and Mortality Weekly Report*, *68*(33), 724–728. https://doi.org/10.15585/mmwr.mm6833a3

Smith, N. (2018). Strengthening the Effectiveness of National, State, and Local Efforts to Improve HPV Vaccination Coverage in the United States: Recommendations From the National Vaccine Advisory Committee. *Public Health Reports*, *133*(5), 543–550. https://doi.org/10.1177/0033354918793629

Smith, P. J., Chu, S. Y., & Barker, L. E. (2004). Children who have received no vaccines: Who are they and where do they live? *Pediatrics*, *114*(1), 187–195. https://doi.org/10.1542/peds.114.1.187

United Health Foundation. (2022). *Public Health Impact: HPV Vaccination*. America's Health Rankings, United Health Foundation. Retrieved September 9, 2022, from https://www.americashealthrankings.org/explore/annual/measure/Immunize_HPV/state/ALL?edition-year=2020

Walker, T. Y., Elam-Evans, L. D., Yankey, D., Markowitz, L. E., Williams, C. L., Fredua, B., Singleton, J. A., & Stokley, S. (2019). National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years — United States, 2018. *MMWR Morbidity and Mortality Weekly Report*, *68*(33), 718–723. https://doi.org/10.15585/mmwr.mm6833a2

Walker, T. Y., Elam-Evans, L. D., Yankey, D., Markowitz, L. E., Williams, C. L., Mbaeyi, S. A., Fredua, B., & Stokley, S. (2018). National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years — United States, 2017. *MMWR Morbidity and Mortality Weekly Report*, *67*(33), 909–917. https://doi.org/10.15585/mmwr.mm6733a1

Warner, E. L., Ding, Q., Pappas, L. M., Henry, K., & Kepka, D. (2017). White, affluent, educated parents are least likely to choose HPV vaccination for their children: a cross-sectional study of the National Immunization Study – teen. *BMC Pediatrics*, *17*(1). https://doi.org/10.1186/s12887-017-0953-2