2017

HPV Vaccination, Sociodemographic Variables, and Physician Recommendation in Select U.S. Areas

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This is to certify that the doctoral study by

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Doctor of Public Health

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Abstract

Human papillomavirus (HPV) is the most common sexually transmitted virus, and is causally related to several cancers. HPV vaccination rates are far below HealthyPeople 2020 targets and vary across geographic, socioeconomic, and demographic populations. The purpose of this research was to test the relationships among socioeconomic and demographic variables, HPV vaccination, social vulnerability, and physician recommendation within select local areas in the United States. Fundamental cause theory and behavioral economics informed this quantitative secondary analysis of National Immunization Survey-Teen and Social Vulnerability Index data (n = 43,271). Statistical analyses included chi-square and binomial logistic regression. Teens whose mothers had less than a college degree were more likely to initiate the HPV vaccine series ($p < .01$), while teens living in Hidalgo County and Houston were less likely to initiate the series ($p < .001$). Younger teens ($p < .001$), males ($p < .001$) and teens whose mothers had some college ($p < .01$) were less likely to complete the series, while older teens ($p < .001$) and teens living in Philadelphia and Houston ($p < .01$) were more likely to complete the series. Fewer teens in Bexar County received a physician recommendation ($p < .01$); there was no difference between vaccine initiation and select local area. These findings highlight the need to consider local sociodemographic influences on underlying disparities in health and physician behavior. Informed interventions may produce positive social change by reducing variance in health care quality, tailoring public health efforts to local needs, and moving persons experiencing disparities in health outcomes toward a healthy future.

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Dedication

I dedicate this proposal, this process, and the achievement of my doctorate to Josh Witten and Alex Kalmanofsky. Without Alex's insistent and consistent confidence in me (and a rallying session during a Hot Pocket situation in a back room in Philadelphia), and without Josh's manly reality checks and Socratic-ish method of helping me figure out what I want and how to get there, I would not have had the courage or the follow-through to apply for this doctorate program. If I were to go against a Sicilian when death was on the line, or people-watch at the arrivals gate at Heathrow, I want Josh and Alex at my side. There isn't enough time or money in the universe to pay them back for all they've given me, for how they've helped me to grow (albeit not in stature). Thanks, you guys, for helping me the best me I can be. And after knowing me, being my friend anyway.

Acknowledgments

First and foremost, I am so grateful for my husband, Doug Bachler, and my committee chair, Dr. Anderson. Doug's shoulders must be tired from carrying me all these years; without his undying love and support in every facet of life, this dream of a doctorate could not have been a reality, and I am so lucky that he picked me as his trophy wife. Dr. Anderson is the ideal mentor, and I am eternally in his debt for his patience, his encouragement, his infectious joy for research, and his guidance along this path.

Many others contributed to this process. Ashley Nash, Dr. Zin Htway, and Donald Wilt were my stats experts. Ann Brandstadter provided endless hours of entertainment and laughter throughout my literature review section, and Greg Twachtman contributed nothing at all, no articles of any kind. They were the best roommates a girl could ask for and I miss their daily presence. Evonda Thomas-Smith was an angel on earth, providing moral support and a listening ear in residencies and over the phone. I promised the kid working at the student help desk at Colorado State University that I would acknowledge him for his help in retrieving articles after hours on a Sunday – thanks, library guy! Same goes for Diane at the IAC, going above and beyond. Maggie Ekrem was instrumental with her super relevant, super scholarly suggestions for my proposal presentation slides. Sergei Federpaws was the best ergonomic wrist supporter and lap warmer in the world, and I miss him more than words can convey. Last but not least, Mom and Dad are the craziest, weirdest, most amazing and supportive parents. All I've ever wanted was for them to be proud of who I am. As Anne says, imitation is the sincerest form of flattery, and all the good in me comes from them. Especially the sassiness.

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Section 1: Foundation of the Study and Literature Review

Introduction

Human papillomavirus (HPV) is the most common sexually transmitted virus in the world; every sexually active person will likely be infected with HPV at least once in his or her lifetime (Centers for Disease Control and Prevention [CDC], 2017a). While 90% of infections will clear on their own, the remaining 10%–known as *high risk infections*–are causally related to cervical, oropharyngeal, and anogenital cancers, genital warts, and recurrent respiratory papillomatosis (CDC, 2017a; Galbraith et al., 2016; Kulczycki, Qu, & Shewchuk, 2016; Palmer, Carrico, & Costanzo, 2015). To date, HPV infection cannot be treated, but in the past 10 years three vaccines were approved by the Food and Drug Administration (FDA) covering males and females ages 9 to 26 years to protect against HPV infection (FDA, 2016).

A number of factors contribute to rates of HPV infection as well as receipt of HPV vaccination: age, sexual onset at a young age, socioeconomic status, racial or ethnic background, physician awareness and recommendation, and parental knowledge and attitudes (Burger et al., 2016; Small, Sampselle, Martyn, & Dempsey, 2014).

The narrative around HPV vaccination is unique among other adolescent vaccines, as the focus has been on the behavior leading to infection (e.g., adolescent sexual activity) rather than the diseases prevented (e.g., cervical cancer) (Bailey et al., 2016). In addition, the lack of a clear, strong physician recommendation for the vaccine contributes to parental misperceptions of the importance of the vaccine (Bailey et al., 2016). The Advisory Committee on Immunization Practices (ACIP) recommends HPV vaccination for boys and girls at age 11 to 12 years, as the vaccine is most effective when given prior to sexual activity, has greater immunoreactivity in adolescence, and can be bundled with other adolescent vaccines for efficient delivery (ACIP, 2016; Bailey et al., 2016). In October 2016, ACIP, CDC, and FDA recommended a two-dose series for adolescents ages 9 to 14 years; three doses of the vaccination is still recommended for teens and young adults ages 15 to 26 years (ACIP, 2016; FDA, 2016; Kim, Riley, Harriman, Hunter, & Bridges, 2017).

Although the prevalence of certain HPV types has decreased and vaccination rates have increased since the first HPV vaccine was introduced, initiation and completion of the vaccine series continues to be below the 80% target to achieve herd immunity and protect adolescents, teenagers, and young adults against infection (Berenson, Laz, & Rahman, 2016; Moss, Reiter, Rimer, & Brewer, 2016; Rahman, Laz, McGrath, & Berenson, 2015). As of 2015, only 41.9% of female and 28.1% of male ages 13 to 17 years had completed the HPV vaccine series (Reagan-Steiner et al., 2016). Of primary concern for public health, vaccine initiation and completion vary across geographical region, gender, socioeconomic status, and with different race and ethnic background; low socio-economic status and minority populations are at higher risk for HPV infection and related morbidity and mortality (Bruno, Wilson, Gany, & Aragones, 2014; Collins, Holcomb, Chapman-Davis, Khabele, & Farley, 2014; Daniel-Ulloa, Gilbert, & Parker, 2016; Henry, Stroup, Warner, & Kepka, 2016; Jeudin et al., 2014).

Considering cervical cancer only for today’s cohort of female adolescents ages 12 years and younger, CDC estimates the low rates of vaccination will contribute to over

50,000 cases of cervical cancer; for every year below the 80% target, an additional 4,400 girls will develop cervical cancer (Hswen, Gilkey, Rimer, & Brewer, 2017). Given that African-American and Native American populations are expected to increase in the United States at a modest rate between today and 2050, and Hispanic and Asian populations are expected to grow more than double in that same time period, narrowing the gap in HPV-related disparities is a critical public health need (Colby & Ortman, 2015; Jeudin et al., 2014;). In addition, these minority population increases will require culturally sensitive and relevant interventions and policies to allow for appropriate allocation of resources and program planning, as each population may face unique barriers to HPV vaccination (Galbraith et al., 2016; Reiter et al., 2014).

Researchers have identified lack of awareness of HPV, the cost of the vaccine and office visits, cultural norms, and lack of physician recommendation to be associated with disparities in HPV vaccination (Perkins, Brogly, Adams, & Freund, 2012; Rahman et al., 2015). The strongest predictors of vaccine initiation and completion continue to be low socioeconomic and racial and ethnic minority status, physician recommendation, and provaccine policy (Choi, Eworuke, & Segal, 2016; Galbraith et al., 2016; Henry et al., 2016; Jeudin et al., 2014; Palmer et al., 2015; Rahman et al., 2015; Rahman, Hirth, & Berenson, 2017). However, no researchers to date have examined all of these predictors together at the regional or county levels; while state-wide analyses offer larger sample sizes for greater statistical accuracy, many public health decisions are made at the local level (Waldrop, Moss, Liu, & Zhu, 2017). In addition, physician recommendations vary across geography, minority status, age, socioeconomic status, and gender; policies are patchwork and often ineffectual; and guidelines lack the rigor of legislative mandate (Galbraith et al., 2016; Jeudin et al., 2014; Moss et al., 2016; National Conference of State Legislatures [NCSL], 2017; Perkins et al., 2012; Rahman, Islam, & Berenson, 2015).

Vaccination rates against other diseases near or above 80% needed for herd immunity, in large part due to childcare and school-entry requirements (see Table 1). Of note, Hepatitis B, a viral infection transmitted by sexual activity or sharing drug paraphernalia, has the highest immunization rates (National Center for Health Statistics [NCHS], 2016). National HPV rates are less than half those for other diseases (NCHS, 2016).

Table 1

Immunization Rates for Select Recommended Adolescent Vaccines, 2014-2015

Disease	Immunization Rate (%), 2014	Immunization Rate (%), 2015
Measles, mumps, rubella (≥ 2 doses)	90.7	90.7
Hepatitis B (≥ 3 doses)	91.4	91.1
Varicella (≥ 2 doses, or a history of varicella)	85.0	86.1
Tetanus, diphtheria, pertussis (≥ 1 dose)	87.6	86.4
HPV (≥ 1 dose, females)	60.0	62.8
HPV (≥ 3 doses, females)	39.7	41.9
HPV (≥ 1 dose, males)	41.7	49.8
HPV (≥ 3 doses, males)	21.6	28.1

Note. From Table 67 in the National Center for Health Statistics report (2016).

Many interventions focus on increasing awareness and education of vaccination (including HPV); these efforts may be necessary but insufficient when making a decision to accept vaccination (Brandt, Pierce, & Crary, 2016). Policy-level interventions for HPV vaccination are underutilized, if used at all, despite the use of public health policy in many of the great achievements in public and population health (Brandt et al., 2016). In particular, public health departments make little use of the public health authority as an alternate to legislative action (Abiola, Colgrove, & Mello, 2013; Brandt et al., 2016; Colgrove, Abiola, & Mello, 2010).

Clinics and physicians are not consistently implementing recommended practices for HPV vaccination, especially among low socioeconomic and racial and ethnic minority patients (Askelson, Edmonds, Momany, & Tegegne, 2016). Evidence-based guidelines and recommendations published by ACIP, American Academy of Pediatrics, CDC, Community Preventive Services Task Force, and others include:

- immunization information systems,
- alerts and reminders for physicians and parents,
- standing orders for non-physicians to administer vaccines,
- participation in Vaccines For Children program,
- strategies to discuss the vaccine with parents who request delays or refuse,
- scheduling wellness visits for children 11 and 12 years old,
- allowing walk-in vaccination visits,
- vaccinating during sick visits,
- scheduling visits for subsequent doses at the time of vaccination, and
- individual physician feedback on vaccination rates (Askelson et al., 2016; Bailey et al., 2016).

These recommendations and guidelines reflect the importance of the social determinants of health and the context in which people make decisions and behave (Ferrer, Audrey, Trotter, & Hickman, 2015). A large number of HPV vaccination studies are grounded in individual or interpersonal health behavioral theories, which tend to view people as rational, logical actors wanting to maximize the benefit of health (Ferrer et al., 2015). Yet physicians and patients often make decisions that do not align with evidence-based science to maximize health, and behavior is influenced not only by individual psychology but also structural, economic, social, and political factors (Askelson et al., 2016; Ferrer et al., 2015). As stated by Vanderpool, Crosby, and Stradtman (2014), “The annual death rate from HPV-related cancers demands much more than minor alterations to our current patchwork approach to prevention” (p. 2560). Such comprehensive, evidence-based programs are needed to make progress toward the Healthy People 2020 goals of HPV vaccination coverage and reduction of HPV infection and associated cancers, as well as reduce the nearly $8 billion in annual costs for HPV-associated management (Palmer et al., 2015).

After a decade of research supporting the conclusion that HPV vaccines are safe and effective, vaccine initiation and completion continue to be low; additional research is needed to better understand how to reach those who are eligible for vaccination to protect against multiple HPV-related cancers (Maness, Reitzel, Watkins, & McNeill, 2016; Perkins, 2016). In addition, researchers recently have begun to explore potential relationships among health, local geographic areas, and social vulnerability – a composite of socioeconomic status, household composition and disability, minority status and language, and housing and transportation (Boscoe et al., 2014; Henry et al., 2016; Henry, Swiecki-Sikora, Stroup, Warner, & Kepka, 2017; Rutten et al., 2017). While researchers have published recent analyses on HPV vaccination data and policy, I am not aware of any to date that have tested the influence of the socioeconomic, demographic, cultural, geographical, and health history variables on HPV vaccine initiation and completion alongside the social vulnerability context in which these relationships exist. This will also be the first test of a potential relationship between social vulnerability and HPV vaccination in the literature, to my knowledge.

These implications, such as the identification of the factors most strongly associated with HPV vaccination and common error decision points in physician recommendation, can advance social change by highlighting the need to consider local social and demographic influences on physician behavior. Informed interventions may be able to reduce variance in quality, increase culturally competent health care, and move those persons experiencing disparities in health outcomes toward a positive and healthy future. As noted in Andre et al. (2008), "a comprehensive vaccination programme is a cornerstone of good public health and will reduce inequities" (p. 144).

The remainder of this chapter contains a review of the research problem, the purpose of the study, the research questions and hypotheses, the theoretical foundation and relation to the research questions, and the nature of the study.

Problem Statement

The Chicago Department of Health reported in July of 2015 that a recent in-person training and public education campaign increased rates of HPV vaccination by nearly 20%, as indicated in the 2014 National Immunization Survey-Teen data (City of Chicago, 2015). However, no discussion of data based on key determinants of vaccination, including socioeconomic and racial and ethnic minority status or physician recommendation, has occurred (City of Chicago, 2015).

The hypotheses of minority poverty and diminishing returns suggest that minority populations start life with poorer health and any gains in socioeconomic status result in smaller health improvements than non-minority populations with equivalent gains (Farmer & Ferraro, 2005; Kish et al., 2014; Lu et al., 2015). However, the higher burden of HPV infection, morbidity, and mortality and lower vaccination rates in vulnerable populations have the potential to exacerbate disparities in health outcomes (Braveman, Cubbin, Egerter, Williams, & Pamuk, 2010; Galbraith et al., 2016).

Researchers have focused on individual-level efforts targeting patients, but these programs have yielded little progress in vaccination completion (Ferrer et al., 2015). In addition, despite recommendations and policies set by federal bodies and national associations, physicians continue to recommend the HPV vaccine at lower rates than for other adolescent vaccines (Galbraith et al., 2016; Henry et al., 2016; Osazuwa-Peters et al., 2015; Teplow-Phipps et al., 2016; Vadaparampil et al., 2014).

The relationship between population- and structural-level factors influencing the predictors of HPV vaccination has not yet been clarified, so there is no consensus on which variables may be most appropriate to target in interventions (Ferrer et al., 2015; Oliver, Frawley, & Garland, 2016; Small et al., 2014). While overall HPV vaccination in the United States is rising slowly, incidence and prevalence of HPV-associated cancer in the United States are growing quickly, and disparities in vaccination rates and cancer mortality persist. Without knowledge of factors that influence vaccination in each population, public health practitioners may have difficulty designing effective methods to reduce these disparities. The newly released 2015 NIS-Teen data will provide the opportunity to update relationship and distribution patterns of socioeconomic and demographic variables across the nation. Understanding these patterns and their relationship with persistently low HPV vaccination initiation and completion can inform more cost-effective, culturally-grounded efforts in policy development and other changes to the environment in which vaccine decisions are made (Burger et al., 2016; Ferrer et al., 2015; Small et al., 2014; Zimet, Rosberger, Fisher, Perez, & Stupiansky, 2013).

Purpose of the Study

The purpose of this retrospective quantitative study is to test the relationship between HPV vaccine initiation and completion, socioeconomic status, and demographic variables in eight select local areas in the United States. In addition, I will test the relationship between HPV vaccine initiation, physician recommendation, and social vulnerability in four select local areas.

Research Questions and Hypotheses

I will attempt to answer four research questions:

Research Question 1: Is there a relationship between HPV vaccination initiation (1 dose) and socioeconomic status and demographic variables in selected local areas, using data from the 2015 NIS-Teen?

$H_0$1: There is no relationship between HPV vaccination initiation and socioeconomic and demographic variables in selected local areas.

H_a1: There is a relationship between HPV vaccination initiation and at least one socioeconomic or demographic in selected local areas.

Research Question 2: Is there a relationship between HPV vaccination completion (3 doses) and socioeconomic status and demographic variables in selected local areas using data from the 2015 NIS-Teen?

$H_0$2: There is no relationship between HPV vaccination completion and socioeconomic and demographic variables in selected local areas.

H_a2: There is a relationship between HPV vaccination completion and at least one socioeconomic or demographic variable in selected local areas.

Research Question 3: Is there a relationship between HPV vaccination initiation (1 dose) and social vulnerability by select local area county in the United States using data from the 2014 NIS-Teen and 2014 Social Vulnerability Index?

$H_0$3: There is no relationship between HPV vaccination initiation and social vulnerability by select local area county in the United States.

H_a3: There is a relationship between HPV vaccination initiation and social vulnerability by select local area county in the United States.

Research Question 4: Is there a relationship between physician recommendation (yes/no) and social vulnerability by select local area county in the United States using data from the 2014 NIS-Teen and 2014 Social Vulnerability Index?

$H_0 4$: There is no relationship between physician recommendation and social vulnerability by select local area county in the United States.

$H_a 4$: There is a relationship between physician recommendation and social vulnerability by select local area county in the United States.

Theoretical Foundation for the Study

Two theories provide useful constructs with which to interpret the study results: fundamental cause theory, addressing the presence and persistence of socioeconomic and minority disparities in health, and behavioral economics, establishing a need to consider the context and key influences of an environment on physician decision making.

Fundamental cause theory. Fundamental cause theory (FCT), developed by Link and Phelan (1995), is built on the idea that disparities develop alongside improvements in health care access and innovations due to the unequal distribution of health-promoting resources (Phelan, Link, & Tehranifar, 2010; Polonijo & Carpiano, 2013). The associations between disparities in health and health outcomes for preventable diseases by socioeconomic status and racial and ethnic backgrounds are well established, with poor and minority populations often experiencing poorer health and shortened lifespans (Howlader et al., 2017; Polonijo & Carpiano, 2013; Tehranifar et al., 2009). Those with access to flexible resources are able to take advantage of health-promoting assets in their environment and adapt to future health challenges, while those without access may experience some overall health improvement but at a lower level (Phelan et al., 2010; Polonijo & Carpiano, 2013).

For example, with the advent of cervical cancer screening, overall deaths declined, yet incidence and mortality continues to be highest in Hispanics, African Americans, and Native Americans (Howlader et al., 2017). According to FCT, these populations have fewer resources for learning about and attaining benefits of health innovations such as screening (Phelan et al., 2010). The HPV vaccine is another innovation in knowledge and technology, yet a gradient has emerged in which low socioeconomic status and racial and ethnic minority populations are less likely to be vaccinated (Phelan et al., 2010). The implication of FCT is that interventions must minimize the degree to which flexible resources engender better health (Polonijo & Carpiano, 2013). HPV vaccination is thus an important test of theory; if specific causes are not identified and addressed in interventions and resources are distributed unequally, disparities in HPV-related cancers will persist (Polonijo & Carpiano, 2013).

Behavioral economics theory. Traditional economic models assume people are rational actors who make decisions independent of social or environmental contexts; however, there is consensus among researchers that behavior is strongly influenced by social determinants, and people are consistently irrational in making decisions (Getzen, 2013; Hoff & Stiglitz, 2016; Volpp, Loewenstein, & Asch, 2015). Researchers use the theory of behavioral economics, credited to Kahneman and Tversky (1979), to augment traditional economic models with social influence on human decisions. This theory advocates for the inclusion of common decision errors in interventions with a goal of improving health beyond a quantitative increase or decrease in behavior change in a cost-effective way (Bickel, Moody & Higgins, 2016; Getzen, 2013; Volpp et al., 2015). Of all health economic models, Frank (2004) and Glanz, Rimer, and Viswanath (2015) suggested that physician behavior is most associated with behavioral economics, which can be used to help explain why physicians often deviate from evidence-based medicine; these findings can subsequently be used to inform more appropriate measures of behavior change.

Physicians make decisions about the intensity of treatment within the context of an asymmetrical power relationship with the patient, rigid time constraints, and risk aversion with patient outcomes. In this setting, physicians are influenced by constructs of stereotype and availability heuristics, time discounting, loss aversion, and choice architectures–all suggesting that physicians understandably use shortcuts in assessing patients, stick with treatments that have worked in the past, and select intensity of treatment based on local rather than national norms and evidence-based data (Frank, 2004; Hoff & Stiglitz, 2016). In behavioral economics, framing or choice architecture matters and many common decision error points can be redirected toward making health-promoting, evidence-based decisions. Understanding the internal barriers (such as heuristics) and external factors (such as physician prompts in electronic medical records) that motivate physicians to recommend the HPV vaccine may help guide individual, community, and population-level changes to facilitate physician recommendation for all patients (Dovidio & Fiske, 2012; Emanuel et al., 2016; Gesser-Edelsburg, Walter, Shir-Raz, & Green, 2015; Kao, 2015).

Nature of the Study

The nature of this study is a quantitative retrospective secondary analysis of national, publicly available data. Secondary analysis of large, reliable data sets such as NIS-Teen is less time-consuming and expensive than conducting primary quantitative research, and provides a sufficiently large sample size to make generalizations to the whole population, analyze data with a high level of statistical accuracy, and allow analysis among subgroups (Dale, 2004). Retrospective analysis is similarly a timely and cost-effective way to gather data, rather than waiting for events to occur, and can be reliable when data are objective events and can be verified by other sources (de Vaus, 2006). Gathering and analyzing generalizable data in a timely fashion can help identify potential factors, modifiable or not, that can be used to develop policies and programs aiming to increase U.S. HPV vaccination rates in the near future.

CDC conducts the annual NIS-Teen to monitor vaccination initiation and completion of adolescents aged 13 to 17 years among a stratified probability sample of all 50 states, the District of Columbia, and territories (Henry et al., 2016; Rahman et al., 2015). In addition, selected local areas that receive federal Section 317 funds to purchase vaccines, particularly for priority populations, are sampled and analyzed separately (Reagan-Steiner et al., 2016). The NIS-Teen gathers data in two phases, a telephone survey (both landline and cellular as of 2011) of parents or guardians of the target adolescents to obtain socioeconomic and demographic data, and a mailed survey to parent or guardian-identified providers to verify immunization records (CDC, 2016a; Henry et al., 2016; Rahman et al., 2015).

All analyses will include appropriate sampling weights when determining estimates to account for survey design. As the dependent variables are considered to be nominal (yes / no), statistical tests will include Chi-square and binomial logistic regression. This approach will be used to assess the relationship among a number of independent variables hypothesized to influence the dependent variables: HPV vaccination initiation and completion and physician recommendation of the HPV vaccine (Rahman et al., 2015; Perkins, 2016). Key variables as described in the 2014 and 2015 Data User's Guide (CDC, National Center for Immunization and Respiratory Diseases, & National Center for Health Statistics, 2015, 2016) are defined as follows.

Ethnic and racial minority status. A categorical independent variable describing the race/ethnicity of the adolescent or teen. Options are Hispanic, Non-Hispanic White Only, Non-Hispanic Black Only, Non-Hispanic Other + Multiple Races, and Other + Multiple Race (a recode of NHO + Multiple Races) (CDC et al., 2015, 2016).

HPV vaccination completion. A nominal dependent variable indicating the adolescent or teen has received three or more doses of the HPV vaccine. Some teens may have received more than three recommended doses; a secondary calculation by the CDC refers to a teen who, among those who received one or more HPV dose and over a minimum of 24 weeks between the first dose and the interview date, received a total of three or more doses (Reagan-Steiner et al., 2015).

HPV vaccination initiation. A nominal dependent variable indicating the adolescent or teen has received one or more doses of the HPV vaccine (Reagan-Steiner et al., 2015).

Physician recommendation. A categorical dependent variable (research question 4) indicating whether the person participating in the survey recalls receiving a recommendation from a physician or health care professional for the adolescent or teen to receive the HPV vaccination (CDC et al., 2015; 2016).

Selected local areas. Seven specific estimation areas highlighted in the 2015 NIS-Teen dataset (Bexar County, TX; Chicago, IL; El Paso County, TX; Hidalgo County, TX; Houston, TX; New York City; and Philadelphia County, PA) (CDC et al., 2015; 2016). As Washington, D.C. is sampled separately, I have included it as one of the select local areas. These local areas receive federal Section 317 funds to purchase vaccines, particularly for priority populations, and are sampled and analyzed separately; El Paso County and Hidalgo County were oversampled (Reagan-Steiner et al., 2016). Given the demonstrated differences in HPV vaccination by geography, as well as the hypothesized relationship between social vulnerability and HPV vaccination, inclusion of local areas will add significant value to the research. In order to compare county-level data from the Social Vulnerability Index (described below) and the NIS-Teen database, I will include only four selected local areas that are stand-alone counties from the 2014 NIS-Teen in the SVI portion of my analysis: Bexar County, District of Columbia, El Paso County, and Philadelphia (Hidalgo County was added in 2015).

Social vulnerability. As defined by the CDC and Agency for Toxic Substances and Disease Registry [ATSDR], social vulnerability refers to the extent to which the health of communities is likely to be affected by socioeconomic and demographic factors (CDC & ATSDR, 2017). Vulnerable populations are those who are disproportionately burdened by a combination of factors, are less likely to be able to cope with stressors, and whose needs are inadequately accounted for in resource allocation plans (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011). The CDC and ATSDR's Social Vulnerability Index ranks each census tract or county on overall vulnerability, comprised of four themes and 15 social factors affecting health: socioeconomic status (below poverty, unemployed, income, no high school diploma); household composition and disability (aged 65 and older, aged 17 or younger, civilian with a disability, single-parent households); minority status and language (minority, speak English less than well); and housing and transportation (multi-unit structures, mobile homes, crowding, no vehicle, group quarters) (CDC & ATSDR, 2017). As the most recent data set was published in 2014, I will compare the 2014 NIS-Teen dataset with the 2014 SVI.

Socioeconomic status. Categorical independent variables including income (poverty status, family income), health insurance and education (the current level of education of the adolescent or teen and the mother) (CDC et al., 2015; 2016).

Literature Review

In the decade since the first HPV vaccine was approved for use, researchers have proposed many theories and arguments to explain the low levels of HPV vaccine uptake. In this chapter, I present the literature on the themes relevant to my study: health disparities and social determinants of health including racial and ethnic minority status, socioeconomic status, and geography; policy and guidelines relating to vaccination; and physician recommendation of the HPV vaccine. In addition, I will present the literature on epidemiology of HPV for context, as well as propose two theories that may be useful for guiding future interventions in HPV vaccination research.

Literature Search Strategy

The literature search was conducted using search engines and databases in the Walden University Library, specifically CINAHL & MEDLINE Simultaneous Search, Expanded Academic ASAP, Google, Google Scholar, PsycINFO, PubMed, SAGE Premier, and ScienceDirect. In addition, a small number of journals featuring issues dedicated to HPV research (including *Human Vaccines & Immunotherapeutics* in June 2016 and *Vaccines* in November 2012) and an annually published journal (*Papillomavirus Research*) were reviewed for relevant publications.

Search terms within these databases and search engines included *behavioral economics theory* (with or without *health* or *health behavior*), *fundamental cause of health*, *fundamental cause theory* (with or without *health*), *HPV or human papillomavirus* (with or without *vaccin**), *papillomavirus history*, and *social determinants of health* (with or without *policy*). In addition, *HPV or human papillomavirus* with or without *vaccin** was combined with *behavioral economics*, *cancer*, *disparities*, *fundamental cause theory*, *minority*, *physician recommendation*, *policy*, and *socioeconomic*. The scope of the literature review in terms of years included (a) 1935-2017 for seminal literature regarding the history of HPV research, fundamental cause theory, and behavioral economics, (b) 2010-2017 for statistics on the most current data available on applicable variables, and (c) 2011-2017 for current peer-reviewed articles; peer-reviewed articles published 2015 through 2017 were prioritized.

Selection criteria for peer-reviewed articles included (a) publication in English, (b) original research or review articles, commentary, and editorials, (c) discussion or description of the aforementioned variables and their relationships to health and health outcomes in the United States, (d) HPV vaccination research with a primary focus on adolescents and teenagers ages 11 to 17, and (e) discussion or description of the theoretical foundations of this proposal and their application to health, policy, and economics. Literature on the application of the selected theoretical foundations to HPV vaccination was scarce; therefore, articles discussing these theories and their application to health in general were reviewed. In addition, literature regarding global trends in the aforementioned variables was reviewed if information was directly relevant to, or including a data collection component within, the United States.

Epidemiology of Human Papillomavirus and HPV-Associated Disease

Over 200 types of human papillomaviruses have been isolated and characterized and classified as one of two types: (a) low-risk, causing benign or low-grade tissue abnormalities, anogenital warts, and recurrent respiratory papillomatosis; and (b) high-risk, causing cervical, vaginal, vulvar, penile, anal, and oropharyngeal cancers (Hutter & Decker, 2016).

Global infection and cancer. HPV is the only cancer-causing virus to be endemic worldwide and is one of the most important infectious carcinogens in humans (Chan, Wong, Qin, & Chan, 2016; zur Hausen, 2009). HPV infects an estimated 12% of women of all ages worldwide, with a peak infection rate of 24% for those under 25 years old (Handler, Handler, Majewski, & Schwartz, 2015). Over half a billion cancers annually are associated with HPV infection annually worldwide; the population-attributable fraction (PAF), or the proportional reduction in disease that would occur if HPV were not present, is nearly 90% (Forman et al., 2012; World Health Organization, 2016).

U.S. incidence. Both HPV and genital wart figures are estimates; testing for HPV in cancer diagnoses does not happen routinely, nor do registries collect data on HPV status (with the exception of New Mexico for cervical cancer), so HPV infection rates are calculated based on the estimated infection rate within tissue known to be associated with HPV (CDC, 2016b; Katzel, Merchant, Chaturvedi, & Silverberg, 2015). Genital wart incidence is estimated based on persons who seek treatment, so true incidence is likely underrepresented (CDC, 2016b). However, previous studies support 70-80% concordance between estimates and direct measurement of HPV infection, and therefore national estimates are considered reliable (Katzel et al., 2015).

In the United States, annual incidence of HPV infection is 14 to 20 million people, while prevalence is 79 to 110 million (CDC, 2017b; Handler et al., 2015). An estimated $8 billion are spent annually managing HPV-related morbidity and mortality, second only to HIV (Chesson, Markowitz, Hariri, Ekwueme, & Saraiya, 2016). Initial visits to physician's offices for genital warts has increased over 730% in the past 50 years, with over 465,000 initial visits in 2014 (CDC, 2017c). Finally, annual incidence of HPV-associated cancers has increased over time, with an estimated 40,000 cases annually (8 per 100,000), although estimates vary by cancer site, ethnicity, study methodology, and geographic location (Handler et al., 2015; Viens et al., 2016). The incidence of HPV-associated cancers differs by geography, from 7.5 per 100,000 in Utah to 14.7 per 100,000 in Kentucky (Saraiya et al., 2015; Viens et al., 2016).

U.S. HPV infection by cancer site. The estimated detection of HPV in the United States is (a) 99% in cervical cancer and cervical cancer in situ, (b) 91% in anal cancer, (c) 75% in vaginal cancer, (d) 70% to 90% in oropharyngeal cancer, (e) 70% in vulvar cancer, (f) 63% in penile cancer, and (g) 53% in oral cavity and laryngeal cancer (Bailey et al., 2016; Garland et al., 2016; Saraiya et al., 2015). Cervical, anal, and oropharyngeal cancers are of particular interest to researchers given their incidence and risk factors.

Cervical cancer. Knowing patterns of preventable, evidence-based population risk factors contributing to incidence of HPV infection and associated cancers are key for creating benchmarks in public health policy and planning efforts (Franco, Shinder, Tota, & Isidean, 2015). For example, mortality for cancers for which early detection, prevention, and/or treatment exist and were adequately implemented was reduced by 50% between 1990 and 2015 (Byers, Wender, Jemal, Baskies, Ward, & Brawley, 2016). Of the HPV-associated cancers, only cervical cancer has an established early detection program and treatment algorithm; cervical cancer efforts are a model for programs that can reliably detect precancerous lesions and effectively remove the tissue, and have reduced cervical cancer mortality by 60% since 1955 (Dizon et al., 2016; Ferlay et al., 2015; Franco et al., 2015; Hutter & Decker, 2016). However, screening is not 100% effective: many women infected with high-risk HPV may have normal Papanicolaou (Pap) test results; screening is less effective in preventing cervical adenocarcinoma than squamous cell carcinoma; and only 81% of women get up to date regular pap smears (Castanon, Landy, & Sasieni, 2016; Hutter & Decker, 2016; Viens et al., 2016).

Cervical screening compliance is even lower among women who are of minority descent, uninsured or publicly insured, and low socioeconomic status (Reiter et al., 2013; Viens et al., 2016). This is particularly troubling, as Blacks clear HPV more slowly than White women, and cervical cancer incidence is highest among Blacks and Hispanics, women in poverty, and women with low educational attainment (Reiter et al., 2013; Viens et al., 2016). It is therefore crucial to understand HPV prevalence and vaccination coverage among populations to more effectively address existing and potential future cervical cancer disparities (Reiter et al., 2013).

Anal cancer. Anal cancer is one of only five cancers whose incidence has increased in the past 40 years (another HPV-associated cancer, HPV-positive oropharyngeal squamous cell carcinoma, is among the five) (Amini et al., 2016; Jemal et al., 2013). Incidence and mortality rates of anal cancer in the United States are highest in White females and Black males; overall, anal cancer is slightly more common in females (Viens et al., 2016). Receptive anal sex is strongly associated with HPV infection and anal cancer in males; men who have sex with men (MSM) have higher rates of anal cancer than men who have sex with women (Handler et al., 2015). Rates of anal cancer in U.S. HIV-positive MSM are on par with rates of cervical cancer sub-Saharan African women, which are the highest in the world (Forman et al., 2012). However, even individuals who do not participate in anal sex are still at risk given the proximity of the anal canal and genitals (Hutter & Decker, 2016).

Oropharyngeal cancer. Head and neck squamous cell carcinoma incidence overall is declining in the United States., including a 50% reduction in HPV-negative oropharyngeal cancer in less than 20 years, as tobacco and alcohol use have declined in recent birth cohorts (Allison & Maleki, 2016; Amini et al., 2016; Chaturvedi, Engels, Anderson, & Gillison, 2008; Chaturvedi et al., 2011; Gillison, 2016). Conversely, HPV-positive oropharyngeal cancer (HPV OSCC) has risen steeply, jumping 225% during the same time period (Allison & Maleki, 2016; Chaturvedi et al., 2011). Given that smoking tobacco is an established risk factor for HNSCC but smoking rates have decreased, another causal agent–HPV–must be driving the rise in HPV OSCC in younger individuals (Allison & Maleki, 2016; Chaturvedi et al., 2011). Researchers estimate incidence of HPV OSCC will surpass incidence of HPV-positive cervical cancer by 2020, if not sooner; the dramatic increase of HPV OSCC as smoking has decreased has been described as virus-related epidemic (Allison & Maleki, 2016; Marur, D'Souza, Westra, & Forastiere, 2010).

HPV OSCC is distinctive from HPV-negative OSCC not only in incidence, but in molecular pathophysiology, presentation, and prognosis (Mallen-St Clair et al., 2016). The differences are so great that survival rates for HPV OSCC patients cannot be predicted using the current TNM staging system; to aid researchers and physicians, the American Journal of Cancer will publish an updated staging manual including HPV OSCC in late 2016 (Mallen-St Clair et al., 2016). If treated with radiation, HPV OSCC is associated with improved overall survival rates (Allison & Maleki, 2016). Researchers have yet to identify a lesion or map progression to HPV OSCC, however, and have not determined why HPV-positive tumors are more sensitive to radiation treatment than HPV-negative tumors (Mallen-St. Clair et al., 2016).

Risk factors and other considerations. HPV infection and HPV-associated cancers share a number of risk factors–sexual behavior, smoking marijuana, and other epidemiological considerations including age, educational attainment, health care coverage, socioeconomic status, and racial and ethnic minority background (Mullins et al., 2016). Although these issues will be explored more fully later in the remainder of this section, a brief discussion on their relevance to incidence is warranted.

HPV infection (and consequently development of HPV-associated cancers) is associated with early age of first sexual encounter, high number of sexual partners, and smoking marijuana (Chaturvedi et al., 2011; Chesson, Dunne, Hariri, & Markowitz, 2014; Mullins et al., 2016). Immunosuppressed and HIV-positive individuals are at much higher risk of HPV infection than the general population, as their immune systems cannot clear the infection as effectively (Forman et al., 2012).

Prevalence of male HPV infection is generally correlated with female HPV infection, while prevention of infection in males protects both females in heterosexual relationships and males in homosexual relationships (Allison & Maleki, 2016; Fairley, Zou, Zhang, & Chow, 2017). Incidence of infections leading to cervical cancer tends to peak near the age of sexual debut (teens to early 20s) while incidence of infections leading to HPV OSCC and anal and penile cancers has a bimodal peak, one at 30 to 34 years and another at 60 to 64 years (Allison & Maleki, 2016). The age at which individuals develop cancer influences outcomes, as younger individuals with HPV-associated cancers often present at higher stages and are exposed to toxic treatments that affect long-term quality of life (Amini et al., 2016; Gillison, 2016).

Finally, incidence of HPV infections and associated cancers tends to be disproportionately higher in persons of low socioeconomic status and racial and ethnic minority populations; one exception is HPV OSCC, which occurs more often among young, educated, affluent White males (Allison & Maleki, 2016, Byers et al., 2016).

In the past decade, the Food and Drug Administration approved three prophylactic HPV vaccines (see Table 2) (Onon, 2011). Currently, clinical trials are testing efficacy in alternate dosing schedules, efficacy and safety in pediatric and immunocompromised patients, safety when administered in combination with other vaccines, and efficacy of behavioral interventions to increase vaccine uptake (Onon, 2011).

Table 2

Approved HPV Vaccines and Their Indications

	Initial Approval	Initial Indication	Subsequent Approvals	Covered HPV Types
Gardasil (Merck & Co)	June, 2006	Girls and women ages 9 to 26 years: Cervical cancer; genital warts; cervical adenocarcinoma *in situ*; cervical, vulvar, and vaginal intraepithelial lesions	Vulvar and vaginal cancer (September 2012). Males and females ages 9 to 26 years, anal cancer and anal intraepithelial lesions (December 2010)	HPV6, 11, 16, 18
Cervarix (GlaxoSmithKline)	October, 2009	Girls and women ages 10 to 25 years: Cervical cancer; cervical adenocarcinoma *in situ*; cervical intraepithelial lesions	Girls aged 9 years (2011)	HPV16, 18
Gardasil-9 (Merck & Co)	December, 2014	Girls and women ages 9 to 26 years: Cervical, vulvar, vaginal, and anal cancer; genital warts; cervical, vulvar, vaginal, and anal intraepithelial lesions. Boys ages 9 to 15 years: anal cancer; genital warts, anal intraepithelial lesions	Men ages 16 to 26 (December 2015) Two-dose regimen for individuals ages 9 to 14 years (October 2016)	HPV6, 11, 16, 18, 31, 33, 45, 52, 58

Note. From FDA (2016). Approvals current as of July 1, 2017.

Health Disparities and Social Determinants of Health

Health is shaped by the social determinants of health, or "conditions in the environments in which people are born, live, learn, work, play, worship, and age" (Healthypeople.gov, 2017, "Understanding Social Determinants of Health," para. 1). Researchers have demonstrated strong links between a number of determinants and disparities in health and health outcomes, including race and ethnicity, socioeconomic status, and geographic location (CDC, 2013). Of particular relevance to my study, these determinants, along with physician recommendation, have been linked with HPV vaccination (Burger et al., 2016). These determinants underpin how health-promoting resources are distributed, as in the fundamental cause theory, and inform physician decision-making, as in behavioral economics. Although these data on vaccination and relationships with health determinants are useful and consistent, there continue to be gaps in HPV vaccine research. To date, most research in the HPV vaccine space has focused on individual-level determinants in isolation, or has been analyzed at the aggregate level, masking inter- and intra-population differences in HPV vaccine rates (Bodson et al., 2017; Kreuter, McQueen, Boyum, & Fu, 2016; Romaguera et al., 2016; Rutten et al., 2017; Whittemore et al., 2016).

This leads to the questions about the relationships among a number of individual and structural determinants known to interact with HPV vaccination, as well as whether there are other determinants that have not yet been examined (Kreuter et al., 2016). Testing the relationships of these determinants on multiple levels with HPV vaccine uptake is necessary if researchers are to identify modifiable factors that contribute to existing inequalities in HPV-related morbidity and mortality (Bodson et al., 2017). I will address this gap and build on the body of research in this space by testing socioeconomic and demographic variables and social vulnerability as independent variables, with HPV vaccine initiation and completion and physician recommendation as dependent variables. In the following discussion, I present the literature supporting the importance of disparities in race and ethnicity, socioeconomic status, and geography, and how I will address gaps in the literature through this study.

Racial and ethnic minority status. Researchers have established strong relationships among disparities in health due to cumulative, differential experience of racial and ethnic minorities with structural and interpersonal inequities; these disparities have been linked to HPV-related health outcomes and HPV vaccination rates (Benz et al., 2011; Braun et al., 2015; Chang, Moonesinghe, Athar, & Truman, 2016; Gelman et al., 2013; Jeudin et al., 2014; Reagan-Steiner et al., 2016; Williams, Priest, & Anderson, 2016). An individual's racial and ethnic background is a non-modifiable factor, but is so strongly linked with other social determinants and health outcomes that any examination of disparities HPV vaccine uptake must include this variable to be valid and useful for knowledge and practice (Burger et al., 2016).

Tehranifar et al. (2009) suggested that racial and ethnic disparities in cancer incidence and mortality have been consistent despite the advancement of screening techniques and treatment. This is supported by Burger et al. (2016) and others, who presented data showing differential burden of incidence and mortality by racial and ethnic background (see Table 3) (Bakir & Skarzynski, 2015; Gelman et al., 2013; Ramer et al., 2016; Reagan-Steiner et al., 2016). For example, the U.S. Cancer Statistics Working Group (2016) showed that White and Black populations tend to have higher incidence of anal and oropharyngeal cancer. In another example, Bakir & Skarzynski (2015) reported that while Black women are slightly less likely to develop cervical cancer than Hispanic women, they are substantially more likely to die from the disease.

Table 3

Age-Adjusted Cancer Incidence and Mortality by Primary Tumor Site and Race

Primary Site	Anus		Cervix		Oropharynx	
	Incidence	Mortality	Incidence	Mortality	Incidence	Mortality
All Races	1.8	0.2	7.2	2.3	11.5	2.4
White	1.9	0.3	7.0	2.2	11.8	2.4
Black	1.8	0.3	9.0	3.9	9.0	2.8
A/PI	0.5	0.1	5.9	1.9	7.8	1.9
AI/AN	0.9	[c]	6.3	1.7	7.1	1.0
Hispanic	1.3	0.1	9.2	2.5	6.7	1.4

Note. From Adapted from 2013 data from United States Cancer Statistics (the most recent year available). A/PI: Asian / Pacific Islander. AI/AN: American Indian / Alaska Native. [a] Female only. Anus and Oropharynx represent male and female data. [b] Incidence and mortality rates are per 100,000 persons and are age-adjusted to the 2000 U.S. standard population. [c] Not sufficient data

Conclusions regarding incidence and mortality by racial and ethnic background are similar and researchers consistently show that disparities exist over time, in different age groups, and from different population-level data sets (the National Health Interview Survey, NIS-Teen, National Program of Cancer Registries, Surveillance, Epidemiology, and End Results Program, and others). The number of races and ethnicities included, however, varies by research methodology. For example, Reagan-Steiner et al. (2016) and Burger et al. (2016) tested the relationships among non-Hispanic White, Black, Hispanic, Asian, and American Indian / Alaska Native and HPV vaccine uptake, providing a comprehensive snapshot of national vaccination trends (see Table 4). In contrast, Jeudin et al. (2014) focused on subpopulations of Black, Hispanic, and Asian females and reviewed drivers of vaccination, while Daniel-Ulloa et al. (2016) tested vaccination by sexual orientation among Black, Hispanic, and White females. The scope of this research is to test the relationships among specific determinants of health and vaccination at local and national levels, and thus inclusion of all races and ethnicities available is appropriate.

Table 4

HPV Vaccine Coverage among Females Ages 13-17 Years, by Race

Race	≥1 dose			≥3 doses		
	2013	2014	2015	2013	2014	2015
White	53.1%	56.1%	59.2%	34.9%	37.5%	39.6%
Black	55.8%	66.4%	66.9%	34.2%	39.0%	40.8%
Hispanic	67.5%	66.3%	68.4%	44.8%	46.9%	46.2%
AI/AN	73.3%	71.2%	70.5%	43.2%	39.4%	38.7%
Asian	57.0%	54.9%	63.8%	40.4%	35.7%	53.5%

Note. Adapted from Elam-Evans et al. (2014; 2013 data), Reagan-Steiner et al. (2015; 2014 data), and Reagan-Steiner et al. (2016; 2015 data). ≥1 dose indicates HPV vaccine initiation, ≥3 doses indicates HPV vaccine completion. Overall in 2015, 42% of females completed the HPV vaccine series (Hswen et al., 2017).

Khan et al. (2016) predicted that the consistently observed differences in cancer incidence and mortality by racial and ethnic minority background will persist despite the introduction of the HPV vaccine until the ecological factors influencing the health of these populations have been addressed (Alligood-Percoco & Kesterson, 2015; Burdette, Webb, Hill, & Jokinen-Gordon, 2016; DeSantis et al., 2016). However, researchers including a comprehensive set of such variables (a) explored associations within small subgroups in specific locations (Romaguera et al., 2016), limiting external validity; or (b) tested relationships among the population as a whole (Galbraith et al., 2016), obscuring differences at the local level. Given available data and other constraints, these approaches are logical but do little to capture the diversity of resources and barriers to health in heterogeneous populations.

To account for external validity as well as relevance to local public health officials, I will test the relationship of the major racial and ethnic minority categories available in a national dataset with HPV vaccination at the national and county level. As asserted by Burger et al. (2016), the lack of targeted interventions may result in future differential outcomes in HPV-related incidence and mortality despite the current availability of an efficacious vaccine. Testing the relationship between race and ethnicity and HPV vaccine is only one piece of the puzzle, however; other local variables such as socioeconomic status and geography influence health outcomes and must be considered for a more comprehensive understanding of local resources and needs.

Socioeconomic status. Socioeconomic status (SES) is a multi-dimensional variable and has a strong and significant association with health (Cutler, Lleras-Muney, & Vogl, 2008). The socioeconomic-health gradient has been firmly established through decades of research and observation across societies; the most commonly used proxies for assessing SES including education, income, and occupational status.

Despite the clear links between dimensions of SES and health outcomes, one or a few dimensions tested in isolation is insufficient to explain health outcomes, as the dimensions are inextricably linked. As stated by Cutler et al. (2008) and Krieger et al. (2005), the unique mix of individual-, community-, and population-level factors influencing health poses a significant challenge in creating a unified theory to explain the relationship between SES and health outcomes. Researchers must extend SES considerations beyond a single or small number of SES dimensions in order to address heterogeneous and multidimensional fundamental needs for public health programs to truly be effective.

The challenges and resulting health outcomes vary even among a population with the same income, education, or occupation. For example, Kreuter et al. (2016) found that while one family living below the poverty level may have adequate housing and a strong social support network, another may face food insecurity and cultural isolation. Interpreting any tested relationships between SES and vaccine uptake through the lens of an ecological perspective, as in the FCT, Farmer and Ferraro's (2005) *minority poverty hypothesis*, or the economic principle of *diminishing returns* as described by Phelan et al. (2010) may contribute to more comprehensive research designs and program planning.

An ecological perspective to SES. Farmer and Ferraro (2005) developed the *minority poverty hypothesis* from the observation that the greatest disparities in health are concentrated among low-socioeconomic, racial and ethnic minority populations as a result of the compound stressors of poverty and racial and ethnic minority background on these populations (Kish et al., 2014). In contrast, *diminishing returns* is used to predict that the greatest disparities in health will be concentrated among high-socioeconomic status, racial and ethnic minority populations, as these populations do not experience the same return on health investment as non-Hispanic Whites do at the same SES level (Getzen, 2013; Kish et al., 2014). Finally, the FCT is interpreted to suggest that low-socioeconomic populations do not benefit from advances in health care at the same rate or level as high-socioeconomic populations do, no matter the racial and ethnic minority status of the population (Phelan et al., 2010). In sum, both SES and race and ethnicity are consistently and strongly linked with access to health-promoting resources and associated with health outcomes. This raises the question of whether SES and race and ethnicity contribute equally to health outcomes, and whether race and ethnicity can be considered a component of SES (Polonijo, Carpiano, Reiter, & Brewer, 2016).

In general, SES and race and ethnicity are positively correlated. Davids, Hutchins, Jones, and Hood (2014) and others have shown that the best health outcomes tend to be found in high-socioeconomic communities with large Asian or native-born non-Hispanic White populations, while the worst health outcomes are found in low-socioeconomic, mainly Black or immigrant communities (Froment, Gomez, Roux, DeRouen, & Kidd, 2014). This is supported by Proctor, Semega, and Kollar (2016), who reported that a higher percentage of racial and ethnic minority populations live in poverty, compared with non-Hispanic Whites – while 9.1% of NHW lived in poverty in 2015, 21.4% of Hispanics and 24.1% of Blacks lived below the poverty level.

The association between SES and racial and ethnic minority status extends to HPV vaccination as well. Reagan-Steiner et al. (2016) showed that among males ages 13 to 17 years living below the poverty level, HPV vaccine initiation rates in 2015 were higher among Hispanics (70.8%) than Blacks (60.2%). Even within the same racial and ethnic populations, Reagan-Steiner et al. (2016) found differences in HPV vaccine initiation rates, with lower rates in Black males living at or above the poverty level (51.9%) than those below the poverty level. In support of these findings, Henry et al. (2016) showed that female initiation rates followed similar trends, with the highest rates in low-SES urban communities with predominantly Hispanic or Black populations. Thus, although the link between racial and ethnic minority background and SES is clear, one can argue that it is not perfectly dependent, whether in the context of HPV vaccine uptake or not. Consequently, I will separate racial and ethnic minority status from an SES variable in my study.

Health insurance and SES. Researchers consistently have shown a positive gradient between health insurance and SES components (income, occupation, and education) (DeNavas-Walt, Proctor, & Lee, 2006). Rather than subsume health insurance status under SES, however, I agree with Barnett and Vornovitsky (2016), Churilla et al. (2016), and others that health insurance should be tested as a separate variable. The type of health insurance an individual has not only differs between income levels, but within income levels as well. For example, Barnett and Vornovitsky (2016) reported that of Americans living below the poverty level–and therefore all considered low socioeconomic status–in 2015, 28.6% had a private plan, 62.1% had government health insurance, and 17.4% were uninsured. In contrast, of those at or above 400% of the poverty level, 86.4% had a private plan, 22.6% had a government plan, and 4.5% were uninsured (Barnett & Vornovitsky, 2016).

In addition, different types of insurance may result in different health outcomes, Abdus and Selden (2013) and Churilla et al. (2016) observed that the type of insurance coverage an individual has is associated with stage at diagnosis of cancer, treatment, and mortality. The authors demonstrated that privately insured patients with cervical cancer tend to have a usual source of care, and as such tend to present earlier in their disease course and live longer. Medicaid-insured patients with cervical cancer tend to present at a later stage and die sooner than privately insured patients, while uninsured patients have the poorest outcomes in terms of stage of diagnosis and survival than both privately insured and Medicaid patients.

These differences by insurance type and outcomes extend to HPV vaccine uptake as well. Agawu et al. (2015) found that adolescents who were covered by Medicaid and lived below the poverty level were more likely to initiate the HPV vaccine than children with non-Medicaid insurance and living at or above the poverty level; these rates were reportedly due to the Vaccines for Children program, which provides vaccines for Medicaid-insured children and adolescents. These data were supported by Henry et al. (2016), and Reagan-Steiner et al. (2016), who found significant differences in HPV vaccine initiation by racial and ethnic minority status, SES, and health insurance type.

Finally, Kish et al. (2014) and others stated that access to the same type of health insurance does not guarantee better health outcomes. For example, Booth, Li, Zhang-Salomons, and Mackillop (2010) and Du, Lin, Johnson, and Altekruse (2011) expressed their surprise at finding disparities in cancer morbidity and mortality in Canada and the U.K., where everyone has access to the same basic health care coverage. Based on these findings, I will test the types of health insurance separately from SES and racial and ethnic minority status, provided each subgroup has sufficient sample size. Understanding the relationship between components of SES, health insurance, and racial and ethnic minority status could advance knowledge in the field and encourage researchers to look at variables in more detail to better target their interventions. However, given the importance of social determinants in health decisions, additional factors such as geography should be included for a more comprehensive analysis.

Geography. While national estimates of disease and vaccination rates are more readily available and may be useful metrics to measure change in population health, state and local-level data are more relevant to the local contexts in which needs exist and resources are allocated (Hunt, Tran, & Whitman, 2015). For example, the National Program of Cancer Registries [NPCR] (2015) reported that the age-adjusted incidence rate of cervical cancer in the United States fell to 7.6 per 100,000 between 2009 and 2013, yet rates ranged from 4.6 per 100,000 in New Hampshire to 10.0 per 100,000 in West Virginia.

As reported in Kish et al. (2016), incidence among similar racial and ethnic minorities also varied by state. For example, rates of cervical cancer in Hispanic women ranged from 5.5 per 100,000 in Maryland to 19.5 per 100,000 in Arkansas, while rates for Black women in those same states ranged from 8.0 per 100,000 in Maryland to 12.9 per 100,000 in Arkansas.

Even in neighboring states with significant interstate interaction and access to health care, racial and ethnic groups may have different health outcomes. For example, the NPCR (2015) reports that in New York, Hispanic women have lower incidence of cervical cancer but are more likely to die from the disease than Hispanic women in New Jersey; in New York; Black women have higher incidence of cervical cancer but are less likely to die than Black women in New Jersey; and in New York Non-Hispanic White women are less likely to be diagnosed with and die from cervical cancer than in New

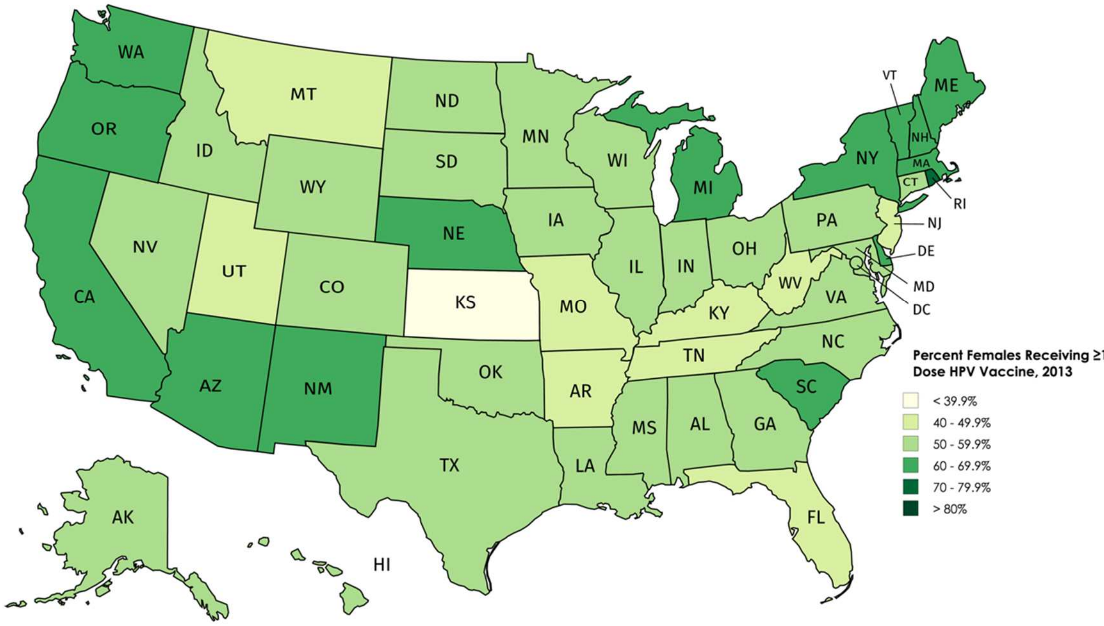
Jersey. The varying rates cannot be solely a product of access to state-specific preventive measures, as Blacks and Hispanics have equal rates (and greater than rates of White women) of Pap screenings (and greater than rates of White women) in both New York and New Jersey (NPCR, 2015).

These data lead to the question about differences within and between states among the same racial and ethnic populations. While state-level data are useful in monitoring shifts in disease and disease outcomes, a single statistic does not represent the differential burden experienced by subpopulations within the state. Therefore, as suggested by Egen, Beatty, Blackley, Brown, and Wykoff (2017), an additional level of detail is needed to capture intra-state differences hidden by state-level data and highlight the areas of greatest vulnerability.

The smallest unit of analysis in national databases tends to be the county or census tract, and although sample sizes are smaller, researchers have found significant differences in health and health outcomes. Egen et al. (2017) showed that individuals living in the poorest counties of a state may have similar life expectancy to populations in developing countries, and live 7 to 10 fewer years than those in the wealthiest counties in the same state. Lin, Schootman, and Zhan (2015) and McCarthy, Dumanovsky, Visvanathan, Kahn, and Schymura (2010) are among the very few researchers who have conducted studies on differences in health outcomes at the local level; they cited concerns with external validity and small sample sizes as main barriers to this approach. However, Lin et al. (2015) and McCarthy et al. (2010) have maintained that their results are consistent with researchers using larger state- or national-level datasets: namely, race and ethnicity tend to be predictive of later-stage cervical cancer diagnosis (especially for Black and Hispanic women), while race and ethnicity, geography, and other contextual factors tend to predict mortality. I interpret these data as supporting the need for local-level data to best inform resource needs and program planning, in combination with state- or national-level data to monitor changes in population health. Furthermore, these data raise the question of how HPV vaccine uptake differs by county when broken down by social determinant variables.

HPV vaccine uptake and geography. As reported by Galbraith et al. (2016), Glenn et al. (2015) and others, HPV vaccination initiation and completion have been shown to vary significantly both inter- and intra-state (see Figure 1 and Tables 5 – 6) (Henry et al., 2016; Rahman, Islam, & Berenson, 2015). While Bharmal, Tseng, Kaplan, and Wong (2012) and many others have examined relative differences between states, few have examined absolute differences within states. In one such study, Reagan-Steiner et al. (2016) showed that while rates for female adolescents in Texas were 56%, 51%, and 60% in 2013, 2014, and 2015, respectively, Bexar County rates did not match the state during that time period (see Figure 1 and Table 5). By reporting only state-level HPV vaccinations, researchers may unintentionally mask intrastate variation in health determinants and thus reduce effectiveness of targeted program planning and resource allocation.

(a)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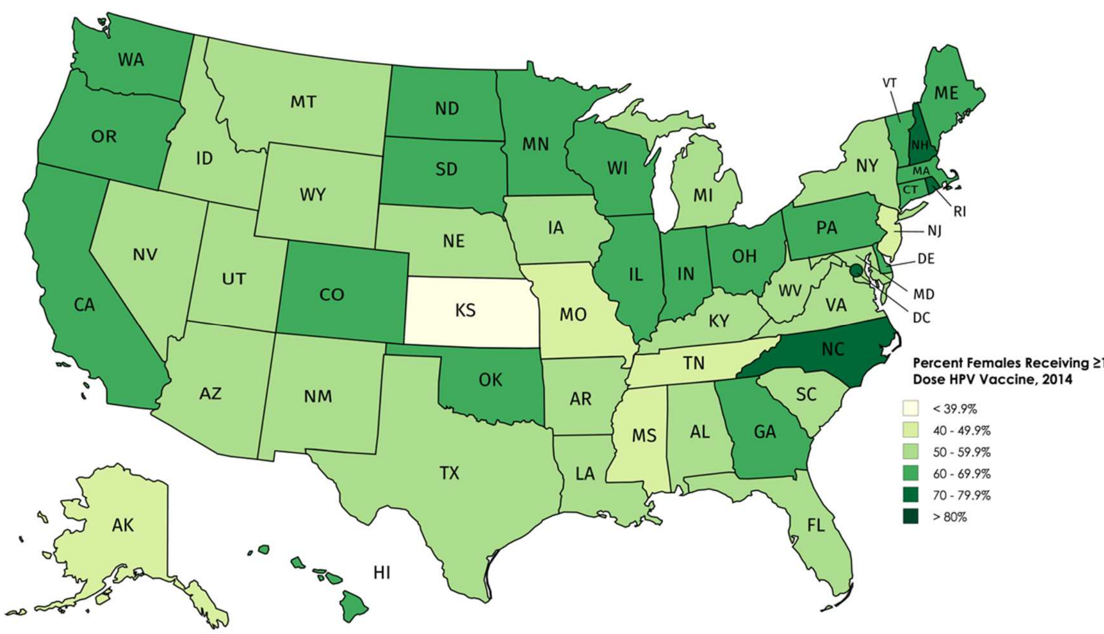
Percent Females Receiving ≥1 Dose HPV Vaccine, 2013
< 39.9%
40 - 49.9%
50 - 59.9%
60 - 69.9%
70 - 79.9%
> 80%

(b)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(c)

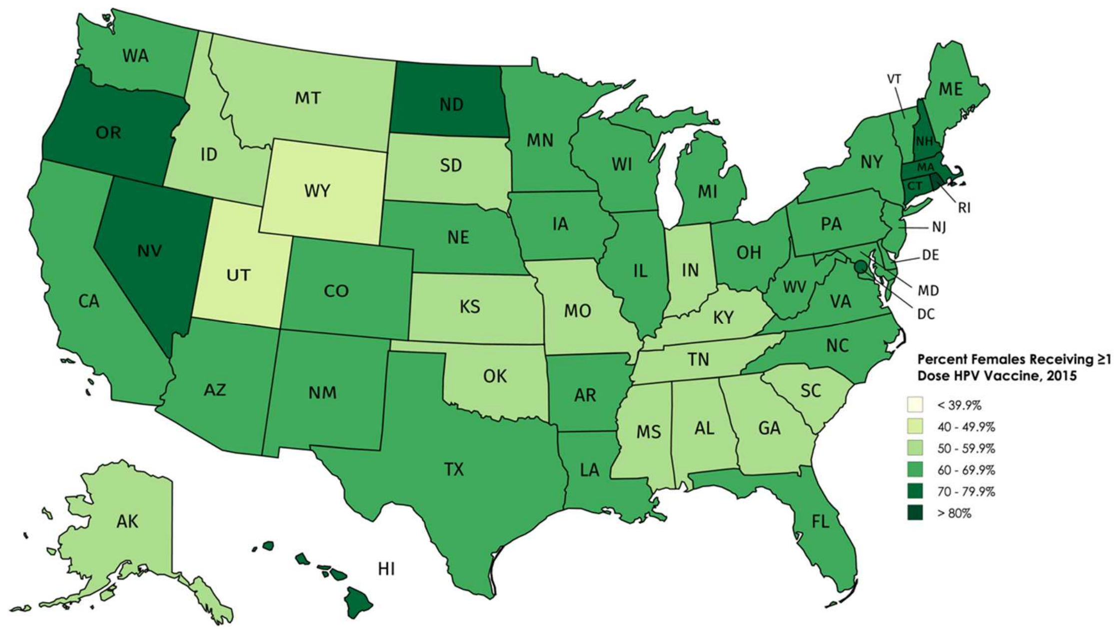

Figure 1. Percent females, ages 13-17, receiving >1 dose HPV vaccination, 2013–2015. (a) Percent females, ages 13–17, receiving ≥1 dose HPV vaccination, 2013. Adapted from Elam-Evans et al. (2014). (b) Percent females, ages 13–17, receiving ≥1 dose HPV vaccination, 2014. Adapted from Reagan-Steiner et al. (2015). (c) Percent females, ages 13–17, receiving ≥1 dose HPV vaccination, 2015. Adapted from Reagan-Steiner et al. (2016). Charts created using mapchart.net.©

Table 5

HPV Vaccine Coverage (1 dose) among Females Ages 13-17 Years by Location, 2013-2015

Year	United States	Rhode Island	Kansas	Chicago (IL)	Bexar County (TX)
2013	57.3%	76.6%	39.9%	61.8%	54.8%
2014	60.0%	76.0%	38.3%	78.1%	47.7%
2015	62.8%	87.9%	50.9%	70.8%	56.2%

Note. From Adapted from Elam-Evans et al. (2014; 2013 data), Reagan-Steiner et al. (2015; 2014 data), and Reagan-Steiner et al. (2016; 2015 data). ≥1 dose indicates HPV vaccine initiation. For all years, Rhode Island had the highest coverage nationwide, while Kansas had the lowest in 2013-2014 (in 2015, Wyoming had the lowest, with 47.7%).

Table 6

HPV Vaccine Coverage (1 dose) among Males Ages 13-17 Years by Location, 2013-2015

Year	United States	Rhode Island	Kansas	Chicago (IL)	Bexar County (TX)
2013	34.6%	69.3%	25.1%	50%	32.4%
2014	41.7%	69.0%	32.8%	64.9%	35.6%
2015	49.8%	80.6%	36.0%	68.1%	40.3%

Note. Adapted from Elam-Evans et al. (2014; 2013 data), Reagan-Steiner et al. (2015; 2014 data), and Reagan-Steiner et al. (2016; 2015 data). ≥1 dose indicates HPV vaccine initiation. For all years, Rhode Island had the highest coverage nationwide; Kansas provided for comparison to females (Table 5). Lowest male coverage was in Utah (11.0%, 2013), Indiana (23.2%, 2014), and Kentucky (34.8%, 2015)

Burger et al. (2016) concluded that the intent of increasing HPV vaccination among those who are most burdened by HPV-related morbidity and mortality is to decrease disparities in health outcomes. However, disparities will persist and potentially increase if the underlying structural issues contributing to these differences in HPV infection, vaccination, and related morbidity and mortality are not addressed at the state and local level in a culturally appropriate way. I will advance public health practice and knowledge in the field by being the first (to my knowledge) to test the relationships between HPV vaccine uptake and certain social determinant variables at the county level.

Expanding HPV vaccine research beyond the individual. Despite an understanding among the public health community that multiple levels of determinants influence HPV vaccine uptake, the bulk of intervention research for HPV vaccination has focused on the individual level, particularly with constructs including belief, knowledge, and attitudes of parents and adolescents. While these constructs do play a role in parental willingness to vaccinate, awareness of the vaccine is near saturation after a decade on the market, and changes in knowledge and awareness are reported to be insufficient to increase receipt of the vaccine (Joseph et al., 2016; Rahman et al., 2015; Wilson et al., 2016). Joseph et al. (2016) suggested that even among hard-to-reach populations with limited knowledge of the vaccine, intention to vaccinate is high. Future research efforts will benefit from inclusion of structural and interpersonal variables alongside individual factors (Galbraith et al., 2016; Joseph et al., 2016).

Structural and interpersonal variables influencing differences in HPV vaccine initiation and completion are reported to include school vaccine requirements; vaccine policy implementation; physician recommendations; physician decision-making processes; national, regional, and local partnerships funding HPV vaccine work; immunization information systems; technical assistance and funding by CDC; and clinical quality improvement strategies (Elam-Evans et al., 2014; Reagan-Steiner et al., 2015; 2016). Jeudin et al. (2014), Perkins (2016), and Rahman et al. (2015) have refined these suggestions and focused on physician recommendation as one of the most critical factors to influence HPV vaccine uptake. The following discussion reviews potential causes and implications of physician recommendation.

HPV Vaccination and Physician Recommendation

In reviews of the past decade of HPV vaccine research, Gilkey and McRee (2016) and others have suggested that a physician's recommendation is one of the most significant and strongest predictors of HPV vaccine uptake across sociodemographic categories (Hswen et al., 2017; Mohammed et al., 2016; Perkins, 2016). Despite a strong consensus that physician recommendation significantly increases HPV vaccine uptake across racial and ethnic minority background, socioeconomic status, and other variables, there are few links between research, theory, and practice. Specifically, a minority of studies comprehensively address the most documented factors influencing physician recommendation of HPV vaccine: provider factors, audience, and message content (Gilkey, Malo, Shah, Hall, & Brewer, 2015; Gilkey & McRee, 2016). Two additional factors, guidelines and policy, will be discussed later. As physician recommendation is so strongly correlated with vaccine initiation and completion, I will test this as an independent variable in my research.

Physician recommendation rates for adolescents have increased overall in the years since the vaccine has been available, from fewer than 50% of female adolescents ages 13 to 17 receiving a recommendation in 2008 to nearly 66% of females in 2014. (Burdette et al., 2017). The increase in recommendations has accompanied a concurrent increase in HPV vaccinations, but Burdette et al. (2017), Hswen et al. (2017), and others have challenged the idea that the increase in recommendation has been solely responsible for vaccination rates. The authors also maintained that physicians do not consistently recommend the vaccine across gender, racial and ethnic minorities, or age groups (Jeudin et al., 2014; Perkins et al., 2016; Rahman et al., 2015; Ylitalo, Lee, & Mehta, 2013). Zimet (2015) contended that years of reports from parents corroborate these claims, as parents noted lack of physician recommendation, or a weak or ambivalent recommendation, as among the most important reasons to delay or refuse vaccination. As the drivers behind this inconsistency are multifaceted, the nominal measurement of physician recommendation in NIS-Teen survey restricts any assessment of causal determinants in the decision-making process.

Gilkey et al. (2015) argued that physicians do not consistently adhere to or implement evidence-based strategies to increase vaccination among patients, with physicians citing barriers in interpersonal, clinical, and political environments to recommendation. Gilkey and McRee (2016), Hswen et al. (2017), Mohammed et al. (2016), and others suggested that interpretation of physician recommendation data from NIS-Teen include the context of these environments. As several of the factors in these environments are reflected in the theoretical underpinnings of this research, I will briefly describe how provider-, audience-, and message-level factors influence physician recommendation of the HPV vaccine.

Providers. Pediatricians are reported to have the highest recommendation rates, likely due to more favorable attitudes toward and routine administration of childhood vaccines. Building on the general consensus in the literature, Gilkey et al. (2015) found that family physicians had second-highest recommendation rates, followed by gynecologists and internists (Berkowitz, Malone, Rodriguez, & Saraiya, 2015; Dempsey et al., 2015). Current surveys such as NIS-Teen include only pediatricians, general and family practitioners, OB/GYNs, and internists in their sample (CDC et al., 2015, 2016; Gilkey et al., 2016). Osazuwa-Peters et al. (2016) has argued that dentists should be included in HPV vaccine interventions, given the growing rates of oropharyngeal cancer and dentists' yearly visits with children and adolescents. Limited data exist for recommendation rates among dentists, however, so I will exclude them from this discussion of provider factors.

Across qualitative, quantitative, and mixed methods approaches with physician, parent, and adolescent samples, researchers have observed consistent and significant inverse relationship between HPV vaccine recommendation and provider factors: physician comfort discussing sexuality; physician perception of parental hesitation; physician self-efficacy of discussing HPV vaccination; and physician assessment of an adolescent's risk of infection. As discussed in a review by Gilkey and McRee (2016), data reported on the association between knowledge of the HPV vaccine and recommendation were mixed; no data were observed that supported a correlation between perceptions of vaccine safety and recommendation, likely due to relatively less common concerns about vaccine safety among physicians. These data are not collected in NIS-Teen but provide important context for interpretation and suggestions for future research.

Whether by direct admission from physicians or through indirect analyses of physician knowledge and beliefs, physicians have limited ability to accurately assess risk of infection and sexual activity among their adolescent patients, and reportedly overestimate parental concern about the vaccine (Dempsey, Gebremariam, Koutsky, & Manhart, 2008; Gilkey et al., 2015; Healy, Montesinos, & Middleman, 2014; Kepka, Berkowitz, Yabroff, Roland, & Saraiya, 2012). Such risk-based strategies reportedly have not been effective, given the ubiquity of HPV in the population, and researchers have suggested these strategies are counter to guidelines and the self-reported expectations of adolescents and parents (Alexander et al., 2014; Alexander et al., 2016; Gilkey & McRee, 2016; Zimet, 2015). These strategies are directly linked to the behavioral economics construct of stereotype heuristics, as described in Frank (2004), in which physicians make decisions based on limited or erroneous information.

Although physicians reported feeling competent in taking a patient's sexual history, they have expressed discomfort and lack of self-confidence in discussing sex and sexuality (Alexander et al., 2014; Alexander et al., 2016; Bynum et al., 2014; Fuzzell, Fedesco, Alexander, Fortenberry, & Shields, 2016). This reported discomfort is not new; Alexander et al. (2016) and Merzel et al. (2004) argued that even prior to the launch of the HPV vaccine, physicians discussed sex and sexuality less often than what guidelines from professional organizations recommended. When sex and sexuality are discussed during patient visits, Alexander et al. (2014) and (2016) observed that conversations tended to be short, vary widely in content, and omit key education on topics including sexually transmitted infections. The lack of consistent opportunity for adolescents to discuss questions and concerns about sex, sexuality, and behavior is a missed opportunity for the physician to engage with the patient on healthy behaviors including HPV vaccination. Although not captured in NIS-Teen, understanding these provider factors can inform interpretation of physician recommendation. However, additional contexts in which these communications take place may facilitate or hamper an effective interaction with a patient. One is audience, the other is the message.

Audience. Disparities in HPV vaccine recommendation – in which minority parents and adolescents receive recommendations less often than non-Hispanic Whites – have been observed across national datasets, statewide vaccine registries, managed care databases, qualitative and quantitative approaches, longitudinally and in single-timepoint studies (Gilkey & McRee, 2016; Jeudin et al., 2014; Kepka, Balch, Warner, & Spigarelli, 2015; Mohammed et al., 2016; Rahman et al., 2015; Ylitalo et al., 2013).

As discussed in Mohammed et al. (2016), recommendation rates are reportedly lower among populations living below the poverty level; mothers with less than a high school education; living in the South; and no well-child or preventive visits with a physician in the prior 12 months. Even among adolescents who are adherent with well-child visits, physicians reportedly are not consistently recommending the vaccine, so adolescents who do not have a usual source of care are at even greater risk of a missed opportunity for vaccine recommendation if the only physician interaction is with acute care (Ford et al., 2016; Gilkey & McRee, 2016; Vadaparampil et al., 2011). In addition, family physicians and internists, who are less likely than pediatricians to recommend the HPV vaccine, tend to be the sole providers in rural or low socioeconomic areas. These observations helped refine my selection of independent variables among the data collected in NIS-Teen.

Gilkey and McRee (2016) and others showed that physicians cite low self-confidence in influencing parental decision-making with vaccines through recommendation. Aragones, Genoff, Gonzalez, Shuk, and Gany (2016) argued that these concerns are unfounded, and showed that parents ranked physician recommendation as one of the strongest factors in their decision to initiate, delay, or refuse the vaccine. This argument expanded on observations by Bhatta and Phillips (2015) and Maurer, Harris, and Uscher-Pines (2014), who found that parents are significantly more likely to trust and follow a physician's advice about vaccination, whether the recommendation is for a yearly influenza shot or the HPV vaccine. The authors maintained that levels of trust are even higher among parents of racial and ethnic minority and low socioeconomic populations. This discordance in trust – a behavioral economics construct – between a physician's lack of confidence in his or her capabilities and a parent's trust of the physician's advice is a significant barrier that has not yet been addressed in research or practice (Polonijo et al., 2016). Although outside the scope of this research, these data link to behavioral economics, a theory underpinning this research. For example, physicians have been reported to be influenced by biases such as omission (the potential for harm to a relationship is worse if a physician discusses HPV vaccination, versus not initiating a conversation), impact (physicians inaccurately estimate emotional states of parents), and availability (physicians inaccurately estimate the likelihood of a parent pushing back on a recommendation, or their own ability to convince a parent, based on recall rather than evidence).

In addition to disparities by racial and ethnic minority background, recommendation rates reportedly vary significantly by age of the patient (see Table 7). Vadaparampil et al. (2016) and others have found that few physicians, even pediatricians, follow the guidelines to recommend the HPV vaccine at age 11 to 12 years, despite data supporting stronger vaccine efficacy when given at this age (Elam-Evans et al., 2014; Reagan-Steiner et al., 2016; Vadaparampil et al., 2011; Vadaparampil et al., 2014). The delay in vaccine initiation may reduce vaccine effectiveness as well as the likelihood of series completion. Although I cannot assign causality to variables in my study, I will consider age independently, as controlling for this variable would obscure the demonstrated differences in physician recommendation.

Table 7

HPV Vaccine Coverage (*1 dose) among Females, by Age at NIS-Teen Interview*

Year	13	14	15	16	17	All Ages
2013	50.6%	55.1%	58.8%	60.0%	62.3%	57.3%
2015	56.4%	61.2%	62.7%	63.0%	70.6%	62.8%

Note. Adapted from Elam-Evans et al. (2014; 2013 data) and Reagan-Steiner et al. (2016; 2015 data). ≥1 dose indicates HPV vaccine initiation. 2014 data by age not provided; total all females ≥1 dose in 2014 was 60% (Reagan-Steiner et al., 2016).

As noted in the discussion above, physicians have been reported to express discomfort discussing sex and sexuality, especially as parents and physicians assume adolescents are not sexually active at such an early age, and in the first few years of the vaccine's availability reportedly had concerns that the vaccine may encourage sexual behavior (Vadaparampil et al., 2016). However, consistent, replicated quantitative, qualitative, longitudinal, and single time point studies using data from schools and universities, population-based datasets, and medical and insurance databases in countries around the world have shown that there is no evidence of risky sexual behavior (such as decreased contraceptive use), age of sexual debut, number of partners, or increased STI diagnoses after HPV vaccination (Hansen et al., 2014; Kasting, Shapiro, Rosberger, Kahn, & Zimet, 2016; Madhivanan et al., 2016; Mullins et al., 2016; Smith, Kaufman, Strumpf, & Levesque, 2015). Of note, many researchers observed an increase in protective behaviors when engaging in sexual activity after HPV vaccination, although to date, there have not been studies published addressing the drivers behind this observation

(Mullins et al., 2016). Based on the preponderance of evidence, I will not consider concern about increased sexual behavior as a driver of vaccine recommendation hesitation.

Given the reported importance of physician recommendation and the high level of intent to vaccinate among racial and ethnic minority populations, the inconsistent rate of physician recommendation in these populations should be of great concern to public health practitioners and physicians (Jeudin et al., 2014; Kepka et al., 2015; Perkins, 2016; Rahman et al., 2015; Ylitalo et al., 2013). I will test physician recommendation as a dependent variable in relation to social vulnerability (pending an appropriate sample size). By doing so, I may provide researchers with knowledge on potential determinants of recommendation trends as well as confirm relationships with HPV vaccination.

Message. Researchers have observed in recent years that the who and what in the context of a recommendation plays a large role in vaccine uptake, in addition to whether a recommendation is given (Caskey, Andes, & Walton, 2016; Darden & Jacobson, 2014; Ford et al., 2016; Gilkey et al., 2016; Gilkey & McRee, 2016; Moss, Gilkey, Rimer, & Brewer, 2016; Perkins, 2016; Shay et al., 2016).

Tdap and MCV vaccines, launched within the same year as HPV, are at or above herd immunity levels and Healthy People 2020 goals (see Table 1) (Moss et al., 2016). Darden and Jacobson (2014), Moss et al. (2016) and others have found that rather than presenting the HPV vaccine as routine and required, some physicians presented the HPV vaccine separately from other required adolescent vaccines, and reportedly used language encouraging parents to question the need for the vaccine (Caskey et al., 2016; Gilkey &

McRee, 2016; Perkins, 2016). This approach, the authors suggested, conveyed a sense of physician ambiguity about the vaccine, and framed the vaccine as optional rather than routine or required–creating an environment in which some parents delayed or refused vaccination. For example, Shay et al. (2016) observed that Hispanics and Non-Hispanic Blacks were more resistant to vaccination when the physician used a participatory style for the HPV vaccine, encouraging questions, versus those whose physicians used a presumptive style. These observations may in part explain why initiation and completion are not the same within or across racial and ethnic and socioeconomic subgroups, and I will include these considerations in my interpretation of this study's findings.

Health Policy and Professional Guidelines

Medical organization guidelines tend to reflect best evidence-based practice for health care providers, but in most instances, lack the compulsion of policy; health care policies may not reflect the latest scientific evidence, and may be weakened by broad language or provisions (Camargo & Grant, 2015; Descourouez & Hayney, 2013; Omer, Richards, Ward, & Bednarczyk, 2012). Without clear, specific guidelines and policies, health care providers may interpret or implement language differently and not adopt best practices for their patients (Camargo & Grant, 2015). Both guidelines and policy are developed using scientific data, and some guidelines dictate clinical practice. For example, guidelines published by the National Comprehensive Cancer Network are typically used to update treatment algorithms and determine insurance coverage for oncology drugs (NCCN, 2017). I will briefly discuss guidelines for HPV vaccination to provide context into professional pressure for physicians regarding vaccination.

Guidelines. Hswen et al. (2017) and others have shown that nearly half of family physicians and pediatricians surveyed have cited professional organizations as their preferred source of information. Researchers also found that surveyed physicians who reportedly perceived such organizations as influential were more likely to recommend the HPV vaccine to patients (Bynum, Malo, Lee, Guiliano, & Vadaparampil, 2011; Gilkey & McRee, 2016; Scherr, Augusto, Ali, Malo, & Vadaparampil, 2016). As outlined by Saslow et al. (2016) and others, a number of professional organizations support ACIP's guidelines on strong, consistent recommendations for the HPV vaccine and ask their members to follow these guidelines (Bailey et al., 2016; IPVS, 2016; Kulczycki et al., 2016):

- American Academy of Family Physicians
- American Academy of Pediatrics
- American Cancer Society
- American College of Obstetrics and Gynecology
- American College of Physicians
- American Dental Association
- American Head and Neck Society
- American Nurses Association
- American Pharmacists Association
- American Society of Clinical Oncology
- Association of Immunization Managers
- International Papillomavirus Society

- Society of Adolescent Medicine
- Society of Gynecologic Oncology

Physician practices do not always align with professional guidelines, however. For example, Kulczycki et al. (2016) observed that many family physicians and pediatricians do not follow evidence-based recommendations regarding HPV vaccination, particularly among adolescents 11 years to 12 years old. Using the same American Medical Association database, Malo, Perkins, Lee, and Vadaparampil (2016a) showed that some family physicians, pediatricians, and obstetrician/gynecologists use HPV and Pap test results as a pre-vaccination assessment for eligibility, contrary to evidence-based guidelines. These findings suggest that despite expert recommendations, physicians only moderately adhere to HPV vaccine guidelines (Malo et al., 2016a). While guidelines can and do play a role in daily practice decisions, they may not have the same power to compel physician behavior as policies.

In addition to the lack of full adherence to guidelines, Vadaparampil et al. (2016) and many others have demonstrated that a majority of physicians do not use tools developed by national organizations and agencies such as the CDC to facilitate adoption of best practices (Askelson et al., 2016; Berkowitz, Nair, & Saraiya, 2016; Roland, Benard, Greek, Hawkins, & Saraiya, 2014; Scherr et al., 2016). For example, Askelson et al. (2016) and others have described the numerous evidence-based strategies for health care providers published by the CDC and Guide to Community Preventive Service to improve vaccination coverage (Dempsey et al., 2015; Community Preventive Services Task Force, 2015):

- Implementation of an Immunization Information System for state-wide access to patient records
- Parent reminders and recalls when immunizations and well-child visits for 11 to 12 year olds are due or overdue
- Provider reminders and recalls in electronic or paper records when immunizations are due or overdue
- Standing orders for non-physician health care providers – pharmacists, obstetrician/gynecologists, nurses, medical assistants – to provide education and vaccination services
- Participation in Vaccines for Children program to reduce cost of the HPV vaccine series
- Reduce or eliminate clinic wait times for vaccination, such as instituting walk-in immunizations for second and third doses
- Partner with community organizations and services including schools as alternate immunization service locations
- Bundle the HPV vaccine with other routine, recommended adolescent vaccines

Askelson et al. (2016) reported that few clinics have reminder / recall processes in place for parents or physicians or standing orders for other health care providers to vaccinate adolescents, yet found that clinic managers most frequently cited parents forgetting to bring their adolescents in to complete the series as the biggest barrier to

HPV vaccine initiation and completion. Askelson et al. (2016) and others found that another barrier named by providers was the lack of opportunity to vaccinate adolescents, as these patients reportedly did not visit the clinic regularly (Gilkey & McRee, 2016; Kulczycki et al., 2016). However, rates for other adolescent vaccines are near or above 90% per guidelines and policies (see Table 1), suggesting that other factors beyond guidelines have a stronger influence specifically on HPV vaccination (see *HPV Vaccination and Physician Recommendation*) (Askelson et al., 2016; Gilkey & McRee, 2016; Kulczycki et al., 2016). Based on these observations, my interpretation of physician recommendation data will be applicable to HPV vaccines only, rather than immunization in general.

Policy. Public health policy is one of the most effective ways to protect population health, as evidenced by seat belt use, tobacco control, or immunizations (Calo, Gilkey, Shah, Moss, & Brewer, 2016; Hawkes, Kismödi, Larson, & Buse, 2014; Mello et al., 2013). Policy, however, is often not considered as a means to changing population health:

> Law remains an underutilized resource in public health. … Some interventions require new law, whereas others simply require stronger or more creative use of existing authority. At the same time, some laws with unintended adverse effects have not been amended, clarified, or repealed. (Mello et al., 2013, p. 1979)

Carey and Crammond (2015) and Embrett and Randall (2014) argued that policymaking does not follow a rational process, in which knowledge is transferred and policy is changed; nor does it move quickly or adopt the latest science. For example, current HPV vaccine policies do not reflect oropharyngeal cancer rates and the role of HPV in the disease, how HPV is transmitted, views of adolescents receiving the vaccine, or recent vaccine efficacy and safety data (Osazuwa-Peters, 2013; Parrella et al., 2016).

Knight, Benjamin, and Yanich (2016) and others suggested that policy cannot be separated from politics, and the political environment is especially important when considering health issues traditionally associated with individual behaviors such as smoking, obesity, or sexually transmitted infections (Abiola et al., 2013; Hawkes et al., 2014). Policymaking is a complex effort in which competing priorities, short attention spans, and capacity for action mix with evidence, expert testimony, and values of those in power (Carey & Crammond, 2015; Embrett & Randall, 2014; Knight, Benjamin, & Yanich, 2016; Lillvis, Kirkland, & Frick, 2014; Moreland-Russel et al., 2015; Speybroeck, Harper, de Savigny, & Victora, 2012). Knight et al. (2016) stated that most efforts in health policy are focused on medical solutions to health care, rather than social determinants of health and preventive measures. Carey and Crammond (2015) suggested that this may in part be due to policymakers' reported unfamiliarity with the importance of social determinants of health, and public health advocates' analogous "out of touch" perceptions of the policymaking process. HPV vaccine policy is an excellent example of this disconnect, in which policymakers have been observed to support policies not based on evidence and best practices, and public health advocates have reportedly not engaged the political process in an efficient way to promote health (Carey & Crammond, Knight et al., 2016).

States introduced and passed a number of policies after the HPV vaccine came to market, but with a few exceptions focused solely on increasing education to parents and adolescents, providing funding, and adjusting private insurance coverage for the vaccine (Brandt et al., 2016; Laugesen et al., 2014). However, education policies reportedly have had little if any return on investment; for example, Moghtaderi and Adams (2016) found that vaccination rates in states with education policies were not significantly different from states with no education policies. The authors argued that this finding may in large part be due to the lack of evidence that parents access and understand educational materials, and school districts are not required to include information about HPV in the curriculum.

In contrast to education policies, Durham et al. (2016) observed that funding and coverage policies had significantly improved HPV vaccination rates, albeit inconsistently across states. Although the United States does not have a national vaccination program, Brandt et al. (2016) stated that the federal government does fund some immunizations through the Vaccines for Children program for un- or under-insured, Medicaid-eligible, or American Indian / Alaska Native children up to 18 years old, but states have the final say on who qualifies. Of the states and jurisdictions with expanded coverage and supplemental resources from the CDC's Prevention Public Health Fund and national organizations, Durham et al. (2016) concluded that these areas had higher rates of vaccination compared with those that did not. However, given the extended latency period between exposure and HPV-associated cancer and the prevalence of interstate travel, states may not capture the true benefit of their policies (Durham et al., 2016).

School-entry mandates. Perkins et al. (2016) and others have claimed that the two most potent and polarizing policy options to influence vaccination rates are school-entry mandates and exemptions (Brandt et al., 2014; Califano, Calo, Weinberger, Gilkey, & Brewer, 2016; Calo et al., 2016). Both the state legislature and state health agency have the power to require vaccines for school entry, but the legislature must allocate funds for the logistics in implementing the mandate, and the vaccine must meet several criteria to be considered for mandated status (Calo et al., 2016; Perkins, Lin, Wallington, & Hanchate, 2016). Perkins et al. (2016) concluded that the HPV vaccine meets most criteria: ACIP recommendation; proven efficacy, safety, cost-effectiveness; reduction of transmission risk; prevention of significant morbidity and mortality related to the disease; and reasonable burdens on parents and adolescents to comply with the mandate. Perkins et al. (2016) contended that HPV vaccine does not meet the two remaining criteria: the potential administrative burden on schools and health care providers may be considered unreasonable given low vaccination rates and disjointed immunization infrastructure; and vaccine acceptability to the community and the public is not uniformly positive.

For example, researchers have found low to moderate support among parental and physicians for a school-entry mandate if religious, personal, or philosophical exemptions are not allowed (Brandt et al., 2016; Califano et al., 2016; Calo et al., 2016; Horn, Howard, Waller, & Ferris, 2010; Perkins et al., 2016; Robitz et al., 2011). If these exemptions are allowed alongside school-entry mandates, the level of support increases significantly. Calo et al. (2016) found that parents' willingness to accept a mandate increased from 21% to 57%. The authors reported that parents had several reasons for opposing a mandate, including infringement of their autonomy in making decisions for their children and the perception from physician interactions that the HPV vaccine is optional. In this study, Calo et al. (2016) observed that parents of racial and ethnic minority background and lower socioeconomic status had slightly higher approval ratings of a school entry mandate, compared with non-Hispanic White, higher socioeconomic parents. Separately, Califano et al. (2016) showed that physicians' support increased from 47% to 74%. Despite this strong support from physicians, and considering nearly 90% of pediatricians and family physicians believe delaying vaccination is risky for adolescents, Califano et al. (2016) reported that just over 70% of physicians were willing to accommodate parents' wishes in order to build trust.

Although several states have attempted to pass legislation requiring the HPV vaccine for school entry, currently the HPV vaccine is mandated only in two states and one jurisdiction (Barraza, Weidenaar, Campos-Outcalt, & Yang, 2016; Brandt et al., 2016; Lemons, 2016; Perkins et al., 2016). As of 2008, girls in Virginia must initiate the vaccine prior to entering sixth grade; as of 2009, girls and boys in the District of Columbia must initiate the vaccine at 11 years old and prior to entering the sixth grade; and as of 2015, girls and boys in Rhode Island must initiate the first dose prior to entering seventh grade and complete the series prior to entering ninth grade (Barraza et al., 2016; Brandt et al., 2016; Calo et al., 2016; Lemons, 2016; Perkins et al., 2016). Virginia and D.C. passed the mandate through the legislative process, while Rhode Island used the Department of Health's authority to require vaccination for school entry (Barraza et al., 2016). Since October 1, 2017, only New York has proposed legislation in the 2017 session requiring HPV vaccination for all children entering seventh grade (S.B. 132, A.B. 933, 2017). Although outside the scope of this research, it will be important for future scholars to consider the political context in which physicians must operate in each of the select local areas in the results discussion.

HPV Vaccination: Theoretical Considerations

Glanz et al. (2015) noted that theory and practice are not diametrically opposed, but inform each other and provide a foundation for transforming data and experience into evidence-based interventions. For particularly complex issues, such as HPV vaccination, theories and practices must reflect the milieu in which vaccination decisions are made (Ferrer et al., 2015). However, as Ferrer et al. (2015) outlined in a systemic review, the most frequently cited theories in HPV literature are individual, rational models such as the theory of planned behavior and the health belief model. The authors reported that fewer than half of reviewed interventions based on individual-level theory were effective or sustainable, with determinants varying widely across populations. Ferrer et al. (2015) argued that these interventions could not account for interactions among individuals and their environments, or for scenarios in which people do not make decisions and behave in a rational manner. The following two models, fundamental cause theory and behavioral economics, address each of these shortcomings in the individual, rational models. I will use these theories as the lens through which I will interpret the data, focusing on the importance of considering systemic variables and the irrational players that make up these systems.

Fundamental cause theory. Link and Phelan (1995) developed the fundamental cause theory during the time period in which epidemiologists could not explain why elimination of risk factors for certain diseases did not reduce inequalities in morbidity and mortality, and in some instances, gave rise to new risk factors. In the first iteration of the FCT, Link and Phelan (1995) observed that a relationship between socioeconomic status and mortality persists in modifiable risk factors and disease outcomes despite, and sometimes as a result of, advances in knowledge and treatment (Phelan et al., 2010). Clouston, Rubin, Phelan, and Link (2016) maintained that in the two decades since its introduction, FCT has been tested and refined, with its constructs applied across conditions including HIV, cardiovascular disease, a number of cancers, suicides, kidney infections, diabetes, multiple sclerosis, tuberculosis, polio, and others.

Øversveen, Rydland, Bambra, and Eikemo (2017) contended that in developing the FCT, Link and Phelan introduced the importance of fundamental or root causes, or the “risk of being at risk,” focusing on upstream social determinants and the complex interactions leading to health outcomes. Phelan et al. (2010) defined a cause as fundamental if it gives rise to multiple diseases, affects disease outcomes through multiple risk factors, involves access to flexible resources, and persists over time. As reviewed in Mackenbach (2017) and others, access to flexible resources is a unique and key component of the FCT, and encompasses a person’s access to money, knowledge, power, prestige, and social connections (Goldberg, 2014; Polonijo & Carpiano, 2013). Clouston et al. (2016) and Mackenbach (2017) argued that if access to such resources is unequal, the benefits of any innovation in technology or knowledge will be distributed unequally; thus, the capacity to avoid risks or minimize consequences of a disease will be unequal and give rise to social inequalities in health and health outcomes. Polonijo and Carpiano (2013) maintained that the HPV vaccine may act as an empirical test of the FCT, as the fundamental causes behind HPV-related morbidity and mortality give rise to other diseases, HPV vaccines are the result of an innovation in cancer knowledge, the vaccines themselves are innovations in preventive care, and significant disparities exist in HPV vaccine uptake.

Two well-researched fundamental causes of HPV vaccine rates and other diseases are low socioeconomic and racial and ethnic minority status (Goldberg, 2014; Phelan et al., 2010). When an innovation or improvement occurs, a new *mechanism* appears in which an individual's health outcome will change disproportionately with their income level or racial and ethnic minority status (Øversveen et al., 2017; Polonijo & Carpiano, 2013). Øversveen et al. (2017) stated that as long as the structural and social determinants of a population remain stable, inequalities in health based on root causes will persist. Similarly, Goldberg (2014) noted that targeting only proximal risk factors, as in the risk-reduction model practiced in medicine, will be ineffective in addressing health disparities as the risk factors arise from the underlying structural and social determinants of disease.

For example, during infectious diseases outbreaks in the mid-1800s, wealthy Americans had resources to flee their cities or prevent entry of infected people into their neighborhoods; as public health efforts in the 1900s improved structural determinants such as sanitation and hygiene standards – indoor plumbing, chlorination of drinking water, animal and pest control, universal vaccination, and improved housing conditions –

the socioeconomic gradient disappeared and many of these diseases were eradicated (CDC, 1999; Phelan et al., 2010). Expanding on these ideas, Epstein (2017) claimed that these innovations in public health played a significant role in reducing inequalities long before modern medical interventions.

In contrast, Viens et al. (2016) and others asserted that despite the introduction of the innovative Pap screening test for cervical cancer nearly 70 years ago, disparities in cervical cancer screening, incidence, and mortality by SES and racial and ethnic minority status persist today (Malagón, Drolet, Boily, Laprise, & Brisson, 2015; Phelan et al., 2010; Polonijo & Carpiano, 2013). Efforts to increase access to resources such as health insurance and screening programs for cervical cancer, which is highly preventable, have not mitigated disparities in outcomes – even in countries such as England and Canada, where universal safety nets are designed to reduce such inequalities (Phelan et al., 2010; Polonijo & Carpiano, 2013). Based on these examples, I agree with Polonijo and Carpiano (2013) that HPV vaccination could be an appropriate test of FCT, and will discuss this idea in the context of future directions based on my findings.

For example, Phelan et al. (2010) predicted that, as alluded to in the FCT, disparities will persist and new mechanisms will arise as individual risk factors for cervical cancer change if the underlying structural population issues are not addressed. An effective intervention such as a vaccine to prevent cervical cancer may reduce or eliminate disparities in the population if administered universally, but researchers have shown a strong gradient for physician recommendation of vaccination along racial and ethnic minority and socioeconomic status lines (Jokinen-Gordon, 2014; Polonijo &

Carpiano, 2013). Therefore, through the lens of the FCT, disparities in HPV-associated cancer rates will persist as long as researchers focus on individual behaviors or isolated risk factors, such as cost of the vaccine (Polonijo & Carpiano, 2013). In my study, I will test relationships among variables on multiple levels in order to provide potential targets for future fundamental cause research in HPV vaccination.

While the assumptions of the FCT are generally borne out in studies, Øversveen et al. (2017) and others have noted some limitations of the theory's application to practice, including the temporal nature of rising and declining *mechanisms* of inequalities; the difficulty in conducting systemic research; and the definition of variables and at-risk populations (Clouston et al., 2016; Goldberg et al., 2014; Mackenbach, 2017; Phelan et al., 2010).

For example, Clouston et al. (2016) used FCT to link the control of preventable disease with development of social inequalities, suggesting that the time period in which inequality mechanisms rise, stabilize, and decline may vary. The authors proposed adding a four-stage temporal component to the FCT: (a) *natural mortality* of a disease, prior to any knowledge or capacity to control disease; (b) *increasing inequalities*, in which innovations and resources are diffused unequally; (c) *reducing inequalities*, perhaps through increased access to health knowledge and resources; and (d) *reduced mortality*, in which prevention and treatment resources are universally available. Clouston et al. (2016) contended that the time spent in each stage will vary by disease type, risk factors, the innovation, and the underlying social, economic, and political structures. In the case of HPV infection and vaccination, the underlying mechanisms are multifaceted, and thus the time to equitable vaccine uptake and reduced mortality may be longer than other infectious disease scenarios (Clouston et al., 2016). Any reductions in mortality due to HPV vaccination will not be detected for decades, given the long latency period between infection and cancer, so I will focus my analysis only on the factors related to HPV vaccine initiation and completion.

Regarding the difficulty in conducting systemic research, Mackenbach (2017) and others suggested that upstream interventions may result in more equitable outcomes than individual downstream interventions by changing underlying power structures that contribute to inequity, but are less feasible to conduct and may face stronger opposition by those in power (Golden, McLeroy, Green, Earp, & Lieberman, 2015). Mackenbach (2017) and Golden et al. (2015) stated that most research conducted, even on organizational or political levels, is done with individual behavior change as an end goal; while less efficient and sustainable, individual and interpersonal variables and relationships tend to be more easily defined and the results more immediate and tangible.

For example, socioeconomic status is a multi-faceted, dynamic measure that would require changes to education, employment, and wage; nested within each of these metrics are issues surrounding transportation, nutrition, perinatal care, childhood development, safe housing, and many more ancillary variables that contribute to the capacity of an individual to learn, work, and earn a living wage (Joshua, Zwi, Moran, & White, 2015; Mechanic & Tanner, 2007). Researchers may have limited ability to identify the true causes of persistent unequal distribution of resources, but by using known and suspected fundamental cause variables, they may be able to test potential relationships on many levels (Øversveen et al., 2017). How these variables are defined, however, can change the statistical analyses and interpretation of findings (Ratnapradipa, McDaniel, & Barger, 2017; Willis & Fitton, 2016). Given the importance of social determinants of health in the FCT and inequalities in HPV vaccine uptake specifically, and my use of social vulnerability as a variable in this study, a brief discussion of how social vulnerability is defined is warranted.

Social vulnerability. Ratnapradipa et al. (2017) argued that determinants of vulnerability and exposure to risk factors are multifaceted and evolving, and direct measurement may not be possible. The Institute of Medicine and the National Research Council (2011) claimed that there is no universal consensus on how to determine vulnerability; for convenience, most assessments use symptoms of vulnerability such as poverty or low educational attainment as proxy measures of risk factors or outcomes (Joshua et al., 2015). Burnell (2012) suggested that exposure to a risk factor does not always equate to vulnerability; for example, while the entire population may have a similar likelihood of exposure to an infectious agent such as HPV, not everyone will share the same burden of morbidity and mortality. Researchers have found that relationships exist between social vulnerability and incidence of Lyme's Disease, erectile dysfunction treatment, physician recommendation in prostate cancer, diabetes, acceptance of an oral cholera vaccine, and HIV treatment outcomes (An & Xiang, 2015; Grabovschi, Loignon, & Fortin, 2013; Ratnapradipa et al., 2017; Socio-economic Inequalities and HIV Working Group, 2017; Sundaram et al., 2016). If not addressed, the inequities in systemic structures governing a hierarchy of human value and differential resource allocation will persist horizontally and vertically across generations (Quiroga, Medina, & Glick, 2014).

At a high level, social vulnerability may be defined as the differential capacity of an individual or population to anticipate, cope with, resist, and recover from the impact of cumulative external stressors (Gallagher et al., 2016; Joshua et al., 2015). Stressors, such as determinants in the built, natural, social, economic, and political environments, may be difficult to measure, but if identified could be mitigated to maximize the opportunity for healthy choices (Ratnapradipa et al., 2017; Willis & Fitton, 2016). The bulk of vulnerability literature focuses on mapping vulnerability predictors to protect against natural and human-made disasters, but a tool developed by the Agency for Toxic Substances and Disease Registry (ATSDR) has the potential for linking social vulnerability with HPV vaccination uptake and providing context to the predictors of vaccination in the NIS-Teen survey (Gay, Robb, Benson, & White, 2016; Juster et al., 2016). I will be the first, to my knowledge, to test the relationships between scores from the Social Vulnerability Index and HPV vaccine uptake. By using this tool, I may identify new variables for future researchers to consider in systemic interventions.

Social Vulnerability Index. Flanagan et al. (2011) stated that until the mid-2000s, disaster management mapping tools focused exclusively on natural and built environment hazards at the local and population level. In response to a growing recognition of the importance of social vulnerability in outcomes and the need to identify particularly vulnerable communities for disaster planning, ATSDR collaborated with the CDC and National Center for Environmental Health to create the Social Vulnerability Index (SVI)

(ATSDR, 2014; Flanagan et al., 2011). The SVI draws from U.S. Census data and ranks each census tract or county on 15 factors contributing to social vulnerability; each tract or county is then given a vulnerability score on four different themes (encompassing the 15 social factors) and an overall vulnerability score (see Section 2 for more details) (ATSDR, 2014). The tool was constructed to support resource allocation before, during, and after a disaster, but a small number of researchers have recognized the utility in linking compounded vulnerability factors and disparities in health care (An & Xiang, 2015; Grabovschi et al., 2013). To date, researchers have used the tool to assess the level of vulnerability with physical fitness and obesity (An & Xiang, 2015; Gay et al., 2016).

Individuals and populations living in areas of social vulnerability experience economic, physical, political, and social barriers to understanding and making healthy choices, yet few studies consider multiple barriers simultaneously (An & Xiang, 2015; Gay et al., 2016; Grabovschi et al., 2013). Many of these same barriers exist for HPV vaccine uptake, such as low socioeconomic and racial and ethnic minority status (see Table 8).

Table 8

Correlating Social Vulnerability Index Themes and Predictors of HPV Vaccine Uptake

SVI Themes [a]	Example SVI Variables [a]	Association with HPV Vaccination [b]
Minority Status and Language	Minority Race / Ethnicity Speak English "Less than Well"	Significant and persistent relationship among racial and ethnic minority status, physician recommendation, language, and HPV vaccine uptake

Household Composition and Disability	Aged 17 or Younger Single-Parent Households	Significant relationship between age of patient and physician recommendation and marital status of parent and vaccine uptake
Socioeconomic Status	Below Poverty Unemployed Income No High School Diploma	Significant and persistent relationship among socioeconomic status variables, HPV vaccine uptake, and physician recommendation
Housing and Transportation	Multi-Unit Structures No Vehicle	Significant difference in HPV vaccine uptake by urban versus rural location, as well as within urban centers

Note. Adapted from Gay et al., 2016. [a] ATSDR, 2017. [b] Reagan-Steiner et al., 2016.

The SVI is a useful tool to indicate available flexible resources and understand community-level social factors that influence health and health decisions, such as HPV vaccination. No researchers testing the relationship between social vulnerability and health to date have connected a theoretical perspective to their published research, and to my knowledge only five articles to date have examined sociodemographic and geographic variation in HPV vaccination (one in a 7-county region, one in the Intermountain West region of the United States., and three in the United States overall) (Bodson et al., 2017; Grabovschi et al., 2013; Henry et al., 2017; Monnat, Rhubart, & Wallington, 2016; Pruitt & Schootman, 2010; Rutten et al., 2017). A small number of researchers also have recently published articles looking at geographic factors and HPV vaccination (Henry et al., 2016; Tsui et al., 2013). Given the FCT's emphasis on flexible resources, which may be limited in areas of vulnerability, and the need to identify fundamental causes to best mitigate disparities in health outcomes, the use of the SVI in this research will add context to the quantitative data in the NIS-Teen database.

FCT, SVI, and HPV. Few studies have tested the association between multiple social variables and predictors of HPV vaccine (Jokinen-Gordon, 2014). By testing relationships among known fundamental causes of disease such as socioeconomic status and racial and ethnic background, as well as other influences specific to HPV vaccine such physician recommendation, this research may help researchers design more comprehensive interventions that reduce disparities in vaccine uptake (Schmeler & Sturgis, 2016).

Dovidio and Fiske (2012) asserted that even with access to flexible resources or professional commitment to optimizing health, human decision-making is not always rational (Phelan et al., 2010; Polonijo & Carpiano, 2013). Mackenbach (2017) and others contended that researchers should consider these implicit or cognitive biases that may result in irrational behaviors when assessing factors influencing the unequal distribution of resources in a free market economy (Arrow, 1963; Dovidio & Fiske, 2012). I will use a *theory of action* describing these behaviors; behavioral economics will complement FCT's *theory of the problem* in identifying why health disparities exist and how interventions should be designed (Glanz et al., 2015). Although testing specific components of behavioral economics and HPV vaccine rates is not feasible for this study, the theory has been linked to physician decision-making and could provide important context for interpreting physician recommendation.

Behavioral economics. Emanuel et al. (2016), Hoff and Stiglitz (2016), and others suggested that standard economic theory and many public health promotion programs rely on the assumptions that, given sufficient information about specific choice sets and motivation to act, individuals will make rational decisions to improve their circumstances out of self-interest. However, Hansen, Skov, and Skov (2016) and others argued that individuals often include seemingly irrelevant factors in their decision-making processes and are predictably unpredictable, whether making an economic decision such as buying a new or used car, or a health decision such as going to the gym or sitting on the couch (Dovidio & Fiske, 2012; Hoff & Stiglitz, 2016). As MacLeod (2016) noted, "rational choice *per se* is not required to explain why humans are able to perform at such a high level in a wide variety of tasks, while at the same time capable of making some really dumb mistakes" (p. 24).

In addition, behavior change is more than just increasing or decreasing frequency; individuals may adopt or reverse behaviors at different rates or need more help than others to stabilize behavior change (Bickel et al., 2016; Bickel, Quisenberry, & Snider, 2016). Frank (2004) and Hansen et al. (2016) asserted that, given the potential for irrational decision-making at different rates, health policies and interventions created using rational, linear models fall short in bridging the gaps between preferences, decision-making, and behavior change. These observations are particularly important when interpreting physician behavior, as physicians are expected to be sufficiently informed and motivated to act in the best interests of the patient. As described in the *HPV Vaccination and Physician Recommendation* section, however, physicians may unconsciously and unintentionally act in their own self-interests (Mohammed et al, 2016). Understanding the key processes in behavioral economics may help provide context to any differences in physician recommendation in this study.

Social determinants play a role in physician and patient decisions about health, whether through access to flexible resources or influence on cognitive development, preferences, and perceptions (Hansen et al., 2016; Hoff & Stiglitz, 2016). Expanding on this observation, Alm and Sheffrin (2017) suggested that the way a choice is framed, the individual's cognitive capacity, perceptions of the costs, self-control, social norms, and the current environment all play a role in the decision process. Researchers designing interventions and advocating for policies, therefore, should take cognitive processes, social determinants, and structural factors into account. The theory of behavioral economics provides researchers with a conceptual approach to understanding behavioral decision-making in light of these important influencers, potentially improving the efficiency and efficacy of interventions and policies (Alm & Sheffrin, 2017).

Behavioral economics (a) allows researchers the opportunity to measure behavior change beyond simply increasing or decreasing in frequency; (b) highlights the application of learnings across diseases and contexts, much like a fundamental cause; (c) uses technology to maximize cost-effectiveness, generalizability, and efficacy of interventions; and (d), integrates economic, psychological, and social frameworks to inform more real-world programs and policies (Alm & Sheffrin, 2017; Bickel et al., 2016; Gennetian, Darling, & Aber, 2016). Behavioral economics is both a complement and counterpoint to the FCT; the two theories informing this study are used to highlight the importance of social determinants and the need to address behavior on multiple levels (Link & Phelan, 1995; Bickel et al., 2016). However, the FCT is often used to identify *bottom-up* causes of disparities, while behavioral economics is often used to identify *top-*

down cognitive processes in the context of bottom-up causes and promote behavior change (Link & Phelan, 1995; Bickel et al., 2016). A small number of researchers have considered HPV vaccination using the FCT or behavioral economics, but no one to my knowledge has considered the two theories together.

Arrow (1963) and Frank (2004) argued that nowhere are these advantages of using behavioral economics more closely linked than with physician behavior. Physicians may unconsciously and repeatedly make suboptimal choices in the face of clinical uncertainty regarding patient response and outcomes (Bickel et al., 2016; Frank, 2004). Researchers have found that physicians are creatures of habit and may unconsciously work through a number of cognitive processes to make health care decisions (Arrow, 1963; Bickel et al., 2016; Frank, 2004). Saposnik, Redelmeier, Ruff, and Tobler (2016) observed that few studies on cognitive processes that influence physician decisions in health care exist, despite the strong link between physician recommendation and HPV vaccination. I argue that the dearth of published research on this topic is a missed opportunity for researchers designing physician-targeted interventions, and will note in my discussion of the results how reporting quantifiable data on physician recommendation has limited use for researchers without the context of why physicians vary in their recommendations. While collecting these qualitative data is outside the scope of my research, I will provide a brief description of key processes cited in behavioral economics for context in this later discussion.

Heuristics. Given time constraints and clinical uncertainty, physicians reportedly often rely on heuristics, or rules of thumb to make decisions (Frank, 2004; Shuval et al., 2017). The *availability heuristic* is reliance on a personal memory, a story from a colleague, or discussion at a local meeting – in other words, a physician may extrapolate the probability of a singular outcome or small number of events to the population, as a personal story is more top-of-mind than representative data (Blumenthal-Barby & Krieger, 2015). Frank (2004) proposed that this heuristic is in large part responsible as one of the two core questions of health economics: what causes persistent geographic variation in treatment patterns. The author reported that physicians, whether consciously or not, follow the advice of trusted colleagues, even at the expense of using newer or evidence-based practices, as these sources are readily available and more personal. The availability heuristic is a critical process to consider when assessing physician recommendation patterns and designing programs or policies to influence HPV vaccine recommendation, as it highlights the importance of intervening at the local level (Blumenthal-Barby & Krieger, 2015; Saini et al., 2017).

As first mentioned in Tversky and Kahneman's (1975) seminal article on heuristics and biases, the *stereotype heuristic* is a reliance on a physician's perception of how closely the patient resembles another patient based on personal attributes. When the resemblance is perceived to be high, then the probability that one patient's outcomes will be similar to another also is perceived to be high (Blumenthal-Barby & Krieger, 2015; Frank, 2004; Tversky & Kahneman, 1975). For example, if a physician believes that White female adolescents are less likely to engage in sexual activity at a younger age and her parents are more likely to challenge the HPV vaccination, the physician will likely stereotype the next young White female adolescent patient and delay recommendation.

The limited ability of physicians to accurately assess patient and parental needs and wishes already has been discussed, and can lead to biases in care that unintentionally influence patient outcomes (Frank, 2004). Thus, heuristics may play a role in influencing physician recommendation, particularly if this differs by geography. I will test physician recommendation by select local areas listed in NIS-Teen.

Biases. Cognitive bias, or a systematic error in decision-making informed by heuristics, leads to the second core question of health economics: what accounts for disparities in health care (Blumenthal-Barby & Krieger, 2015; Frank, 2004). Biases are not all negative, nor are they all explicit; rather, implicit (unconscious) biases often influence physician behavior and impact recommendations and communication with patients (Dovidio & Fiske, 2012). In a large, critical review of studies on heuristics and biases among health care providers, Blumenthal-Barby and Krieger (2016) found confirmation of biases in 80% of the studies (Blumenthal-Barby & Krieger, 2015).

Blumenthal-Barby and Krieger (2015) and Hoff and Stiglitz (2016) argued that physicians may allow their beliefs and expectations to affect interpretation of a patient, data, or patient outcomes (*confirmatory bias*), and reportedly recommended the current practice or default option (*default or status quo bias*) rather than change prescribing habits. The authors also found that when considering a recommendation or a particular course of therapy for a patient, physicians reportedly focused on the losses rather than the gains of the action (*loss / gain framing bias*), under- or over-estimated the future impact of an action (*impact bias*), or viewed the harm from an action as more damaging than the harm of doing nothing at all (*omission bias*).

Finally, Blumenthal-Barby and Krieger (2015) showed that family physicians reportedly had a greater susceptibility to biases and heuristics (91%), followed by obstetricians and gynecologists (85%). Again, while not all biases and heuristics are explicit or negative, they significantly influence a physician's ability to process information and estimate probabilities, which are central to the practice of health care (Dovidio & Fiske, 2012). While data on biases and heuristics are not collected for NIS-Teen and are thus outside the scope of my analysis, I will consider these factors when discussing my findings of physician recommendation.

Discounting. Delayed or hyperbolic discounting is a well-researched process in economics (Bickel et al., 2016). In simple terms, the value of a reward received at a future point is perceived to be worth less than the value of a reward received immediately – individuals discount the reward if it is delayed (Bickel & Marsch, 2001; Bickel et al., 2016; Emanuel et al., 2016; Murphy & Dennhardt, 2016). While delayed discounting is accounted for in traditional economics, Bickel et al. (2016) suggested that behavioral economics expands the concept and considers that individuals may reverse their preference for immediate versus future rewards. Supporting this idea, Emanuel et al. (2016) and others showed that not all individuals discount delayed rewards to the same degree, with some having greater self-control and a more balanced consideration of future benefits than others (Murphy & Dennhardt, 2016; Shuval et al., 2017).

Although the most frequently reported discounting studies are with patients and use financial incentives for smoking cessation, weight loss, or sobriety, delayed discounting may be an important process for physicians as well (Bickel et al., 2016;

Buttenheim et al., 2016). For example, Siegler, Kable, and Chatterjee (2016) argued that the benefits of prescribing opioids for patients in pain or antibiotics to a child with an illness are more immediate on many levels, while the risks of not adhering to best practices and potentially contributing to opioid dependence or antibiotic resistance are delayed. In HPV specifically, the benefit of not recommending the vaccine to parents (or giving a weak recommendation) may allay the physician's immediate discomfort of discussing sex or fear of upsetting the parents, while the risk that the adolescent will not be vaccinated or develop a disease is delayed. Given the responsibility costs of the physician's decision for the patient's health and wellbeing, a physician may err on the side of caution as a near-term reward (Frank, 2004). These observations may play a role in researchers' findings that physicians reportedly discuss the HPV vaccine more often with older adolescents, rather than with 11 and 12-year-olds as advised by ACIP. I will consider these factors when discussing my findings of physician recommendation by age.

Nudging. Bickel et al. (2016) and Hansen et al. (2016) concluded that nudging is a cost-effective population-level strategy, as it makes use of framing and default bias processes to *nudge* individuals toward optimal choices and minimize some of the irrational factors influencing decision-making. The authors suggested that behavior patterns influenced by heuristics and biases could be shifted by promoting salient, endorsed choices, creating a *choice architecture* in which the easiest course of action is the optimal one. As with discounting, nudging has been tested in a variety of health settings with patients, such as placing fruit and vegetables at eye level in grocery stores, providing graphic warning images on cigarette packages, changing organ donation on driver's license applications to opt-out, smaller plates in restaurants, or showcasing a choice that a majority of the population makes to leverage social norms (Bickel et al., 2016; Hansen et al. 2016).

With the increased use of technology in daily medical practice and knowledge of behavioral economics processes, however, nudges may be a useful tool in shifting physician behavior. For example, a small number of researchers have demonstrated that automatic prompts during a patient visit increased the number of conversations physicians had with patients about a particular health issue; setting specific treatment algorithms or diagnostics as the default in automated systems reduced unnecessary ordering and spending; and bundling adolescent vaccines that were often ordered together decreased the focus on any one component, such as HPV (Bickel et al., 2016; Olson, Hollenbeak, Donaldson, Abendroth, & Castellani, 2015; Patel et al., 2016). Such nudges were particularly effective when physicians were given immediate and public feedback, such as sharing vaccination rates with peers or the public (MacLeod, 2016).

Nudging may be particularly useful in HPV vaccination, as the strategy inherently avoids restricting freedom of choice (Hansen et al., 2016). Mariner (2014) asserted that the fundamental argument against vaccine mandates is the tension between government authority to protect the public from harm and parental rights to decide for their children. As outlined in Mariner (2014) and Hansen et al. (2016), nudging does not take away or ban choices, impose mandatory obligations, regulate a specific individual's behavior, or rely on rational behavior. Rather, the modified choice architecture targets cognitive biases to protect the public from harm and makes the optimal choice easier to make

(Mariner, 2014). By designing and evaluating policies that reduce cognitive errors that influence health outcomes, rather than policies that restrict individual freedom of choice, nudging may be a more palatable strategy to address disparities in health (Frank, 2004). These observations on nudging will provided context in my interpretation of the data.

Definitions

The independent and dependent variables and covariates are defined as follows.

Ethnic and racial minority status. A categorical independent variable describing the race/ethnicity of the teen. Options are Hispanic, Non-Hispanic White Only, Non-Hispanic Black Only, Non-Hispanic Other + Multiple Races, and Other + Multiple Race (a recode of NHO + Multiple Races) (CDC et al., 2015; 2016).

HPV vaccination completion. A nominal dependent variable indicating the teen has received three or more doses of the HPV vaccine among those who have initiated the series (Gilkey et al., 2016). Some teens may have received more than three recommended doses; a secondary calculation by the CDC refers to a teen who, among those who received one or more HPV dose and over a minimum of 24 weeks between the first dose and the interview date, received a total of three or more doses (Reagan-Steiner et al., 2015). However, using the Gilkey et al. (2016) measure allows for capturing teens who continue the vaccine series, albeit not in the recommended time-frame.

HPV vaccination initiation. A nominal dependent variable indicating the teen has received one or more doses of the HPV vaccine (Reagan-Steiner et al., 2015).

Physician recommendation. A categorical dependent variable (research question 4) indicating whether the person participating in the survey recalls receiving a recommendation from a physician or health care professional for the teen to receive the HPV vaccination (CDC et al., 2015; 2016).

Selected local areas. Seven specific estimation areas highlighted in the 2015 NIS-Teen dataset (Bexar County, TX; Chicago, IL; El Paso County, TX; Hidalgo County, TX; Houston, TX; New York City; and Philadelphia County, PA) (CDC et al., 2015; 2016). As Washington, D.C. is sampled separately, I will include D.C. as one of the select local areas. These local areas receive federal Section 317 funds to purchase vaccines, particularly for priority populations, are sampled and analyzed separately (Reagan-Steiner et al., 2016). Given the demonstrated differences in HPV vaccination by geography, as well as the hypothesized relationship between social vulnerability and HPV vaccination, inclusion of local areas will add significant value to the research. In order to compare county-level data from the Social Vulnerability Index (described below) and the NIS-Teen database, I will include only selected local areas that are stand-alone counties from the 2014 NIS-Teen in the SVI portion of my analysis: Bexar County, El Paso County, Philadelphia, and Washington, D.C. (Hidalgo County was added in 2015.)

Social vulnerability. As defined by the CDC and Agency for Toxic Substances and Disease Registry [ATSDR], social vulnerability refers to the extent to which the health of communities is likely to be affected by socioeconomic and demographic factors (CDC & ATSDR, 2017). Vulnerable populations are those who are disproportionately burdened by a combination of factors, are less likely to be able to cope with stressors, and whose needs are inadequately accounted for in resource allocation plans (Flanagan et al., 2011). The CDC and ATSDR's Social Vulnerability Index ranks each census tract or county on overall vulnerability, comprised of four themes and 15 social factors affecting health: socioeconomic status (below poverty, unemployed, income, no high school diploma); household composition and disability (aged 65 and older, aged 17 or younger, civilian with a disability, single-parent households); minority status and language (minority, speak English less than well); and housing and transportation (multi-unit structures, mobile homes, crowding, no vehicle, group quarters) (CDC & ATSDR, 2017).

Socioeconomic status. Categorical independent variables including income (poverty status, family income), health insurance status, and education (the current level of education of the mother) (CDC et al., 2015; 2016).

Assumptions

Multiple government agencies developed the questionnaires and provided the datasets for NIS-Teen, as well as the index and dataset for the Social Vulnerability Index. For the NIS-Teen, participants self-report the data, and I assume they answer honestly. Boakye et al. (2016) demonstrated that parental and provider recall of HPV vaccine initiation in the 2014 NIS-Teen dataset is comparable; parental and provider recall are slightly less comparable for HPV vaccine completion, although still substantial ($\kappa = 0.64$). Although sensitivity and specificity may differ in other NIS-Teen dataset years, I assume this level of agreement indicates the self-report data is generally trustworthy.

Scope and Delimitations

The scope of this study is to test the relationship between HPV vaccine initiation and completion, socioeconomic status, and demographic variables in eight select local areas in the United States. In addition, I will test the relationship between HPV vaccine initiation, physician recommendation, and social vulnerability in four select local areas.

Internal validity of the study data is supported by random sample selection in the NIS-Teen using landline and cell phone numbers across the United States, application of sampling weights, and validation of both the NIS-Teen and Social Vulnerability Index instruments and outcomes (Brewer, 2004; Flanagan et al., 2011; Reagan-Steiner et al., 2016). External validity of the study data is supported by the national sample set and real-world observation rather than a laboratory setting (Ondercin, 2004). However, there are limitations that affect the ability to draw causal inferences about the data and generalize the findings to the entire U.S. population. Overall, there may be unknown confounders influencing the relationship between the independent and dependent variables; these may be masked by aggregate data, not currently measurable, or be in flux as dynamic processes influencing health and health outcomes.

The NIS-Teen survey is cross-sectional, and thus it can support inferences but not prove causality. The household response rates for NIS-Teen vary from year to year, with approximately 60% and 31% response rates for landline and cell phones, respectively, in 2014 (compared with 56% and 30% in 2015), and approximately half of respondents have adequate provider data (Reagan-Steiner et al., 2015; Reagan-Steiner et al., 2016). Estimates may be biased due to errors in respondent recall, non-responders or small sample sizes in specific variables or selected local areas (Reagan-Steiner et al., 2016).

As with the NIS-Teen, the SVI is cross-sectional. Although the SVI incorporates multiple facets of social vulnerability, it is an incomplete list; others may include specific built environment structures or diffusion of information (Flanagan et al., 2011). In addition, the SVI uses decennial census data, and may not accurately reflect the most current measurements in a community (Flanagan et al., 2011).

Conclusions

Human papillomavirus (HPV) is the most common sexually transmitted infection in the world and causes an estimated 700,000 cancer cases each year worldwide (Perkins, 2016). In the decade since the first vaccine against HPV came to market, researchers and health care providers have made progress in reducing disparities in vaccine uptake among racial and ethnic minority and low socioeconomic status populations (Galbraith et al., 2016; Rahman et al., 2017). However, sociodemographic and geographic variation in HPV vaccine uptake persists, as do differences in physician recommendation, determinants of vulnerability, and state laws regarding vaccination (Perkins, 2016; Rutten et al., 2017). Given the multifactorial influences on cognitive and behavioral decision-making in HPV vaccination, a more ecological approach to research may uncover relationships influencing HPV vaccine uptake that are missed when studying determinants in isolation (Yanez, McGinty, Buitrago, Ramirez, & Penedo, 2016).

This study may lend support to findings of experts in the field regarding variation in vaccine uptake by a number of variables, including sociodemographic factors and physician recommendation. In addition, this study may expand on data supporting geographic variation in HPV vaccination. This study may advance knowledge in the discipline by being the first, to my knowledge, to test the influence of the socioeconomic, demographic, cultural, and health history variables on HPV vaccine initiation and completion alongside the social vulnerability context in which these relationships exist. This will also be the first test of a potential relationship between social vulnerability and HPV vaccination nationwide in the literature.

These implications, such as the identification of the variables most strongly associated with HPV vaccination and local factors in physician recommendation, can advance social change by highlighting the need to consider local socioeconomic and demographic influences on health behavior, with a focus on physician recommendation. Informed interventions may help local, state, and national efforts to improve vaccination efforts and reduce disparities in health care.

The following chapter describes the research methodology, including the design and data collection procedures.

Section 2: Research Design and Data Collection

Introduction

The purpose of this study is to test the relationship between HPV vaccine initiation and completion, socioeconomic status, and demographic variables in eight select local areas in the United States. In addition, I will test the relationship between HPV vaccine initiation, physician recommendation, and social vulnerability in four select local areas.

The remainder of this chapter will describe the research design and rationale, followed by the methodology, including sampling, data analysis, threats to validity, and ethical considerations.

Research Design and Rationale

I will conduct a quantitative secondary analysis of the NIS-Teen, a cross-sectional study, and the Social Vulnerability Index, a cross-sectional analysis tool, to test relationships among the study variables. The independent variables are socioeconomic status indicators, demographic variables, and county-level social vulnerability. The dependent variables are HPV vaccine initiation and completion and physician recommendation.

Secondary analysis is an efficient and cost-effective way to generalize findings from a large sample size to a population for greater external validity, analyze the findings using statistical procedures, and identify subgroups with sufficient sample size for additional analyses (Creswell, 2009; Dale, 2004). In addition, use of validated, reliable instruments increases confidence in internal validity and the minimization of bias in data collection to the extent possible (Creswell, 2009).

Quantitative analysis of county- and national-level databases will advance knowledge in the field regarding relationships likely to influence HPV vaccine uptake by identifying specific variables to assess and resources needed at each level.

Methodology

The NIS-Teen is a well-known and much-used instrument to examine relationships among variables of interest and immunization behaviors in the United States. The Social Vulnerability Index is used frequently by emergency planners and other officials responsible for disaster planning and recovery.

Population

The Centers for Disease Control and Prevention conducts the annual NIS-Teen to monitor vaccination initiation and completion of adolescents aged 13 to 17 years in non-institutionalized households in the United States. In 2015, NIS-Teen collected data from 61 geographic strata: all 50 states, the District of Columbia, three territories, and seven selected local areas (Chicago, New York, Philadelphia, Bexar County [TX], Houston, El Paso County [TX], and Hidalgo County [TX]).

Sampling and Sampling Procedures

NIS-Teen uses dual-frame sampling, with both landline and cell-phone sampling frames with households, followed by a mailed questionnaire to the identified vaccine providers. Interviewers use independent, quarterly updated samples provided by Marketing Systems Group; the landline sampling frame includes banks of numbers with at least one directory-listed telephone number, while the cell-phone sampling frame includes all banks of cell phone numbers (CDC, 2015). Numbers that are non-working, non-residential, or on the NIS do-not-call list are eliminated prior to release to a telephone center. Interviewers contact households to identify those with adolescents aged 13 to 17 years; if more than one child is eligible, one child is randomly selected to be the subject of the interview. Households that do not have adolescents at this age are excluded. Interviewers use the NIS-Teen household questionnaire to collect household-reported vaccination and health information, demographic and socioeconomic information, geographic information, and vaccine provider information from a parent or guardian (CDC, 2015). As adolescents and teens under age 18 must have parental or guardian consent to be vaccinated, the parent or guardian is the appropriate respondent (Burdette et al., 2017).

For households who provide sufficient information and consent to contact the vaccine provider, a questionnaire is mailed to vaccine providers to obtain immunization history from an adolescent's medical records. The provider is asked to mail or fax the immunization history form; in some instances, histories are completed over the phone during follow-up phone calls to providers who have not yet responded. In 2015, 61.4% of parents or guardians from the landline sample gave consent to contact providers (2014: 64.4%), while 58.1% from the cell-phone sample gave consent (2014: 61.2%) (CDC et al., 2015; 2016). Of the questionnaires mailed to providers, 93.4% of questionnaires from the landline sample and 93.6% of questionnaires from the cell-phone sample were returned (2014: 94.9% and 94.8%, respectively) (CDC et al., 2015; 2016). Finally, of the questionnaires returned, 53.4% of adolescents from the landline sample had adequate provider data, and 48.9% of adolescents from the cell-phone sample had adequate provider data (2014: 57.1% and 52.3%, respectively) (CDC et al., 2015; 2016).

The sample size was designed specifically with a target coefficient of variation of 6.5% from provider-reported vaccine histories in each geographic area, to give a true coverage parameter of 50% (CDC et al., 2015; 2016). Overall, the coverage parameter in 2015 was 49.9% (2014: 54.4%); for landlines, a total of 84.4% of households were successfully screened, 5.7% of households had an age-eligible teen, and 81.3% of these households completed the interview (2014: 87.2%, 6.2%, and 83.8%, respectively) (CDC et al., 2015; 2016). For cell phones, 73.4% of households were successfully screened, 6.9% were eligible, and 71.7% completed the interview (2014: 72.9%, 6.9%, and 72.7%, respectively) (CDC et al., 2015; 2016). A total sample of 10.1 million telephone numbers resulted in completed household interviews for 44,773 teens, of which 22,214 [including 133 unvaccinated children] had adequate provider data to verify whether the adolescent was up to date on vaccines (2014: a total of 38,703 teens, 21,057 [including 92 unvaccinated adolescents] with adequate provider data) (CDC et al., 2015; 2016). The revised definition of adequate provider data, beginning in 2014, is any adolescent for whom a provider reports vaccine history, or any adolescent who is unvaccinated as reported by parent or provider (CDC et al., 2015; 2016).

Selected local areas that receive federal Section 317 funds to purchase vaccines, particularly for priority populations, are sampled and analyzed separately (Reagan-Steiner et al., 2016). Researchers may analyze all completed household interviews or only those with adequate provider data, as well as choose whether to include adolescents from territories in the analysis (CDC et al., 2015; 2016). Adolescents from the territories are excluded from national estimates (CDC et al., 2015; 2016).

Both the NIS-Teen and Social Vulnerability Index are public-use data files and do not require permission to gain access to the data.

Instrumentation

The National Immunization Survey was launched in 1994 to monitor vaccine coverage among children ages 19 months to 35 months after a series of measles outbreaks in the early 1990s (CDC, 2017d). The NIS-Teen was launched in 2006 to monitor vaccine coverage among adolescents and teens for routine immunizations and provide a consistent dataset for tracking needs and outcomes related to routine vaccines in a single year and over time (CDC, 2017d; Jain, Singleton, Montgomery, & Skalland, 2009). Prior surveys, such as the National Health Interview Survey, relied on personal immunization cards or parental recall, but few households kept immunization cards and parental recall was less accurate than the cards (Jain et al., 2009). Other surveys relied on local data or registries. In NIS-Teen, analysts use weights to estimate vaccine coverage for the entire nation, as well as by state and selected local area; researchers can also stratify by variables of interest (CDC, 2017d).

Researchers collect data from both parents and vaccine providers of adolescents to enhance the validity and reliability of the self-reported data in NIS-Teen (CDC, 2017d). Dorell, Jain, and Yankey (2011) and others reported that parent-reported vaccine histories varied by vaccine, especially for recently recommended vaccines, and the use of provider validation of parent reports increased the validity of the NIS-Teen. Analysts also use adequate-provider data when reporting estimates of vaccine coverage, given the differences between estimates obtained from households with and without adequate provider data in the early years of the survey (Jain et al., 2009).

Researchers use the dual-frame design to increase reliability of sampling in NIS-Teen and validity of survey results (Dorell et al., 2011). Shin, Molinari, and Wolter (2008) determined that dual-frame sampling, versus the single random-digit dialing frame, increased statistical efficiency and cost-effectiveness of the survey without introducing new bias into immunization coverage estimates. For example, the public-use data file for the 2014 NIS-Teen includes only dual-frame weights as a way to minimize any bias resulting from incomplete landline sampling (CDC et al., 2015; 2016).

In addition to these methodological designs, validity and reliability of NIS-Teen can be assessed by comparing results with other immunization data sources, such as registries, the National Health Interview Survey-Child, or the Behavioral Risk Factor Surveillance System, and by comparing results among researchers using the same data set and the same questions (Boakye et al., 2016; Jain et al., 2009).

Operationalization of Variables

The objective of this study is to test the relationship between HPV vaccine initiation and completion, socioeconomic status, and demographic variables in eight select local areas in the United States. In addition, I will test the relationship between HPV vaccine initiation, physician recommendation, and social vulnerability in four select local areas.

What follows is a description of the dependent and independent variables (see Table 9 for a brief overview of the variable levels).

Table 9

Measurement Levels of Variables in Analysis

Measurement Level	Variables
Nominal	HPV vaccine initiation
	HPV vaccine completion
	Physician recommendation
	Ethnicity and racial background
	Health insurance status
	Gender
	Select local area
Ordinal	Poverty
	Education
	Social Vulnerability Index ratings
Interval	Age

Note. HPV vaccine initiation, completion, and physician recommendation are dichotomous variables, which indicates binomial logistic regression as the appropriate final statistical model.

HPV vaccination completion. One of the key dependent variables, HPV vaccination completion reflects whether the respondent indicates that his or her adolescent child had received three or more doses of the HPV vaccine series. Although the NIS-Teen survey collects data on up to 9 reported HPV shots received for variable *HPVI_NUM_TOT* (*HPV1_NUM_REC* in 2014; position 113-114), the series is made up of 3 shots, with recent recommendations to administer 2 shots for eligible adolescents. Only 145 responses of 33,809 completed household interviews and 89 of 16,875 interviews with adequate provider data answered 4 or more shots, with the majority answering 4. I will consider 3 and 4 shots as ≥3 shots received, indicating completion, and will recode as 3 in analysis.

HPV vaccination initiation. Another key dependent variable, HPV vaccination initiation reflects whether the respondent indicates that his or her adolescent child had received at least one dose of the HPV vaccine series. I will consider 1 and 2 shots as reported for variable *HPVI_NUM_TOT* as ≥1 shot received, indicating initiation, and will recode as 2 in the analysis. For adolescents reporting 0 HPV shots received, I will recode as 1 to indicate unvaccinated status.

Physician recommendation. As a dependent variable in research question 4, physician recommendation reflects whether the respondent recalls receiving a recommendation from a physician or health care professional for the adolescent or teen to receive the HPV vaccination. As indicated in the NIS-Teen codebook for variable *HPVI_RECOM* (position 167-168), I will code yes as 1 and no as 2. Based on prior research, I will exclude *don't know*, *refused*, or *missing* responses from my analysis, as these answers comprise only 4,630 responses of the 44,773 completed interviews and 2,005 responses of 22,214 interviews with adequate provider data.

Ethnic and racial status. One of the key independent variables, ethnic and racial status reflects the race / ethnicity of the adolescent. Responses to the question in NIS-Teen for variable *RACEETHK* (position 311-311) may be Hispanic, Non-Hispanic White Only, Non-Hispanic Black Only, and Non-Hispanic Other + Multiple Races. Based on prior studies in which researchers focus on Hispanic, White, and Black in their studies given the sufficient sample size in the survey, and the lack of any additional subcategorization for the 4,488 responses for *other* out of 44,773 household interviews

(2,202 responses of the 22,214 teens with adequate provider data) in the public-use data file, I will use only Hispanic, White, and Black in my analysis. As indicated in the codebook, I will code Hispanic as 1, White as 2, and Black as 3.

Social vulnerability. The CDC and ATSDR's Social Vulnerability Index ranks each census tract or county on overall vulnerability, comprised of four themes and 15 social factors affecting health: socioeconomic status (below poverty, unemployed, income, no high school diploma); household composition and disability (aged 65 and older, aged 17 or younger, civilian with a disability, single-parent households); minority status and language (minority, speak English less than well); and housing and transportation (multi-unit structures, mobile homes, crowding, no vehicle, group quarters) (CDC & ATSDR, 2017). Two adjunct variables, estimates for uninsured persons and daytime population, are included in the SVI 2014 data but are excluded from the ranking calculations.

SVI data can be mapped and analyzed at the national level, ranking tracts or counties against each other, or at the individual state level, where tracts or counties are ranked only against those in the same state. I will use counties in this research as a more appropriate comparison for counties in NIS-Teen. Percentile ranks closer to zero indicate lower vulnerability, while ranks closer to 1 indicate high vulnerability. CDC and ATSDR calculate percentile ranks for each county for the 15 variables, and sum the percentiles to generate the theme score (variables *RPL_THEME1* for socioeconomic, *RPL_THEME2* for housing composition and disability, *RPL_THEME3* for minority status and language, and *RPL_THEME4* for housing and transportation). Finally, the sum of each theme is added together to calculate the overall percentile ranking (variable *RPL_THEMES*). I will code the themes using their designated numbers from the SVI (1 through 4), and the overall ranking as 5.

Socioeconomic status. Socioeconomic status is reflected through a collection of independent variables including income and education. While American Psychological Association (2007) and Diemer, Mistry, Wadsworth, Lopez and Reimers (2013) suggested including a number of measures such as resources, absolute and relative poverty, and subjective social status, data are collected only on resource-based measures (total family income) and absolute poverty (federal poverty threshold). While family income is a more nuanced measure, there may not be sufficient sample size for subgroup analysis, and poverty status is an accepted variable in reports by CDC and other researchers.

As noted in the NIS-Teen codebook, poverty status, the variable *INCPOV1* (position 298-298), is calculated as above poverty (income greater than $75,000, coded 1), above poverty (income less than or equal to $75,000, coded 2), and below poverty (coded 3). Responses to variable *EDUC1* (position 279-279), the mother's level of education, are less than 12 years (coded 1), 12 years (coded 2), more than 12 years / non-college graduate (coded 3), and college graduate (coded 4).

Selected local areas. An independent variable describing where the teen lives at the time of the survey. Responses are drawn from ESTIAPT15 and ESTIAPT14 from the 2015 and 2014 NIS-Teen surveys, respectively. Eight specific estimation areas in 2015 will be tested, as well as the four that are stand-alone counties from the 2014 NIS-Teen in the SVI portion of my analysis: Bexar County, District of Columbia, El Paso County, and Philadelphia.

Health insurance. An independent variable describing whether an adolescent has no insurance, employee or union insurance, or other government insurance. Responses are drawn from variables *TIS_INS_1* (position 1207-1208 in 2015, 1190-1191 in 2014) to indicate whether an adolescent is covered through the respondent's employer or union (responding yes, coded as 1), *TIS_INS_2, _3, _3A, and _4_5* (2015: positions 1211-1212, 1213-1214, 1215-1216, and 1217-1218; 2014: positions 1194-1195, 1196-1197, 1198-1199, and 1200-1201, respectively) to indicate other government insurance (responding yes to Medicaid, S-CHIP, Tricare, or Indian Health Service, coded as 2), or *TIS_INS_11* (position 1209-1210, 2014: 1192-1193) to indicate uninsured (responding yes, coded as 3).

Sex. An independent variable, sex reflects the gender of the adolescent as identified by the respondent. Responses for the variable *SEX* (position 315-315) can be male or female; as noted in the codebook, male will be coded as 1 and female will be coded as 2.

Control variables. Researchers have identified a number of correlates to HPV vaccine initiation, completion, and physician recommendation: age of the adolescent, age of the mother, number of children under 18 years in the household, relationship of the respondent to the adolescent, mother's marital status, and number of adolescent visits to a healthcare profession in the past 12 months (Burdette et al., 2017). These correlates may confound results, and therefore I will control for each in my four research questions.

However, age of the adolescent will be included as an independent variable in research question 4, as researchers have shown a significant relationship between age of the adolescent and physician recommendation. Any additional confounding variables among the aforementioned independent variables will be determined using logistic regression (described in the *Data Analysis Plan* section).

Data Analysis Plan

The datasets, formats, and codebooks will be downloaded from the NIS-Teen website, and all analyses will be conducted using the Complex Samples procedures in SPSS version 24 for Mac OS Sierra when possible to account for the complexity of the weighted survey data.

CDC analysts prepare and process the household and provider data collected through NIS-Teen (CDC et al., 2015; 2016). Editing and cleaning procedures follow the standards set by the National Health Interview Survey, and are completed after every quarter of data collection (CDC et al., 2015; 2016). The CDC uses a computer-assisted telephone interviewing system to reconcile any critical errors during the household interview in real time, followed by a review of data values for any out-of-range values and extraneous codes, production of cross tabulations, recoding of any verbatim responses, and creation of several composite variables (CDC et al., 2015; 2016). Provider data are edited through an initial manual review of the returned immunization history forms, removal of any responses for the incorrect adolescent, consolidation of multiple-provider responses for a single teen merged into one single history, and then cleaned.

Household and provider data are merged, with any multiple-provider responses for a single adolescent merged into one single history. Analysts conduct a quality assessment using an adolescent's date of birth, gender, and name to confirm eligibility of the teen (by age) and to ensure the correct adolescent is matched with the correct provider (CDC et al., 2015; 2016). Finally, analysts perform imputations using a sequential hot-deck method for any non-responses to socioeconomic and demographic variables used in weighting. Missing value codes are used for household data, while missing or other provider data are recoded using a vaccination recoding table and reviewed by the National Center for Immunization and Respiratory Diseases (CDC et al., 2015; 2016).

NIS-Teen is the only survey that includes provider-reported vaccination data along with household-reported history; even with this corroboration and standardized editing and cleaning procedures, there may be some inconsistent data present in the data file, as households are not re-contacted to verify any differences in provider reporting (CDC et al., 2015; 2016). As provider data are considered more accurate than household-reported vaccine history, the CDC uses the subset of data of adolescents with adequate provider data for reported estimations of vaccine coverage, and assigns a separate weight to these records (CDC et al., 2015; 2016).

Research questions. The objective of this study is to test the relationship between HPV vaccine initiation and completion, socioeconomic and demographic variables, and physician recommendation. In addition, I will test the relationship between HPV vaccine initiation, physician recommendation, and social vulnerability. I will attempt to answer four research questions:

Research Question 1: Is there a relationship between HPV vaccination initiation (1 dose) and socioeconomic status and demographic variables in selected local areas, using data from the 2015 NIS-Teen?

$H_0$1: There is no relationship between HPV vaccination initiation and socioeconomic and demographic variables in selected local areas.

H_a1: There is a relationship between HPV vaccination initiation and at least one socioeconomic or demographic in selected local areas.

Research Question 2: Is there a relationship between HPV vaccination completion (3 doses) and socioeconomic status and demographic variables in selected local areas using data from the 2015 NIS-Teen?

$H_0$2: There is no relationship between HPV vaccination completion and socioeconomic and demographic variables in selected local areas.

H_a2: There is a relationship between HPV vaccination completion and at least one socioeconomic or demographic variable in selected local areas.

Research Question 3: Is there a relationship between HPV vaccination initiation (1 dose) and social vulnerability by select local area county in the United States using data from the 2014 NIS-Teen and 2014 Social Vulnerability Index?

$H_0$3: There is no relationship between HPV vaccination initiation and social vulnerability by select local area county in the United States.

H_a3: There is a relationship between HPV vaccination initiation and social vulnerability by select local area county in the United States.

Research Question 4: Is there a relationship between physician recommendation (yes/no) and social vulnerability by select local area county in the United States using data from the 2014 NIS-Teen and 2014 Social Vulnerability Index?

$H_0$4: There is no relationship between physician recommendation and social vulnerability by select local area county in the United States.

H_a4: There is a relationship between physician recommendation and social vulnerability by select local area county in the United States.

Statistical analyses. The pre-determined α level for all tests is < 0.05. First, I will conduct a descriptive, univariate analysis to calculate weighted frequencies and 95% confidence intervals for all study variables to describe the survey respondent population.

Second, I will conduct inferential bivariate analyses, using chi-square tests, to determine the interactions between adolescent characteristics and the three dependent variables: HPV vaccine initiation, completion, and physician recommendation.

Third, I will conduct a preliminary series of logistic regression models to test for multicollinearity, which indicates if two or more independent variables are highly correlated. Multicollinearity, which increases the standard errors of the coefficients and thus decreases the reliability of the outcome data, can be tested by calculating the Variance Inflation Factors. A VIF greater than 10 indicates multicollinearity; depending on the variable in question, I may remove the variable, recode it, or control for it in the analysis. In addition, I will assess the results of the Wald test in the regression output to understand the contribution of each independent variable to the model, as well as its statistical significance. I will include independent variables with $p \leq 0.05$ in the final model and exclude those with $p > 0.05$.

Finally, I will conduct a binomial logistic regression to test associations between the independent and selected dependent variables that were statistically significant in the preliminary regression analysis. My study meets the assumptions for binomial logistic regression, as I have dichotomous dependent variables (all are yes or no), one or more independent variables measured on a continuous or nominal scale (with ordinal variables treated as continuous or nominal), the data have independence of observations, and no multicollinearity (as tested in the third analysis step). The final results will be presented as odds ratios with 95% confidence intervals.

Threats to Validity

Threats to validity may arise from external, internal, statistical conclusion, or construct factors. External threats include extrapolating inferences from the sample data to populations or settings that do not reflect the sample population, as well as the interaction between population selection, taking the survey, and the setting in which they take the survey. The CDC employs oversampling techniques and weights responses to the NIS-Teen survey in order to calculate a population-level estimate of vaccine coverage and minimize any interaction between selection and taking the survey. In addition, CDC collects data at a number of administrative levels (such as national, state, and select local area) to address the interaction between selection and the setting in which the population live and experience differing external events. However, I cannot control for any unknown confounders that may influence the relationships between the independent and dependent variables, especially if these confounders are not measurable or vary according to unidentified population characteristics.

Internal threats to validity include the procedures or experiences of the respondents that influence whether I can correctly infer conclusions about the population. As NIS-Teen is a one-time survey, factors such as history, maturation, experimental mortality, diffusion of treatment, or statistical regression do not apply to the survey or analysis. In addition, respondents are selected through random digit-dialing for both landline and cell phones, phone numbers are updated quarterly, and the CDC uses probability sampling adjustments to reduce any potential for sampling errors; these efforts address threats of selection bias and history. Respondents are not compensated, mitigating any compensatory demoralization or rivalry factors. The CDC collects data from both parents and providers of the HPV vaccine to verify parental recall. There are no pre- or post-test interviews and the survey is routinely reviewed, thus removing any concerns about instrumentation. Finally, I will conduct analyses to determine any presence of multicollinearity in research variables, and will not assign causality to variable relationships as my statistical model is not designed for that purpose.

Threats to construct validity result from insufficient measures or definitions of variables in the study. To minimize this threat, the CDC reports on data from respondents with adequate provider verification; in addition, comparison to other health surveys such as the National Health Interview Survey, which uses different methodology and sampling procedures, shows comparable coverage estimates. In my study, I have defined the variables using the body of HPV literature and the CDC's reports as guides to ensure I will be measuring and defining the same variables for testing.

Finally, threats to statistical conclusion can occur if the analysis is not powered adequately, or statistical assumptions are violated. According to a preliminary analysis of sample size using the G*Power (version 3.1.9.2), the sample size required for 95% power ranges from 1,649 to 1,653 for females and 1,629 to 2,318 for males in 2014, far below the 10,084 females and 10,743 males in the 2014 sample (the smaller of the two years' samples in the full U.S. sample). To obtain this sample estimate, I used the following parameters: a two-tailed test, an odds ratio of 1.2 for a small effect size, $\alpha > 0.05$, and hypothesized HPV vaccine coverage ranging from 39.7% to 60.0% in females and 21.6% to 41.7% in males, based on 2014 data (the lower of the two years' samples) (Reagan-Steiner et al., 2015). Using the same parameters, the sample size required for 95% power for the select local area ranges from 310 for females and 274 for males, again below the 367 females and 394 males in 2014 (the smaller of the two years' samples in the select local area sample).

In addition, the statistical assumptions for the planned statistical tests are met: for chi-square goodness of fit and independence, I have categorical variables, independence of observations, cross-sectional sampling, and an expected frequency of at minimum 5 cases per group in each categorical variable. For binomial logistic regression, I have a dichotomous dependent variable, two or more independent variables (continuous or nominal), independence of observations, mutually exclusive and exhaustive categories within each variable, a lack of multicollinearity, and an expected frequency of at minimum 15 cases per group in each variable. If the assumptions are not met in the chi-square tests, I may collapse the cells with other sample groups where possible to increase the sample. If the assumptions are not met in the binomial logistic regression test, I may collapse the cells or transform or remove outliers where applicable.

Ethical Procedures

The CDC and all other staff involved with the NIS-Teen are bound by confidentiality agreements to protect the privacy and confidentiality of protected health information, including disclosure of data (CDC et al., 2015; 2016). The collected data can be used only for research, and the public-use data file is reviewed by the National Center for Health Statistics Disclosure Review Board prior to release to ensure privacy and confidentiality are maintained (CDC et al., 2015; 2016). In addition, some variables that could potentially identify participants are not included in the public-use data file or have the categories collapsed and reported in aggregate.

Summary

I will conduct a quantitative secondary analysis of the NIS-Teen and Social Vulnerability Index databases to test the relationship between HPV vaccine initiation, completion, socioeconomic and demographic variables, physician recommendation, and social vulnerability in selected local areas in the United States. Specifically, I will use descriptive, univariate analysis to calculate weighted frequencies and 95% confidence intervals for all study variables to describe the survey respondent population, followed by chi-square tests and weighted frequencies to determine the interactions between HPV vaccination, physician recommendation, and select adolescent characteristics. Next, I will test for multicollinearity using logistic regression, followed by binomial logistic regression to test associations between the independent and selected dependent variables that were statistically significant in the preliminary regression analysis. Finally, I will evaluate my research questions in the context of what is known in the literature and how this study can contribute to progress in the field. Data collection and results will be discussed in the following section.

Section 3: Presentation of the Results and Findings

Introduction

The purpose of this study was to test the relationship between HPV vaccine initiation and completion, socioeconomic and demographic variables, and physician recommendation. In addition, I tested the relationship between HPV vaccine initiation and completion, physician recommendation, and social vulnerability using the 2014 NIS-Teen and 2014 Social Vulnerability Index databases. I attempted to answer four research questions:

Research Question 1: Is there a relationship between HPV vaccination initiation (1 dose) and socioeconomic status and demographic variables in selected local areas, using data from the 2015 NIS-Teen?

$H_0$1: There is no relationship between HPV vaccination initiation and socioeconomic and demographic variables in selected local areas.

H_a1: There is a relationship between HPV vaccination initiation and at least one socioeconomic or demographic in selected local areas.

Research Question 2: Is there a relationship between HPV vaccination completion (3 doses) and socioeconomic status and demographic variables in selected local areas using data from the 2015 NIS-Teen?

$H_0$2: There is no relationship between HPV vaccination completion and socioeconomic and demographic variables in selected local areas.

H_a2: There is a relationship between HPV vaccination completion and at least one socioeconomic or demographic variable in selected local areas.

Research Question 3: Is there a relationship between HPV vaccination initiation (1 dose) and social vulnerability by select local area county in the United States using data from the 2014 NIS-Teen and 2014 Social Vulnerability Index?

$H_0 3$: There is no relationship between HPV vaccination initiation and social vulnerability by select local area county in the United States.

$H_a 3$: There is a relationship between HPV vaccination initiation and social vulnerability by select local area county in the United States.

Research Question 4: Is there a relationship between physician recommendation (yes/no) and social vulnerability by select local area county in the United States using data from the 2014 NIS-Teen and 2014 Social Vulnerability Index?

$H_0 4$: There is no relationship between physician recommendation and social vulnerability by select local area county in the United States.

$H_a 4$: There is a relationship between physician recommendation and social vulnerability by select local area county in the United States.

The remainder of this chapter will describe the data collection for the study, followed by the results of the retrospective, quantitative analysis of the secondary dataset.

Data Collection of Secondary Data Set

As noted above in *Sampling and Sampling Procedures*, 2015 recruitment resulted in completed household interviews for 44,773 teens, of which 22,214 had adequate provider data, while in 2014 there were a total of 38,703 teens, 21,057 with adequate provider data (CDC et al., 2015; 2016). For the 2015 NIS-Teen, data were collected between January 26, 2014 and February 15, 2015 for the household interviews and from

March 2015 through April 2016 for the provider surveys (CDC et al., 2016). For the 2014 NIS-Teen, data were collected between January 9, 2014 and February 8, 2015 for the household interviews and between from February 2014 through April 2015. For the 2014 SVI, data were collected using the Census Bureau's 2010-2014 American Community Survey (CDC & ATSDR, 2017).

For the 2015 NIS-Teen data, this study was limited to 11,855 adolescents in the full U.S. sample and 1,564 adolescents in selected local areas, while the 2014 dataset was limited to 11,488 adolescents in the U.S. sample and 1,235 adolescents in selected local areas (see Figure 2). Adolescents in the sample met the following criteria: adequate provider data; between 0 and 3 HPV shots received; fewer than 8 visits to a physician in the past 12 months; of Non-Hispanic White, Hispanic, or Non-Hispanic Black race and ethnicity; and living in one of the eight select local areas (for the select local area sample only). Finally, respondents answering *don't know* or *refused* or marked as *missing* data were excluded from the analysis. No variables contained more than 10% missing data, with the exception of whether an adolescent had a well-child visit at ages 11 or 12 years (13.6% [2015] and 15.0% [2014] of the full U.S. sample). Assessments using listwise deletion and imputation showed the differences in the population were not significant, $t(83379) = 0.03$, $p > .05$ for 2015 and $t(71715) = 0.05$, $p > .05$ for 2014.

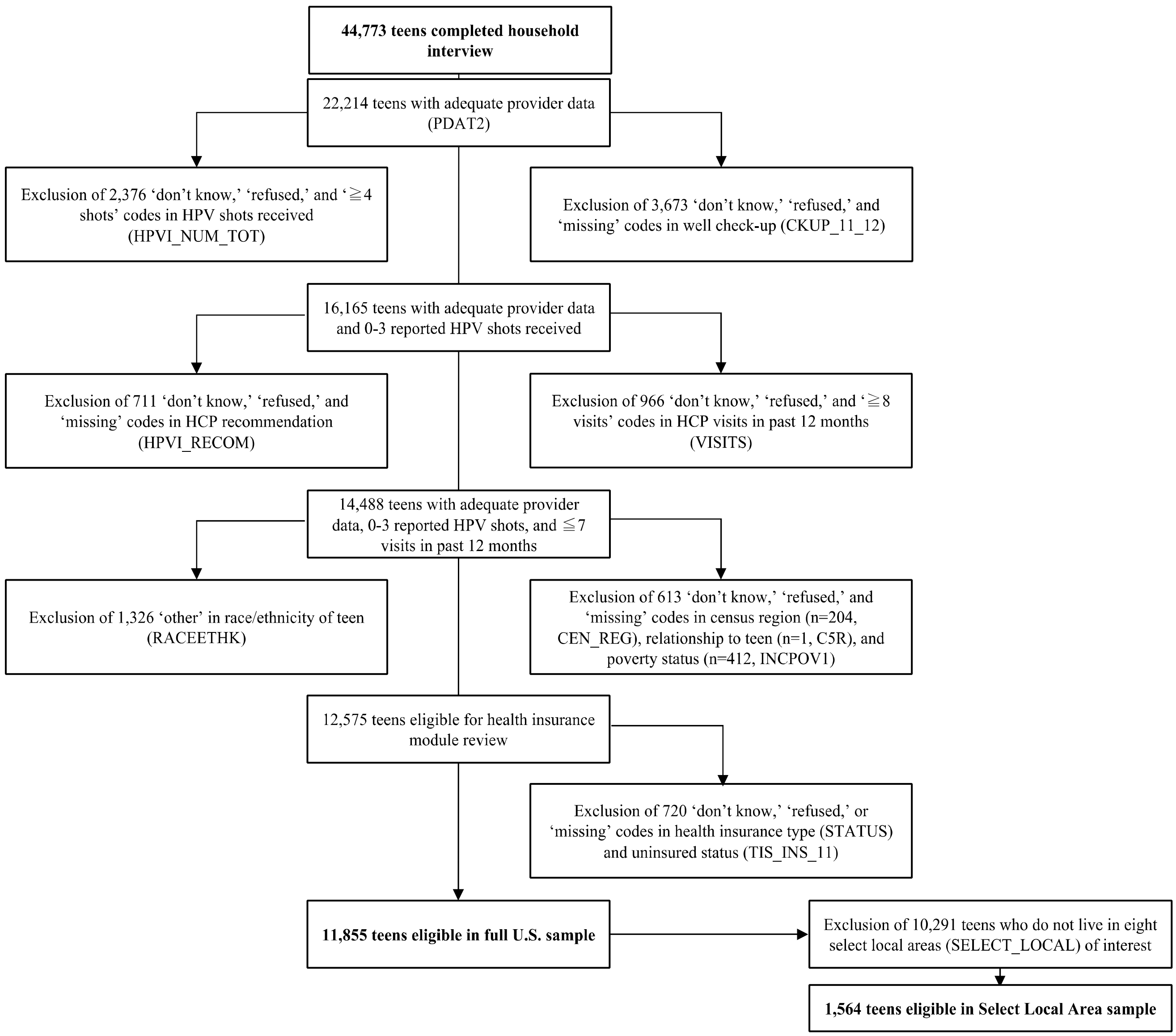

Figure 2. Criteria used to determine the final full U.S. sample and Select Local Area sample from the 2015 NIS-Teen. The same criteria were used for the 2014 dataset.

In addition, Little's MCAR test showed that the 2015 well-check data were missing completely at random, $\chi^2(1) = 0.53$, $p > .05$ for select local area and $\chi^2(1) = 2.78$, $p > .05$ for age of teen. The missing data were missing completely at random in 2014 as well, according to Little's MCAR test, $\chi^2(1) = 0.35$, $p > .05$ for select local area and $\chi^2(1) = 0.03$, $p > .05$ for age of the teen.

Survey design allows respondents to recall the teen receiving up to 9 HPV shots, despite the series having only three shots at the time of the interviews; as such, those answering 4 or more shots ($n = 78$) were excluded from the sample. In addition, a number of researchers have reported that physicians typically do not offer vaccines during acute illness visits or if the adolescent has a chronic illness or is immunocompromised (Malo et al., 2016b; Richards, Peters, & Sheeder, 2016; Vadaparampil et al., 2011). Therefore, respondents answering that the teen had seen a health care professional more frequently than every two months ($n = 866$, or 5.6% of the sample, having 8 or more visits per year) were excluded from the sample.

Tests indicated a low level of multicollinearity, as assessed by the tolerance and VIF collinearity statistics in a linear regression analysis. All independent variables had a tolerance greater than .10 and a VIF between 1 and 10, suggesting the independent variables were not correlated and the effects of each on the dependent variable were similar regardless of other independent variables in the model (see Tables B1-2 in Appendix B).

Data Analysis Plan Revisions

The SPSS program did not account for the weighted sample's total population, so when weighting cases using the provider-phase weight variable (PROVWT_D) the standard error assumed $\sqrt{n}$ using the sum of the weight variable rather than the sum of the sample population and predictors were all highly significant (IBM Support, 2016). To account for this, I used two methodologies, the Complex Samples option in SPSS and a scaled weight approach, and compared the two regarding agreement on rejection or acceptance of the null hypothesis on each research question. In the Complex Samples approach, I created a sample plan using the sum of the provider-phase weight variable, stratified by the STRATUM variable, and included a Bonferroni correction for multiple comparisons (Glantz, 2005; IBM Support, n.d.). In the scaled weight approach, I applied a factor ([$\sum \text{PROVWT\_D}/N$) to the provider-phase weight variable to create a scaled $\sqrt{n}$ for the standard error (IBM Support, 2016).

As the dependent variables were dichotomous, I had more than three variables, and the independent variables were measured at nominal and continuous levels, binomial logistic regression was more appropriate than a chi-square test to analyze the dataset (Laerd Statistics, 2015). Given this determination, running chi-square analyses to identify variables to include in the binomial logistic regression model was not necessary. Last, independent variables must be either continuous or nominal when using binomial logistic regression analyses, so I recoded the ordinal variables from Table 9 and included them as categorical variables (Laerd Statistics, 2015).

Finally, with the SVI rankings recoded as categorical variables, and with the SVI ranking and select local area county variables containing more than two categories, the chi-square test for independence was more appropriate than a binomial logistic regression (Laerd Statistics, 2016).

Baseline Sample Characteristics

The 2015 NIS-Teen unweighted dataset included 11,855 teens in the full U.S. sample and 1,564 teens in the select local area sample. Table 10 summarizes the descriptive and sociodemographic characteristics of the sample.

Table 10

Characteristics of adolescents aged 13-17 years with adequate provider data: 2015 NIS-Teen

	United States	Local Area
Gender		
Male	50.9	50.1
Female	49.1	49.9
Adolescent's age (years)		
13	12.6	12.2
14	20.6	22.2
15	23.6	22.3
16	22.6	21.8
17	20.7	21.5
Race/ethnicity		
Non-Hispanic White	63.0	24.3**
Hispanic	22.3	48.6**
Non-Hispanic Black	14.7	27.2**
Poverty status		
Above $75K	44.9	30.9**
Poverty to $75K	34.5	36.0
Below	20.6	33.1**
Mother's education		
Less than high school	10.0	17.6**
High school graduate	21.4	22.5
Some college	26.0	23.4*
College graduate	42.7	36.4**
Physician recommendation of HPV vaccine		
Yes	71.9	74.7*
No	28.1	25.3*
HPV vaccination status		
No shots	43.5	37.8**

(table continues)

	United States	Local Area
Initiation (1 shot)	23.6	30.1**
Completion (3 shots)	32.9	32.0
Well-child checkup		
Yes	95.8	96.6
No	4.2	3.4
Type of health insurance[a]		
Employee-based	62.8	48.2**
Public (government)	37.2	51.8**
Ever uninsured, since age 11		
Yes	7.6	9.7**
No	92.4	90.3**
Mother's marital status		
Married	64.2	50.7**
Not married	35.8	49.3**
Mother's age (years)		
≤ 34	7.9	9.2
35-44	43.1	48.2**
≥ 45	49.0	42.6**
Number of children under 18 years in house		
One	32.4	32.3
Two to three	55.6	53.6
Four or more	12.0	14.1*
Number of visits to HCP in past 12 months		
None	11.0	9.6
One	32.4	32.6
Two to three	39.1	41.8*
Four to five	12.8	13.3
Five to six	4.7	2.6**
Relationship to teen		
Mother / female guardian	72.6	77.2**
Father / male guardian	21.5	16.2**
Grandparent	3.8	4.2
Other	2.1	2.4

Note. In the Complex Samples columns, all percentages were weighted with the PROVWT_D sampling weight using a weighted sum population size of 10,773,199 (U.S. sample) and 550,303 (local area sample) and stratified by the STRATUM variable. In the Scaled Sample columns, all percentages were weighted with the scaled factor weight [(Sum[PROVWT_D])/unweighted sample size]. Frequencies were identical between the Complex and Scaled populations. [a] Of the teens who were insured.

* $p < .05$
** $p < .01$

Overall the 2015 sample was split between males and females, with the majority of teens in the U.S. sample ages 14 years or older (87.5%), Non-Hispanic White (63.0%), lived above the poverty line (79.4%), had a college-educated mother (42.7%), had received a physician recommendation for the HPV vaccine (71.9%), had initiated or completed the HPV vaccine series (67.1%), had a well-child checkup at age 11 or 12 years (95.8%), and had employee-based insurance (62.8% of the teens who were insured). Regarding the control variables, the majority of teens had a married mother (64.2%), a mother aged 35 years or older (92.1%), two to three children under 18 in the household (55.6%), between one and three visits to a health care professional in the past 12 months (71.5%), and the mother completed the survey (72.6%). When compared to the select local area subset, the U.S. sample proportions were significantly different for most variables as assessed by the chi-square test, with the exception of gender, age, and well-checkup at ages 11 or 12. Given the differences between the two populations, I analyzed the select local area sample first, followed by the U.S. sample, as I would not be able to generalize the results of the select local area sample to the U.S. sample.

The 2014 NIS-Teen unweighted dataset included 11,488 teens in the full U.S. sample and 1,235 teens in the select local area sample. Table 11 summarizes the descriptive and sociodemographic characteristics of the sample.

Table 11

Characteristics of adolescents aged 13-17 years with adequate provider data: 2014 NIS-Teen

	United States	Local Area
Gender		
Male	51.4	48.7
Female	48.6	51.3
Adolescent's age (years)		
13	12.3	15.6**
14	21.0	21.3
15	21.1	16.4**
16	23.0	23.7
17	22.5	23.0
Race/ethnicity		
Non-Hispanic White	64.5	20.6**
Hispanic	20.5	47.0**
Non-Hispanic Black	15.0	32.4**
Poverty status		
Above $75K	44.2	27.8**
Poverty to $75K	36.6	35.4
Below	19.2	36.7**
Mother's education		
Less than high school	9.6	19.4**
High school graduate	20.7	24.1**
Some college	27.3	24.7
College graduate	42.3	31.8**
Physician recommendation of HPV vaccine		
Yes	68.0	72.7**
No	32.0	27.3**
HPV vaccination status		
No shots	46.6	39.5**
Initiation (1 shot)	23.6	30.2**
Completion (3 shots)	29.8	30.3
Well-child checkup		
Yes	94.8	94.8
No	5.2	5.2
Type of health insurance[a]		
Employee-based	64.3	47.2**
Public (government)	35.7	52.8**
Ever uninsured, since age 11		
Yes	8.5	7.5

(table continues)

	United States	Local Area
No	91.5	92.5
Mother's marital status		
Married	68.7	51.9**
Not married	31.3	48.1**
Mother's age (years)		
≤ 34	7.6	9.8**
35-44	41.9	43.1
≥ 45	50.5	47.1*
Number of children under 18 years in house		
One	33.2	33.1
Two to three	55.7	52.5*
Four or more	11.1	14.4**
Number of visits to HCP in past 12 months		
None	13.7	6.3**
One	30.4	30.9
Two to three	39.4	47.5**
Four to five	12.8	11.5
Five to six	3.7	3.9
Relationship to teen		
Mother / female guardian	74.4	78.1**
Father / male guardian	20.5	14.8**
Grandparent	3.4	3.6
Other	1.7	3.4**

Note. In the Complex Samples columns, all percentages were weighted with the PROVWT_D sampling weight using a weighted sum population size of 10,799,442 (U.S. sample) and 478,148 (local area sample) and stratified by the STRATUM variable. In the Scaled Sample columns, all percentages were weighted with the scaled factor weight [(Sum[PROVWT_D])/unweighted sample size]. Frequencies were identical between the Complex and Scaled populations. [a] Of the teens who were insured.
* $p < .05$
** $p < .01$

Overall the 2014 sample was split between males and females; the majority of teens in the U.S. sample were ages 14 years or older (87.6%), Non-Hispanic White (64.5%), lived above the poverty line (80.8%), had a college-educated mother (42.3%), had received a physician recommendation for the HPV vaccine (68.0%), had initiated or completed the HPV vaccine series (53.4%), had a well-child checkup at age 11 or 12 years (94.8%), and had employee-based insurance (64.3% of teens who were insured). Regarding the control variables, the majority of teens had a married mother (68.7%), a mother aged 35 years or older (92.4%), two to three children under 18 in the household (55.7%), between one and three visits to a health care professional in the past 12 months (69.8%), and the mother completed the survey (74.4%). When compared to the select local area subset, the U.S. sample proportions were significantly different as assessed by the chi-square test, with the exception of gender, well-child checkup at ages 11 or 12, and ever being uninsured. As with the 2015 population, given the differences between the two populations, I analyzed both the select local area and U.S. samples, focusing specifically on select local area for my research questions.

Results

Research Question One

In RQ1, I used binomial logistic regression to examine whether there is a relationship between initiation of the HPV vaccine series and socioeconomic and demographic variables in the 2015 select local area dataset, controlling for known confounders (Table 12). Model 1 included gender, race and ethnicity, poverty status, mother's education level, and select local areas of interest; Model 2 added clinical parameters: well-check visits, number of visits in the past 12 months, type of health insurance, and if the teen was ever uninsured since age 11. Model 3 added control factors: age of teen, relationship of respondent to teen, number of children in house under

18, mother's marital status, and age of the teen's mother. Variables meeting statistical significance ($p < .05$) were carried into the next iteration.

Table 12

Relationships between HPV vaccine initiation and socioeconomic and demographic variables, Select Local Area, 2015

	Model 1 OR [95% CI]	Model 2 OR [95% CI]	Model 3 OR [95% CI]
Gender			
Male	1.18 [.94-1.47]	-	-
Female	-		
Race/ethnicity			
Hispanic	1.10 [.80-1.52]	-	-
Black	.95 [.67-1.35]	-	-
White	-		
Poverty			
Below	1.35 [.95-1.92]	1.34 [.90-1.98]	-
Poverty to $75K	1.49 [1.10-2.03]**	1.41 [1.02-1.97]	-
Above $75K	-		
Mother's education			
< 12 years	1.74 [1.20-2.53]**	1.74 [1.19-2.53]**	1.87 [1.34-2.62]***
High school	1.06 [.76-1.49]	1.06 [.76-1.49]	1.16 [.84-1.60]
Some college	1.31 [.95-1.80]	1.30 [.95-1.79]	1.41 [1.04-1.93]*
College	-		
Select local area			
New York	1.08 [.78-1.49]	1.14 [.83-1.58]	1.15 [.84-1.60]
Washington, D.C.	1.00 [.47-2.10]	.99 [.47-2.09]	1.00 [.47-2.11]
Philadelphia	.95 [.59-1.53]	.95 [.59-.1.53]	.98[.60-1.59]
Hidalgo County	.45 [.26-.80]**	.49 [.28-.84]**	.51 [.29-.89]*
El Paso County	.59 [.34-1.03]	.68 [.40-1.16]	.66 [.39-1.12]
Houston	.43 [.27-.69]***	.43 [.27-.68]***	.42 [.26-.68]***
Bexar County	.75 [.49-1.15]	.85 [.56-1.29]	.85 [.56-1.29]
Chicago	-		

Note. CI, Confidence Interval. OR, odds ratio. Model 3 was the best fit as determined by -2 Log likelihood at $\alpha = .05$, $\chi^2(4) < 21.92$. Fit was calculated by comparing the chi-square distribution value given degrees of freedom (the difference in parameters between the two models) with the difference of -2LL between the two models. If the chi-square value was larger, H_0 was accepted and the smaller model was the better fit (IBM Knowledge Center, n.d.).
* $p < .05$

** $p < .01$
*** $p < .001$

Model 1 was statistically significant, $\chi^2(15) = 55.53$, $p < .001$. The model explained 4.9% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 70.4% of cases. Of the five predictors, education ($p < .05$), poverty ($p < .05$), and select local area ($p < .001$) were significantly associated with initiation of the HPV vaccine series (Table 12). Teens with mothers having less than 12 years of education were 74% were more likely to initiate the series than teens with college-educated mothers (OR = 1.74, CI [1.20-2.53], $p < .01$). Teens living just above the poverty line were 49% more likely to initiate the HPV vaccine series compared to those living at the highest income level (OR = 1.49, CI [1.10-2.03], $p < .01$). Finally, teens living in Hidalgo County and Houston were 55% and 57% less likely, respectively, to initiate the series than teens living in Chicago (OR = .45, CI [.26-.80], $p < .01$ and OR = .43, CI [.27-.69], $p < .001$).

Model 2 was statistically significant, $\chi^2(19) = 63.37$, $p < .001$. The model explained 5.6% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 69.3% of cases. Of the predictors, education, select local area ($p < .001$), and ever being uninsured ($p < .05$), were statistically significant. Teens with mothers having less than 12 years of education were 74% more likely to initiate the series than teens with college-educated mothers (OR = 1.74, CI [1.19-2.53], $p < .01$). Teens living in Hidalgo County and Houston were 51% and 57% less likely, respectively, to initiate the series than teens living in Chicago (OR = .49, CI [.28-.84], $p < .01$ and OR = .43, CI [.27-.68], $p < .001$). Of the clinical variables added to the model, teens who had not been covered by insurance at least once since age 11 were 52% more likely to initiate the vaccine than teens who had been covered since age 11 (OR = 1.52, CI [1.02-2.27], $p < .05$).

Model 3 was statistically significant, $\chi^2(23) = 85.29$, $p < .001$. The model explained 7.5% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 69.5% of cases. Of the predictors, education ($p < .01$), select local area ($p < .001$), and respondent's relationship to the teen ($p < .05$) were statistically significant. Teens with mothers having less than 12 years of education or some college were 87% and 41% more likely, respectively, to initiate the series than teens with college-educated mothers (OR = 1.87, CI [1.34-2.62], $p < .001$ and OR = 1.41, CI [1.04-1.93], $p < .05$). Teens living in Hidalgo County and Houston were 49% and 58% less likely, respectively, to initiate the series than teens living in Chicago (OR = .51, CI [.29-.89], $p < .01$ and OR = .42, CI [.26-.68], $p < .001$). Of the remaining variables added to the model, teens whose friends or other family members and grandparents answered the survey were 108% and 74% more likely, respectively, to have initiated the HPV vaccine (OR = 2.08, CI [1.05-4.13], $p < .05$, and OR = 1.74, CI [1.02-2.97], $p < .05$).

Overall, for RQ1 I rejected the null hypothesis, showing instead that there was a relationship between initiation of the HPV vaccine series and at least one socioeconomic or demographic variable in select local areas in unadjusted and adjusted models. Across all three models, teens whose mothers had less than a college degree were more likely to initiate the HPV vaccine, while teens living in Houston and Hidalgo County were less likely to initiate the HPV vaccine. The null hypothesis was rejected using the Complex

Samples methodology as well, based on significant relationships between initiation and select local area (Table A1 in Appendix A).

Research Question Two

In RQ2, I examined whether there is a relationship between completion of the HPV vaccine series and socioeconomic and demographic variables in the 2015 select local area dataset, controlling for known confounders (Table 13). As with RQ1, Model 1 included gender, race and ethnicity, poverty status, mother's education level, and select local areas of interest; Model 2 added clinical parameters: well-check visits, number of visits in the past 12 months, type of health insurance, and if the teen was ever uninsured since age 11. Model 3 added control factors: age of teen, relationship of respondent to teen, number of children in house under 18, mother's marital status, and age of the teen's mother.

Table 13

Relationships between HPV vaccine completion and socioeconomic and demographic variables, Select Local Area, 2015

	Model 1 OR [95% CI]	Model 2 OR [95% CI]	Model 3 OR [95% CI]
Gender			
Male	.65 [.52-.81]***	.67 [.54-.84]***	.64 [.51-.80]***
Female	-		
Race/ethnicity			
Hispanic	1.28 [.93-1.74]	-	-
Black	1.12 [.79-1.57]	-	-
White	-		
Poverty			
Below	1.15 [.82-1.63]	-	-
Poverty to $75K	1.07 [.80-1.44]	-	-
Above $75K	-		
Mother's education			
< 12 years	.55 [.38-.81]**	.64 [.45-.92]*	.71 [.51-.1.00]
High school	.82 [.60-1.13]	.90 [.66-1.21]	1.11 [.82-1.50]
Some college	.57 [.41-.78]***	.60 [.44-.81]***	.69 [.51-.95]*
College	-		
Select local area			
New York	.95 [.68-1.32]	.95 [.68-1.34]	.93 [.66-1.31]
Washington, D.C.	1.41 [.68-2.90]	1.37 [.67-2.83]	1.35 [.65-2.82]
Philadelphia	2.00 [1.25-3.19]**	1.98 [1.25-3.16]**	2. 03 [1.26-3.26**
Hidalgo County	1.18 [.70-1.99]	1.29 [.78-2.15]	1.33 [.79-2.22]
El Paso County	1.24 [.74-2.09]	1.34 [.81-2.21]	1.41 [.84-2.35]
Houston	1.46 [.96-2.21]	1.46 [.97-2.22]	1.64 [1.07-2.51]*
Bexar County	1.09 [.71-1.67]	1.13 [.75-1.71]	1.09 [.72-1.66]
Chicago	-		

Note. CI, Confidence Interval. OR, odds ratio.
* $p < .05$
** $p < .01$
*** $p < .001$

Model 1 was statistically significant, $\chi^2(15) = 48.65$, $p < .001$. The model explained 4.3% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 68.2% of cases. Of the five predictors, gender, education ($p < .001$), and select local area ($p < .05$) were statistically associated with completion of the HPV vaccine series (Table 13). Males were 35% less likely than females to complete the series (OR = .65, CI [.52-.81], $p < .001$). Teens with mothers having less than 12 years of education or some college were 45% and 43% less likely, respectively, to complete the series than teens with college-educated mothers (OR = .55, CI [.38-.81], $p < .01$, and OR = .57, CI [41-.78], $p < .001$). Last, teens living in Philadelphia were 100% more likely to complete the series than teens living in Chicago (OR = 2.00, CI [1.25-3.19], $p < .01$).

Model 2 was statistically significant, $\chi^2(18) = 53.12$, $p < .001$. The model explained 4.7% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 67.8% of cases. Of the predictors, gender ($p < .010$), education ($p < .01$), and select local area ($p < .05$) were statistically associated with completion of the HPV vaccine series. Males were 33% less likely than females to complete the series (OR = .67, CI [.54-.84], $p < .001$). Teens with mothers having less than 12 years of education or some college were 36% and 40% less likely, respectively, to complete the series than teens with college-educated mothers (OR = .64, CI [.45-.92], $p < .05$, and OR = .60, CI [.44-.81], $p < .001$). Last, teens living in Philadelphia were 98% more likely to complete the series than teens living in Chicago (OR = 1.98, CI [1.25-3.16], $p < .01$). None of the clinical variables added to the model were significantly associated with completing the HPV vaccine series.

Model 3 was statistically significant, $\chi^2(23) = 111.56$, $p < .001$. The model explained 9.6% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 69.5% of cases. Of the predictors, education ($p < .05$), select local area ($p <$

.01), relationship of the respondent to the teen, age of the teen, and gender ($p < .001$) were significantly associated with completing the HPV vaccine series. Males were 36% less likely than females to complete the series (OR = .64, CI [.51-.80], $p < .001$). Teens with mothers having some college were 31% less likely to complete the series than teens with college-educated mothers (OR = .69, CI [.51-.95], $p < .05$). Teens living in Philadelphia and Houston were 103% and 64% more likely, respectively, to complete the series than teens living in Chicago (OR = 2.03, CI [1.26-3.26], $p < .01$, and OR = 1.64, CI [1.07-2.51], $p < .05$). Teens were less likely to complete the series if other family members or friends (70% less likely), grandparents (67%), or fathers (39%) answered the survey rather than mothers (all $p < .01$). Last, teens were 41% less likely to complete the series if they were 14 years old ($p < .01$) but 63% more likely to complete the series if they were 15 years old ($p < .01$) compared to teens aged 17 years old.

Overall, for RQ2 I rejected the null hypothesis, showing instead that there was a relationship between completion of the HPV vaccine series and at least one socioeconomic or demographic variable in select local areas in unadjusted and adjusted models. Across all three models, males and teens whose mothers had less than a college education were less likely to complete the HPV vaccine series, while teens living in Philadelphia and Houston were more likely to complete the series. The null hypothesis was rejected using the Complex Samples methodology as well, based on significant relationships between completion and gender (Table A2 in Appendix A).

Research Question Three

In RQ3, I examined whether there is a relationship between initiation of the HPV vaccine series and social vulnerability by select local area county, using a chi-square test of independence and data from the 2014 NIS-Teen and the 2014 Social Vulnerability Index (Table 14). All expected cell frequencies were greater than five.

Table 14

Relationship between HPV vaccine initiation and overall county social vulnerability ranking, 2014

	Social Vulnerability percentile ranking	HPV Vaccine Initiation	
		Yes	No
Washington, D.C.	.59 (Med-High)		
Count		20	54
Expected Count		19.7	54.3
Adjusted Residuals		0.1	-0.1
Philadelphia	.91 (High)		
Count		73	148
Expected Count		58.9	162.1
Adjusted Residuals		2.6	-2.6
El Paso County	.95 (High)		
Count		47	139
Expected Count		49.6	136.4
Adjusted Residuals		-.05	0.5
Bexar County	.82 (High)		
Count		63	218
Expected Count		74.9	206.1
Adjusted Residuals		-2.0	2.0

Note. Med-High indicates a medium-high vulnerability, or being in the third-highest percentile of vulnerability.

There was not a statistically significant association found between the two variables, $\chi^2(3) = 7.37$, $p = .06$. The adjusted standardized residuals were greater than or equal to 2 in Philadelphia and Bexar County, with the largest difference between observed and expected counts in Philadelphia.

For RQ3 I could not reject the null hypothesis, as the relationship between HPV vaccine initiation and social vulnerability ranking did not meet statistical significance. The null hypothesis was not rejected using the Complex Samples methodology as well, as there was no significant relationship between the variables (Table A3 in Appendix A).

Research Question Four

In RQ4, I examined whether there is a relationship between physician recommendation of the HPV vaccine series and social vulnerability by select local area county, using a chi-square test of independence and data from the 2014 NIS-Teen and the 2014 Social Vulnerability Index (Table 15).

Table 15

Relationship between physician recommendation and overall county social vulnerability ranking, 2014

	Social Vulnerability percentile ranking	Physician Recommendation	
		Yes	No
Washington, D.C.	.59 (Med-High)		
Count		60	14
Expected Count		51	23
Adjusted Residuals		2.4	-2.4
Philadelphia	.91 (High)		
Count		168	53
Expected Count		152.2	68.8
Adjusted Residuals		2.7	-2.7
El Paso County	.95 (High)		
Count		128	57
Expected Count		127.4	57.6
Adjusted Residuals		.1	-.1
Bexar County	.82 (High)		
Count		168	113
Expected Count		193.5	87.5
Adjusted Residuals		-4.1	4.1*

Note. Med-High indicates a medium-high vulnerability, or being in the third-highest percentile of vulnerability.

* $p < .05$

There was a statistically significant association between the two variables, $\chi^2(3) = 21.23$, $p < .001$, and the association was small, Cramer's V = 0.17, $p < .001$. The adjusted standardized residuals were greater than 2 in Washington, D.C., Philadelphia, and Bexar County, with the largest difference between observed and expected counts in Bexar County.

For RQ4 I rejected the null hypothesis, as the relationship between physician recommendation and social vulnerability ranking was statistically significant. The null hypothesis was rejected using the Complex Samples methodology as well, as there was a significant relationship between the two variables (Table A4 in Appendix A).

Although the following analyses were not included in the original research questions, they provide additional context in the testing of relationships between HPV vaccination, physician recommendation, and select independent variables.

U.S. Sample Analyses

Initiation. In the U.S. sample (Table 16), initiation of the HPV vaccine series correlated with gender, race and ethnicity, poverty status, and select local area across all three models.

Table 16

Relationships between HPV vaccine initiation and socioeconomic and demographic variables, United States, 2015

	Model 1 OR [95% CI]	Model 2 OR [95% CI]	Model 3 OR [95% CI]
Gender			
Male	.80 [.74-.87]***	.80 [.73-.87]***	.80 [.74-.87]***
Female	-		
Race/ethnicity			
Hispanic	1.11 [.98-1.26]	1.13 [1.00-1.28]*	1.15 [1.02-1.31]*
Black	1.28 [1.12-1.45]***	1.25 [1.09-1.42]***	1.27 [1.11-1.45]***
White	-		
Poverty			
Below	1.37 [1.19-1.58]***	1.33 [1.16-1.53]***	1.33 [1.16-1.51]***
Poverty to $75K	.97 [.87-1.08]	.95 [.85-1.06]	.95 [.86-1.06]
Above $75K	-		
Mother's education			
< 12 years	1.13 [.95-1.34]	-	-
High school	.97 [.85-1.10]	-	-
Some college	1.00 [.89-1.12]	-	-
College	-		
Select local area			
New York	1.09 [.66-1.81]	1.06 [.64-1.76]	1.06 [.64-1.76]
Washington, D.C.	.89 [.27-2.90]	.90 [.27-2.94]	.88 [.27-2.90]
Philadelphia	.90 [.42-1.92]	.95 [.59-.1.53]	.89 [.42-.1.91]
Hidalgo County	.53 [.22-1.26]	.52 [.22-1.25]	.51 [.21-1.22]
El Paso County	.69 [.30-1.60]	.68 [.29-1.58]	.68 [.29-1.58]
Houston	.45 [.21-.95]*	.43 [.20-.90]*	.41 [.20-.88]*
Bexar County	.81 [.42-1.58]	.84 [.43-1.62]	.82 [.42-1.59]
Chicago	-		

Note. CI, Confidence Interval. OR, odds ratio.
* $p < .05$
** $p < .01$
*** $p < .001$

Model 1 was statistically significant, $\chi^2(65) = 192.49$, $p < .001$. The model explained 2.4% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 76.4% of cases. Of the five predictors, gender, race, poverty ($p < .001$), and select local area ($p < .01$) were significantly associated with initiation of the HPV vaccine series (Table 16). This differed from the select local area sample, in which mother's education level was significant and gender was not (Table 12). Teens were less likely to initiate the HPV vaccine series if they were male (20% less) or lived in Houston (55%), compared to females or teens who lived in Chicago. Teens were more likely to initiate the series if they were Black (28% more) or lived below the poverty level (37%) than teens who were White or lived at the highest income level.

Model 2 was statistically significant, $\chi^2(69) = 235.77$, $p < .001$. The model explained 3.0% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 76.4% of cases. Of the predictors, gender, poverty, number of visits to a health care professional in the past year, ($p < .001$), race, and select local area ($p < .01$) were significantly associated with initiation of the HPV vaccine series (Table 16). This differed from the select local area sample, in which only mother's education level, ever being uninsured, and select local area were significant (Table 12). Teens were less likely to initiate the HPV vaccine series if they were male (20% less) or lived in Houston (57% less), compared to females or teens who lived in Chicago. Teens were more likely to initiate the series if they were Hispanic (13% more), Black (25%) or lived below the poverty level (33%) compared to teens who were White or lived at the highest income level. Last, teens who had between one and five visits with a health care professional in the past 12 months were 43% to 58% more likely to initiate the vaccine than teens who had no visits.

Model 3 was statistically significant, $\chi^2(76) = 306.40$, $p < .001$. The model explained 3.8% (Nagelkerke R^2) of the variance in vaccine initiation and correctly classified 76.5% of cases. Of the predictors, gender, poverty, race, select local area, number of visits to a health care professional in the past year, relationship of the respondent to the teen, number of children in the household under age 18 years, age of the teen, ($p < .001$), and mother's marital status ($p < .05$) were significantly associated with initiation of the HPV vaccine series (Table 16). This differed from the select local area sample, in which only mother's education level and select local area were significant (Table 12). Teens were less likely to initiate the HPV vaccine series if they were male (20% less) or lived in Houston (59%), compared to females or teens who lived in Chicago. Teens were more likely to initiate the series if they were Hispanic (15% more), Black (27%) or lived below the poverty level (33%) compared to teens who were White or lived at the highest income level.

Completion. In the U.S. sample (Table 17), completion of the HPV vaccine series was associated with gender, mother's education, and select local area across all three models.

Table 17

Relationships between HPV vaccine completion and socioeconomic and demographic variables, United States, 2015

	Model 1 OR [95% CI]	Model 2 OR [95% CI]	Model 3 OR [95% CI]
Gender			
Male	.52 [.48-.56]***	.52 [.48-.56]***	.52 [.48-.56]***
Female	-		
Race/ethnicity			
Hispanic	1.13 [1.00-1.26]*	1.12 [1.00-1.26]*	1.10 [.98-1.24]
Black	.93 [.82-1.05]	.94 [.83-1.07]	.91 [.80-1.04]
White	-		
Poverty			
Below	.94 [.82-1.07]		
Poverty to $75K	.90 [.82-1.00]		
Above $75K	-		
Mother's education			
< 12 years	.98 [.83-1.15]	.97 [.83-1.14]	1.01 [.87-1.18]
High school	.81 [.72-.92]***	.79 [.71-.89]***	.85 [.76-.96]**
Some college	.86 [.77-.95]**	.85 [.76-.94]***	.86 [.77-.95]**
College	-		
Select local area			
New York	.98 [.58-1.68]	1.03 [.60-1.76]	1.04 [.61-1.79]
Washington, D.C.	1.50 [.47-4.77]	1.54 [.48-4.95]	1.60 [.49-5.19]
Philadelphia	2.20 [1.05-4.63]*	2.24 [1.06-4.72]*	2.30 [1.08-4.90]*
Hidalgo County	1.13 [.50-2.54]	1.11 [.49-2.52]	1.17 [.51-2.67]
El Paso County	1.28 [.57-2.87]	1.33 [.59-2.99]	1.38 [.61-3.13]
Houston	1.46 [.75-2.86]	1.46 [.75-2.86]	1.52 [.77-3.00]
Bexar County	1.12 [.58-2.18]	1.21 [.62-2.35]	1.24 [.63-2.42]
Chicago	-		

Note. CI, Confidence Interval. OR, odds ratio.
* $p < .05$
** $p < .01$
*** $p < .001$

Model 1 was statistically significant, $\chi^2(65) = 482.08$, $p < .001$. The model explained 5.5% (Nagelkerke R^2) of the variance in vaccine completion and correctly classified 66.8% of cases. Of the predictors, gender, mother's education level, select local area ($p < .001$), and race ($p < .05$) were significantly associated with completion of the HPV vaccine series (Table 17). This differed from the select local area sample, in which only gender, mother's education level, and select local area were significant (Table 13). Teens were less likely to complete the HPV vaccine series if they were male (48% less), if their mothers were high school graduates (19%) or had some college education (14%) compared to females or teens whose mothers had less than 12 years of education or a college degree. Teens were more likely to complete the vaccine series if they were Hispanic (13% more) or lived in Philadelphia (120%) compared to teens who were White or lived in Chicago.

Model 2 was statistically significant, $\chi^2(70) = 576.64$, $p < .001$. The model explained 6.6% (Nagelkerke R^2) of the variance in vaccine completion and correctly classified 67.7% of cases. Of the predictors, gender, mother's education level, select local area, a well-check visit at age 11 or 12, number of visits to a health care professional in the past 12 months ($p < .001$), and race ($p < .05$) were significantly associated with completion of the HPV vaccine series (Table 17). This differed from the select local area sample, in which only gender, mother's education level, and select local area were significant (Table 13). Teens were less likely to complete the HPV vaccine series if they were male (48% less), if their mothers were high school graduates (21%) or had some college education (15%) compared to females or teens whose mothers had less than 12 years of education or a college degree. Teens were more likely to complete the vaccine series if they were Hispanic (12% more) or lived in Philadelphia (124%) compared to teens who were White or lived in Chicago.

Model 3 was statistically significant, $\chi^2(80) = 847.79$, $p < .001$. The model explained 9.6% (Nagelkerke R^2) of the variance in vaccine completion and correctly classified 69.4% of cases. Of the predictors, gender, select local area, a well-check visit at age 11 or 12, number of visits to a health care professional in the past 12 months, number of children in the household under 18 years, age of the teen, ($p < .001$) mother's education level ($p < .01$), and mother's age ($p < .05$) were significantly associated with completion of the HPV vaccine series (Table 17). This differed from the select local area sample, in which only gender, mother's education level, and select local area were significant (Table 13). Teens were less likely to complete the HPV vaccine series if they were male (48% less), if their mothers were high school graduates (15%) or had some college education (14%) compared to females or teens whose mothers had less than 12 years of education or a college degree. Teens were more likely to complete the vaccine series if they lived in Philadelphia (130% more) compared to teens who lived in Chicago.

Finally, the relationship between HPV initiation and completion was significant across the United States (Table D1 in Appendix D). Teens were less likely to initiate the vaccine series if they lived in Arizona, Florida, Iowa, Louisiana, Missouri, New Mexico, Ohio, Pennsylvania, Tennessee, and Texas than teens who lived in Chicago. Teens were more likely to complete the series if they lived in Arizona, California, Iowa, Maine, Massachusetts, New Hampshire, Oklahoma, Pennsylvania, and Rhode Island.

No Shots Analysis

Binominal logistic regression was used to test the relationship between receiving no shots in the HPV vaccine series in the United States and select local areas (Table 18).

Table 18

Relationships between no receipt of HPV vaccine and socioeconomic and demographic variables, United States and Select Local Areas, 2015

	U.S. sample OR [95% CI]	Select Local Area sample OR [95% CI]
Gender		
Male	2.14 [1.98-2.31]***	1.30 [1.05-1.60]*
Female	-	
Race/ethnicity		
Hispanic	.83 [74-.93]***	.73 [.54-.98]*
Black	.88 [.78-.99]*	.94 [.68-1.30]
White	-	
Poverty		
Below	0.82 [.72-.93]**	.69 [.49-.95]*
Poverty to $75K	1.13 [1.03-1.24]*	.67 [.51-.89]**
Above $75K	-	
Mother's education		
< 12 years	.91 [.77-1.06]	1.04 [.72-1.51]
High school	1.24 [1.11-1.38]***	1.15 [.84-1.58]
Some college	1.15 [1.04-1.27]**	1.33 [.98-1.79]
College	-	
Select local area		
New York	.95 [.58-1.58]	.98 [.71-1.34]
Washington, D.C.	.77 [.24-2.52]	.73 [.35-1.52]
Philadelphia	.48 [.22-1.09]	.50 [.30-.83]**
Hidalgo County	1.57 [.72-3.41]	1.69 [1.03-2.78]*
El Paso County	1.13 [.52-2.48]	1.29 [.78-2.13]
Houston	1.35 [.70-2.58]	1.37 [.92-2.06]
Bexar County	1.11 [.59-2.08]	1.20 [.80-1.79]
Chicago	-	

Note. CI, Confidence Interval. OR, odds ratio.
* $p < .05$
** $p < .01$
*** $p < .001$

In the U.S. sample, teens were more likely to receive no shots if they were male (114% more likely), living just above the poverty level (13%), or had mothers with a high school (24%) or some college education (15%) compared to the reference groups. Teens were less likely to receive no shots if they were Hispanic (17% less likely), Black (12%), or lived below the poverty level (18%).

In the select local area sample, teens were more likely to receive no shots if they were male (30% more likely) compared to females or lived in Hidalgo County (69%) versus Chicago; teens were less likely to receive no shots if they lived below (31% less likely) or just above the poverty line (33%), were Hispanic (27%), or lived in Philadelphia (50%) compared to the reference groups.

Select Local Area and Vulnerability Analyses

Using a chi-square test of independence, I tested the relationships between receipt of no HPV shots, completion of the HPV series, and select local area county using data from the 2014 NIS-Teen and the 2014 Social Vulnerability Index (Table 19).

Table 10

Relationship between no shots, completion of the series, and overall county social vulnerability ranking, 2014

	SVI rank	No shots		Completion	
		Yes	No	Yes	No
Washington, D.C.	.59 (Med-High)				
Count		23	51	31	43
Expected Count		29	45	25.5	48.5
Adjusted Residuals		-1.5	1.5	1.4	-1.4
Philadelphia	.91 (High)				
Count		62	159	86	135
Expected Count		86.5	134.5	76.1	144.9
Adjusted Residuals		-4.0	4.0*	1.7	-1.7
El Paso County	.95 (High)				
Count		67	118	72	113
Expected Count		72.4	112.6	63.7	121.3
Adjusted Residuals		-.9	.9	1.5	-1.5
Bexar County	.82 (High)				
Count		146	135	73	208
Expected Count		110	171	96.7	184.3
Adjusted Residuals		5.5	-5.5**	-3.8	3.8*

Note. Med-High indicates a medium-high vulnerability, or being in the third-highest percentile of vulnerability.
* $p < .05$
* $p < .01$

There was a statistically significant association between the counties and receipt of no shots, $\chi^2(3) = 33.46$, $p < .001$, and the association was small to moderate, Cramer's V = 0.21, $p < .01$. The adjusted standardized residuals were greater than 2 in Bexar County and Philadelphia. With completion of the series and the select counties, there was a statistically significant association, $\chi^2(3) = 14.34$, $p < .01$, and the association was small, Cramer's V = 0.14, $p < .001$. The adjusted standardized residuals were greater than 2 in Bexar County.

Select Local Areas Versus States Analysis

As select local area samples were removed from states as a whole in NIS-Teen, I conducted a chi-square test of independence to test the association between no shots, HPV vaccine initiation, vaccine completion, and physician recommendation between select local areas and their states (Table 20).

Table 11

Significant Relationships between Select Local Areas and States, 2015

	No shots χ^2(df) (Cramer's V)	Initiation χ^2(df) (Cramer's V)	Completion χ^2(df) (Cramer's V)	Recommendation χ^2(df) (Cramer's V)
New York City vs. New York	$\chi^2(1) = 2.13$ (.06)	$\chi^2(1) = 12.32$*** (.13)***	$\chi^2(1) = 2.99$ (.07)	$\chi^2(1) = .09$ (.01)
Philadelphia vs. Pennsylvania	$\chi^2(1) = 5.35$* (.11)*	$\chi^2(1) = 5.06$* (.11)*	$\chi^2(1) = .28$ (.03)	$\chi^2(1) = .96$ (.05)
Chicago vs. Illinois	$\chi^2(1) = 3.71$ (.08)	$\chi^2(1) = 5.68$* (.10)*	$\chi^2(1) = .01$ (.01)	$\chi^2(1) = 1.73$ (.06)
Hidalgo County vs. Texas	$\chi^2(1) = 1.18$ (.04)	$\chi^2(1) = .06$ (.01)	$\chi^2(1) = 1.45$ (.04)	$\chi^2(1) = .30$ (.02)
El Paso County vs. Texas	$\chi^2(1) = 2.96$ (-.06)	$\chi^2(1) = .38$ (.02)	$\chi^2(1) = 2.45$ (.05)	$\chi^2(1) = .78$ (.03)
Houston vs. Texas	$\chi^2(1) = 2.71$ (.05)	$\chi^2(1) = .21$ (.02)	$\chi^2(1) = 5.99$* (.08)*	$\chi^2(1) = 4.66$* (.07)*
Bexar County vs. Texas	$\chi^2(1) = 4.68$* (.07)*	$\chi^2(1) = 1.38$ (.04)	$\chi^2(1) = 2.21$ (.04)	$\chi^2(1) = 2.31$ (.05)

Note. df, degrees of freedom.
* $p < .05$

*** $p < .001$

There was a significant relationship between Philadelphia and Pennsylvania and Bexar County and Texas in receiving no HPV shots, both with small effects as measured by Cramer's V. Fewer teens than expected received no shots in Philadelphia and Bexar County. Regarding HPV vaccine initiation, there was a significant relationship between New York City, Philadelphia, and Chicago and their respective states, all with small effects. Fewer teens than expected initiated the HPV vaccine in New York state, Pennsylvania, and Illinois. The only significant relationship for completion of the HPV vaccine series was observed between Houston and Texas, in which fewer teens than expected in Texas completed the series, with a small effect. Last, there was a significant relationship between Houston and Texas regarding physician recommendation, in which fewer teens than expected in Texas had a physician recommendation, with small effect.

Finally, physician recommendation differed significantly by state (Table D1 in Appendix D). Teens who lived in Alabama, Arkansas, Mississippi, Missouri, Tennessee, and Texas were less likely to receive a physician recommendation, while teens who lived in Rhode Island were more likely to receive a physician recommendation.

Summary

In summary, I rejected the null hypothesis for research question 1, as there was a significant relationship between HPV vaccine initiation, the mother's level of education, and select local area. Teens whose mothers had less than a college degree were more likely to initiate the HPV vaccine, while teens living in Houston and Hidalgo County were less likely to initiate the HPV vaccine.

I rejected the null hypothesis for research question 2, as there was a significant relationship between HPV vaccine completion, teen's gender, the mother's level of education, and select local area. Teens living in Philadelphia and Houston were more likely to complete the series, while males and teens whose mothers had less than a college education were less likely to complete the HPV vaccine series.

I did not reject the null hypothesis for research question 3, as there was not a significant relationship between HPV vaccine initiation and select local area county. Finally, I rejected the null hypothesis for research question 4, as there was a significant relationship between physician recommendation of the HPV vaccine and select local area county.

I presented several additional analyses of the 2014 and 2015 NIS-Teen data, including analyses of the U.S. sample; relationships between receipt of no HPV shots and independent variables; relationships between receipt of no shots, completion of the series, and select local area county; and relationships between select local area and respective states with the dependent variables.

In the following chapter, I discuss the interpretation of the results and how these results reflect findings in the peer-reviewed literature, as well as present recommendations for professional practice and the implications for social change.

Section 4: Application to Professional Practice and Implications for Social Change

Introduction

Rates of the HPV vaccine and physician recommendation for the vaccine continue to be lower than any other adolescent vaccine, and vary across gender, socioeconomic status, racial and ethnic background, and geographic location (Henry et al., 2017; Mohammed et al., 2016; Reagan-Steiner et al., 2016; Rutten et al., 2017). Researchers have focused on inter- and intra-personal efforts to promote behavior change regarding vaccination, but these interventions have had little effect on increasing HPV vaccination rates (Askelson et al., 2016; Brandt et al., 2016). Additional research on other potential factors influencing vaccination is needed to increase rates, as well as physician recommendation of the HPV vaccine, to better protect against multiple HPV-related cancers (Maness et al., 2016; Perkins, 2016).

The purpose of this quantitative, retrospective, secondary analysis of national, publicly available data was to test the relationships between HPV vaccine initiation and completion, socioeconomic and demographic variables, physician recommendation, and social vulnerability in select local areas in the United States. In these analyses, I showed that teens were more likely to initiate the HPV vaccine series if their mothers had less education than a college degree versus teens whose mothers had graduated college; teens were less likely to initiate the series if they lived in Houston or Hidalgo County versus teens living in Chicago. Teens were more likely to complete the HPV vaccine series if they lived in Philadelphia or Houston versus teens living in Chicago; teens were less likely to complete the series if they were males or their mothers had less than a college education versus those who had graduated college. Finally, I did not find a relationship between initiation of the series and select local area, but did find a relationship between physician recommendation of the vaccine and select local area.

Interpretation of the Findings

Socioeconomic Variables

The definition of socioeconomic status is complex and dynamic, and how it is measured within a study affects the findings and interpretations (Joshua et al., 2015; Ratnapradipa et al., 2017; Willis & Fitton, 2016). In peer-reviewed literature, most researchers used metrics including poverty level and the mother's level of education, and have found an inverse relationship between HPV vaccination, poverty, and education level in the United States (Galbraith et al., 2016; Henry et al., 2017; Jeudin et al., 2014; Monnat et al., 2016; Perkins, 2016; Polonijo et al., 2016; Reagan-Steiner et al., 2016).

My findings reflected the literature regarding a significant relationship between mother's level of education and HPV vaccination, in which an inverse relationship has been demonstrated between educational attainment, the teen's vaccination, and physician recommendation (Mohammed et al., 2016; Henry et al., 2017). Of note, teens whose mothers had less than a high school education or some college were more likely to initiate the HPV vaccine, but teens whose mothers had some college were less likely to complete the series than teens whose mothers had a college education. The higher likelihood of initiation may have reflected greater access to the HPV vaccine through the Vaccines For Children program to initiate the series, while the lower likelihood of completion may have been due to lower rates of physician recommendation within lower educational attainment levels, or less awareness of the importance of completing the series (Mohammed et al., 2016; Henry et al., 2017).

My findings within the select local area sample regarding the relationship between poverty and vaccination were not consistent with current literature, although my findings using the U.S. sample did align with published findings that teens living below the poverty level were more likely to be vaccinated than teens at the highest income levels (see *Additional Analyses* section below). Poverty was not significantly associated with HPV vaccine initiation or completion in the final models in research questions 1 and 2. The discrepancy between my findings regarding poverty and those in the literature may have been due to the differences in sample selection, both geographically and in the dataset.

Researchers have demonstrated variations in relationships using the same socioeconomic data across different geographic levels, a phenomenon known as the modifiable area unit problem (Krieger et al., 2005; Pruitt & Schootman, 2010; Rutten et al., 2017). For example, Henry et al. (2017) found an inverse relationship between poverty level and Zip code tabulation areas across the United States using 2012-2013 NIS-Teen data; Rutten et al. (2017) showed a positive relationship between socioeconomic status and census block group with American Community Survey data; and Pruitt and Schootman (2010) and Krieger et al. (2005) demonstrated that the relationship between socioeconomic status and variables changed across state, county, block group, census tract, and Zip code. While I could not discount the small sample size in the select local areas as a potential influence on my findings, I believe the inconsistency between my findings at the select local area versus other published research supported the importance of using multiple geographic areas of analysis and working within each local community when assessing public health needs to distribute resources where they are most needed.

Demographic Variables

In peer-reviewed literature, the majority of researchers have shown a relationship between gender, race, age, and HPV vaccination, as well as physician recommendation, across geographic levels (Bodson et al., 2016; Gilkey et al., 2016; Jeudin et al., 2014; Mohammed et al., 2016; Malo et al., 2016b; Rahman et al., 2015; Reagan-Steiner et al., 2016; Rutten et al., 2017; Vadaparampil et al., 2016). My findings regarding HPV vaccine completion were consistent with the current literature, in that males were significantly less likely to complete the vaccine series than females. These results were consistently demonstrated across datasets, geographic levels, and over time, and were likely due to the 5-year delay in approval and insurance coverage of the HPV vaccine for males, as well as lower rates of physician recommendation for males versus females (ACIP, 2016; Jeudin et al., 2014; Vadaparampil et al., 2016; Walker et al., 2017).

In addition, researchers have argued that knowledge and awareness of HPV's role in several male cancers was low, as was male awareness of the HPV vaccine (Boakye et al., 2017; Osazuwa-Peters et al., 2017). I did not find a significant relationship between gender and HPV vaccine initiation in the select local area sample, although I did find males were less likely to be vaccinated in the U.S. sample as reported in the literature (see *Additional Analyses*). This may have been due to the lower rates of physician recommendation for males, as once males began the series based on a recommendation, they would have been more likely to complete it (see *Limitations*). However, this hypothesis was not testable using the NIS-Teen database. In addition, while males living below the poverty line were more likely to initiate the vaccine series, there was a higher frequency of males in the above poverty categories in this study.

My findings regarding HPV vaccination and race were not consistent with the current literature, as there was no relationship between the two variables, or with physician recommendation. I did find a significant relationship between race and ethnicity and HPV completion in the U.S. sample, however, with Hispanics and Non-Hispanic Blacks more likely to initiate the HPV vaccine series than Non-Hispanic Whites (see *Additional Analyses*). This may have been due to the small number of select local areas used for comparison, as well as the significant difference in race and ethnicity populations between the United States and select local area samples (Table 11). In addition, there was not a significant relationship between physician recommendation and race and ethnicity (see *Limitations*).

Social Vulnerability

As noted previously, direct measurement of vulnerability may not be possible, and within geographic areas the same exposure to a risk factor does not mean each individual has the same vulnerability (Burnell, 2012; Ratnapradipa et al., 2017). Researchers recently have begun to test vulnerability rankings from the Social Vulnerability Index with a variety of health behaviors. For example, An and Xiang (2015) demonstrated differences in physical inactivity and vulnerability in a national sample, while Ratnapradipa et al. (2017) found a difference in incidence of Lyme Disease by vulnerability ranking across the United States. Given the importance of social determinants of health connected with vulnerability and with HPV vaccination, I used a novel approach to test any potential links between vulnerability and factors contributing to HPV vaccination by matching vulnerability rankings from the SVI with data in NIS-Teen at the county level (Gay et al., 2016; Grabovschi et al., 2013; Juster et al., 2016).

There was a significant relationship between overall social vulnerability ranking at the county level and physician recommendation, as teens who lived in Washington, D.C. and Philadelphia were more likely to receive a physician recommendation than teens in Bexar County, but not with initiation of the HPV vaccine series. There was a relationship between no shots and completion of the series as well; teens who lived in Philadelphia were less likely to receive no shots, while teens who lived in Bexar county were more likely to receive no shots and less likely to complete the vaccine series (see *Additional Analyses*). The findings were an important proof of concept in showing differences in dependent variables at the county level within NIS-Teen, and can provide a foundation for a number of questions for future research examining vulnerability in HPV vaccination and physician recommendation.

Additional Analyses

As noted above, my findings regarding the relationships between poverty, gender, race and ethnicity, HPV vaccination, and physician recommendation were consistent with findings in the current literature, as the sample population in this study reflected other research with national samples (Tables 16 and 17; Henry et al., 2017; Reagan-Steiner et al., 2016; Walker et al., 2017).

Few researchers have examined the relationship between socioeconomic and demographic variables and receipt of no HPV shots, as they would be expected to be the reverse of relationships with initiation and completion. While most of the independent variables were in line with these expectations, the findings regarding poverty were of note. In the United States, teens living just above the poverty level were more likely to receive no HPV shots. This may have been due to several factors; for example, the teens may not have qualified for free shots through Vaccines For Children, or they may have lived in marginally impoverished or wealthier areas with little access to free or low-cost health care clinics (Lin et al., 2015; Monnat et al., 2016; Tsui et al., 2013). In the select local area sample, teens living just above the poverty line were less likely to receive no shots; this may have reflected the influence of the federal Section 317 funds to purchase vaccines in these select local areas (Reagan-Steiner et al., 2016).

Theoretical Considerations

The theories underpinning this study were the fundamental cause theory (FCT) and bhavioral economics (BE). Together, the two stress the value in considering multiple levels of behavior and social determinants when assessing problems and solutions in public health (Bickel et al., 2016; Link & Phelan, 1995).

Link and Phelan (1995) posited in the FCT that resources and the capacity to use resources and innovations to avoid risks or minimize morbidity and mortality are distributed unequally. I found that resources such as education and poverty were unequal within the U.S. and select local area samples, as well as between the two samples, suggesting that the capacity to be proactive or to cope with health issues differs among populations (Clouston et al., 2016; Link & Phelan, 1995; Mackenbach, 2017). In addition, I found that uptake of the innovative HPV vaccine was unequal within and between populations in my study. While testing FCT directly is outside the scope of my study, I believe my findings support considering HPV vaccination as a modern empirical test of the FCT (Polonijo & Carpiano, 2013).

However, even if individuals have similar access (or lack of access) to health-promoting resources, Frank (2004) and Dovidio and Fiske (2012) argued that humans tend to make irrational decisions about health despite evidence pointing to the benefit of a more rational choice. The authors and others have advanced the use of BE in patient and physician decision-making, and in particular with physicians (Arrow, 1963; Mackenbach, 2017). I found that physician recommendation differs across geographic areas, as well as a number of socioeconomic and demographic variables that have been associated with HPV vaccination (Table C1 in Appendix C). Although NIS-Teen does not collect data on physician decision-making, and direct testing of behavioral economics is outside the scope of this study, I believe my findings provide initial evidence that physician decision-making (as measured by recommendation) is not consistent across geographic areas despite the body of evidence supporting HPV vaccination. In addition, I believe that the difference in recommendation across select local areas highlighted the role local biases and heuristics play in decision-making, as well as the importance of assessing and intervening in public health issues at the local level (Blumenthal-Barby & Krieger, 2015; Saini et al., 2017).

Limitations of the Study

There were several limitations to generalizability and validity in my study. First, as a national survey reliant on current, active telephone numbers for non-institutionalized heads of household, the NIS-Teen may have been subject to non-response and sampling biases. For example, data for teens whose guardians did not have a cell phone or landline number, or those with institutionalized guardians, were not captured. CDC used random-digit dialing methods and probability sampling adjustments to reduce any potential for sampling errors in the eligible population, but the data were not reflective of the above-mentioned population and should not be used to generalize to teens ineligible for the survey (CDC et al., 2015; 2016). Second, guardian recall or understanding of the questions in the self-reported survey may have been inaccurate or biased. CDC collected data from providers to verify household-reported data, and I used only data from teens with adequate provider data verification; using both household- and provider-collected data may have altered my findings and interpretation of the data (CDC et al., 2015; 2016). Third, provider data collected by NIS-Teen could not be analyzed for individual teens, given privacy and confidentiality constraints, and therefore analyzing trends in provider recommendation by specialty, facility type, or other characteristics was not possible. While quantifiable data on physician recommendation could provide direction to researchers, the use of such data would be of limited use without an understanding of the context in which physicians practice, as this may have influenced their recommendations. Fourth, sample sizes for states and select local areas were smaller than those of the nation as a whole, and therefore the confidence intervals were wider; as such, estimates of vaccine coverage were interpreted with caution (CDC et al., 2015; 2016). In addition, population characteristics were significantly different between the U.S. and select local area samples, preventing any generalizability from my select local area findings to the states or U.S. population as a whole. Fifth, the cross-sectional design of the NIS-Teen survey precluded any causal inferences about the relationships among variables.

The two limitations with the highest potential to influence my findings were the exclusion of physician recommendation from research questions one through three, and the specific geographic areas in which data for the NIS-Teen and SVI were collected. Physician recommendation across select local areas was tested in research question four, and would have been a redundant independent variable in the prior three questions. However, researchers consistently have shown the importance of physician recommendation on HPV vaccine initiation and completion (Burdette et al., 2017; Gilkey et al., 2016; Mohammed et al., 2016).

For example, in the select local area sample, physician recommendation was significantly associated with gender, poverty, mother's education level, select local area, number of visits to a health care professional in the past 12 months, mother's age, and age of the teen (Table C1 in Appendix C). In addition, in the absence of any confounding variables, the odds of initiating the series if a physician recommended the HPV vaccine were 5.21 times greater (95% CI, [3.68-7.37]) than if the physician did not recommend the HPV vaccine; the odds of completion were 35.69 times greater (95% CI, [17.53-72.46]) with a physician recommendation; and the odds of not receiving a shot if the physician recommended the vaccine were .04 times smaller than if a physician did not recommend the vaccine (Table C2 in Appendix C). While outside the scope of my study, the exclusion of physician recommendation from research questions one through three may have influenced my findings and interpretation of the data.

Finally, while Social Vulnerability Index data were available at the census tract level, the smallest geographic levels in NIS-Teen data were the teen's county in the public-use data file and Zip codes in the restricted data set. One strength of the SVI was the demonstration of intra-county variability in vulnerability among several factors; however, the reported vulnerability ranking scores were reported for the county as a whole, and each individual in that county had the same vulnerability score (CDC et al., 2017). As a result, comparisons to dependent variables could be made only between counties as a whole, rather than variations within a county compared to variations within another county, and a single value may have masked underlying disparities. While additional granularity could shed light on any flexible resources described in the fundamental cause theory, and Henry et al., (2017) recently demonstrated the value of using Zip code tabulation areas in NIS-Teen analyses, the scope of this study and the level of measurement in the SVI precluded testing relationships at this level of detail.

Recommendations for Professional Practice

Analyzing the NIS-Teen data in the context of social vulnerability is a unique contribution to the existing literature, and my findings indicate that additional exploration into the relationships among social vulnerability, HPV vaccination, and physician recommendation is warranted. Given the limitations of one vulnerability score being applied to each person within a county, however, future researchers may want to consider using more granular geographic areas, such as Zip codes or census tracts, to understand the true effect of variation of fundamental causes and vulnerability on health outcomes. In addition, assessing vaccination and physician recommendation by the four SVI themes may help researchers identify specific local factors that influence patient and physician behavior, and provide a foundation for testing the FCT through HPV vaccination. In particular, given the continued diversification of the U.S. population, an understanding of the racial and ethnic makeup of a specific area may be critical in interpreting results in the future (Chin, 2017). These recommendations highlight the importance of data collection and needs assessment by public health practitioners at the local level when allocating public health resources, as well as moving away from individual- and interpersonal-level models toward an ecological approach to managing HPV infection and related cancers. In doing so, researchers can design and practitioners can implement more cost-effective and tailored interventions for the specific environments in which vaccine initiation and completion decisions are made (Burger et al., 2016; Ferrer et al., 2015).

My findings regarding differences in physician recommendation across teen variables and geographic area suggest the need for future researchers to better understand what drives physician behavior on a structural, interpersonal, and individual level. Assessing recommendations rates from a quantitative perspective tells only part of the story; the lack of behavioral economics-informed studies is a missed opportunity, and in the future researchers should investigate how and why physicians make patient care decisions to supplement their quantitative data. Public health practitioners could apply these findings in efforts to nudge physician behavior qualitatively and quantitatively to reflect evidence-based health care.

Implications for Social Change

While overall HPV vaccination in the United States is rising slowly, incidence and prevalence of HPV-associated cancer in the United States are growing quickly, and disparities in vaccination rates and cancer mortality persist. As there is not consensus on which population and structural variables are most strongly associated with HPV vaccine initiation and completion, public health practitioners may continue to struggle to reduce disparities in vaccination, physician recommendation, and future HPV-related outcomes (Ferrer et al., 2015; Oliver et al., 2016). Using national and local data can help elucidate the influential factors in HPV infection, HPV morbidity and mortality, and HPV vaccination, as well as how these factors interact.

This locally-focused, ecological approach may help identify populations, geographic areas, and multi-level factors relating to HPV infection and vaccination (McCree, Purcell Cleveland, & Brooks, 2017; Montez, Zajacova, & Hawyard, 2017). This knowledge could advance positive social change by encouraging evaluation and management of the fundamental causes of social and health disparities at the local level; fostering an environment in which healthy choices about HPV vaccination can be made; and equitably improving HPV vaccination rates among teens across the United States.

Conclusion

The HPV vaccine has been available for a decade, but physician recommendation, initiation and completion of the series is persistently low and varies across socioeconomic, demographic, and geographic variables (Henry et al., 2017; Perkins, 2016). Disparities also are noted in HPV-associated genital warts and cancers (Burger et al., 2016). The purpose of this study was to test the relationship between HPV vaccine initiation and completion, socioeconomic and demographic variables, and physician recommendation using data from the NIS-Teen 2015 survey. In addition, I tested the relationship between HPV vaccine initiation and completion, physician recommendation, and social vulnerability using the 2014 NIS-Teen and 2014 Social Vulnerability Index databases. I found that significant relationships between variables within select local areas in the United States differed from other select local areas as well as relationships detected at the national level. These findings could contribute to positive social change by identifying local structural, interpersonal, and individual factors that affect HPV vaccination and informing more effective interventions. Future studies should examine needs and population patterns at the local level, as well as seek to determine the context in which HPV vaccination decisions are made among physicians and teens in the United States. By reducing incidence and prevalence of HPV infections through vaccination, practitioners and providers may reduce disparities in HPV-associated cancers and facilitate improved health and wellbeing in individuals and communities.

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Appendix A: Complex Samples Results

Research Question One

In RQ1, I examined whether there is a relationship between initiation of the HPV vaccine series and socioeconomic and demographic variables in the 2015 select local area dataset, controlling for known confounders (Table A1). Model 1 included gender, race and ethnicity, poverty status, mother's education level, and select local areas of interest; Model 2 added clinical parameters: well-check visits, number of visits in the past 12 months, type of health insurance, and if the teen was ever uninsured since age 11. Model 3 added control factors: age of teen, relationship of respondent to teen, number of children in house under 18, mother's marital status, and age of the teen's mother.

Table A1

Relationships between HPV vaccine initiation and socioeconomic and demographic variables, Select Local Area, 2015

	Model 1 (OR, 95% CI)	Model 2 (OR, 95% CI)	Model 3 (OR, 95% CI)
Gender			
Male	1.18 [0.81-1.71]	-	-
Female	-	-	-
Race/ethnicity			
Non-Hispanic White	-		-
Hispanic	1.10 [0.63-1.93]	-	-
Non-Hispanic Black	0.95 [0.52-1.75]	-	-
Poverty status			
Above (> $75,000)	-	-	-
Above (≤ $75,000)	1.49 [0.87-2.54]	-	-
Below	1.35 [0.72-2.54]	-	-
Mother's education level			
Less than high school	1.74 [0.90-3.35]	-	-
High school graduate	1.06 [0.57-1.96]	-	-
Some college	1.31 [0.77-2.24]	-	-
College graduate	-	-	-
Select local area			
New York City	1.08 [0.61-1.91]	1.05 [0.60-1.84]	1.07 [0.60-1.88]
Washington, D.C.	1.00 [0.57-1.75]	0.89 [0.52-1.51]	0.93 [0.53-1.62]
Philadelphia	0.95 [0.55-1.65]	0.90 [0.53-1.55]	0.89 [0.50-1.57]
Chicago	-	-	-
El Paso	0.59 [0.33-1.06]	0.68 [0.41-1.13]	0.63 [0.37-1.07]
Houston	0.43 [0.23-0.83]*	0.41 [0.22-0.77]**	0.42 [0.22-0.82]**
Bexar County	0.75 [0.42-1.34]	0.79 [0.46-1.36]	0.79 [0.46-1.37]
Hidalgo County	0.45 [0.25-0.82]**	0.52 [0.31-0.88]*	0.55 [0.32-0.94]*

Note. CI, Confidence Interval. OR, odds ratio.
* $p < .05$
** $p < .01$

Overall, for RQ1 I rejected the null hypothesis, showing instead that there was a relationship between initiation of the HPV vaccine series and at least one socioeconomic or demographic variable in select local areas in unadjusted and adjusted models. Teens were significantly less likely to initiate the vaccine if they lived in Houston (58% less likely) or Hidalgo County (45%) than teens who lived in Chicago.

Research Question Two

In RQ2, I examined whether there is a relationship between completion of the HPV vaccine series and socioeconomic and demographic variables in the 2015 select local area dataset, controlling for known confounders (Table A2).

Table A2

Relationships between HPV vaccine completion and socioeconomic and demographic variables, Select Local Area, 2015

	Model 1 (OR, 95% CI)	Model 2 (OR, 95% CI)	Model 3 (OR, 95% CI)
Gender			
Male	0.65 [0.45-0.93]*	0.68 [0.48-0.95]*	0.65 [0.46-0.92]*
Female	-	-	-
Race/ethnicity			
Non-Hispanic White	-	-	-
Hispanic	1.28 [0.76-2.14]	-	-
Non-Hispanic Black	1.12 [0.64-1.94]	-	-
Poverty status			
Above (> $75,000)	-	-	-
Above (≤ $75,000)	1.07 [0.65-1.75]	-	-
Below	1.15 [0.67-1.98]	-	-
Mother's education level			
Less than high school	0.55 [0.30-1.04]	-	-
High school graduate	0.82 [0.47-1.44]	-	-
Some college	0.57 [0.34-0.94]	-	-
College graduate	-	-	-
Select local area			
New York City	0.95 [0.53-1.70]	-	-
Washington, D.C.	1.41 [0.81-2.45]	-	-
Philadelphia	2.00 [1.14-3.51]	-	-
Chicago	-	-	-
El Paso	1.24 [0.71-2.17]	-	-
Houston	1.46 [0.78-2.72]	-	-
Bexar County	1.09 [0.61-1.93]	-	-
Hidalgo County	1.18 [0.66-2.11]	-	-

Note. CI, Confidence Interval. OR, odds ratio.
* $p < .05$
** $p < .01$

Overall, for RQ2 I rejected the null hypothesis, showing instead that there was a relationship between completion of the HPV vaccine series and at least one socioeconomic or demographic variable in select local areas in unadjusted and adjusted models. In the select local area sample, only gender was significantly associated. Males were significantly less likely to initiate the vaccine (35%) than females.

Research Question Three

In RQ3, I examined whether there is a relationship between initiation of the HPV vaccine series and social vulnerability by select local area county, using logistic regression and data from the 2014 NIS-Teen and the 2014 Social Vulnerability Index (Table A3).

Table A3

Relationship between HPV vaccine initiation and overall county social vulnerability ranking, 2014

	Social Vulnerability percentile ranking	HPV Vaccine Initiation	
		OR	95% CI
Washington, D.C.	.59 (Med-High)	1.29	.68 – 2.43
Philadelphia	.91 (High)	1.71	.94 – 3.12
El Paso County	.95 (High)	1.17	.61 – 2.24
Bexar County	.82 (High)	-	-

Note. Med-High indicates a medium-high vulnerability, or being in the third-highest percentile of vulnerability. CI, Confidence Interval. OR, odds ratio.

Overall, for RQ3 I could not reject the null hypothesis, as the relationship between HPV vaccine initiation and social vulnerability ranking did not meet statistical significance.

Research Question Four

In RQ4, I examined whether there is a relationship between physician recommendation of the HPV vaccine series and social vulnerability by select local area county, using logistic regression and data from the 2014 NIS-Teen and the 2014 Social Vulnerability Index (Table A4).

Table A4

Relationship between physician recommendation of the HPV vaccine and overall county social vulnerability ranking, 2014

	Social Vulnerability percentile ranking	Physician Recommendation	
		OR	95% CI
Washington, D.C.	.59 (Med-High)	2.90	1.54 – 5.46***
Philadelphia	.91 (High)	2.14	1.19 – 3.87*
El Paso County	.95 (High)	1.50	.83 – 2.70
Bexar County	.82 (High)	-	-

Note. Med-High indicates a medium-high vulnerability, or being in the third-highest percentile of vulnerability. CI, Confidence Interval. OR, odds ratio.
* $p < .05$
*** $p < .001$

Overall, for RQ4 I rejected the null hypothesis, as the relationship between HPV vaccine initiation and social vulnerability ranking was significantly different. Teens were significantly more likely to receive a physician recommendation if they lived in Washington, D.C. (190% more likely) and Philadelphia (114%) than teens living in Chicago.

Appendix B: Multicollinearity Tests

Table B1

Multicollinearity Model Summaries

	R	R^2	Adjusted R^2	*SEM*
HPV Initiation	.31	.09	.08	.44
HPV Completion	.40	.16	.15	.43
No Shots	.61	.37	.37	.39

Note. SEM, Standard Error of the Mean.

Table B2

Multicollinearity Tolerance and Variance Inflation Factors

	HPV Vaccine Initiation VIF (Tolerance)
Physician recommendation	1.04 (.96)
Gender	1.06 (.94)
Race and ethnicity	1.27 (.79)
Poverty level	2.21 (.45)
Mother's education level	1.60 (.62)
Select local area	1.04 (.96)
Number of visits	1.04 (.96)
Type of health insurance	1.68 (.59)
Ever uninsured	1.05 (.95)
Well-check visit	1.02 (.98)
Relationship to teen	1.08 (.93)
Children under 18 in household	1.13 (.89)
Mother's marital status	1.24 (.81)
Mother's age	1.26 (.80)
Teen's age	1.08 (.93)

Note. VIF, Variance Inflation Factor. A VIF between 1 and 10 and a tolerance value closer to 1.0 (versus closer to 0) indicate no multicollinearity.

Appendix C: Physician Recommendation

Table 12

Relationships between physician recommendation and socioeconomic and demographic variables, Select Local Area

	2014 $\chi 2$ (df)	2015 $\chi 2$ (df)
Gender	37.90 (1)***	15.29 (1)***
Race/ethnicity	4.29 (2)	1.58 (2)
Poverty status	6.88 (2)*	14.45 (2)***
Mother's education level	14.05 (3)**	11.32 (3)**
Select local area	21.23 (3)***	17.74 (7)**
Number of visits in 12 months	18.23 (4)***	10.96 (4)*
Type of health insurance	.29 (1)	.04 (1)
Ever uninsured since age 11	.16 (1)	.48 (1)
Well-check visit	31.92 (1)***	3.22 (1)
Respondent relationship to teen	3.27 (3)	27.25 (3)***
Number of children under 18	1.32 (2)	15.58 (2)***
Mother's marital status	1.18 (1)	.58 (1)
Mother's age	7.19 (2)*	26.23 (2)***
Teen's age	12.59 (4)**	10.61 (4)*
HPV vaccine initiation	30.03 (1)***	100.92 (1)***
HPV vaccine completion	95.57 (1)***	220.64 (1)***
No shots received	209.23 (1)***	567.31 (1)***

Note. $\chi 2$, chi-square statistic. df, degrees of freedom.
* $p < .05$
** $p < .01$
*** $p < .001$

Table 13

Relationships between physician recommendation and vaccination, Select Local Area

	2014 OR [95% CI]	2015 OR (95% CI)
HPV vaccine initiation	3.08 [2.03-4.66]	5.21 [3.68-7.37]
HPV vaccine completion	8.20 [5.12-12.13]	35.64 [17.53-72.46]
No shots received	.08 [.06-.12]	.04 [.03-.05]

Note. CI, Confidence Interval. OR, odds ratio

Appendix D: HPV Vaccination and States

Table 14

HPV vaccine initiation, completion, and physician recommendation by U.S. state, 2015

	Initiation OR [95% CI]	Completion OR [95% CI]	Physician recommendation OR [95% CI]
Alabama	-	-	.46 [.26-.82]**
Arizona	.60 [.35-1.00]*	1.82 [1.09-3.05]*	-
Arkansas	-	-	.55 [.30-1.00]*
California	-	1.70 [1.07-2.72]*	-
Florida	.60 [.38-.95]*	-	-
Iowa	.52 [.28-.98]*	1.90 [1.05-3.41]*	-
Louisiana	.45 [.26-.79]**	-	-
Maine	-	2.17 [1.06-4.46]*	-
Massachusetts	-	1.68 [1.00-2.84]*	-
Mississippi	-	-	.37 [.20-.68]***
Missouri	.55 [.32-.93]*	-	.53 [.31-.90]*
New Hampshire	-	2.18 [1.09-4.37]*	-
New Mexico	.46 [.23-.94]*	-	-
Ohio	.50 [.31-.82]**	-	-
Oklahoma	-	2.03 [1.14-3.64]*	-
Pennsylvania	.49 [.29-.80]**	1.80 [1.10-2.96]*	-
Rhode Island	-	2.67 [1.24-5.78]*	3.89 [1.20-12.57]*
Tennessee	.46 [26-.80]**	-	.47 [.27-.82]**
Texas	.58 [.37-.92]*	-	.55 [.33-.89]*

Note. CI, Confidence Interval. OR, odds ratio. Only states with a statistically significant relationship are included in the table. Data from 2015 U.S. NIS-Teen sample; all dependent variables were controlled for significant sociodemographic variables.
* $p < .05$
** $p < .01$
*** $p < .001$

Of note, teens who lived in three states were both less likely to initiate and more likely to complete the HPV vaccine than teens who lived in Chicago: Arizona, Iowa, and Pennsylvania. In addition, teens living in three states who were less likely to initiate the HPV vaccine series were also less likely to receive a physician recommendation:

Missouri, Tennessee, and Texas. Teens who lived in Rhode Island were more likely to complete the HPV vaccine series as well as receive a physician recommendation. However, teens who lived in Alabama, Arkansas, and Mississippi were less likely to receive a physician recommendation, but the relationships between these states in initiating or completing the HPV vaccine were not significant compared with teens living in Chicago.