Distribution Agreement

Distribution Agreement

In presenting this thesis or dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

_____ _____

Jennifer Lyn Grant Date

Approval Sheet

Trends in HPV Vaccination of US Adolescent Females:

How Policies, Education, and Health Care Providers Influence Immunization Rates

By

Jennifer Lyn Grant
Ph.D.

Health Services Research

_____ [Advisor's signature]
David Howard, Ph.D.
Advisor

_____ [Member's signature]
Paula Frew, Ph.D.
Committee Member

_____ [Member's signature]
Tami Thomas, Ph.D., C.P.N.P.
Committee Member

Accepted:

_____
Lisa A. Tedesco, Ph.D.
Dean of the James T. Laney School of Graduate Studies

_____
Date

Abstract Cover Page

Trends in HPV Vaccination of US Adolescent Females:

How Policies, Education, and Health Care Providers Influence Immunization Rates

By

Jennifer Lyn Grant

BA, Stanford University, 2005

Advisor: David Howard, Ph.D.

An abstract of a dissertation submitted to the Faculty of the James T. Laney School of Graduate Studies of Emory University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Health Services Research

2013

Abstract

In my first paper, *The Impact of State Immunization Financing Policies on HPV Vaccination Rates among US Adolescent Females*, I examine the impact of expanded enrollment eligibility for The Vaccines for Children (VFC) program on HPV vaccine series initiation and completion among US adolescent girls. The VFC program provides certain vaccines at a reduced or no cost to eligible children. It was designed to help ensure all children receive recommended vaccinations on schedule, even if their parents are not be able to afford them. Specifically, I hypothesized that adolescent girls living in states in which all recommended vaccines were provided free of cost to all children in the state would be more likely to initiate and complete the HPV vaccine series than their peers living in states with more restricted VFC eligibility requirements.

In my second paper, *Maternal Educational Inequalities in HPV Vaccine Utilization among US adolescent females– The relative roles of economics and awareness,* I evaluate the relative influences of household-level socioeconomic status, specific health knowledge, and general healthcare utilization and timeliness in mediating the relationship between maternal educational attainment and HPV vaccine utilization among adolescent girls.

In my third and final paper, *Factors Associated with Health Care Provider Recommendation of the Human Papillomavirus Vaccine and effect of provider recommendation on vaccine series initiation and completion,* I examine the relative influences of adolescent and household sociodemographic characteristics and characteristics of their health-seeking behavior on the likelihood of receiving a health care provider recommendation of the HPV vaccine for US Adolescent girls. I also estimate the effect of provider recommendation on vaccine series initiation and completion

Cover Page

Trends in HPV Vaccination of US Adolescent Females:

How Policies, Education, and Health Care Providers Influence Immunization Rates

By

Jennifer Lyn Grant

BA, Stanford University, 2005

Advisor: David Howard, Ph.D.

A dissertation submitted to the Faculty of the James T. Laney School of Graduate Studies of Emory University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Health Services Research

2013

Table of Contents

Tables and Figures

Paper One: The Impact of State Immunization Financing Policies on HPV Vaccination Rates among US adolescent females

PAPER TWO: MATERNAL EDUCATIONAL INEQUALITIES IN HPV VACCINE UTILIZATION AMONG US ADOLESCENT FEMALES– THE RELATIVE ROLES OF ECONOMICS AND AWARENESS

PAPER THREE: FACTORS ASSOCIATED WITH HEALTH CARE PROVIDER RECOMMENDATION OF THE HUMAN PAPILLOMAVIRUS VACCINE, AND EFFECT OF PROVIDER RECOMMENDATION ON VACCINE SERIES INITIATION AND COMPLETION

The Impact of State Immunization Financing Policies on HPV Vaccination Rates among US adolescent females

Introduction

The Vaccines for Children (VFC) program is a federally-funded entitlement plan[1] that was designed to help ensure all children receive recommended vaccinations on schedule, even if their parents are not be able to afford them. The VFC program provides all vaccines recommended by the Advisory Committee on Immunization Practices (ACIP) at no cost to doctors who serve VFC-eligible children [1].

Children under the age of 18 who are eligible for Medicaid, have no health insurance, or are American Indian/Alaska Native are eligible to receive vaccines through the VFC program [1]. Additionally, underinsured children[2] may receive VFC vaccines at federally qualified health centers (FQHCs) or rural health clinics (RHCs)[3] [1]. Approximately one third of adolescents in the United States are VFC-eligible [2].

Although the VFC program was designed to provide immunizations to the majority of children who might not otherwise be vaccinated because of inability to pay, evidence suggests that cost may still be a barrier to full vaccination for some adolescents who are not VFC-eligible [2]. This is of particular concern for high-cost, multi-dose vaccines.

[1] Entitlement program: a right granted by law

[2] Underinsured Children: Children who have private health insurance but whose coverage does not include vaccines, or whose insurance covers only selected vaccines, or whose insurance caps vaccine coverage at a certain amount. Children whose insurance covers only selected vaccines are VFC-eligible for non-covered vaccines only. Children whose insurance caps vaccine coverage at a certain amount, are only VFC-eligible after that cap amount is reached

[3] Underinsured Children: Children who have private health insurance but whose coverage does not include vaccines, or whose insurance covers only selected vaccines, or whose insurance caps vaccine coverage at a certain amount. Children whose insurance covers only selected vaccines are VFC-eligible for non-covered vaccines only. Children whose insurance caps vaccine coverage at a certain amount, are only VFC-eligible after that cap amount is reached

To supply vaccines to additional populations, several states have opted to use their own sources of funding to expand VFC eligibility.[4] For example, states categorized as 'VFC and Underinsured' supply additional vaccines to enrolled providers so that underinsured children can be vaccinated within their medical home rather than at a state or local health department (see Tables 1 and 2). 'Universal' and 'Universal-select' states provide, respectively, all or almost all ACIP-recommended vaccines free of cost to all children in the state [3].

Table 1. Childhood Vaccine Supply Definitions

VFC-Only: The immunization project supplies all routinely recommended pediatric vaccines to VFC eligible children only.
VFC & Underinsured: In addition to vaccines for VFC eligible children, the immunization project provides all routinely recommended pediatric vaccines to under-insured children.
VFC & Underinsured-Select: In addition to providing all routinely recommended vaccines for VFC eligible children, the immunization project provides all but a few recommended pediatric vaccines to under-insured children.
Universal: The immunization project supplies all routinely recommended pediatric vaccines to all children in the project area.
Universal-Select: The immunization project supplies all but a few routinely recommended pediatric vaccines to all children in the project area.
Other: Policy not described in any of the options posted above.

Source: CDC. (2010). "VFC/Projects/Data/Childhood Vaccine Supply Policy 2009." Retrieved June 14, 2012, from http://www.cdc.gov/vaccines/programs/VFC/projects/vacc-supply-policy/vacc-supply-public-2009.htm

Recent studies mostly suggest eliminating cost barriers to immunization leads to higher immunization rates [4, 5]. However, analyses of the impact of state participation in more expansive VFC programs have shown mixed results [6-12].

Lurie, Manning et al. evaluated evidence from the well-known RAND health insurance study and found that children enrolled in health insurance plans with free preventative care had 20% higher rates of immunization than those enrolled in plans with copayments [4]. The extent of cost sharing in the study was not limited to immunizations, but also included other types of care received during the same encounter. Thus the relative influence of immunization costs compared with other costs associated with the provider visit is unclear.

[4] States supply vaccines free of charge to additional populations using Section 317 program funds. Unlike VFC, which is a federal entitlement program, Congress appropriates Section 317 funds annually. These appropriations typically do not increase in direct response to new vaccine recommendations [3,4]. State discretionary funds are also used to finance vaccine purchases for non-VFC-eligible populations, particularly in Universal states. Similar to Section 317 funding, this mechanism leaves vaccine-purchasing programs vulnerable to funding shortfalls, and can require ongoing effort on the part of the health department to ensure continued support.

Rodewald, Szilagyi et al. specifically looked at immunization costs, evaluating how immunization coverage was affected by CHPlus, a statewide program in New York that enabled children to receive free vaccines from providers throughout the state [9]. The study found that the program increased immunization rates by 5.8 percentage points for those without insurance and by 2.9 percentage points for those enrolled in Medicaid. However, this study took place prior to the VFC program; therefore, the findings cannot be extended to the current system.

Similarly, an evaluation of 2003 benefit-plan data for private and public health plans registered in Georgia found that out of pocket costs were negatively correlated with up-to-date status for the 4:3:1:3:3 immunization series[5] [5]. Yet, the study also found the cost of the supplying the vaccine represented the smallest component of out of pocket costs. This study evaluated costs associated with relatively low-cost vaccines, which limits the ability to apply these findings to high-cost multi-dose vaccines.

Freed, Clark et al. also looked the effects of immunization costs at the state-level [11]. They estimated how North Carolina's VFC program expansion to a Universal policy affected immunization rates among children with different types of health insurance. Unlike the findings from Georgia, Freed's analysis found that supplying free vaccines was related to increased immunization rates among children in all insurance categories, with the largest increases being in the Medicaid and uninsured categories. However, Freed and colleagues did not control for other variables that might have affected immunization rates over the study period, such as history of well-child visits, type of facility used for preventive heath visits, and potential language barriers. Additionally, data from a single state were analyzed, limiting the generalizability of the study's findings across populations.

[5] The 4:3:1:3:3 immunization series: ≥4 doses of diphtheria, tetanus, and acellular pertussis vaccines, ≥3 doses of poliovirus vaccine, ≥1 dose of measles, mumps, and rubella vaccine, ≥3 doses of *Haemophilus influenzae* type b vaccine, and ≥3 doses of hepatitis B vaccine

Table 2. VFC Childhood Vaccine Supply 2007- 2009

	Year		
	2007	**2008**	**2009**
Alabama	VFC Only	VFC Only	VFC Only
Alaska	Universal	Universal	Universal Select
Arizona	Other	VFC & Underinsured	Other
Arkansas	VFC & Underinsured Select	Other	Other
California	VFC Only	VFC Only	VFC Only
Colorado	VFC Only	VFC Only	VFC Only
Connecticut	Universal Select	Universal Select	VFC & Underinsured Select
Delaware	VFC Only	VFC Only	VFC Only
District of Columbia	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
Florida	VFC Only	VFC Only	VFC Only
Georgia	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
Hawaii	Universal Select	Universal Select	Universal Select
Idaho	Universal Select	Universal Select	Other
Illinois	VFC & Underinsured Select	VFC & Underinsured Select	VFC & Underinsured Select
Indiana	VFC Only	VFC & Underinsured Select	VFC & Underinsured
Iowa	VFC Only	VFC Only	VFC Only
Kansas	VFC Only	Other	Other
Kentucky	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
Louisiana	VFC Only	VFC Only	VFC Only
Maine	Universal Select	Universal Select	Universal Select
Maryland	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
Massachusetts	Universal Select	Universal Select	Universal Select
Michigan	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
Minnesota	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
Mississippi	VFC Only	VFC Only	VFC Only
Missouri	VFC Only	VFC Only	VFC Only
Montana	VFC Only	Other	Other
Nebraska	VFC Only	VFC Only	VFC Only
Nevada	Universal Select	Universal Select	VFC Only
New Hampshire	Universal	Universal	Universal
New Jersey	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
New Mexico	Universal	Universal	Universal
New York	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
North Carolina	Universal Select	Universal Select	Universal Select
North Dakota	Universal Select	VFC Only	Other
Ohio	VFC Only	VFC Only	VFC Only
Oklahoma	VFC Only	VFC & Underinsured	VFC & Underinsured
Oregon	Other	Other	Other
Pennsylvania	VFC Only	VFC Only	VFC Only
Rhode Island	Universal	Universal	Universal
South Carolina	VFC & Underinsured Select	VFC & Underinsured Select	VFC & Underinsured
South Dakota	Universal Select	Universal Select	Universal Select
Tennessee	VFC Only	VFC Only	VFC Only
Texas	VFC & Underinsured	VFC & Underinsured	Other
Utah	VFC & Underinsured	VFC & Underinsured	VFC & Underinsured
Vermont	Universal	Universal	Universal
Virginia	VFC Only	VFC Only	VFC Only
Washington	Universal	Universal	Universal Select
West Virginia	VFC Only	VFC Only	VFC Only
Wisconsin	Universal Select	Universal Select	Universal
Wyoming	Universal	Universal	Universal

Source: CDC. (2009, June 9, 2009). "VFC/Projects/Data/Childhood Vaccine Supply Policy 2007." http://www.cdc.gov/vaccines/programs/VFC/projects/data/vacc-supply-public-2007.htm.

In contrast to Freed's findings, after evaluating the relative impact of parental characteristics, provider behavior, and the provision of free vaccines through state-sponsored vaccine programs, Taylor, Darden et al. found no significant differences in immunization status attributable to free vaccines [10]. However, two rather significant limitations prevent relating this study's results to today's conditions. First, at the time of evaluation, the cost to fully vaccinate a child through the age of 18 in the private sector was around $361, (estimated in 2008 dollars). Due to the adoption of new vaccines, that amount increased to $1666 for males and to $2042 for females in the year 2008 [2]. With such drastic changes in cost, it cannot be assumed that the availability of free vaccines still has no effect on immunization status. Second, the practices evaluated in Taylor's study all participated in the American Academy of Pediatrics research network. By virtue of self-selection, this sample was not representative of typical practices across the United States.

A more recent study by Olshen, Mahon et al. evaluated the relative impact of several state policies on Hepatitis B and Varicella vaccine coverage among children with managed care insurance [12]. Similar to the Taylor, Darden study, their analysis found that state universal vaccine purchase policies were not associated with increased vaccine coverage in this insured population. However, the study evaluated population characteristics of 28 states and, as a result, the statistical power to detect the impact of state policies was limited. Additionally, managed care organizations tend to offer immunization coverage within basic benefit packages. Therefore, the population evaluated in this study would be the least likely to benefit from a universal vaccine purchase policy.

And finally, the most recent study evaluating the impact of universal purchase policies contradicts Olshen and Taylors findings and supports the suggestion that supplying free vaccines leads to higher immunization rates. Using data from the 2009 NIS-Teen survey, Gowda and

Dempsey performed a cross-sectional analysis of state-level Medicaid reimbursement rates and universal vaccine supply programs on adolescent vaccination coverage [7]. They found that participation in a more expansive VFC program was significantly associated with greater HPV vaccine coverage in states with other vaccine mandates. However, choices made in analysis may have skewed the author's findings. The authors grouped states having Universal vaccination policies with states having Universal-select policies, although no Universal-select states supplied the HPV vaccine free of charge. They also stratified their analysis by school mandates although no states had HPV mandates. This may have led to an underestimation of the actual association between expanded VFC programs and HPV vaccination status.

Previous studies evaluating the impact of state finance policies on immunization rates have been limited by focusing on a single state, or on a population covered by a specific type of health insurance [5, 9, 11, 12]. And, due to policy changes after the study period or limitations in analysis, many previous studies' findings cannot be generalized to new high-cost vaccines.

The potential for federal and state vaccine finance policies to reduce immunization cost barriers is particularly important for new high-cost vaccine such as the Human Papillomavirus (HPV) vaccine. The first HPV vaccine (Gardasil®, Merck) was licensed for use in June 2006. Gardasil provides protection against four high-risk HPV types associated with approximately 70% of cervical cancers and more than 90% of genital warts. A second, vaccine (Cervarix®, GlaxoSmithKline) providing protection against two high-risk HPV types was approved for use in women in 2009. ACIP began recommending routine HPV vaccination of 11- and 12-year-old girls, and catch-up vaccinations for females age 13 through 26 years in 2007 [13]. And as of 2011, ACIP recommends Gardasil in 11- and 12-year-old boys with catch-up vaccination for males aged 13 to 21 years [14]. Both vaccines are administered in a series of 3 doses over a 6-month period at a price of approximately $95-$130 per dose [15].

Widespread use of the HPV vaccine is central to lowering risk of HPV infection and related illnesses. However, just over half of adolescent females 13–17 years old initiated the HPV vaccination series in 2011 and less than 35% completed the series [16]. Coverage rates were even lower for low-income populations [17]. High out of pocket costs resulting from the vaccine's high purchase price may be contributing to low HPV vaccination rates [2, 7, 15, 18]. Only one previous study has specifically looked at the impact of expanded VFC eligibility on HPV vaccination coverage [7] and findings from other child and adolescent vaccines can either not be applied to the HPV vaccine or show mixed results.

Given the need to improve HPV vaccine coverage and the limited information on the impact of vaccine financing on vaccination rates, the goal of this study was to evaluate the impact of expanding VFC eligibility to all children in a state or region. Specifically, I hypothesized that adolescent girls living in states with Universal vaccine supply policies would be more likely to initiate and complete the HPV vaccine series than their peers living in VFC-only states.

Methods

Data Source

I analyzed data from the 2008 –2010 National Immunization Survey – Teen (NIS-Teen). The NIS-Teen is a list-assisted random-digit-dialing telephone survey that is followed by a mailed survey to children's immunization providers. It is conducted jointly by the National Center for Immunizations and Respiratory Diseases and the National Center for Health Statistics, Centers for Disease Control and Prevention. The NIS-Teen is the most comprehensive national survey of adolescent vaccination behavior, obtaining accurate national and state-specific estimates of vaccination coverage in all 50 states and selected local areas [19]. The survey is conducted

annually to monitor coverage with recommended vaccines during ages 11--17 years and to identify groups with lower coverage [19]. Data specific to HPV vaccine uptake have been collected in the NIS-Teen survey since 2007. The NIS-Teen uses the same sampling and weighting methodology as the National Immunization Survey, the details of which have been described elsewhere [20].

Data on state vaccine supply financing were self-reported by state immunization programs via the annual CDC-administered VFC Management Survey [3, 21, 22]. Adolescents surveyed in 2008 were categorized based on their state's supply policies in 2007. Similarly, adolescents surveyed in 2009 and 2010 are categorized based on their states supply policy in 2008 and 2009, respectively.

Study Participants

Analyses were limited to NIS-Teen participants who were female, had complete household interview data and adequate provider data for the HPV vaccine (including unvaccinated adolescents). In order to estimate the effect of Universal vaccine supply policies on HPV vaccine utilization, I further restricted analysis to adolescents living in Universal states or VFC-only states. Adolescents living in VFC-only states served as a control group when estimating treatment effect, since the VFC program is the federal standard for vaccine purchase financing. I refer to girls living in states with universal vaccination policies as the treatment group and girls living in VFC-only states as the control group.

Definitions and Variables

There were two dependent variables of interest - HPV vaccine series initiation and HPV vaccine series completion. HPV vaccine series initiation was defined as at least one dose of the vaccine received before the survey date. HPV vaccine series completion was defined as receipt

of three or more vaccine doses before the survey date. Total number of HPV vaccines doses received was obtained from provider-verified vaccination records.

Other than provider-reported vaccination information and state vaccine supply policies, all variables were created from responses to the telephone portion of the NIS-Teen survey. Race/ethnicity of the teen was categorized as Hispanic, Non-Hispanic White only, Non-Hispanic Black only, and Non-Hispanic Other/Multiple race. I classified adolescent's health insurance as one of 6 types – employer-provided, provided by the Medicaid or the State Children's Health Insurance Program (S-CHIP), provided by the military or Indian Health Service (IHS), provided by some other entity, none, or missing. Household income was categorized into one of 12 ranges, starting with $0-$7,500 and ending with $75,000+. Measures of specific health knowledge include survey respondents' answers to two survey questions about general HPV infection and vaccine awareness: whether they had ever heard of HPV and whether they had heard of the HPV vaccine[6][20]. For all independent variables, missing values were classified into a separate group rather than omitted from analysis.

Statistical Analysis

Direct comparisons between adolescents living in states with universal vaccine supply policies (the treatment group) and adolescents living in states with VFC-only policies (the control group) would be biased. Individual level characteristics may vary systematically between states with different immunization financing. Because universal vaccine supply policies are partially funded through state discretionary funds, there may be factors related to the availability of such funds that also influence uptake of vaccines. States with higher median incomes have higher tax

[6] TIS_AHPV: Have you ever heard of Human Papillomavirus or HPV? This is different from Human Immunodeficiency virus or HIV, which you may have heard of.
TIS_AHPV_KNOWLEDGE: The human papillomavirus is a common virus known to cause genital warts and some cancers, such as cervical cancer in women. A vaccine to prevent HPV infection is available and is called the cervical cancer vaccine, HPV shot, or GARDASIL. Before today, have you ever heard of the cervical cancer vaccine, HPV shot, or Gardasil?

revenues, which may lead to greater availability of state discretionary funds. Families with higher incomes are more likely to utilize vaccine services, receive preventive health care, and have insurance plans that cover a greater proportion of the cost of vaccination [23-26].

In order to eliminate potential nonrandom or systematic differences between adolescents in the treatment and control groups, I employed a propensity score analysis. Propensity score analysis assesses the likelihood that adolescents in the treatment group receive the HPV vaccine, relative to the control group, with group differences controlled for. I used logistic regression to predict the probability of living in a universal state as a function of fourteen categorical variables, including household income, race/ethnicity, age, family size, and type of health insurance. Matching treatment and control observations based on the resulting propensity scores, I was able to compare HPV vaccine utilization of individuals with similar observable characteristics but whose state vaccine supply policies differed.

Variable Selection

Early Propensity Score algorithms [27] recommend starting with a parsimonious specification of the logistic equation. However, recent studies have found that one could get biased results [28] or an imbalance in covariates in matched samples [29] if only known confounders are included. I chose to include all variables within the dataset that could be associated the outcome variables. I did not include variables related to the treatment but not the outcome (i.e. instrumental variables).

Propensity Score Matching

After a propensity score was estimated for each treatment and control observation, each treatment unit was matched to a set of control units with similar propensity scores. In order to ensure the robustness of results, I applied four different criteria for determining how

observations should be matched – nearest neighbor matching, and the caliper method using three different maximum distance settings.

Using the nearest-neighbor method, I selected the one comparison unit whose propensity score was closest to the treatment unit in question. With the caliper method, I matched all the comparison units falling within a predefined propensity score radius (or "caliper") of the treatment unit. A benefit of caliper matching is that it uses only as many comparison units as are available within the calipers, allowing for the use of extra (fewer) units when good matches are (not) available [27]. If more than one control observation fell within the allowable caliper distance, the matched dataset included the multiple matched control observations. The matched controls were weighted to reflect the multiple matches. Therefore the sum of the weighted observations still equaled the original number of observations [30]. The predetermined calipers used were 0.01; 0.005; and 0.001.

All matches were made with replacement; meaning control observations could serve as a match for multiple treatment observations. Matching with replacement decreases bias by minimizing propensity score distance between the matched control units and treatment unit[7] [27].

I used the Matching library within the R statistical package [30] to perform the matching process.

Checking for Match Balance

After matching treatment and control observations, I used the MatchBalance function in the Matching library to examine how well the matching procedure performed in producing covariate balance – the difference in distribution of potential confounders in the treatment and

[7] However, if there is a great deal of overlap between treatment and control groups, matching without replacement allows more units of comparison to be included, thereby improving precision of the estimates (improved efficiency) [10].

control groups. For comparison, I also tested whether pre-matched covariates differed statistically between treatment and control observations [31]. Balance was determined by examining cumulative probability distribution functions of a variety of standardized statistics: paired t-tests, univariate and multivariate Kolmogorov-Smirnov (KS) tests, and a variety of descriptive statistics based on empirical-qq plots. I ran 1000 bootstrap samples when calculating KS estimates in order to ensure correct coverage in the event that discontinuous segments existed in the probability distributions being compared.

The ideal Balance statistics were as follows. For each covariate evaluated in MatchBalance:

a. Standardized differences in treatment and control means are not statistically significant from zero.
b. The standardized mean, median and maximum difference in the eQQ plots are decreased after matching.
c. The variance ratio of treatment over control (which should equal 1 if there is perfect balance), is closer to 1 after matching

If many covariates are not balanced, Dehejia and Wahba recommend making modifications to the matching procedure, such as caliper size for caliper matching, or number of matches to be found for each treatment observation [32]. If some covariates are not balanced, they recommend adding additional variables, and/or interaction terms and/or higher-order terms of the covariates in question. A key property of this procedure is that it makes use of a well-defined criterion for determining which interaction terms to use in the estimation, namely those terms that balance covariates. This method also makes no use of the outcome variable.

Estimating Average Treatment Effect on the Treated

After propensity score matching and checking for balance, the outcome variable (HPV vaccine series initiation or completion) of the set of control units was subtracted from the outcome of the set of treatment units. Averaging this result across treatment units resulted in an estimate of the average treatment effect on the treated (ATT). The estimated ATT, for this analysis, was defined as the expected average change in HPV vaccine series initiation or completion for adolescent females living in Universal states, if they were to live in VFC-only states, after controlling for observed differences between groups.

After the initial comparison between treatment and control groups, comparisons of immunization status were survey year, age, VFC eligibility, race/ethnicity, type of health insurance, and household income . In these stratified analyses, separate treatment effects were calculated for each stratum.

All analyses were performed using the R 2.15.0 statistical software package [33]. *P* values less than 0.05 were considered statistically significant.

Results

Study Participants

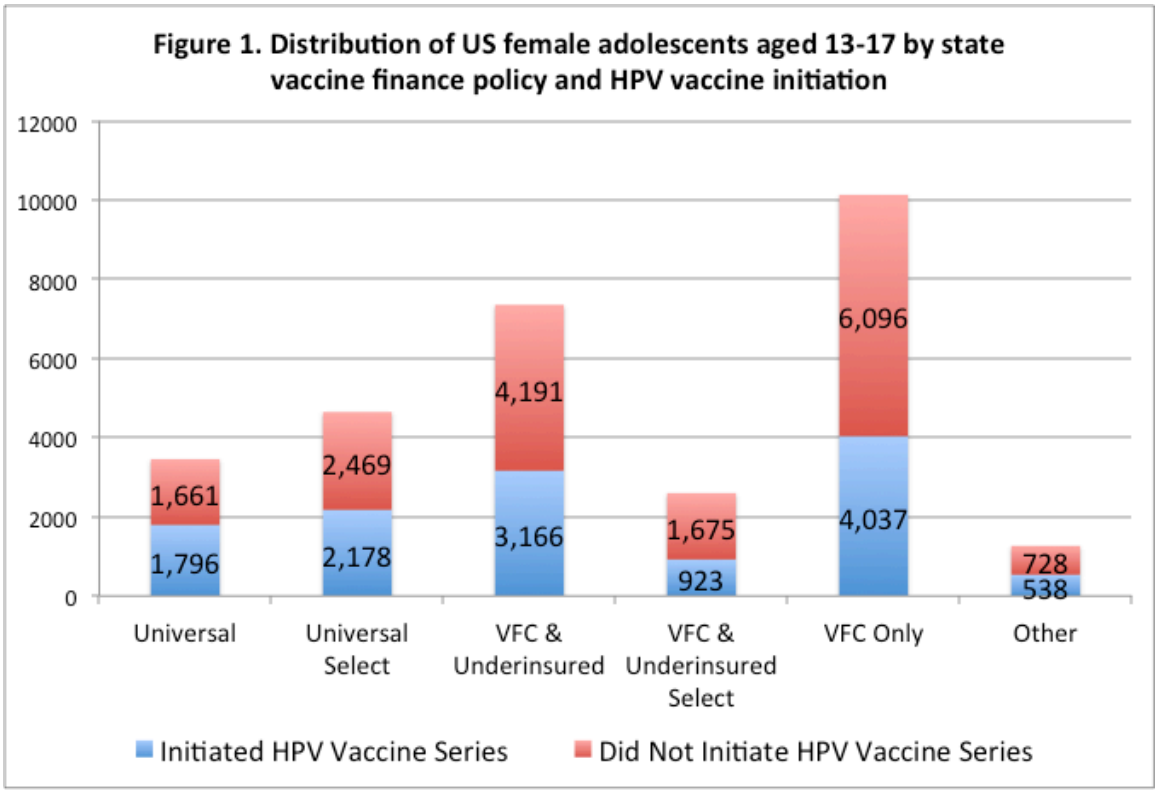
For the 2008-2010 NIS-Teen surveys, there were 99,251 (47,430 girls) eligible adolescents with complete household interviews. Of the 47,430 girls, 29,458 (62%) had provider-verified HPV vaccination records. The sample was further limited to teens living in Universal and VFC only states, 13,590 (29%). Of the 13,590 adolescent girls included in analysis, 3,457 (25%) lived in states with universal vaccine policies the year prior to their survey date and 10,133 (75%) lived in states with VFC-only policies. Table 3 and figures 1 and 2 show the

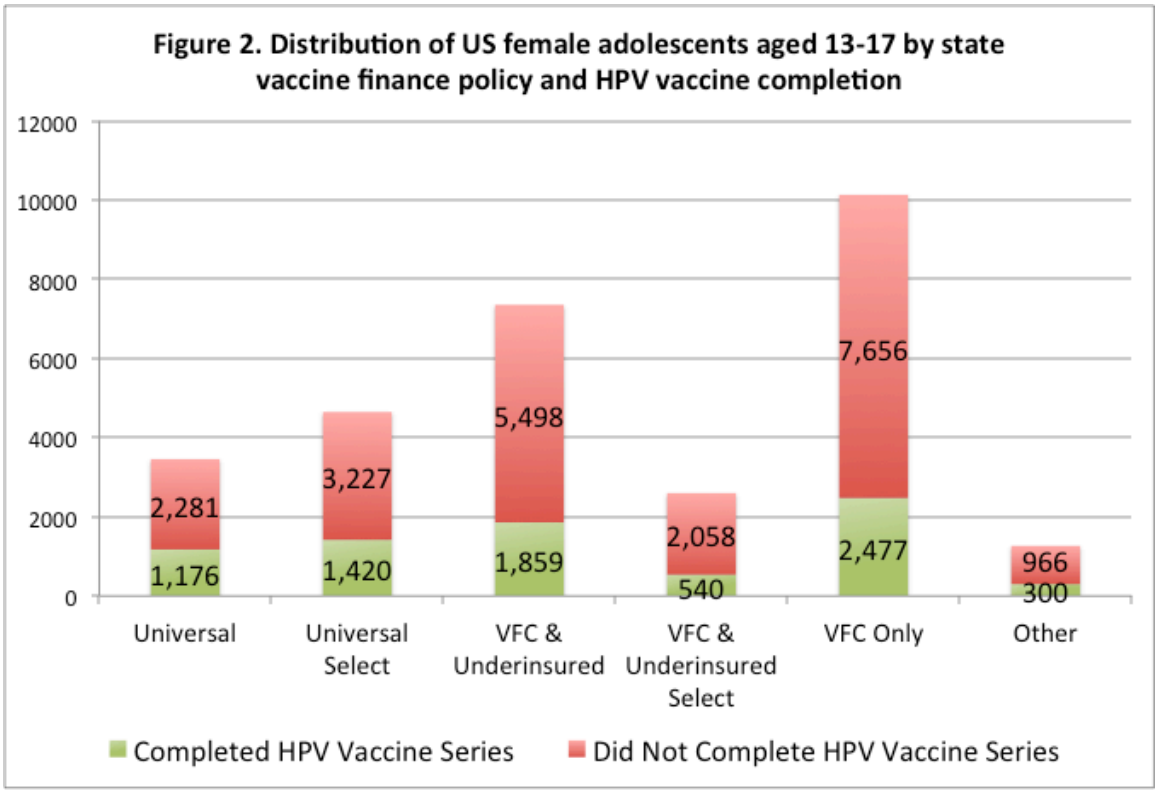
distribution of adolescent girls by state vaccine finance policy and the percentage of adolescents who initiated and completed HPV vaccine series in each group.

Generally, adolescents living in states with more comprehensive vaccine finance policies had higher rates of HPV vaccine series initiation and completion than those living in VFC-only states. For instance, 52% of girls living in Universal states initiated the HPV vaccine series between 2008 and 2010. By comparison, HPV vaccine series initiation was 12 percentage points (pp) lower for adolescent girls living in VFC only states. Thirty four percent of girls living in Universal states completed the HPV vaccine series. Only 24% of girls living in VFC only states completed the series during the same time period (10pp difference).

Table 3. HPV vaccine series initiation and completion among US female adolescents aged 13-17 years by State Vaccine Finance Policy: National Immunization Survey-Teen 2008-2010

	Universal (n= 3,457)	Universal Select (n= 4,647)	VFC & Underinsured (n= 7,357)	VFC & Underinsured Select (n= 2,598)	VFC Only (n= 10,133)	Other (n= 1,266)
HPV Vaccine Series Initiation	52%	47%	43%	36%	40%	42%
HPV Vaccine Series Completion	34%	31%	25%	21%	24%	24%





Demographic Characteristics and Matching

Table 4 shows the descriptive statistics for adolescent girls living in Universal states (treatment group) and girls living in VFC only states (control group), before and after the nearest-neighbor matching procedure. The table also reports the standardized mean differences in the empirical CDF between groups and p values from standardized t-tests.

Before matching, adolescents in the treatment and control groups differed significantly across almost all observed characteristics. Girls in the control group were more likely to be an ethnic minority, live in a single parent household, and have younger mothers and lower household incomes.

With respect to healthcare access and utilization, those in the treatment group were more likely to utilize all private immunization facilities, report having an 11-12 year old well-child exam, and be up-to-date for other adolescent vaccines. And finally, survey respondents in Universal states were more likely to be aware of the human papillomavirus and the HPV vaccine.

Before matching, the covariate having the largest difference in standardized means (109) and smallest p value (<2.22e=16) was Race: Non-Hispanic Black Only. After matching, no standardized t-tests between treatment and control covariates were statistically significant. The covariate with the largest difference in standardized mean (2.05) was immunization facility type: STD/School/Teen clinic, with a p value of 0.35. Of the 4 matching functions, nearest neighbor matching with replacement produced the strongest balance statistics.

Figures 3 and 4 display histograms of treatment and control propensity scores before and after nearest neighbor matching. It is clear that the similarity of propensity score distributions greatly improves with matching. In sum, the results of the propensity score function suggest a high level of overlapping between the treated and control observations.

Estimated ATT of Universal vaccine purchase policies on HPV vaccine

Table 5 reports the estimated average treatment effect on the treated (ATT) for HPV vaccine series initiation from each of the 4 matching functions. The bootstrapped standard errors are reported in parentheses. Lower and upper bound statistically significant estimates of the ATT are also reported. For comparison, the last column specifies the unadjusted differences in HPV vaccine series initiation and completion.

In unadjusted analysis, HPV vaccine series initiation was significantly greater for the treatment group than the control group (12pp difference; p<0.01) and remained significantly greater after propensity score adjustment (9pp ATT; 95 percent confidence interval [CI]: [7pp, 11pp]; p<0.01). Based on these estimates, if VFC coverage in Universal states were to drop to

VFC-only, holding all other variables constant, the average HPV vaccine series initiation rate for adolescent girls living in those states would decrease by 9 percentage points.

The estimated ATT for HPV vaccine series completion is also reported in table 5. Compared with HPV vaccine series initiation, the gains in series completion associated with universal vaccine supply policies were smaller, though still statistically significant, ranging from 2.2pp to 2.9pp. Overall, estimates support the hypothesis that the Universal vaccine supply policy increases HPV vaccine series initiation and completion among adolescent girls living in those states.

Stratified Analyses

Table 6 reports the estimated ATT for HPV vaccine series initiation stratified by survey year, age, VFC eligibility, race/ethnicity, type of health insurance, and household income. Significant differences in adjusted vaccine series initiation rates were evident within each age category, among white and black adolescents, adolescents with employee health insurance, those with annual household incomes above $40,000, and those not eligible for the VFC program. Significant differences between treatment and control groups were not observed among Hispanic and other/multiple race adolescents, adolescents covered by Medicaid or military health insurance, those with annual household incomes below $40,000 and those eligible for the VFC program.

Adjusted differences in HPV vaccine series initiation rates between treatment and control groups remained relatively stable between 2008 and 2010. However, adjusted differences in HPV vaccine series initiation between adolescents living in universal and VFC-only states increase with adolescent's age. For 13 year olds, the gap between universal and VFC only states was only 6 percentage points. By age 16, the gap increased to 11 percentage points.

Table 7 reports the stratified estimated ATTs for HPV vaccine series completion, stratified by survey year, age, VFC eligibility, race/ethnicity, type of health insurance, and household income. Similar to differences in vaccine series initiation, stratified analyses revealed significant differences in vaccine series completion among adolescents with employee health insurance, those who were not VFC-eligible and those who had household incomes above $40,000. Unlike the previous analysis, significant differences were only seen for girls aged 14 to 17 and, for Whites non-Hispanic. Significant differences in HPV vaccine series completion were not observed among Hispanic, Black, and other/multiple race adolescents, those covered by Medicaid or military health insurance, those eligible for the VFC program and adolescents with household incomes below $40,000.

Table 4. Sociodemographic characteristics of US female adolescents aged 13-17 years by State Vaccine Finance Policy before and after propensity score Matching[a,b]

	Before Matching				After Matching			
Covariate	Universal (n=3,457)	VFC only (n=10,133)	Standardized Mean Difference [c]	$P^{d,e}$	Universal (n=3,457)	VFC only (n=10,133)	Absolute Imbalance[f]	P^{a}
Survey Year								
2008	31%	34%	-7.5	<0.01	31%	32%	-3.3	0.16
2009	36%	32%	8.8	<0.01	36%	35%	1.6	0.47
2010	34%	35%	-1.6	0.43	34%	33%	1.6	0.49
Age								
13	19%	19%	0.0	0.99	19%	19%	0.0	1.00
14	20%	20%	0.5	0.78	20%	20%	0.4	0.85
15	21%	21%	-0.3	0.89	21%	20%	0.6	0.78
16	21%	21%	0.1	0.96	21%	21%	-0.5	0.83
17								
Race or ethnic group								
Non-Hispanic white only								
Hispanic	13%	9%	14.2	<0.01	13%	14%	-1.1	0.62
Non-Hispanic black only	1%	14%	-108.9	<0.01	1%	1%	-0.1	0.96
Non-Hispanic other + multiple race	9%	6%	9.6	<0.01	9%	9%	1.4	0.51
Language								
English								
Other	1%	1%	1.6	0.41	1%	1%	0.1	0.97
Spanish	4%	3%	4.2	0.03	4%	4%	-0.7	0.76
Mother's Age Group								
<= 34 years	7%	8%	-4.5	0.03	7%	6%	0.9	0.69
35 to 44 years	41%	45%	-8.7	<0.01	41%	40%	2.0	0.40
>= 45 years								
Education Level of Mother								
Less than 12 years	8%	10%	-5.4	0.01	8%	8%	0.6	0.81
12 years	18%	22%	-11.1	<0.01	18%	18%	0.5	0.81
More than 12 years, non-college grad	30%	29%	0.9	0.65	30%	30%	0.0	0.99
College Graduate								
Family Income								
$0 - $7500	1%	3%	-9.2	<0.01	1%	1%	0.1	0.95
$7501 - $10000	2%	2%	-6.1	<0.01	2%	1%	1.0	0.68
$10001 - $17500	3%	4%	-8.8	<0.01	3%	3%	0.3	0.89
$17501 - $20000	2%	3%	-2.7	0.18	2%	2%	1.2	0.62
$20001 - $25000	3%	4%	-1.8	0.36	3%	3%	-1.0	0.67
$25001 - $30000	3%	4%	-5.9	<0.01	3%	3%	-0.8	0.75
$30001 - $35000	3%	3%	-3.1	0.12	3%	3%	-0.3	0.89
$35001 - $40000	4%	5%	-2.6	0.20	4%	4%	0.6	0.82
$40001 - $50000	7%	8%	-7.5	<0.01	7%	6%	0.8	0.74
$50001 - $60000	7%	7%	-0.6	0.77	7%	7%	1.2	0.62
$60001 - $75000	13%	10%	7.1	<0.01	13%	12%	0.5	0.84
$75001+								
Don't know	2%	2%	-2.6	0.19	2%	2%	-0.6	0.80
Refused	3%	4%	-3.0	0.13	3%	4%	-1.4	0.57
Health Insurance								
Employee health insurance								
Medicaid or SCHIP	20%	20%	0.7	0.72	20%	20%	-0.3	0.88
Military health care, Tricare, CHAPMUS or CHAMP-VA	8%	4%	13.6	<0.01	8%	7%	0.7	0.72
Other	9%	10%	-4.5	0.02	9%	9%	-0.4	0.88
Uninsured	5%	7%	-9.1	<0.01	5%	4%	1.0	0.66

Table 4 contd. Sociodemographic characteristics of US female adolescents aged 13-17 years by State Vaccine Finance Policy before and after propensity score Matching[a,b]

	Before Adjustment				After Adjustment			
Covariate	Universal	VFC only	Absolute Imbalance	*P*	Universal	VFC only	Absolute Imbalanc	*P*
Number of Children Under 18 in Household								
One								
Two or three	51%	51%	-0.1	0.97	51%	51%	1.4	0.56
Four or more	9%	9%	1.3	0.52	9%	9%	0.3	0.89
Mother's Marital Status								
Married								
Never married / widowed / divorced / separated / deceased	22%	25%	-7.0	<0.01	22%	22%	1.0	0.68
Have you ever heard of human papillomavirus? *								
Yes								
No	4%	6%	-10.3	<0.01	11%	10%	1.2	0.60
Don't know	1%	1%	2.5	0.20	2%	2%	-1.7	0.48
Have you ever heard of the cervical cancer vaccine, hpv shot, or Gardasil? *								
Yes								
No	11%	14%	-9.3	<0.01	4%	4%	0.6	0.81
Don't know	2%	1%	2.5	0.19	1%	1%	-0.5	0.84
Facility Type								
All private facilities								
All hospital facilities	9%	8%	3.5	0.07	9%	9%	-0.6	0.78
All public facilities	16%	19%	-10.6	<0.01	16%	15%	2.0	0.38
All std/school/teen clinics or other facilities	5%	3%	9.7	<0.01	5%	5%	2.0	0.36
Mixed	16%	16%	-0.4	0.83	16%	16%	-1.2	0.62
Unknown	6%	7%	-5.2	0.01	6%	6%	-0.5	0.83
Did teen have an 11-12 year old well-child exam or check-up?								
Yes								
No	6%	9%	-9.7	<0.01	6%	6%	1.1	0.65
Don't know	18%	21%	-7.4	<0.01	18%	18%	0.4	0.86
Vaccination Status								
HPV vaccination series initiation	52%	40%	24.2	<.001	52%	43%	17.6	<0.01
HPV vaccination series completion	34%	24%	20.2	<.001	34%	27%	14.0	<0.01
Tetanus vaccine (Td/Tdap)	84%	71%	32.6	<.001	84%	74%	26.8	<.001
Measles, Mumps, and Rubella vaccine (MMR)	88%	87%	4.2	0.04	88%	87%	3.6	0.14
Hepatitis B vaccine	88%	85%	7.6	<.001	88%	86%	6.7	0.01
Meningococcal vaccine	54%	49%	10.0	<.001	54%	53%	2.6	0.28
Average preadjustment imbalance (absolute value):			7.5		Average postadjustment imbalance:		0.82	
Before Matching Minimum p.value:			<0.01		After Matching Minimum p.value:		0.36	

a. Data are presented as percentages. b. the number of observations is in parentheses. c. The standardized mean differences in the empirical CDF. d. t-test p-value. e. Statisically significant at 0.05 p-value. f. absolute imbalance

Figure 3. Histogram of treatment and control group propensity scores - Before Matching

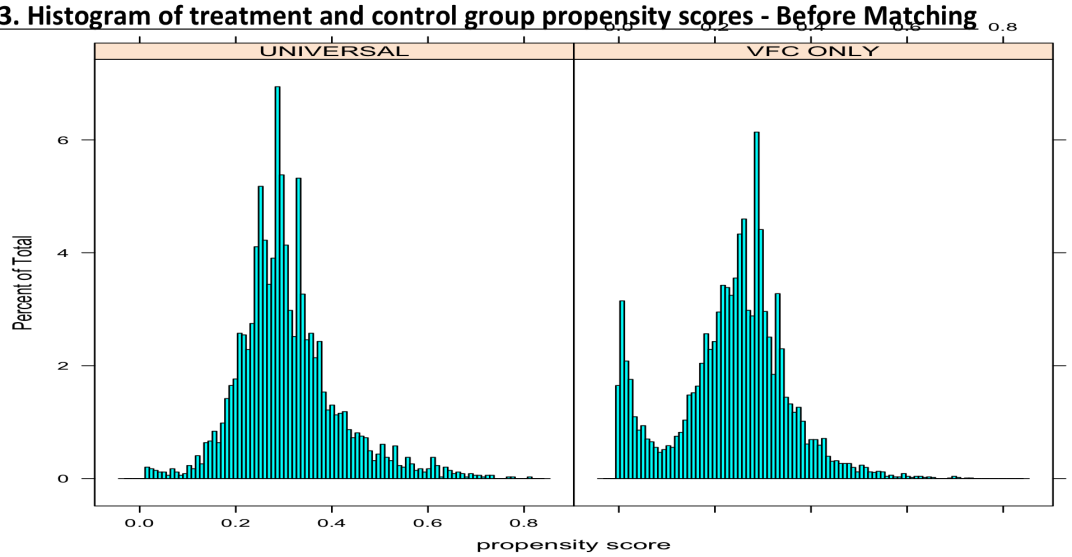


Figure 4. Histogram of treatment and congrol group propensity scores - After Matching

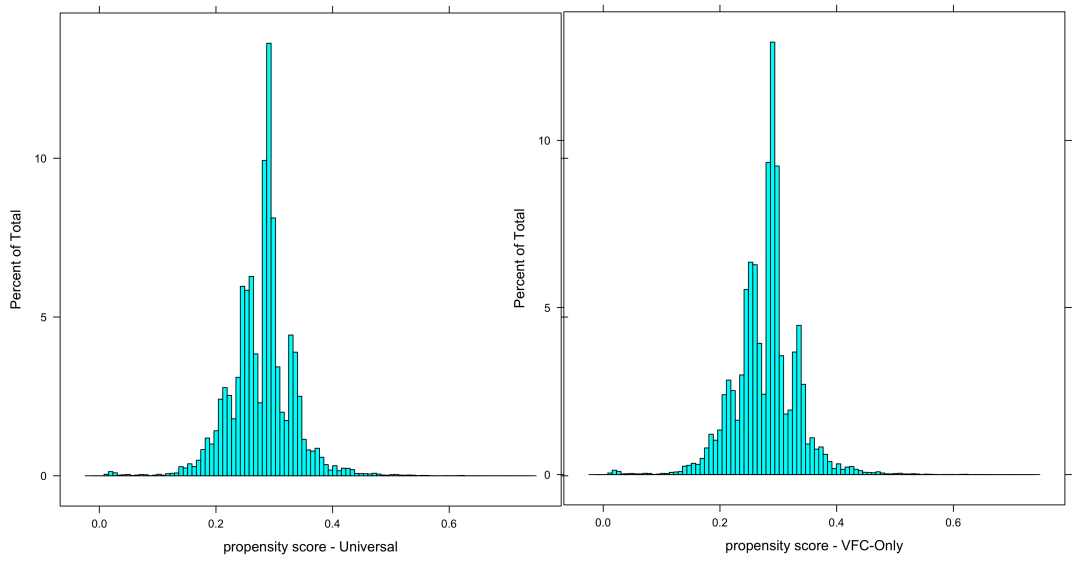


Table 5. Propensity score matching results - estimated average effect of Universal Vaccine Purchase policies on HPV vaccination rates

	Matching method[a,b]					
	Nearest neighbor	**Caliper 0.01**	**Caliper 0.005**	**Caliper 0.001**		
Vaccination status	percentage point change (standard error)	percentage point change (standard error)	percentage point change (standard error)	percentage point change (standard error)	**Lower and Upper Bounds[c] (sig. at p <0.1)**	**Unadjusted difference in means[d]**
HPV Vaccination Series Initiation	8.82 (0.011) ***	9.12 (0.011) ***	9.28 (0.011) ***	9.71 (0.011) ***	[8.8, 9.7]	12.11
HPV Vaccination Series Completion	2.62 (0.008) ***	2.45 (0.008) ***	2.24 (0.008) ***	2.90 (0.008) ***	[2.2, 2.9]	9.57

a. ***t value significant atp < 0.01, **t value significant at p < 0.05, *t value significant at p < 0.1. b. Bootstrapped Standard Errors in parenthesis. c. Lower and upper bound statistically significant estimates of the program effect on the treated. d. For comparison, the last column repeats the expected treatment effect (ET) already reported in Table 1.

Table 6. Stratified Adjusted HPV Vaccine Initiation Rates among Adolescent Girls, 2008-2010

Stratification Category	Universal	Matched Controls	percentage point difference	95% CI	SE	t-statistic	P Value
Survey Year							
2008; n=1055	34%	29%	5.3	(2.0 , 8.6)	0.02	3.1	<0.01
2009; n=1235	40%	32%	7.6	(4.0 , 11.3)	0.02	4.1	<0.01
2010; n=1167	46%	40%	5.3	(1.5 , 9.1)	0.02	2.7	<0.01
Age							
17; n=638	58%	48%	10.4	(5.2 , 15.5)	0.03	3.6	<0.01
16; n=729	56%	45%	11.1	(6.3 , 15.9)	0.02	3.0	<0.01
15; n=714	51%	44%	6.9	(2.0 , 11.8)	0.03	2.0	0.05
14; n=706	50%	43%	7.5	(2.4 , 12.5)	0.03	2.9	<0.01
13; n=670	44%	38%	6.0	(0.8 , 11.3)	0.03	2.3	0.02
VFC Eligibility							
VFC Eligible; n=668	55%	54%	1.2	(-4.8 , 7.3)	0.03	0.4	0.69
Not VFC Eligible; n=1629	56%	47%	9.0	(5.8 , 12.2)	0.02	5.6	<0.01
Race / Ethnicity							
White, Non-Hispanic; n=2630	51%	42%	9.5	(7.1 , 12.0)	0.01	7.6	<0.01
Hispanic; n=463	51%	47%	4.3	(-2.4 , 11.1)	0.03	1.3	0.21
Black, Non-Hispanic; n=49	57%	39%	18.1	(1.1 , 35.1)	0.09	2.1	0.04
Other; n=315	57%	48%	8.2	(-1.4 , 17.9)	0.05	1.7	0.09
Health Insurance							
Employee; n=2037	53%	43%	9.9	(7.2 , 12.6)	0.01	7.1	<0.01
Medicaid; n=694	50%	48%	2.2	(-3.1 , 7.5)	0.03	0.8	0.42
Military; n=263	56%	48%	7.7	(-3.3 , 18.7)	0.06	1.4	0.17
Other; n=315	53%	37%	15.8	(7.7 , 24.0)	0.04	3.8	<0.01
Income Category							
$0 - $10,000; n=104	43%	37%	6.5	(-9.3 , 22.3)	0.08	0.8	0.4
$10,001 - $20,000; n=180	44%	39%	4.9	(-5.9 , 15.8)	0.06	0.9	0.4
$20,001 - $30,000; n=224	39%	30%	9.4	(1.4 , 17.4)	0.04	2.3	<0.01
$30,001 - $40,000; n=236	34%	30%	4.7	(-4.0 , 13.4)	0.04	1.1	0.3
$40,001 - $60,000; n=478	34%	24%	9.7	(3.8 , 15.6)	0.03	3.2	<0.01
$60,001+ ; n=2045	41%	33%	7.8	(5.1 , 10.5)	0.01	5.6	<0.01
Missing; n=650	46%	45%	0.5	(-8.1 , 9.1)	0.04	0.1	0.9

n=sample size of matched treatment observations

Table 7. Stratified Adjusted HPV Vaccine Completion Rates among Adolescent Girls, 2008-2010

Stratification Category	Universal	Matched Controls	Difference	95% CI	SE	t statistic	P Value
Survey Year							
2008;n=1055	24%	19%	5%	(2%, 9%)	0.02	3.1	<0.01
2009; n=1235	37%	30%	8%	(4%, 11%)	0.02	4.1	<0.01
2010; n=1167	54%	49%	5%	(1%, 9%)	0.02	2.7	0.01
Age							
17; n=638	40%	31%	9%	(4%, 14%)	0.03	3.6	<0.01
16; n=729	39%	31%	7%	(3%, 12%)	0.02	3.0	<0.01
15; n=714	33%	28%	5%	(0%, 10%)	0.03	2.0	0.05
14; n=706	33%	26%	7%	(2%, 12%)	0.02	2.7	0.01
13; n=670	25%	21%	4%	(-1%, 9%)	0.02	1.7	0.09
VFC Eligibility							
VFC Eligible; n=668	35%	33%	2%	(-3%, 8%)	0.03	0.8	0.41
Not VFC Eligible; n=1629	40%	33%	7%	(4%, 10%)	0.02	4.6	<0.01
Race / Ethnicity							
White, Non-Hispanic; n=2630	35%	28%	7%	(5%, 9%)	0.01	5.8	<0.01
Hispanic; n=463	29%	27%	2%	(-4%, 8%)	0.03	0.6	0.57
Black, Non-Hispanic; n=49	20%	22%	-1%	(-17%, 14%)	0.08	-0.2	0.85
Other; n=315	36%	29%	7%	(-2%, 16%)	0.05	1.4	0.15
Health Insurance							
Employee; n=2037	37%	28%	8%	(6%, 11%)	0.01	6.3	<0.01
Medicaid; n=694	28%	28%	0%	(-5%, 5%)	0.02	3.5E-02	0.97
Military; n=263	35%	30%	5%	(-5%, 15%)	0.05	0.9	0.36
Other; n=315	34%	26%	8%	(1%, 16%)	0.04	2.1	0.04
Income Category							
$0 - $10,000; n=104	31%	25%	6%	(-8%, 20%)	0.07	0.9	0.39
$10,001 - $20,000; n=180	29%	24%	5%	(-6, 16%)	0.06	0.9	0.37
$20,001 - $30,000; n=224	31%	21%	9%	(1%, 17%)	0.04	2.3	0.02
$30,001 - $40,000; n=236	31%	27%	5%	(-4%, 13%)	0.04	1.1	0.29
$40,001 - $60,000; n=478	32%	22%	10%	(4%, 16%)	0.03	3.2	<0.01
$60,001 +; n=2045	36%	29%	8%	(5%, 11%)	0.01	5.6	<0.01
Missing; n=650	28%	28%	1%	(-8%, 9%)	0.04	0.1	0.91

n=sample size of matched treatment observations

Discussion

This study shows that adolescent girls living in states with Universal vaccine supply policies are more likely to initiate and complete the HPV vaccine series than their peers living in VFC-only states. Furthermore, in this study, I provide evidence that a large proportion of these observed differences can be attributed to differences in state VFC policies.

Two primary findings provide evidence that Universal vaccine supply policies result in increased HPV vaccination among adolescent girls. First, differences in HPV vaccine series initiation and completion between the treatment and control groups remained after adjustment using the propensity score method. Second, I found that, in populations who would receive vaccines free of charge in both VFC-only and Universal states, namely those with Medicaid, Military health insurance, or annual house hold incomes below $20,000; there were no significant difference in HPV vaccine series initiation or completion. The absence of a treatment effect for these groups suggests higher vaccination rates in Universal states are driven by expansion of free vaccine availability beyond those who are VFC-eligible.

A surprising finding was that observed gains in vaccine series initiation were greater than in completion. This finding is perhaps the result of including adolescents in analysis who, based on the timing of their first dose, were not yet due to complete the series. The HPV vaccine is given in a series of 3 shots with no maximum interval between doses. If a similar proportion of girls in both treatment and control groups were not yet scheduled to complete the series, then groups would have the same amount of adolescents falling into the not-completed category. As a result, regardless of finance policy or observed covariates, the difference in this measure between groups would be reduced. This explanation is supported by the fact that significant differences in HPV vaccine completion were not observed in 13 year olds, an age at which few would be scheduled to complete the vaccination series.

Another unexpected finding was that HPV vaccine series completion was similar for Black adolescents living in Universal and VFC-only states and significantly lower than other racial/ethnic groups. This suggests that controlling immunization costs alone may not increase series completion rates for certain populations. In general, even with low out-of-pocket costs, black adolescents face greater barriers to preventive care and receive lower-quality care than

whites [34, 35]. This may result from lack of a regular source of care, greater use of the Emergency Department for primary care, and possibly a historical distrust of the health care system [34, 35]. This observation exemplifies an even larger issue, namely that even with reduced out of pocket costs, some adolescents face great barriers to preventive care. Thus low rates of vaccine uptake among adolescents must be overcome with more than one type of intervention.

This study's findings are consistent with the conclusions of two previous studies of the relationship between finance policies and vaccination status [7, 11]. Both studies also reported higher rates of HPV vaccination among adolescents living in states with Universal vaccine supply policies, compared with their peers living in VFC-only states. However, my findings add to the literature in the following ways.

My analysis explicitly measures the impact of universal purchase policies on HPV vaccination rates in the adolescent female population, adjusting for demographic variables shown to be independently associated with immunization behavior. Such an analysis was not present in the most recent study of this topic [7]. Since NIS-Teen data allowed for a wide overlap in relevant observable covariates, the estimated average treatment effects on the treated gave a more accurate estimate of the real program impact. In addition, performing sensitivity analyses with different matching techniques provided an estimate of the lower and upper bounds of such an impact. This study also provides more recent estimates of HPV vaccination coverage as well as estimates across several years.

Although, compared to previous studies, this analysis provides a more unambiguous estimate of the impact of universal purchase policies on HPV vaccination rates, it is not without limitations.

One limitation of this analysis is the use of cross-sectional data, meaning I observed each subject only once. Observed changes were not changes over time for the same subject but changes from one subject to another. Ideally, to prove Universal purchase policies cause increases in HPV vaccination rates I would analyze changes over time, before and after policy implementation, for the same subject. Modeling and estimation approaches like propensity score matching are designed to address this problem but not without limitations.

The main limitation of propensity score matching is that it only controls for observed differences between the treatment and control groups. Despite the breadth of variables included in this analysis, unobserved factors could have explained my findings. However, findings from the MatchBalance function, which examined how well the matching procedure performed in producing covariate balance, suggest that this limitation may not have greatly affected my findings. In the MatchBalance function, I included additional variables, plus interaction terms and higher-order terms of the variables included in the propensity score estimation. Balance was achieved for all variables in the MatchBalance function, including those that were not included in the propensity score estimation. In other words, propensity score matching reduced bias in variables not included in the propensity score estimate. This suggests unobserved factors were likely balanced as well.

A third limitation of this analysis is that many of the measures used in this study were self-reported. Responses to questions about the past are subject to recall bias and self-reported outcomes are subject to reporting bias [36]. In addition, insurance status classification was based on reports from a single point in time. If adolescents shifted between insurance categories at any point within the previous year, the association between insurance type and vaccination status would be inaccurate.

A fourth limitation is that the NIS-Teen survey only captures households that have landline telephones. Therefore, teens living in households with wireless telephones only and non-telephone households were not covered by the survey. Although earlier analysis of NHIS data, which samples both "landline telephone" and "non-landline telephone" households, indicated that children living in households without telephones may have lower vaccination coverage [37], recent analyses of NIS and NHIS data suggest little or no difference in vaccination coverage rates between children living in households with landline telephones and those living in households with wireless telephones only [38-40]. Because the difference in vaccination coverage rates between adolescents living in households covered by the NIS-Teen and adolescents living in households not covered by the NIS is expected to be small, I anticipate that the bias in my estimates also would be small [41].

Finally, it is possible that individuals received vaccines in states other than their state of residence at the time of the survey interview. Some vaccine doses may have been received before the current survey year and state vaccine finance policies may have been different during that time. Individuals meeting either of those conditions would be misclassified in the analysis.

Despite limitations in my method of data analysis, my findings have important implications for immunization finance policy.

By focusing on a vaccine targeted for the adolescent population, I assessed an age group that faces great barriers to preventative health care and is thus more likely to benefit from policies that effectively improve healthcare access. Vaccination coverage for adolescents remains significantly lower than for infants and children [2, 42]. Differences in frequency of healthcare contact and type of provider seen are known reasons for lower vaccination rates among adolescents [24, 42-45]. Additionally, the HPV vaccine's high-cost and multi-shot series makes it less likely to be covered by health insurance and more likely to pose a high out of

pocket cost to families and individuals [46]. Although underinsured children and adolescents are entitled to receive VFC vaccines at no cost at FQHCs and RHCs, receiving vaccines outside of the medical home increases risk of not receiving all recommended vaccines [2]. Additionally, FQHCs and RHCs are mandated to provide care in specific geographic areas that may be inconvenient for some parents to access. In such cases, increased out-of-pocket costs for high-cost vaccines could indirectly impact immunization coverage through the inconvenience of travel, and break in continuity of medical care. Finally, unlike other adolescent and childhood vaccines, the HPV vaccine is not associated with any school entry mandates, which are known to increase immunization rates among children [47].

My findings suggest that expanding the VFC program to all adolescents may greatly increase HPV vaccination uptake for this vulnerable group. The policy options for expanding coverage must, however, address major challenges. Funding sources for Universal supply policies are not secure from year to year nor are they similar between states. Particularly for a high-cost vaccine, such as the HPV vaccine, universal coverage could present a serious burden to state budgets if not accompanied by other policies designed to control costs and availability of funds. Additionally, vaccine-purchase policies do not influence patient costs associated with vaccine administration or the doctor's visit, which could both present significant cost barriers to individuals and families. Similarly, Universal vaccine purchasing would not influence coverage of the HPV vaccine by insurance companies. If an adolescent were underinsured for the HPV vaccine, and her main healthcare provider was not enrolled in the VFC program, she would still have to go outside of her medical home to get vaccinated, which presents an additional barrier.

My findings suggest that several provisions in the Patient Protection and Affordable Care Act (PPACA) will effectively address many of these challenges and increase access to vaccines and immunization services. The PPACA will expand Medicaid eligibility to all non-elderly

persons with family incomes below 133 percent of the Federal poverty level regardless of health status [48], effectively increasing the number of adolescents eligible to receive immunizations through the VFC program. In addition, the Section 317 program funds, which states use to supply vaccines free of charge to additional populations, was reauthorized in 2011 with a $100 million increase from FY2010 [48]. And finally, PPACA will close the current VFC program's structural gap of underinsured children. Presently, children whose insurance does not cover selected vaccines whose insurance caps vaccine coverage at a certain amount, may receive VFC vaccines at federally qualified health centers (FQHCs) or rural health clinics (RHCs). Those who do not live in geographic areas where FQHCs or RHCs are located cannot receive the VFC benefit. After full PPACA implementation, insurance plans must cover all ACIP-recommended vaccines and their administration at no cost-sharing (i.e., no deductibles or co-pays) for children and adolescents [48].

Maternal Educational Inequalities in HPV Vaccine Utilization among US adolescent females– The relative roles of economics and awareness

Introduction

Medical, public health, and economic literature all show a positive association between education and health behaviors (defined as actions taken to maintain, attain, or regain good health and to prevent illness) [49-56]. For example, college graduates are more likely to exercise, less likely to smoke, and less likely to be obese compared to non-college graduates [57, 58]. The associated health outcomes are significant: In 1999, the age-adjusted mortality rate for high school dropouts, ages 25 to 64, was more than twice that of individuals with some college education [52].

Studies have also demonstrated that maternal education is a strong and consistent predictor of child health outcomes, specifically reduced child morbidity and mortality [50, 59-64]. And, similar to the adult population, these differences in outcomes are believed to be associated with differences in mothers' health behaviors. Education may alter the ways in which mothers prevent, recognize, and treat childhood illnesses [51].

Potential Pathways

Economic theory suggests education influences health behaviors through several probable channels. First, education may have an indirect effect on health behaviors that is mediated through higher income or socioeconomic status (SES). The better educated can expect to earn more, allowing them to purchase a greater amount of goods that improve health, such as better health insurance. Second, education may increase health knowledge and

awareness, which may lead to increased preventive health measures, such as exercise and healthier eating. Third, education may raise the efficiency of one's health-seeking behaviors. In other words, more educated individuals may interacts with the health care system more effectively – seeking health care with greater timeliness or seeking a greater quality of care [65].

Numerous empirical studies have tested the validity of these possible pathways in the adult population [53, 55, 65-68]. Fewer have evaluated the link between maternal education and child health [23, 56, 69, 70].

Household income and Socioeconomic Status

Many studies from the adult and child populations support the theory that education influences health by improving one's ability to acquire health-producing resources [49, 50, 52, 53]. For example, as labor market returns to education rose in the 1980s and 1990s, health returns to education rose as well [49]. In addition, a study from the developing world showed maternal educational differences in health outcomes were attenuated once socioeconomic factors, such as household income and community of residence, were controlled for [48].

It is unlikely, however, that income or other labor market returns to education account for the entire association between education and health. In a study examining the pattern of interaction between maternal education and public health programs in child health production, the author found that increases in family income due to improved maternal education were not the primary mechanisms of influence [50]. Finally, health behaviors differ across education groups even when neither income nor health insurance are important, such as in seat belt use, exercise and reading food labels [52].

Health Knowledge

Recent studies support the theory that, in addition to the influence of SES, health knowledge and awareness are also important determinants health behaviors [54, 60, 71, 72]. Knowledge barriers potentially associated with low educational attainment include being unaware of the advantages to receiving preventive services or not knowing what benefits are available through one's insurance policy [73]. For example, one study found that individuals who were better able to comprehend materials commonly encountered in health care settings were more likely to seek out preventive services, such as influenza and pneumococcal vaccinations, mammograms, and Pap smears [72].

Similar conclusions have been made for the maternal education, child health relationship. Reviews of the literature report that, with additional years of education, mothers gain greater access to and become more receptive to modern health information [51]. Interestingly, because the reviewed studies suggest no apparent threshold in terms of years of education, the authors propose that this enhanced health knowledge does not come from the formal content of schooling.

More educated individuals also appear to become aware of and make use of new health information sooner. For example, after the first Surgeon General's report publicizing the dangers of smoking was released in 1964, the more educated knew more information about the harmful effects of smoking and were more likely to stop smoking [54, 60].

Healthcare Utilization and Timeliness

It is likely that educated mothers seek medical attention for their children with greater timeliness, pursue a higher quality of care and adhere to advice with greater persistence. Many studies from the developing world show a positive correlation between maternal education and

greater use of modern preventive health services [50, 59, 63, 64]. Even after adjusting for maternal age, parity, rural-urban residence and husband's occupation, differences according to maternal education in utilization of maternal and child health services remain large [2, 11]. These differences may be a function of some or all of the factors described previously, namely financial ability or knowledge.

Though several studies support the influence of these pathways, few studies to date have looked at their relative influence in relation to each other. And, particularly for the maternal education – child health relationship, few studies have tested the relative influences of these pathways outside of the developing world.

The relationship between maternal education and human papilloma virus (HPV) vaccine utilization among adolescent girls could be a useful model for testing the relative influences of socioeconomic status, awareness, and healthcare utilization and timeliness. Genital HPV is the most common sexually transmitted infection in the United States and has been established as a necessary precursor for the development of cervical cancer [74, 75]. The first HPV vaccine (Gardasil®, Merck) was licensed for use in the United States in June 2006. A second, vaccine (Cervarix®, GlaxoSmithKline was approved for use in women in 2009. Subsequently, the Advisory Committee on Immunization Practices (ACIP) recommended routine HPV vaccination of 11- and 12-year-old girls, and catch-up vaccinations for females 13 through 26 years of age [13]. And as of 2011, ACIP recommends Gardasil in 11- and 12-year-old boys with catch-up vaccination for males aged 13 to 21 years [14]. Both vaccines are administered in a series of 3 doses over a 6-month period.

The decision to vaccinate for HPV may be particularly sensitive to factors related to maternal educational attainment, including income and health insurance status, vaccine knowledge and awareness, and healthcare utilization and timeliness. As an adolescent vaccine,

the HPV vaccine is not part of the standard immunization series provided during early childhood and very few states include the HPV vaccine in school entry immunization requirements [76]. Additionally, on average, costs for the HPV vaccine are significantly higher than for other vaccines and, as a result, the HPV vaccine less likely to be covered by some health insurance plans [2, 15]. Eligibility for certain cost-controlling federal programs, such as the Vaccines for Children (VFC) program, is primarily based on socioeconomic status and therefore may also be related to maternal educational attainment. The VFC program was designed to help children receive recommended vaccinations on schedule, even if their parents are not able to afford them [1]. Children under the age of 18 who are eligible for Medicaid, have no health insurance, or are American Indian/Alaska native are eligible to receive vaccines through the VFC program at reduce or no out-of-pocket cost [1]. Finally, because vaccine is given in a series of 3 shots, it requires repeated engagement with the health care system. Certain patients may forget to receive follow-up doses, be unable to afford them, or miss doses due to the inconvenience of returning to the immunization provider.

Furthermore, an in-depth understanding of the causes of maternal educational disparities in HPV vaccine utilization is vital, as they could have tremendous consequences. Unequal access to and use of Pap smear screening services, which enables early identification of cancerous and precancerous cervical lesions, has led to significant variation in cervical cancer death rates across race and income categories [18, 46, 77]. Similar disparities exist in cervical cancer incidence rates by geography and education [46]. Concerns have been raised that the same populations that currently underutilize testing services may also be less likely to receive the HPV vaccine and less likely to vaccinate their daughters [46]. Additionally, early evidence has shown that groups with lower attained education and socioeconomic status are the least likely

to be vaccinated against HPV [78-80]. These are the same groups that are disproportionately affected by cervical cancer and, consequently, most likely to benefit from the vaccine.

Given the need to reduce disparities in HPV vaccine access and utilization, and the opportunity to deepen our understanding of the theories linking maternal education and health behaviors, the goal of this study was to evaluate the relative influences of household-level socioeconomic status, specific health knowledge, and general healthcare utilization and timeliness in mediating the relationship between maternal educational attainment and HPV vaccine utilization among adolescent girls.

Methods

Data Source

I analyzed data from the 2008 –2010 National Immunization Survey – Teen (NIS-Teen). The NIS-Teen is a list-assisted random-digit-dialing telephone survey that is followed by a mailed survey to children's immunization providers. It is conducted jointly by the National Center for Immunizations and Respiratory Diseases and the National Center for Health Statistics, Centers for Disease Control and Prevention. The NIS-Teen is the most comprehensive national survey of adolescent vaccination behavior, obtaining accurate national and state-specific estimates of vaccination coverage in all 50 states and selected local areas [19]. The survey is conducted annually to monitor coverage with recommended vaccines during ages 11--17 years and to identify groups with lower coverage [19]. Data specific to HPV vaccine uptake have been collected in the NIS-Teen survey since 2007. The NIS-Teen uses the same sampling and weighting methodology as the National Immunization Survey, the details of which have been described elsewhere [20].

Study Participants

Analyses were limited to NIS-Teen participants who were female, had complete household interview data and adequate provider data for the HPV vaccine (including unvaccinated adolescents). Because the present study looked at maternal education level, the sample was limited to teens for whom the household interview respondent was the teen's mother. Although the data set included four categories for mother's education level, in order to increase the likelihood of studying parents who had distinctively different levels of education, I restricted analyses to teens of mothers with college degrees and teens of mothers with 12-years of education or less.

Definitions and Variables

There were two dependent variables of interest: (a) the gap in HPV vaccine series initiation rates between teens whose mothers had a high school-level education or less and teens whose mothers were college graduates (referred to as the High school and College groups) and the gap in HPV vaccine series completion between the High school and College groups. HPV vaccine series initiation was defined as at least one dose of the vaccine received before the survey date. HPV vaccine series completion was defined as receipt of three or more vaccine doses before the survey date. Total number of HPV vaccines doses received was obtained from provider-verified vaccination records.

Other than provider-reported vaccination data, all variables were created from information reported by the telephone survey respondent. Race/ethnicity of the teen was categorized as Hispanic, Non-Hispanic White only, Non-Hispanic Black only, and Non-Hispanic Other/Multiple race. I classified adolescent's health insurance as one of 6 types – employer-provided, provided by the Medicaid or the State Children's Health Insurance Program (S-CHIP),

provided by the military or Indian Health Service (IHS), provided by some other entity, none, or missing. Household income was categorized into one of 12 ranges, starting with $0-$7,500 and ending with $75,000+. Measures of specific health knowledge include survey respondents' answers to two survey questions about general HPV infection and vaccine awareness: (a) whether they had ever heard of HPV and (b) whether they had heard of the HPV vaccine[8][20]. For all independent variables, missing values were classified into a separate group rather than omitted from analysis.

Statistical Analyses

Logistic Regression Analysis

First, two separate multivariable logistic regression analyses were performed to estimate how much the probability of initiating or completing the HPV vaccine changed with each unit change in a set of explanatory sociodemographic variables. I included variables that have been identified as important determinants of vaccine utilization and that could vary with maternal educational attainment. Table 1 shows variables included in the regression models, grouped into related categories. These groupings were then used in a decomposition analysis of the regression coefficients, which I explain next.

The first set of variables included potential confounders – individual and family demographic variables that would not be affected by maternal educational attainment but may be associated with HPV vaccine utilization.

The second group of variables served as a proxy for household income and socioeconomic status. In addition to current household income, I included number of children in

[8] TIS_AHPV: Have you ever heard of Human Papillomavirus or HPV? This is different from Human Immunodeficiency virus or HIV, which you may have heard of.
TIS_AHPV_KNOWLEDGE: The human papillomavirus is a common virus known to cause genital warts and some cancers, such as cervical cancer in women. A vaccine to prevent HPV infection is available and is called the cervical cancer vaccine, HPV shot, or GARDASIL. Before today, have you ever heard of the cervical cancer vaccine, HPV shot, or Gardasil?

household and mother's marital status as proxies for socioeconomic status. These measures are likely to determine permanent household income and, together with current income, can be affected by educational attainment [81].

The third group – type of health care insurance, served as a measure of healthcare accessibility. And the fourth group included response dummy variables for the two survey questions assessing HPV knowledge and awareness. Together, these questions served as proxies for specific health knowledge.

In the regression model predicting HPV vaccine-series completion, I also included receipt of an 11/12-year-old wellness exam, and up-to-date status for other adolescent vaccines as proxies for healthcare utilization and timeliness. Such factors are scheduled to occur at the time of the HPV vaccine-series initiation and, therefore would not be relevant predictors in the first regression model. However, they may vary with maternal educational attainment and influence HPV vaccine-series completion.

I present the coefficient estimates, standard errors, odds ratios, and associated 95% confidence interval for each variable in the model. *P* values less than 0.05 were considered statistically significant. All analyses were performed using SAS 9.2 [82].

Table 1. Groups of Sociodemographic Variables included in Analysis

Potential Confounders	Adolescent's Age; Maternal Age; Race / Ethnicity
Household income	Household Income; Marital status; Number of Children in Household
Health Insurance	Health Insurance
Health Behaviors	11/12 year wellness exam; Up-to-date status for all other adolescent immunizations
Specific Health Knowledge	Knowledge of HPV; Awarenes of HPV vaccine

Non-Linear Blinder-Oaxaca Decomposition

In order to identify the driving factors contributing to the observed maternal educational differences in HPV vaccine series initiation and completion, I used a non-linear

extension of the Blinder-Oaxaca decomposition technique as described by Fairlie [83]. The Blinder-Oaxaca decomposition is a method of decomposing an observed inequality in health care into contributing factors. The core idea is to explain the distribution of the outcome variable in question – HPV vaccine series initiation or completion, by a set of factors that vary systematically with the variable of interest - maternal educational attainment. The decomposition method reveals how inequalities in one dimension compare to inequalities in another in explaining an overall gap in healthcare utilization between two groups [84].

The original decomposition technique, described by Blinder and Oaxaca, was designed for use with a linear or continuous outcome variable such as wages [85]. Since my outcome variables were dichotomous, (HPV vaccine series initiation or not; HPV vaccine series completion or not,) I use a nonlinear decomposition method proposed by Fairlie [83].

I implemented the non-linear Blinder-Oaxaca decomposition in the following form. For the gap in HPV vaccine series initiation, the difference between high school and college group mean predicted probabilities of initiating the HPV vaccine is:

$$\bar{Y}^C - \bar{Y}^H = [\sum_{i=1}^{N^C} \frac{F(X_i^C \hat{\beta}^C)}{N^C} - \sum_{i=1}^{N^H} \frac{F(X_i^H \hat{\beta}^C)}{N^H}] + [\sum_{i=1}^{N^H} \frac{F(X_i^H \hat{\beta}^C)}{N^H} - \sum_{i=1}^{N^H} \frac{F(X_i^H \hat{\beta}^H)}{N^H}]$$

(1)

Where indices *H* and *C* indicate high school and college samples, $\bar{Y}^H$ and $\bar{Y}^C$ are the mean predicted probabilities of vaccine series initiation for the respective samples, *F* is the cumulative distribution function (CDF) from the logistic distribution, *X* is the vector containing grouped independent variables, and $\hat{\beta}$ is the vector containing coefficient estimates from the logistic regression described previously. The first set of terms in Eq (1) provides an estimate of the contribution of educational differences in the entire set of independent variables to the educational gap in the dependent variable. In other words, to estimate the total contribution of

educational differences in a set of independent variables to the maternal educational gap in vaccine series initiation, one only needs to calculate two sets of predicted probabilities and take the difference between the averaged values of the two.

To identify the contribution of group differences in specific variables to the education gap, I first assumed that that $N_H = N_{C,}$ and there exists a natural one-to-one matching of high school and college observations. The independent contribution of a variable, X_1, to the maternal educational gap can then be expressed as:

$$\frac{1}{N^H}\sum_{i=1}^{N^H} F(\hat{\alpha}^* + X_{1i}^C\hat{\beta}_1^* + X_{2i}^C\hat{\beta}_2^*) - F(\hat{\alpha}^* + X_{1i}^H\hat{\beta}_1^* + X_{2i}^C\hat{\beta}_2^*)$$

(2)

Similarly, the contribution of X_2 can be expressed as:

$$\frac{1}{N^H}\sum_{i=1}^{N^H} F(\hat{\alpha}^* + X_{1i}^H\hat{\beta}_1^* + X_{2i}^C\hat{\beta}_2^*) - F(\hat{\alpha}^* + X_{1i}^H\hat{\beta}_1^* + X_{2i}^H\hat{\beta}_2^*)$$

(3)

The contribution of each variable to the gap is thus equal to the change in the average predicted probability from replacing the high school distribution with the college distribution of that variable while holding the distributions of all other variables constant. The contribution of a set of categorical variables is calculated by simultaneously switching distributions of the entire set of associated dummy variables. A useful property of this technique is that the sum of the contributions from individual variables will be equal to the total contribution of the entire set of independent variables, as estimated using Eq (1).

The independent contribution of each variable X is dependent upon the value of the other variables in the regression. It is, therefore, important to consider the order of switching distributions when calculating contributions to the maternal education gap. As will be described

later, I examined how ordering influenced decomposition estimates in order to see whether different factors represented more than one process.

Because the sample sizes of the high school and college groups were not equal, in order to calculate Eqs (2) and (3), I first calculated predicted probabilities of HPV vaccine series initiation or completion for each high school and college observation using the coefficient estimates from the logistic regression. I then ranked the observations in each group by their predicted probabilities and drew a random sample from the college group equal to the total observations in the high school group. High school and college group observations were then matched one-to-one by their respective rankings, and decomposition estimates were calculated using the above equations. I repeated this procedure 1000 times. The reported results are the mean values of the 1000 decomposition estimates.

I used the delta method to approximate standard errors. For further description of the nonlinear decomposition technique, see [83].

Sensitivity Analysis

I conducted a variety of sensitivity analyses in order to see how the decomposition estimates might change with changes to the model specification. The following three sensitivity analyses were performed: the set of coefficients $\hat{\beta}$ used in the decomposition were estimated from the college subsample rather than the pooled sample; coefficients $\hat{\beta}$ were estimated using the high school subsample; and the order of switching distributions was reversed.

An alternative to weighting the terms in the decomposition equation using coefficient estimates from a pooled sample of the two groups, $\hat{\beta}$, is using coefficient estimates from the college subsample or high school subsample. It can be argued that teens of college-educated

mothers utilize the HPV vaccine at the expected level and teens of mothers with 12 years of education or less underutilize the vaccine. If this is the case, the college coefficients should be taken as the index vaccine utilization distribution. Conversely, if teens of teens of college-educated mothers utilize the HPV vaccine above the expected amount, then the high school coefficients should be used as the index distribution. While both are equally valid expressions for the decomposition, resulting estimates can be quite sensitive to these alternative calculation methods. This is the familiar index problem of the Blinder-Oaxaca decomposition technique [86].

Another potentially important issue regarding this technique is the effect of variable ordering. Because of the nonlinearity of the decomposition equation, the independent contribution of each variable is dependent upon the value of the other variables in the regression. It is, therefore, important to consider the order of switching distributions when calculating contributions to the maternal education gap. To investigate the potential effects of ordering, I calculated decomposition estimated in which the order of switching variable distributions was reversed.

Results

Study Participants

For the 2008-2010 NIS-Teen surveys, there were 99,251 (47,430 girls) eligible adolescents with complete household interviews. Of the 47,430 girls, 29,458 (62%) had provider-verified HPV vaccination records. The dataset was further limited to the 24, 020 (51%) observations, for which the respondent to the household survey was the teen's mother. After limiting the sample to teens of mothers with college degrees and teens of mothers with 12 years of education or less, the final sample size was 16,544 (35%).

Demographic Characteristics

Table 2 shows descriptive statistics for adolescent girls by maternal educational attainment. Forty three percent of girls whose mothers had a high school education or less initiated the HPV vaccine series between 2008 and 2010. Twenty three percent of girls in this group completed the series. HPV vaccine series initiation was slightly higher for girls in the college group, at 45 percent and vaccine series completion rate was several points higher at 30%. The majority of explanatory variables were statistically different for adolescents in the high school group compared to those in the college group. Girls in the high school group were more likely to be an ethnic minority, live in a single parent household, and have younger mothers, lower household incomes, and public health insurance. With respect to healthcare access and utilization, those in the college group were more likely to utilize all private immunization facilities, reported having an 11-12 year old wellness check-up, and be up-to-date for other adolescent vaccines. And finally, mothers with college degrees were more likely to be aware of the human papillomavirus and the HPV vaccine.

Logistic Regression Analysis

Tables 3 and 4 report adjusted odds ratios from the multivariable analysis of factors associated with HPV vaccine series initiation and completion, respectively. Because there was no difference in vaccine series initiation between the high school and college groups in 2010, results for that year are not reported.

After adjusting for other characteristics, there was no longer a significant difference in odds of initiating the HPV vaccine series between teens in the high school and college groups. The estimated odds ratios indicate that being 13 years old, having an annual household income falling within certain ranges between $30,000 and $60,000, and having a mother with no knowledge of HPV or the HPV vaccine, decreased the probability of HPV vaccine series initiation

in both 2008 and 2009. Being Hispanic and having an unmarried mother increased the probability of initiating the vaccine series in both years.

Similar to vaccine series initiation estimates, after adjusting for other factors, there was no longer a significant difference in odds of completing the HPV vaccine series between teens in the high school and college groups in 2008 and 2009. In 2010, teens whose mothers had less than 12 years of education were 44% more likely to complete the HPV vaccine series, compared with teens whose mothers were college graduates. Estimated odds ratios also indicate that younger age, being Black/Non-Hispanic, not receiving an 11-12 year old wellness exam, being uninsured, and having a mother with no knowledge of HPV or the HPV vaccine all significantly decreased the probability of completing the vaccine series.

Table 2- Variable Means by Maternal Education Level 2008-2010

	≤ 12 Years of Education (n= 6714)	College Graduate (n = 9,830)	P [1,2]
Initiated HPV vaccination series			0.01
Yes	42.6	44.6	
No	57.4	55.4	
Completed HPV vaccination series			<0.0001
Yes	23.0	29.9	
No	77.1	70.1	
Survey Year			0.02
2008	32.3	30.2	
2009	34.8	35.7	
2010	32.9	34.0	
Age			0.06
13	19.2	19.9	
14	20.7	20.5	
15	19.6	20.7	
16	22.0	20.3	
17	18.4	18.7	
Race or ethnic group			<0.0001
Hispanic	24.0	6.3	
Non-hispanic white only	53.3	79.3	
Non-hispanic black only	15.4	7.4	
Non-hispanic other + multiple race	7.3	7.0	
Mother's Age Group			<0.0001
<= 34 years	11.9	2.6	
35 to 44 years	49.7	35.1	
>= 45 years	38.5	62.3	
Family Income			<0.0001
$0 - $7500	6.4	0.2	
$7501 - $10000	6.3	0.3	
$10001 - $17500	9.9	0.7	
$17501 - $20000	6.3	0.6	
$20001 - $25000	6.6	0.9	
$25001 - $30000	7.3	1.4	
$30001 - $35000	4.9	1.5	
$35001 - $40000	5.6	2.2	
$40001 - $50000	8.9	5.4	
$50001 - $60000	6.5	5.9	
$60001 - $75000	7.6	10.6	
$75001+	15.2	64.6	
DON'T KNOW	5.1	1.0	
REFUSED	3.5	4.7	
Health Insurance			<0.0001
Employee health insurance	46.3	85.5	
Medicaid or SCHIP	34.8	4.9	
Military health care, tricare, champus, or champ-va	2.3	1.1	
Other	5.1	5.8	
Currently uninsured	10.3	1.8	
Missing	1.2	1.0	
Number of Children Under 18 in Household			<0.0001
One	37.0	38.7	
Two or three	49.2	54.1	
Four or more	13.8	7.2	
Mother's Marital Status			<0.0001
Married	66.5	84.4	
Never married / widowed / divorced / separated /	33.5	15.6	
Have you ever heard of human papillomavirus? *			<0.0001
Yes	77.6	94.1	
No	19.7	5.2	
Don't know	2.7	0.7	
Refused	0.0	0.0	
Have you ever heard of the cervical cancer vaccine, hpv shot, or Gardasil? *			<0.0001
Yes	88.3	98.1	
No	10.2	1.5	
Don't know	1.5	0.4	
Facility Type			<0.0001
All private facilities	26.8	10.5	
All hospital facilities	8.5	7.2	
All public facilities	39.1	57.5	
All std/school/teen clinics or other facilities	3.4	2.7	
Mixed	15.2	15.9	
Unknown	7.1	6.2	
Did teen have an 11-12 year old well-child exam or check-up?			<0.0001
Yes	68.6	76.0	
No	9.6	7.0	
Don't know	21.8	17.1	
Up-to-date on 1:3:2:1 vaccination series[3]	59.3	69.9	<0.0001
Up-to-date on 1:3:2:1:2 vaccination series[4]	33.2	43.1	<0.0001

Notes: (1) Value in the parentheses is the P value for the difference between the US mean and the Canadian mean. statisically significant at 0.05 p-value. (2) The Pearson χ2 tests were used for categorical variables. (3) The series of 1 or more Td/Tdap vaccinations, 3 or more Hep B vaccinations (or 2 or more Hep B 1.0 ml Recombivax vaccinations), 2 or more MMR vaccinations, and 1 or more VRC vaccinations (or a history of chicken pox disease) (4) The series of 1 or more Td/Tdap vaccinations, 3 or more Hep B vaccinations (or 2 or more Hep B 1.0 ml Recombivax vaccinations), 2 or more MMR vaccinations, 1 or more MEN vaccinations, and 2 or more VRC vaccinations (or a history of chicken pox disease)

Table 3 - Multivariable analysis of association between maternal educational attainment and and HPV vaccine series initiation controlling for sociodemographic characteristics in NIS Teen Survey years 2008

	Year[A]			
	2008		2009	
	HPV vaccine Initiation		HPV vaccine Initiation	
Explanatory Variables	Odds ratio	(95% CI)	Odds ratio	(95% CI)
Mother's education				
< 12 y	0.98	(0.78 , 1.23)	0.86	(0.70 , 1.06)
12 y	0.91	(0.78 , 1.06)	0.93	(0.81 , 1.07)
College degree	1.00		1.00	
Mother's Age Group				
<= 34 years	1.12	(0.87 , 1.45)	1.33	(1.04 , 1.71)
35 to 44 years	0.91	(0.80 , 1.04)	0.84 *	(0.74 , 0.94)
>= 45 years	1.00		1.00	
Age				
13	0.77 *	(0.63 , 0.93)	0.78 *	(0.65 , 0.93)
14	0.95	(0.78 , 1.14)	0.83 *	(0.70 , 0.99)
15	1.06	(0.88 , 1.27)	0.97	(0.81 , 1.15)
16	1.00	(0.83 , 1.20)	1.11	(0.94 , 1.32)
17	1.00		1.00	
Race or ethnic group				
Hispanic	1.61 *	(1.31 , 1.97)	1.66 *	(1.38 , 1.98)
Non-Hispanic white only	1.00		1.00	
Non-Hispanic black only	0.83	(0.67 , 1.03)	0.87	(0.72 , 1.05)
Non-Hispanic other + multiple race	1.14	(0.90 , 1.45)	1.17	(0.95 , 1.46)
Household Income:				
$0 to $7500	0.87	(0.55 , 1.36)	0.84	(0.57 , 1.24)
$7501 to $10000	0.88	(0.57 , 1.37)	0.92	(0.64 , 1.34)
$10001 to $17500	1.02	(0.72 , 1.44)	1.08	(0.78 , 1.50)
$17501 to $20000	1.12	(0.74 , 1.68)	0.82	(0.57 , 1.18)
$20001 to $25000	0.87	(0.59 , 1.27)	0.61 *	(0.44 , 0.86)
$25001 to $30000	0.74	(0.53 , 1.05)	0.89	(0.66 , 1.21)
$30001 to $35000	0.67 *	(0.46 , 0.98)	0.62 *	(0.43 , 0.88)
$35001 to $40000	1.01	(0.74 , 1.39)	0.71	(0.52 , 0.97)
$40001 to $50000	0.66 *	(0.52 , 0.84)	0.68 *	(0.54 , 0.85)
$50001 to $60000	0.71 *	(0.55 , 0.91)	0.73 *	(0.57 , 0.93)
$60001 to $75000	0.85	(0.69 , 1.04)	0.76 *	(0.63 , 0.92)
$75000+	1.00		1.00	
Number of Children Under 18 in Household				
One	1.00		1.00	
Two or three	1.01	(0.88 , 1.15)	1.26	(1.12 , 1.42)
Four or more	0.92	(0.73 , 1.15)	1.11	(0.90 , 1.37)
Mother's Marital Status				
Married	1.00		1.00	
Never married / widowed / divorced / separated / deceased	1.23 *	(1.04 , 1.45)	1.20 *	(1.04 , 1.39)
Type of health insurance				
Employee health insurance	1.00		1.00	
Medicaid or SCHIP	1.18	(0.96 , 1.46)	1.49 *	(1.23 , 1.80)
IHS or Military	1.04	(0.62 , 1.74)	1.14	(0.74 , 1.76)
Other	0.95	(0.73 , 1.22)	0.92	(0.73 , 1.17)
Uninsured	0.73	(0.40 , 1.34)	0.49 *	(0.29 , 0.82)
Missing	1.18	(0.66 , 2.10)	0.83	(0.44 , 1.55)
Have you ever heard of the Human Papillomavirus?:				
Yes	1.00		1.00	
No	0.64 *	(0.51 , 0.81)	0.61 *	(0.50 , 0.75)
Don't Know	1.48	(0.86 , 2.52)	1.44	(0.75 , 2.77)
Have you ever heard of the cervical cancer vaccine, hpv shot, or Gardasil? *				
Yes	1.00		1.00	
No	0.31 *	(0.22 , 0.45)	0.39 *	(0.27 , 0.55)
Don't Know	0.54	(0.25 , 1.15)	0.31 *	(0.13 , 0.71)

* 1:3:2:1 series: up-to-date for Td/Tdap, Hepatitis B, MMR, Men and either Varicella-containing vaccine or a history of chicken pox disease

Table 4 - Multivariable analysis of association between maternal educaitonal attainment and and HPV vaccine series completion controlling for sociodemographic characteristics in NIS Teen Survey years 2008 through 2010.

	Year					
	2008		2009		2010	
	HPV vaccine completion		HPV vaccine completion		HPV vaccine completion	
Explanatory Variables	Odds ratio	(95% CI)	Odds ratio	(95% CI)	Odds ratio	(95% CI)
Mother's education						
< 12 y	0.76	(0.56 , 1.05)	0.93	(0.73 , 1.19)	1.44 *	(1.13 , 1.84)
12 y	0.88	(0.72 , 1.08)	0.88	(0.75 , 1.03)	1.00	(0.85 , 1.18)
College degree	1.00		1.00		1.00	
Mother's Age Group						
<= 34 years	0.77	(0.54 , 1.12)	0.96	(0.71 , 1.30)	1.09	(0.81 , 1.46)
35 to 44 years	0.80 *	(0.67 , 0.94)	0.84 *	(0.74 , 0.97)	0.90	(0.78 , 1.03)
>= 45 years	1.00		1.00		1.00	
Age						
13	0.92	(0.71 , 1.20)	0.78 *	(0.63 , 0.98)	0.55 *	(0.44 , 0.68)
14	0.96	(0.76 , 1.22)	0.78 *	(0.64 , 0.94)	0.63 *	(0.52 , 0.76)
15	0.87	(0.69 , 1.09)	0.81 *	(0.67 , 0.98)	0.67 *	(0.56 , 0.81)
16	0.89	(0.71 , 1.11)	1.03	(0.86 , 1.24)	0.89	(0.74 , 1.06)
17	1.00		1.00		1.00	
Race or ethnic group						
Hispanic	1.17	(0.90 , 1.51)	1.09	(0.89 , 1.33)	0.96	(0.79 , 1.17)
Non-Hispanic white only	1.00		1.00		1.00	
Non-Hispanic black only	0.55 *	(0.40 , 0.75)	0.54 *	(0.43 , 0.69)	0.54 *	(0.43 , 0.68)
Non-Hispanic other + multiple race	0.85	(0.62 , 1.16)	1.08	(0.85 , 1.37)	1.22	(0.98 , 1.53)
Household Income:						
$0 to $7500	0.56	(0.27 , 1.15)	0.73	(0.45 , 1.20)	1.09	(0.72 , 1.64)
$7501 to $10000	0.70	(0.36 , 1.35)	1.00	(0.64 , 1.55)	1.24	(0.82 , 1.88)
$10001 to $17500	0.96	(0.61 , 1.54)	1.12	(0.77 , 1.62)	1.04	(0.74 , 1.46)
$17501 to $20000	1.03	(0.59 , 1.80)	0.87	(0.56 , 1.34)	0.90	(0.61 , 1.33)
$20001 to $25000	0.86	(0.51 , 1.46)	0.86	(0.58 , 1.27)	1.21	(0.83 , 1.76)
$25001 to $30000	1.05	(0.68 , 1.62)	1.00	(0.70 , 1.44)	1.08	(0.76 , 1.54)
$30001 to $35000	0.69	(0.41 , 1.15)	1.00	(0.67 , 1.50)	0.90	(0.61 , 1.32)
$35001 to $40000	0.96	(0.63 , 1.47)	0.73	(0.50 , 1.07)	0.75	(0.52 , 1.06)
$40001 to $50000	0.74	(0.54 , 1.01)	0.92	(0.70 , 1.19)	0.83	(0.64 , 1.09)
$50001 to $60000	0.81	(0.59 , 1.11)	0.84	(0.63 , 1.12)	0.84	(0.65 , 1.08)
$60001 to $75000	0.74 *	(0.57 , 0.97)	0.85	(0.69 , 1.06)	0.82	(0.66 , 1.01)
$75000+	1.00		1.00		1.00	
Number of Children Under 18 in Household						
One	1.00		1.00		1.00	
Two or three	0.93	(0.79 , 1.10)	1.01	(0.88 , 1.15)	1.02	(0.89 , 1.16)
Four or more	0.82	(0.61 , 1.12)	0.79	(0.61 , 1.01)	0.85	(0.67 , 1.08)
Mother's Marital Status						
Married	1.00		1.00		1.00	
Never married / widowed / divorced / separated / deceased	1.18	(0.95 , 1.46)	1.04	(0.88 , 1.24)	1.27 *	(1.08 , 1.49)
Type of health insurance						
Employee health insurance	1.00		1.00		1.00	
Medicaid or SCHIP	1.12	(0.84 , 1.49)	1.37 *	(1.10 , 1.70)	1.01	(0.81 , 1.24)
IHS or Military	1.33	(0.70 , 2.54)	0.69	(0.40 , 1.18)	0.96	(0.61 , 1.51)
Other	0.94	(0.68 , 1.30)	1.10	(0.84 , 1.43)	0.73 *	(0.55 , 0.95)
Uninsured	0.53	(0.23 , 1.22)	0.51 *	(0.27 , 0.98)	0.39 *	(0.21 , 0.73)
Missing	1.09	(0.52 , 2.28)	0.91	(0.44 , 1.88)	0.67	(0.35 , 1.30)
Did teen have an 11-12 year old well-child exam or check-up?						
Yes	1.00		1.00		1.00	
No	0.75	(0.56 , 1.00)	0.68 *	(0.53 , 0.87)	0.48 *	(0.37 , 0.62)
Don't know	0.54 *	(0.43 , 0.69)	0.63 *	(0.52 , 0.76)	0.61 *	(0.51 , 0.73)
Up-to-date on 1:3:2:1 vaccination series[a]						
Yes	1.00		1.00		1.00	
No	0.42 *	(0.36 , 0.50)	0.36 *	(0.31 , 0.42)	0.36 *	(0.31 , 0.42)
Have you ever heard of the HPV Papillomavirus?:						
Yes	1.00		1.00		1.00	
No	0.74	(0.53 , 1.02)	0.53 *	(0.41 , 0.69)	0.68 *	(0.55 , 0.84)
Don't Know	0.86	(0.39 , 1.90)	0.73	(0.34 , 1.56)	0.96	(0.46 , 2.01)
Have you ever heard of the cervical cancer vaccine, hpv shot, or Gardasil? *						
Yes	1.00		1.00		1.00	
No	0.18 *	(0.08 , 0.40)	0.33 *	(0.19 , 0.57)	0.53 *	(0.38 , 0.74)
Don't Know	0.63	(0.18 , 2.22)	0.65	(0.23 , 1.82)	0.31	(0.08 , 1.18)

[a] 1:3:2:1 series: up-to-date for Td/Tdap, Hepatitis B, MMR, Men and either Varicella-containing vaccine or a history of chicken pox disease

* statistically significant at p<0.05

Decomposition Analysis

Tables 5 and 6 report estimates from the nonlinear decomposition of the maternal educational gap in HPV vaccination rates, stratified by survey year. For each estimate, the first number reports the portion of gap in HPV vaccine series initiation attributable to that set of factors. In other words, it is the amount the predicted probability of vaccine series initiation or completion decreased when the distribution for that set of variables was switched from the college group to the high school group. The second number in parenthesis is the associated standard error.

Decomposition of Maternal Educational Gaps in HPV Vaccine Series Initiation

The gap HPV vaccine series initiation between the high school and college groups was 4 percent in 2008 and 3 percent in 2009. There was no difference in vaccine series initiation between the two groups in 2010. Regression analysis results for the year 2010 are reported in the appendix. The largest factor contributing to the maternal educational disparity in HPV vaccine series initiation was specific health knowledge. For both years, the predicted probability of HPV vaccine series initiation decreased by 3 percentage points when the variable distribution for specific health knowledge was switched from the college group to the high school group. That means if the distribution of specific health knowledge were switched from the college group to the high school, while holding the distribution of all other variables constant, the college group's predicted probability of HPV vaccine series initiation would decrease by 3 percentage points in both years.

Household income was the second largest contributor. Switching the variable distribution for the household income proxies from the college group to the high school group,

while holding all other variables constant, decreased the predicted probability of vaccine series initiation by 1 percentage point in 2008 and by 2 percentage points in 2009.

Switching variable distributions for basic demographic characteristics from the college group to the high school group increased the predicted probability of vaccine series initiation by 2 percentage points in both 2008 and 2009. In other words, if the distributions of adolescent's race/ethnicity, adolescent's age, and mother's age were switched from the college group to the high school, while holding the distribution of all other variables constant, the predicted probability of vaccine series initiation would increase by 2 percentage points in both years.

Table 5- Non-linear Decompositions of High School / College Graduate Gaps in HPV Vaccine Initiation by Survey Year

	Survey Year	
	2008	2009
College Grad vaccination rate	39%	46%
HS Grad vaccination rate	35%	43%
College / HS gap	4pp	4pp
	Decomposition analysis	
Contribution from Educational differences in:	percentage point change (SE)	percentage point change (SE)
Potential Confounders: Adolescent's Age;	-1.5	-2.0
Maternal Age; Race / Ethnicity	(0.006)	(0.006)
Household income	0.6	1.6
	(0.011)	(0.010)
Health Insurance	0.3	-1.6
	(0.009)	(0.008)
Specific Health Knowledge	3.3	3.2
	(0.004)	(0.003)
All included variables	2.7	1.2
% of gap explained by variables	62%	35%

Notes: (1) The sample used to estimate coefficients consists of adolescents girls ages 13-17 from the college, and high school, and less than high school maternal education groups. (2) Standard errors are reported in parentheses below contribution estimates. (3) The sample sizes used in the decomposition analyses are 4,461, 5,107, respectively. (4) Contribution estimates are mean values of the decomposition using 1000 subsamples of College graduates. (5) pp = percentage point

Table 6- Non-linear Decompositions of High School / College Graduate Gaps in HPV Vaccine Completion by Survey Year

	Survey Year		
	2008	2009	2010
College Grad vaccination rate	22%	31%	36%
HS Grad vaccination rate	14%	23%	31%
College / HS gap	8pp	8pp	8pp
	Decomposition analysis		
Contribution from Educational differences in:	percentage point change (SE)	percentage point change (SE)	percentage point change (SE)
Potential Confounders: Adolescent's Age; Maternal Age; Race / Ethnicity	1.0 (0.005)	0.8 (0.005)	0.8 (0.006)
Household income	0.7 (0.009)	0.8 (0.010)	-1.3 (0.012)
Health Insurance	0.02 (0.007)	-0.8 (0.007)	1.4 (0.009)
Health Behaviors	2.3 (0.002)	2.7 (0.002)	3.5 (0.002)
Specific Health Knowledge	1.7 (0.003)	2.4 (0.003)	2.3 (0.003)
All included variables	5.71	5.92	6.77
% of gap explained by variables	74%	76%	145%

Notes: (1) The sample used to estimate coefficients consists of adolescents girls ages 13-17 from the college, and high school, and less than high school maternal education groups. (2) Standard errors are reported in parentheses below contribution estimates. (3) The sample sizes used in the decomposition analyses are 4,461, 5,107 and 4,839, respectively. (4) Contribution estimates are mean values of the decomposition using 1000 subsamples of College graduates. (5) pp = percentage point

Finally, switching the distribution of health insurance altered the predicted probability of HPV vaccine series initiation by less than 1 percentage point in 2008 and decreased the predicted probability by 2 percentage points in 2009. Overall, the distributions of included variables explained 62% of the maternal educational gap in HPV vaccine series initiation in 2008 and 35% of the gap in 2009.

Decomposition of Maternal Educational Gaps in HPV Vaccine Series Completion

The gap in High School and College group rates of HPV vaccine series completion was 8, 8, and 5 percent in 2008, 2009, and 2010, respectively. Factors explaining the maternal educational gap in vaccine series completion show a slightly different distribution compared to that of vaccine series initiation. The added proxies for health behaviors (receipt of an 11/12 year

old wellness exam and up-to-date status for other adolescent immunizations) were the largest contributors to the gap in series completion. Switching variable distributions from the college group to the high school group decreased the predicted probability of completing the HPV vaccine series by 4 percentage points in 2010, by 3 percentage points in 2009, and by 2 percentage points in 2008. Specific health knowledge was the second largest contributor, decreasing the predicted probability of vaccine series completion by 2 percentage points in all survey years. In 2008 and 2009, potential confounders explained the third largest portion of the gap, although switching variable distributions from the college to high school group decreased the predicted probability by less than 1 percentage point in both survey years. In 2010, health insurance was the third largest contributor to the maternal educational gap in HPV vaccine series completion, with an associated decrease in predicted probability of just over 1 percentage point. Switching distributions for type of health insurance decreased the predicted probability of HPV vaccine series completion by less than 1 percentage point in 2008 and increased the predicted probability by close to one percentage point in 2009. Finally, in 2008 and 2009, switching distributions for household income decreased the predicted probability of vaccine series completion marginally and increased the predicted probability in 2010. Overall, compared with the decomposition analysis of vaccine series initiation, a greater percentage of the maternal educational gap in vaccine series completion was explained by the variables included in the analysis for vaccine series completion (74%, 76%, and 145% in 2008, 2009, and 2010, respectively). The 145% estimated change relates to the predicted probability, estimated from the logistic regression, being greater than the observed value.

Sensitivity Analysis

I conducted sensitivity analyses in order to see how the results might change with changes to the model specification. Tables 7 and 8 report decomposition estimates of the

maternal educational gaps in HPV vaccine series initiation and completion using coefficient estimates from the college subsample, high school subsample, and after reversing the order of switching college and high school variable distributions. The first column reports estimates from the original non-linear decomposition technique for comparison.

Table 7- Sensitivity Analysis of Non-linear Decompositions of High School / College Graduate Gaps in HPV Vaccine Initiation by Year

	Survey Year							
	2008				2009			
College Grad vaccination rate	39%				46%			
HS Grad vaccination rate	35%				43%			
College / HS gap	4pp				3pp			
	Modification to analysis				Modification to analysis			
Contribution from Educational differences in:	High School/College Pooled (pp)	High School (pp)	College (pp)	Reverse Order (pp)	High School/College Pooled (pp)	High School (pp)	College (pp)	Reverse Order (pp)
Potential Confounders	-1.5	-4.4	0.8	-1.0	-2.0	-3.4	-1.8	-1.7
Household income and socioeconomic status	0.6	-0.1	2.4	0.8	1.6	2.3	1.1	1.7
Health Insurance	0.3	-0.1	1.4	0.3	-1.6	-4.1	1.1	-1.6
Specific Health Knowledge	3.3	3.2	3.3	2.6	3.2	3.2	6.2	2.7

pp = percentage point

The estimates in second and third columns of each survey year result from using coefficients estimated from the high school and college subsamples, respectively. Overall, the majority of decomposition estimates remained within one percentage point of the original value. Using high school coefficients in the decomposition estimate of HPV vaccine series initiation decreased the contribution from potential confounders by 2 percentage points in 2008 and decreased the contribution from health insurance by 2 percentage points in 2009. Using college coefficients increased the contribution from specific health knowledge by 3 percentage points in 2009.

Using high school coefficients in the decomposition estimate of HPV vaccine series completion did not change contribution estimates substantially. Similarly, estimates of the decomposition of vaccine series completion using college coefficients were almost identical to those calculated using the original technique.

The last column reports estimates in which the order of switching variable distributions is reversed. Overall, the estimates did not differ substantially from the original estimates.

Table 8- Sensitivity Analysis of Non-linear Decompositions of High School / College Graduate Gaps in HPV Vaccine Completion by Year

	Survey Year											
	2008				2009				2010			
HPV vaccine series completion												
College Grad vaccination rate	22%				31%				36%			
HS Grad vaccination rate	14%				23%				31%			
College / HS gap	8pp				8pp				5pp			
	Modification to analysis				Modification to analysis				Modification to analysis			
Contribution from Educational differ	High School/ College Pooled (pp)	High School (pp)	College (pp)	Reverse Order (pp)	High School/ College Pooled (pp)	High School (pp)	College (pp)	Reverse Order (pp)	High School/ College Pooled (pp)	High School (pp)	College (pp)	Reverse Order (pp)
Potential Confounders	1.0	-0.1	1.1	1.5	0.8	0.4	1.4	1.5	0.8	0.5	1.0	1.7
Household income and socioecono	0.7	0.4	0.1	0.9	0.8	1.1	-0.8	0.8	-1.3	-2.2	0.9	-1.0
Health Insurance	0.0	-0.3	1.4	0.1	-0.8	-1.4	0.4	-0.6	1.4	1.3	0.4	1.4
Health Behaviors	2.3	2.5	2.7	2.2	2.7	2.6	3.6	2.5	3.5	3.5	3.5	2.8
Specific Health Knowledge	1.7	1.4	2.0	1.1	2.4	2.0	3.0	1.6	2.3	2.0	2.9	1.8

Discussion

In this study, I evaluated the relative influences of household-level socioeconomic status, specific health knowledge, and general healthcare utilization and timeliness in mediating the relationship between maternal educational attainment and HPV vaccine utilization among adolescent girls.

Pathways

My results indicate that, in adolescent girls, differences in mother's knowledge of HPV and the HPV vaccine account for most of the maternal educational disparity in HPV vaccine series initiation. Household-level socioeconomic status is the second largest contributor. For HPV vaccine series completion, differences in healthcare utilization and timeliness and specific health knowledge explain the majority of the maternal educational gap. Household income and socioeconomic status do not meaningfully contribute to maternal educational differences in HPV vaccine series completion.

The relative influences of specific health knowledge, health behaviors, and socioeconomic status have been demonstrated in the following ways. In 2008 and 2009, Specific health knowledge comprised 3 percentage points of the 4% gap in HPV vaccines series initiation between adolescents in the high school and college groups. In contrast, household income measures accounted for less than 2 percentage points of the gap in HPV vaccine series initiation in both 2008 and 2009. Similarly, specific health knowledge contributed to the maternal educational gap in HPV vaccine series completion, more than three times the amount of household income in every survey year.

Health Knowledge

Overall, these results are consistent with the literature on education and health. For example, in a 1991 empirical study by Kenkel, the author also concluded that differences in health knowledge explained part of the relationship between schooling and health behaviors, such as the consumption of cigarettes, alcohol, and exercise [58]. However, whereas in the current study, health knowledge accounts for as much as 75 percent of the maternal educational gap in HPV vaccine series initiation, Kenkel found that differences in knowledge only accounted for 5 to 20 percent of schooling's effects on health behaviors.

However, Kenkel's conclusions may suggest a possible explanation for these differences. He explained, schooling may improve health behaviors by improving an individual's knowledge of the relationship between health behaviors and health outcomes [58]. Knowledge may contribute more to maternal educational differences in HPV vaccination than differences in smoking or exercise because knowledge of the benefits of HPV vaccination may be less common across education levels, compared to knowledge of the benefits of exercise or the dangers of smoking.

This explanation for why knowledge may contribute more to maternal educational differences in immunization is supported by another study, conducted by Polonijo and Carpiano, which looked at how social inequalities contributed to health differences in adolescent HPV vaccination [87]. Similar to the current study, the authors found that maternal educational disparities in initiating the HPV vaccine were substantially attenuated and lost statistical significance once those with no vaccine knowledge were eliminated from analysis, indicating the contribution of knowledge to the generation of disparities.

Healthcare Utilization and Timeliness

My proxies for health behaviors – receipt of other adolescent vaccines and an 11-12 year wellness check-up, explained the majority of the maternal educational gap in HPV vaccine completion. These findings are consistent with studies from the developing world that have shown a positive correlation between maternal education and use of preventive health services [63, 64]. However, the exact pathway linking healthcare utilization and timeliness and HPV vaccine series completion is not clear and may be a function of some or all of the other factors included in analysis. For example, it is possible that a doctor's visit for vaccine administration or a wellness check-up provides health care providers (HCPs) an opportunity to discuss the HPV vaccine. Such an encounter could enhance a mother's knowledge of the vaccine, its importance and its immunization schedule, which could, in turn, facilitate completing the series. Alternatively, an unobserved factor could be influencing education's effect on both healthcare utilization and HPV vaccine series completion independently. For instance, higher educational attainment may lead to more positive attitudes and beliefs about healthcare, leading more educated mothers to both seek out preventative care visits as well as ensure the completion of the HPV vaccine series [53, 88-93]. Without added data, it is unclear which mechanism is at play and to what degree.

Household Income and Socioeconomic Status

Previous studies have found that education affects health behavior by increasing economic resources, which can enable greater investment in health. In the current study, I found that differences in household income and socioeconomic status explained between 15 and 41 percent of the maternal educational differences in adolescent HPV vaccine series initiation and approximately 10 percent of the differences in HPV vaccine series completion. In contrast, a 1988 study by Cleland found that economic advantages associated with higher educational attainment (income, water and latrine facilities, housing quality, etc.) accounted for approximately half of the overall relationship between mother's education and survivorship of her children [51]. Similarly, an analysis of data from the National Health Interview Survey (NHIS) found that income accounted for about one third of the effect of education on health in the adult population [52].

However, not all estimates are as high. In a follow-up to an earlier study, Cutler and Lleras-Muney found that material resources accounted for an average of 12 percent of the impact of higher education on health behaviors, less than half of their original estimate [81].

The variation in the magnitude of the effect of income is likely related to the outcome measure of interest. For example, in this study, cost barriers to vaccination are substantially reduced through federal and state programs such as Medicaid, S-CHIP, and the Vaccines for Children (VFC) program. The VFC program in particular, offers ACIP-recommended vaccines, such as the HPV vaccine, at no cost to children who are eligible for Medicaid, uninsured, or underinsured with private insurance. As a result, economic advantages resulting from higher educational attainment may not provide as much of an advantage to accessing vaccines compared with other health outcomes.

Limitations

My findings are subject to limitations. First, because this is an observational study, findings cannot prove that the strong association I observed between maternal education and HPV vaccine utilization is causal.

Second, due to the limited number of measures included in the data set, I was only able to test some of theories linking education to health. The observed unexplained differences in vaccine utilization could include other, more significant explanatory mechanisms.

A third limitation of this analysis relates to the use of self-reported variables in analysis. Self-reported variables are subject to recall bias and reporting bias. Similarly, my analysis required the use of proxies for certain mechanism of interest, which can be very noisy. As a result, it is not clear whether these proxies are only measuring the parameters of interest.

There were additional limitations to the NIS-Teen dataset. NIS-Teen is a landline telephone survey. Because this analysis did not use sampling weights that adjusted for non-coverage for households without landline telephones, nonresponse and non-coverage bias might remain, leading to underestimation or overestimation of coverage rates. Additionally, underestimates of vaccination coverage might have resulted from the exclusive use of provider-verified vaccination histories.

Specific study strengths should also be noted. To my knowledge, this study is among a very few to examine the effects of maternal education on adolescent health, specifically, HPV vaccination [94-96]. Most studies of the influence of maternal education on child health focus on health measures from early childhood [23, 97] or infant mortality rates [51]. This is among the first to evaluate the effects of maternal educational attainment on utilization of preventive health services [50]. The majority of research on the effects of maternal education on child health comes from the developing world, though educational disparities also exist in the United

States. And many control for economic factors, which could actually be pathways through which level of education influences health behaviors and decision-making. The NIS-Teen is one of the largest and most diverse national datasets that contains sociodemographic information and information on vaccination behavior of US adolescents. The robust set of demographic and provider-reported variables allowed me to simultaneously examine the validity of multiple theories linking level of education and healthcare utilization as well as compare the relative importance of each.

This study contributes to the literature by showing that differences in HPV vaccine series initiation and completion by maternal educational attainment can be explained by education-related differences health knowledge and healthcare utilization and timeliness. Economic advantages to educational attainment, such as household income or insurance status, contribute less to maternal educational differences in adolescent HPV vaccination status. While these findings can be interpreted as evidence that programs designed to limit cost barriers to vaccination, such as the VFC program are working, it also shows that differences in awareness and understanding of preventive health services across sociodemographic levels can potentially lead to health disparities. Such disparities are significant, as differences in HPV risk and, subsequently, cancer risk are a natural consequence of differences in HPV vaccine coverage.

Factors associated with health care provider recommendation of the Human Papillomavirus vaccine, and effects of provider recommendation on vaccine-series initiation and completion in US adolescent females.

Introduction

Genital human papilloma virus (HPV) is the most common sexually transmitted infection [98]. New estimates from the Centers for Disease Control and Prevention (CDC) indicate there are approximately 20 million new HPV infections in the United States per year [99]. There are more than 40 types of HPV that can infect the genital areas of males and females as well as the mouth and throat. Certain high-risk HPV types can cause serious diseases including genital warts, cervical and other cancers.

In June 2006, the first HPV vaccine (Gardasil®, Merck) was licensed for use in the United States. Gardasil provides protection against four high-risk HPV types associated with approximately 70% of cervical cancers and more than 90% of genital warts. A second vaccine (Cervarix®, GlaxoSmithKline) providing protection against two high-risk HPV types was approved for use in women in 2009. Subsequently, the Advisory Committee on Immunization Practices (ACIP) recommended routine HPV vaccination of 11- and 12-year-old girls, and catch-up vaccinations for females aged 13 through 26 years [13]. And as of 2011, ACIP recommends Gardasil in 11- and 12-year-old boys with catch-up vaccination for males aged 13 to 21 years [14].

Widespread use of the HPV vaccine is central to lowering risk of HPV infection and related illnesses. However, less than half of adolescent females 13–17 years old received at least one dose of the HPV vaccine in 2010 [80].

Previous studies suggest health care provider (HCP) recommendation is a strong predictor of vaccination for a wide range of vaccines [100-108]. By extension, one potential

explanation for the low levels of HPV vaccine coverage is that health care providers are not recommending it to parents and adolescents.

Finding from a recent study by Almeida, et al support this theory [107]. They found that, among vaccine-eligible women and parents of eligible girls, those who reported hearing about HPV from a health care provider were significantly more likely to have received or intend to receive the vaccine than those who reported hearing about it from other sources. Another study found that parents were more likely to initiate HPV vaccination for their daughters when they heard about the vaccine from their children's healthcare providers but not when they heard about it from other information sources [109]. And Lau, Lin, and Flores found that adolescent girls who initiated the HPV vaccine series were more likely to have had a respondent report of their healthcare provider recommending the HPV vaccine, compared with those who did not initiate the HPV vaccine series, (84% vs. 20%) [102] In the same study, respondent report of a HCP recommendation was associated with approximately 18 times the adjusted odds of initiating the series. Similarly, a recent study, which evaluated factors that influence parental vaccination decisions for adolescents, found that HPV vaccination coverage was much higher among teens whose parents reported receiving a provider recommendation (62% vs. 21.5%) [110].

Despite strong evidence supporting the association between HCP recommendation and HPV vaccination, previous studies also suggest low rates of HCP recommendation [102, 103, 111]. Previous studies have reported that anywhere from 70% to 30% of eligible adolescent girls did not receive a recommendation for the HPV vaccine by their health care provider [103, 111].

Furthermore, there are significant differences between those who receive a recommendation and those who do not. Palli, Mehta, and Aparasu found that the majority of girls who received an HPV vaccine recommendation were white (71%), and had at least one

preventive health visit (94%) [111]. And Lau, Lin, and Flores reported lower adjusted odds of a respondent-reported HCP recommendation of the HPV vaccine for adolescent females who were African-American and uninsured [102]. Ylitalo, Lee, and Mehta also found that Racial/ethnic minorities were less likely to receive a recommendation [103].

While these previous studies have looked at sociodemographic differences between those who received an HCP recommendation and those who do not, their findings do not elucidate the likely reasons for the observed disparities.

It is possible that certain individuals are not receiving recommendations from their healthcare providers because they have fewer encounters. Indeed, many studies have demonstrated that the socioeconomically disadvantaged tend to have less access to health care [105, 112], and therefore fewer encounters with the health care system. By extension, such individuals may have fewer opportunities to discuss the HPV vaccine with a health care provider.

But these observed differences may also be explained by certain individuals having different types of encounters – sick visits versus wellness visits, or seeing providers who are less likely to advise on immunizations. For example providers may be more or less likely to recommend vaccines based on their specialty or practice type. It is also possible that, even with the same number of encounters, certain groups face challenges within that health care encounter, such as language barriers or health insurance that does not cover the HPV vaccine, which make recommendations less likely.

Several studies have looked the impact of HCP recommendation of the HPV vaccine in adolescent females according to parental report [96, 102, 103, 110, 113] and two national studies have examined sociodemographic factors associated with HCP recommendation [102, 103]. However, to my knowledge, none have attempted to explain how sociodemographic factors, health-seeking behavior, and factors associated with the healthcare visit, such as

immunization facility type and language, influenced the likelihood of provider recommendation. This study, therefore, aims to examine the relative influences of adolescent and household sociodemographic characteristics and characteristics of their health-seeking behavior on the likelihood of receiving a health care provider recommendation of the HPV vaccine.

Methods

Data Source

I analyzed data from the 2008 –2010 National Immunization Survey – Teen (NIS-Teen). The NIS-Teen is a list-assisted random-digit-dialing telephone survey followed by a mailed survey to children's immunization providers. It is conducted jointly by the National Center for Immunizations and Respiratory Diseases and the National Center for Health Statistics, Centers for Disease Control and Prevention. The NIS-Teen is the most comprehensive national survey of adolescent vaccination behavior, obtaining accurate national and state-specific estimates of vaccination coverage in all 50 states and selected local areas [19]. The survey is conducted annually to monitor coverage with recommended vaccines during ages 11--17 years and to identify groups with lower coverage [19]. It has collected data related to HPV vaccination since 2007. NIS-Teen uses the same sampling and weighting methodology as the National Immunization Survey, the details of which have been described elsewhere [20]. Provider-reported vaccination histories, obtained from the mailed portion of the survey, were used to determine vaccination status in this study.

Study Participants

Analyses were limited to NIS-Teen participants who were female, had complete household interview data and adequate provider data for the HPV vaccine (including

unvaccinated adolescents). Because the present study looks at provider recommendation of the HPV vaccine, which would most likely occur at a wellness visit at or after age 12, the sample was limited to female adolescents who had received at least one wellness exam since age 12. Observations that were missing information on age at last checkup, provider recommendation of the HPV vaccine, or provider-verified HPV vaccination status were excluded from analysis.

Definitions and Variables

The dependent variable of interest was survey respondent-reported HCP recommendation of the HPV vaccine. Variable data was captured from the following household survey question: "Did a doctor or health care provider recommend that [subject child] receive HPV shots?"

HPV vaccine series initiation was defined as at least one dose of the vaccine received before the survey date. HPV vaccine series completion was defined as receipt of three or more vaccine doses before the survey date. Race/ethnicity of the teen was identified by the survey respondent and categorized as Hispanic, Non-Hispanic White only, Non-Hispanic Black only, or Non-Hispanic Other/Multiple race. Adolescents were categorized into one of 6 health insurance types – employer-provided, provided by the Medicaid or the State Children's Health Insurance Program (S-CHIP), provided by the military or Indian Health Service (IHS), provided by some other entity, none, or missing. Health insurance classifications were taken from the NIS-Teen public use file and were categorized as either below the poverty threshold for the given survey year, above the poverty threshold / less than $75,000, or above the poverty threshold / more than $75,000. For all independent variables, missing values were classified into a separate group rather than omitted from analysis.

Statistical Analyses

All analyses were performed using SAS 9.2 to account for the complex survey sampling design [82]. The subsample weight (RDDWTVI) for teens with completed household interviews was used in all analyses. I used chi-square statistics to test the association of fifteen individual and household-level sociodemographic characteristics with HCP recommendation of the HPV vaccine. Independent variables included adolescent's age and race/ethnicity, type of health insurance, receipt of an 11-12 year old well-child exam or check-up, immunization facility type, mother's age category, maternal educational attainment, mother's marital status, household income, number of children in in the household, language in which the survey interview was conducted, US census region, and survey year. These a priori selected sociodemographic characteristics of the adolescent and the adolescent's household have been shown as important predictors of vaccine decision making in previous studies [25, 53, 56, 96, 100, 102, 114]. A multivariable logistic regression analysis was then performed to examine the adjusted association of these independent variables with HCP recommendation. For all logistic regression models, I present the adjusted odds ratios (ORs) and corresponding 95% confidence intervals (CIs) for each variable in the model. *P* values less than 0.05 were considered statistically significant.

Results

Study Participants

For the 2008-2010 NIS-Teen surveys, there were 99,251 (47,430 girls) eligible adolescents with complete household interviews. Of the 47,430 girls, 29,458 (62%) had provider-verified HPV vaccination records. 27,874 (59%) had at least one wellness exam since

age 12. 1,382 observations were excluded due to missing information on age at last checkup or provider recommendation of the HPV vaccine. The final sample size was 26,492.

Descriptive Data

Overall, almost 60% of the female adolescents included in analysis received a provider recommendation of the HPV vaccine. Almost 45% initiated the vaccination series and approximately 27% completed it (Table 1). There was a significant difference in HPV vaccine series initiation and completion by provider recommendation (Table 1; P<.0001). Almost 60% of adolescents who received an HPV vaccine recommendation from their healthcare provider initiated the vaccine series whereas HPV vaccine series initiation was only 26% of those who did not receive a recommendation. Similarly, almost 40% of those who received a recommendation completed the vaccination series compared with less than 15% of those who did not.

Even after limiting the study sample to individuals who had at least one wellness exam since age 12, adolescent females who did not receive an HPV vaccine recommendation were more likely to have public health insurance or no health insurance or be a racial or ethnic minority.

Adolescent females who received an HPV vaccine recommendation from their provider were more likely to have received an 11-12 year old wellness exam or check-up and be up-to-date on other adolescent vaccines. Those who did not receive a recommendation were also more likely to utilize public immunization facilities.

There was not a significant difference in vaccine recommendation by age.

Significantly more adolescent females who received a vaccine recommendation resided in northeast and Midwest census regions. Adolescents who did not receive a recommendation from their provider resided mostly in the South.

Table 1. Weighted sociodemographic characteristics of US female adolescents aged 13-17 years old who have and have not received a provider recommendation for the HPV vaccine: National Immunization Survey-Teen 2008-2010

		Proportion		
Characteristics	Entire Sample % (SE) *(n= 26,492)*	Received recommendation, % (SE) *(n=15,445)*	Did not receive recommendation, % (SE) *(n= 11,047)*	*P*
HPV Outcomes				
HPV vaccination series initiation (≥1 dose)				
No	56.6 (0.5)	40.7 (0.4)	74.2 (0.5)	<.0001
Yes	43.4 (0.5)	59.3 (0.5)	25.8 (0.4)	
HPV vaccination series completion (≥3 doses)				
No	55.3 (0.5)	63.3 (0.5)	86.8 (0.5)	<.0001
Yes	44.7 (0.5)	36.7 (0.4)	13.2 (0.2)	
Characteristics of female adolescents				
Age				
13	18.0 (0.4)	18.1 (0.3)	17.8 (0.3)	0.95
14	20.2 (0.4)	19.9 (0.3)	20.7 (0.3)	
15	21.4 (0.5)	21.4 (0.4)	21.4 (0.3)	
16	20.8 (0.4)	20.8 (0.3)	20.7 (0.3)	
17	19.6 (0.4)	19.7 (0.3)	19.4 (0.3)	
Race or ethnic group				
Hispanic	16.7 (0.5)	14.5 (0.4)	19.4 (0.4)	<.0001
Non-Hispanic white only	62.4 (0.5)	66.9 (0.5)	56.7 (0.4)	
Non-Hispanic black only	14.1 (0.4)	12.0 (0.3)	16.9 (0.3)	
Non-Hispanic other + multiple race	6.8 (0.3)	6.6 (0.2)	7.0 (0.2)	
Type of health insurance				
Employee health insurance	65.6 (0.5)	69.8 (0.5)	60.2 (0.5)	<.0001
Medicaid or SCHIP	21.8 (0.5)	19.6 (0.4)	**24.6** (0.4)	
IHS or Military	1.3 (0.1)	1.1 (0.1)	1.5 (0.1)	
Other	4.9 (0.2)	5.0 (0.2)	4.7 (0.2)	
Uninsured	5.3 (0.3)	3.5 (0.2)	7.8 (0.2)	
Missing	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	
11-12 year old well-child exam or check-up				
Yes	77.6 (0.5)	82.4 (0.5)	71.4 (0.5)	<.0001
No	7.1 (0.3)	5.1 (0.2)	9.7 (0.2)	
Don't know	15.3 (0.4)	12.5 (0.3)	18.9 (0.3)	
Immunization facility type				
All public facilities	15.7 (0.4)	11.3 (0.3)	**21.4** (0.3)	<.0001
All hospital facilities	6.8 (0.3)	7.2 (0.2)	6.2 (0.2)	
All private facilities	55.0 (0.5)	59.1 (0.5)	49.7 (0.5)	
All std/school/teen clinics or other facilities	3.0 (0.2)	2.6 (0.1)	3.5 (0.1)	
Mixed	13.7 (0.4)	14.1 (0.3)	13.1 (0.2)	
Unknown	5.8 (0.3)	5.6 (0.2)	6.0 (0.2)	
Up-to-date on TD/TDAP				
No	22.1 (0.4)	15.5 (0.3)	30.3 (0.4)	<.0001
Yes	77.9 (0.4)	84.5 (0.5)	53.4 (0.5)	
Up-to-date on meningococcal vaccine				
No	44.6 (0.5)	32.3 (0.4)	60.6 (0.5)	<.0001
Yes	55.4 (0.5)	67.7 (0.5)	39.4 (0.4)	
Characteristics of families				
Mother's Age Group				
<= 34 years	8.2 (0.3)	7.5 (0.2)	9.1 (0.2)	<.0001
35 to 44 years	45.1 (0.5)	43.7 (0.5)	47.0 (0.5)	
>= 45 years	46.7 (0.5)	48.8 (0.5)	43.9 (0.4)	
Mother's education				
Less than 12 years	12.6 (0.4)	9.6 (0.3)	16.4 (0.4)	<.0001
12 years	26.2 (0.5)	24.1 (0.4)	28.9 (0.4)	
More than 12 years, non-college grad	25.9 (0.4)	25.7 (0.3)	26.2 (0.3)	
College graduate	35.4 (0.5)	40.6 (0.4)	28.5 (0.3)	
Mother's Marital Status				
Married	73.8 (0.5)	75.6 (0.5)	71.4 (0.5)	<.0001
Never married / widowed / divorced / separated / deceased	26.2 (0.5)	24.4 (0.4)	28.6 (0.4)	
Poverty status				
Above poverty > $75K	39.9 (0.5)	45.9 (0.4)	32.0 (0.5)	<.0001
Above poverty <= $75K	39.5 (0.5)	37.2 (0.4)	42.4 (0.4)	
Below poverty	16.6 (0.5)	13.3 (0.4)	20.9 (0.3)	
Unknown	4.0 (0.2)	3.6 (0.2)	4.7 (0.1)	
Number of Children Under 18 in Household				
One	30.1 (0.4)	29.3 (0.3)	31.2 (0.3)	<.0001
Two or three	57.2 (0.5)	59.3 (0.5)	54.4 (0.5)	
Four or more	12.7 (0.4)	11.4 (0.3)	14.3 (0.3)	
Survey Year		0.0	0.0	
2008	33.3 (0.5)	30.7 (0.4)	36.7 (0.4)	<.0001
2009	32.7 (0.5)	34.7 (0.4)	30.1 (0.3)	
2010	34.0 (0.5)	34.6 (0.4)	33.2 (0.4)	
Language in which interview was conducted				
English	91.8 (0.4)	94.7 (0.5)	88.1 (0.5)	<.0001
Spanish	7.0 (0.4)	4.6 (0.3)	10.1 (0.3)	
Other	1.1 (0.1)	0.7 (0.1)	1.8 (0.1)	
Census Region				
Northeast	18.2 (0.2)	21.1 (0.2)	14.5 (0.2)	<.0001
Midwest	23.9 (0.2)	24.2 (0.2)	**23.4** (0.2)	
South	35.5 (0.3)	32.3 (0.3)	**39.6** (0.4)	
West	22.4 (0.3)	22.4 (0.4)	22.4 (0.4)	
Frequency Missing = 282				

Note. HPV= human papillomavirus; SCHIP = State Children's Health Insurance Program; IHS = Indian Health Service; TD/TDAP = Tetanus-Diphtheria or Tetanus-Diphtheria-Pertussis vaccines. Data were weighted with RDDWTVI sampling weight. The sample size was n = 26492. The weighted sample size was 5,485,486.

Mothers whose daughters received a recommendation were more likely to be older than 45 years of age, be married, and have an annual household income of greater than $75,000. Approximately 95% of NIS-Teen household interviews for adolescent females who received a recommendation were completed in English, vs. only 88% of those who did not receive a recommendation. Finally, fewer adolescent females received HPV vaccine recommendations in 2008 than in 2009 and 2010.

Multivariable Analysis

Report of HCP recommendation of the HPV vaccine

Table 2 shows adjusted odds ratios from the multivariable analysis of factors associated with survey respondent-reported HCP recommendation of the HPV vaccine. After adjusting for other characteristics, adolescents classified as Black, non-Hispanic were the only racial/ethnic group significantly less likely to report receiving a provider recommendation (OR=0.69; 95% CI=0.60, 0.80). Adolescents without health insurance coverage were also significantly less likely to have received a recommendation (OR=0.70; 95% CI=0.54, 0.91). However, there were no significant differences in vaccine recommendation by type of health insurance coverage.

Adolescent girls who did not receive an 11-12 year old well-child exam were 46% less likely to report receiving an HPV vaccine recommendation, compared with those who received one (OR=0.54; 95% CI=0.45, 0.64). Adolescents who received all of their reported vaccinations at public immunization facilities were 36% less likely to receive an HPV vaccine recommendation, compared with adolescents who received immunizations at all private facilities (OR=0.63; 95% CI=0.55, 0.72).

The association between provider recommendation and maternal education was significant for all maternal education levels. Mothers with some college but no degree were 18%

less likely than those with college degrees to report a vaccine recommendation for their daughters (OR=0.82; 95% CI=0.74, 0.91). Mothers with only 12 years of education were 24% less likely to report a recommendation (OR=0.76; 95% CI=0.67, 0.87); and those with less than 12 years of education were nearly 30% less likely to report a recommendation (OR=0.71; 95% CI=0.59, 0.86).

Compared to adolescents with household income greater than $75,000, the association between household income and provider recommendation was similarly linear. Adolescents with an annual household income above the poverty threshold but less than $75,000 were 23% less likely to have received a provider recommendation of the HPV vaccine (OR=0.77; 95% CI=0.69, 0.86). The difference was even greater for those with household incomes below the poverty threshold (OR=0.69; 95% CI=0.57, 0.84).

Respondents to the 2008 NIS-Teen survey were 20% less likely to report having received an HPV vaccine recommendation, compared with respondents to the 2010 survey. Respondents who completed the NIS-teen telephone interview in languages other than English were approximately half as likely to report receiving a provider recommendation of the HPV vaccine (Spanish: OR=0.63; 95% CI=0.46, 0.86. Other: OR=0.44; 95% CI=0.28, 0.69). Finally, adolescent females who were living in the Midwest, southern, and western regions of the United State had significantly lower odds of a reported provider recommendation, compared with those living in the North East.

Table 2 - Multivariable analysis of factors associated with parental report of a healthcare provider's recommendation of the HPV vaccine in US adolescent females.

Characteristic	HPV vaccine recommendation Odds ratio (95% CI)
Age	
13	1.21 * (1.04 , 1.42)
14	0.97 (0.84 , 1.11)
15	1.00 (0.87 , 1.15)
16	1.00 (0.87 , 1.15)
17	1.00
Race or ethnic group	
Hispanic	0.95 (0.79 , 1.13)
Non-Hispanic white only	1.00
Non-Hispanic black only	0.69 * (0.60 , 0.80)
Non-Hispanic other + multiple race	0.92 (0.77 , 1.10)
Type of health insurance	
Employee health insurance	1.00
Medicaid or SCHIP	1.13 (0.98 , 1.31)
IHS or Military	0.94 (0.68 , 1.28)
Other	1.09 (0.87 , 1.36)
Uninsured	0.70 * (0.54 , 0.91)
Missing	1.20 (0.76 , 1.89)
11-12 year old well-child exam or check-up	
Yes	1.00
No	0.54 * (0.45 , 0.64)
Don't know	0.54 * (0.47 , 0.62)
Immunization facility type	
All public facilities	0.63 * (0.55 , 0.72)
All hospital facilities	1.10 (0.92 , 1.31)
All private facilities	1.00
All std/school/teen clinics or other facilities	0.76 (0.57 , 1.02)
Mixed	1.00 (0.88 , 1.14)
Unknown	0.85 (0.70 , 1.03)
Characteristics of families	
Mother's Age Group	
<= 34 years	1.01 (0.91 , 1.11)
35 to 44 years	1.17 (0.96 , 1.42)
>= 45 years	1.00
Mother's education	
< 12 y	0.71 * (0.59 , 0.86)
12 y	0.76 * (0.67 , 0.87)
> 12 y (no college degree)	0.82 * (0.74 , 0.91)
College degree	1.00
Mother's Marital Status	
Married	1.00
Never married / widowed / divorced / separated / deceased	1.04 (0.93 , 1.18)
Poverty status	
Above poverty > $75K	1.00
Above poverty <= $75K	0.77 * (0.69 , 0.86)
Below poverty	0.69 * (0.57 , 0.84)
Unknown	0.65 * (0.52 , 0.82)
Number of Children Under 18 in Household	
One	1.00
Two or three	1.16 * (1.06 , 1.28)
Four or more	1.00 (0.83 , 1.19)
Survey Year	
2008	0.80 * (0.71 , 0.89)
2009	1.09 (0.98 , 1.20)
2010	1.00
Language in which interview was conducted	
English	1.00
Spanish	0.63 * (0.46 , 0.86)
Other	0.44 * (0.28 , 0.69)
Census Region	
Northeast	1.00
Midwest	0.78 * (0.69 , 0.87)
South	0.66 * (0.59 , 0.74)
West	0.84 * (0.72 , 0.98)
Unknown	0.28 * (0.19 , 0.40)

Note: HPV= human papillomavirus; CI = confidence interval; OR = odds ratio, calculated from weighted multivariable logistic regression; SCHIP = State Children's Health Insurance Program; IHS = Indian Health Service; TD/TDAP = Tetanus-Diphtheria or Tetanus-Diphtheria-Pertussis vaccines. Data were weighted with RDDWTVI sampling weight. The sample size was n = 26492. The weighted sample size was 5,485,486.
*Results significant at the α=.05 level

Discussion

In this study, I examined the relative influences of adolescent and household sociodemographic characteristics and characteristics of their health-seeking behavior on the likelihood of receiving a health care provider recommendation of the HPV vaccine. The results of the study suggest sociodemographic factors related to one's ability to access and effectively utilize preventive health services, such as household income, health insurance status, and native language of the parent, are significantly associated with receipt of a provider recommendation of the HPV vaccine. These findings are consistent with previously published literature [102, 103] and are supported by the results in table 2. Almost all odds ratios less than 0.70 were associated with variables related to access to care, including lack of health insurance, language, poverty level, and immunization facilities used.

Uninsured adolescents had lower odds of a report of HCP recommendation of the HPV vaccine despite having a wellness exam since the age of 12 (the age at which the HPV vaccine is recommended). Research has previously demonstrated that lack of health insurance is associated with being less likely to receive a recommendation for the HPV vaccine and initiate HPV vaccine-series [102, 103]. Being uninsured has also been associated with lack of a HCP recommendation for colorectal screening and mammography in adults [115, 116].

Health insurance facilitates access to health care resources. Lack of such resources would prevent an adolescent from having an encounter in which a provider could recommend the HPV vaccine. Uninsured adolescents are more likely to have fewer physician visits, inadequate preventive services, and a lack of a usual source of medical care [117]. They are also less likely to have a primary healthcare provider [118]. The Affordable Care Act may make

insurance more affordable for the uninsured [34], thereby potentially increasing access to HCP recommendations and vaccines [102].

To my knowledge, this is among the first nationally representative studies to examine the relationship between household income and HCP recommendation of the HPV vaccine [102, 103]. Similar to health insurance status, household income likely impacts receipt of HCP provider recommendation by affecting one's ability to engage in the health care system. Adolescents in low-income households may have fewer encounters with health care providers, and be more likely to seek care in Emergency Departments, where physicians may not have the time or ability to discuss immunizations [117]. HPV recommendations in this population could increase if healthcare providers recommended vaccines during any healthcare visit, whether for preventive or sick care. A pediatric emergency room-based influenza vaccination program successfully increased influenza vaccination rates of children and their families [119]. HCPs in healthcare sites other than a pediatrician's office could thus potentially increase HPV vaccination rates by recommending the HPV vaccine [102].

Consistent with prior work [120-123] I find strong evidence that primary spoken language of the parent is strongly associated with provider recommendations. Previous studies of the adult population have found strong evidence showing language preference is an important factor for immunization, with considerably larger disparities in immunization receipt for Spanish-preferring than English-preferring Hispanic seniors [122, 124]. The study authors suggest factors related to the healthcare system or physician–patient interactions play a roll in these findings. Lack of translators, for example, could result in difficulty communicating potential options for preventive services. Recent studies also suggest that persons with limited English proficiency (LEP) may limit their transactions with the English-speaking world of health care. For example, individuals with LEP tend to have fewer physician visits, receive less

preventive care such as breast and cervical cancer screenings, and tend not to seek care in a consistent service setting, compared to those who have good English proficiency or speak English only [121].

My findings are subject to limitations. Because this is an observational study, my findings cannot prove that the strong associations I observed between HCP recommendation of the HPV vaccine and income, health insurance, or language is causal. Many of the measures used in this study were self-reported, which are subject to recall bias and reporting bias. NIS-Teen is a landline telephone survey. Although this analysis used sampling weights to adjust for non-coverage of households without landline telephones, nonresponse and non-coverage bias may still remain, leading to underestimation or overestimation of vaccination coverage rates. Additionally, underestimates of vaccination coverage might have resulted from the exclusive use of provider-verified vaccination histories.

Specific study strengths should also be noted. The NIS-Teen is one of the largest and most comprehensive national datasets that contains information on vaccination behavior of US adolescents. This study examined factors associated with HCP recommendation of HPV vaccine-series initiation and completion in US adolescent girls using 3 years of the latest NIS-Teen data. Other nationally representative studies used only one year of survey data in analysis [102, 103]. These studies also examined fewer sociodemographic factors and one did not include variables that could potentially be associated with HPV vaccine recommendation, such as language or number of children in household. Finally, to my knowledge, this is the first study to highlight the association of preferred language of the parent with HCP recommendation of the HPV vaccine.

Conclusions

Numerous studies have demonstrated socioeconomic disparities in HPV infection and related diseases. However, despite this population being the most likely to benefit from HPV vaccination, my study finds similarly wide disparities in health care provider recommendations of the vaccine. This suggests that HCP involvement in broader public health efforts is of paramount importance in reducing future socioeconomic disparities in HPV infection and cervical cancer.

References

1. National Center for Immunization and Respiratory Diseases. *Vaccines: VFC/VFC main page*. [web page] 2011 May 27, 2011 [cited 2011 July 15, 2011]; Available from: http://www.cdc.gov/vaccines/programs/vfc/default.htm.
2. Smith, P.J., et al., *Underinsurance and adolescent immunization delivery in the United States.* Pediatrics, 2009. **124 Suppl 5**: p. S515-21.
3. CDC. *VFC/Projects/Data/Childhood Vaccine Supply Policy 2008*. 2009 June 9, 2009 July 3, 2010]; Available from: http://www.cdc.gov/vaccines/programs/vfc/projects/data/vacc-supply-public-2008.htm.
4. Lurie, N., et al., *Preventive care: do we practice what we preach?* Am J Public Health, 1987. **77**(7): p. 801-4.
5. Molinari, N.A., et al., *Out-of-pocket costs of childhood immunizations: a comparison by type of insurance plan.* Pediatrics, 2007. **120**(5): p. e1148-56.
6. Freed, G.L., et al., *Impact of a new universal purchase vaccine program in North Carolina.* Arch Pediatr Adolesc Med, 1997. **151**(11): p. 1117-24.
7. Gowda, C. and A.F. Dempsey, *Medicaid reimbursement and the uptake of adolescent vaccines.* Vaccine, 2012. **30**(9): p. 1682-9.
8. Stokley, S., et al., *Impact of state vaccine financing policy on uptake of heptavalent pneumococcal conjugate vaccine.* Am J Public Health, 2006. **96**(7): p. 1308-13.
9. Rodewald, L.E., et al., *Health insurance for low-income working families. Effect on the provision of immunizations to preschool-age children.* Arch Pediatr Adolesc Med, 1997. **151**(8): p. 798-803.
10. Taylor, J.A., et al., *The influence of provider behavior, parental characteristics, and a public policy initiative on the immunization status of children followed by private pediatricians: a study from Pediatric Research in Office Settings.* Pediatrics, 1997. **99**(2): p. 209-15.
11. Freed, G.L., et al., *Impact of North Carolina's universal vaccine purchase program by children's insurance status.* Arch Pediatr Adolesc Med, 1999. **153**(7): p. 748-54.
12. Olshen, E., et al., *The impact of state policies on vaccine coverage by age 13 in an insured population.* J Adolesc Health, 2007. **40**(5): p. 405-11.
13. Markowitz, L.E., et al., *Quadrivalent Human Papillomavirus Vaccine: Recommendations of the Advisory Committee on Immunization Practices (ACIP).* MMWR Recomm Rep, 2007. **56**(RR-2): p. 1-24.
14. Baker, C., et al., *General recommendations on immunization --- recommendations of the Advisory Committee on Immunization Practices (ACIP).* MMWR Recomm Rep, 2011. **60**(2): p. 1-64.
15. CDC. *CDC vaccine price list*. 2010 July 2, 2010]; Available from: http://www.cdc.gov/vaccines/programs/vfc/cdc-vac-price-list.htm.
16. *National and state vaccination coverage among adolescents aged 13-17 years--United States, 2011.* MMWR Morb Mortal Wkly Rep, 2012. **61**(34): p. 671-7.
17. National Center for Immunization and Respiratory Diseases. *2011 NIS-Teen Vaccination Coverage Table Data*. 2012 [cited 2013 4/1/13]; 2011 NIS-Teen Vaccination Coverage by Poverty Status].
18. Sheinfeld Gorin, S.N., B.A. Glenn, and R.B. Perkins, *The human papillomavirus (HPV) vaccine and cervical cancer: uptake and next steps.* Adv Ther, 2011. **28**(8): p. 615-39.

19. Centers for Disease Control and Prevention, N.C.f.I.a.R.D., ; National Center for Health Statistics,;, *Data User's Guide for the 2009 NIS-Teen Public-Use Data File*, 2010, Centers for Disease Control and Prevention: Hyattsville, MD.
20. Centers for Disease Control and Prevention, National Center for Immunization and Respiratory Diseases, and National Center for Health Statistics, *Data User's Guide for the 2008 NIS-Teen Public-Use Data File*, 2009, Centers for Disease Control and Prevention: Hyattsville, MD.
21. CDC. *VFC/Projects/Data/Childhood Vaccine Supply Policy 2006*. 2008 July 17, 2008 July 3, 2010]; Available from: http://www.cdc.gov/vaccines/programs/vfc/projects/data/vacc-supply-public-2006.htm.
22. CDC. *VFC/Projects/Data/Childhood Vaccine Supply Policy 2007*. 2009 June 9, 2009; Available from: http://www.cdc.gov/vaccines/programs/vfc/projects/data/vacc-supply-public-2007.htm.
23. Bobo, J.K., et al., *Risk factors for delayed immunization in a random sample of 1163 children from Oregon and Washington.* Pediatrics, 1993. **91**(2): p. 308-14.
24. Yu, S.M., et al., *Factors that influence receipt of recommended preventive pediatric health and dental care.* Pediatrics, 2002. **110**(6): p. e73.
25. Sambamoorthi, U. and D.D. McAlpine, *Racial, ethnic, socioeconomic, and access disparities in the use of preventive services among women.* Prev Med, 2003. **37**(5): p. 475-84.
26. Shi, L. and G.D. Stevens, *Disparities in access to care and satisfaction among U.S. children: the roles of race/ethnicity and poverty status.* Public Health Rep, 2005. **120**(4): p. 431-41.
27. Dehejia, R.H. and S. Wahba, *PROPENSITY SCORE-MATCHING METHODS FOR NONEXPERIMENTAL CAUSAL STUDIES.* The Review of Economics and Statistics, 2002. **84**(1): p. 151-161.
28. Brookhart, M.A., et al., *Variable selection for propensity score models.* Am J Epidemiol, 2006. **163**(12): p. 1149-56.
29. Austin, P.C. and M.M. Mamdani, *A comparison of propensity score methods: a case-study estimating the effectiveness of post-AMI statin use.* Stat Med, 2006. **25**(12): p. 2084-106.
30. Sekhon, J.S., *Multivariate and Propensity Score Matching Software with Automated Balance Optimization: The Matching package for R.* Journal of Statistical Software, 2011. **42**(7): p. 1--52.
31. Rosenbaum, P.R. and D.B. Rubin, *The Central Role of the Propensity Score in Observational Studies for Causal Effects.* Biometrika, 1983. **70**: p. 41-55.
32. Dehejia, R. and S. Wahba, *Propensity score-matching methods for nonexperimental causal studies.* Rev Econ Stat, 2002. **84**: p. 151-61.
33. R Development Core Team, *R: A Language and Environment for Statistical Computing*, 2011, R Foundation for Statistical Computing: Vienna, Austria.
34. Cox, S., et al., *Disparities in reproductive health-related visits to the emergency department in Maryland by age and race, 1999-2005.* J Womens Health (Larchmt), 2011. **20**(12): p. 1833-8.
35. Roberson, D.W., *Inequities in screening for sexually transmitted infections in African American adolescents: can health policy help?* J Transcult Nurs, 2007. **18**(3): p. 286-91.
36. Sosa-Rubi, S.G., O. Galarraga, and R. Lopez-Ridaura, *Diabetes treatment and control: the effect of public health insurance for the poor in Mexico.* Bull World Health Organ, 2009. **87**(7): p. 512-9.

37. Bartlett, D.L., Ezzati-Rice, T.M., Stokley, S. and Zhao, Z, *Comparison of NIS and NHIS/NIPRCS Vaccination Coverage Estimates.* American Journal of Preventive Medicine, 2001. **20**(2): p. 25-27.
38. Copeland, K.R., Khare, M., Huang, R., Liu, L, Smith, P.J., and Wolter, K.M., *Assessment of Bias from Incomplete Frame Coverage and Other Sources in a Random Digit Dial Survey: Applications of a Supplement to the National Health Interview Survey.*, in *The American Association for Public Opinion Research Annual Conference.*2011.
39. Copeland, K.R., Khare, M., Ganesh, N., Zhao, Z., and Wouhib, A., *An Evaluation of Sample Weighting in an RDD Survey with Multiple Population Controls.*, in *The Joint Statistical Meetings, Section on Survey Research Methods, American Statistical Association*2009.
40. Molinari, N.A., Singleton, J., Khare, M., Smith, P., Wolter, K., Skalland, B., Montgomery, R., Chowdhury, S., Barron, M., Santos, K., and Copeland, K., *The Distribution of Total Error in a Health Survey: A Progress Update.*, in *International Total Survey Error Workshop*2008.
41. Smith, P.J., N.A. Molinari, and L.E. Rodewald, *Underinsurance and pediatric immunization delivery in the United States.* Pediatrics, 2009. **124 Suppl 5**: p. S507-14.
42. Schaffer, S.J., et al., *Adolescent immunization practices: a national survey of US physicians.* Arch Pediatr Adolesc Med, 2001. **155**(5): p. 566-71.
43. Oster, N.V., et al., *Barriers to adolescent immunization: a survey of family physicians and pediatricians.* J Am Board Fam Pract, 2005. **18**(1): p. 13-9.
44. Humiston, S.G. and S.L. Rosenthal, *Challenges to vaccinating adolescents: vaccine implementation issues.* Pediatr Infect Dis J, 2005. **24**(6 Suppl): p. S134-40.
45. McInerny, T.K., W.L. Cull, and B.K. Yudkowsky, *Physician reimbursement levels and adherence to American Academy of Pediatrics well-visit and immunization recommendations.* Pediatrics, 2005. **115**(4): p. 833-8.
46. Downs, L.S., Jr., et al., *Overcoming the barriers to HPV vaccination in high-risk populations in the US.* Gynecol Oncol, 2010. **117**(3): p. 486-90.
47. Institute of Medicine, *Financing vaccines in the 21st century: assuring access and availability.*, I.o.M. report, Editor 2003.
48. Desai, S. and S. Alva, *Maternal education and child health: is there a strong causal relationship?* Demography, 1998. **35**(1): p. 71-81.
49. Autor, D.H., L.F. Katz, and M.S. Kearney, *Trends in U.S. Wage Inequality: Re-Assessing the Revisionists.* National Bureau of Economic Research Working Paper Series, 2005. **No. 11627**.
50. Barrera, A., *The Role of Maternal Schooling and Its Interaction with Public Health Programs in Child Health Production.* Journal of Development Economics, 1990. **32**(1): p. 69-91.
51. Cleland, J.G. and J.K. van Ginneken, *Maternal education and child survival in developing countries: The search for pathways of influence.* Social Science & Medicine, 1988. **27**(12): p. 1357-1368.
52. Cutler, D.M. and A. Lleras-Muney, *Education and Health: Evaluating Theories and Evidence*, in *Making Americans Healthier: Social and Economic Policy as Health Policy*, R.F. Schoeni, et al., Editors. 2008, National Poverty Center Series on Poverty and Public Policy. New York: Russell Sage Foundation. p. 29-60.
53. Cutler, D.M. and A. Lleras-Muney, *Understanding Differences in Health Behaviors by Education.* Journal of Health Economics, 2010. **29**(1): p. 1-28.
54. De Walque, D., *How does the impact of an HIV/AIDS information campaign vary with educational attainment ? Evidence from rural Uganda*, 2004, The World Bank.

55. Lleras-Muney, A. and F.R. Lichtenberg, *The Effect of Education on Medical Technology Adoption: Are the More Educated More Likely to Use New Drugs.* National Bureau of Economic Research Working Paper Series, 2002. **No. 9185**.
56. Luman, E.T., et al., *Maternal characteristics associated with vaccination of young children.* Pediatrics, 2003. **111**(5 Part 2): p. 1215-8.
57. de Walque, D., *Does education affect smoking behaviors? Evidence using the Vietnam draft as an instrument for college education.* J Health Econ, 2007. **26**(5): p. 877-95.
58. Kenkel, D.S., *Health Behavior, Health Knowledge, and Schooling.* Journal of Political Economy, 1991. **99**(2): p. 287-305.
59. Govindasamy, P.R., B. M., *Maternal Education and the Utilization of Maternal and Child Health Services in India*, in *National family health survey subject reports*1997. p. 28 pages.
60. Chou, S.-Y., et al., *Parental Education and Child Health: Evidence from a Natural Experiment in Taiwan.* National Bureau of Economic Research Working Paper Series, 2007. **No. 13466**.
61. Lindeboom, M., A. Llena-Nozal, and B. van der Klaauw, *Parental Education and Child Health: Evidence from a Schooling Reform.* Journal of Health Economics, 2009. **28**(1): p. 109-131.
62. Streatfield, K., M. Singarimbun, and I. Diamond, *Maternal Education and Child Immunization.* Demography, 1990. **27**(3): p. 447-455.
63. Brown, J., et al., *Identifying the reasons for low immunization coverage. A case study of Yaounde (United Republic of Cameroon).* Rev Epidemiol Sante Publique, 1982. **30**(1): p. 35-47.
64. Benyoussef, A. and A.F. Wessen, *Utilization of health services in developing countries--Tunisia.* Soc Sci Med, 1974. **8**(5): p. 287-304.
65. Kemptner, D., H. Jurges, and S. Reinhold, *Changes in Compulsory Schooling and the Causal Effect of Education on Health: Evidence from Germany.* Journal of Health Economics, 2011. **30**(2): p. 340-354.
66. Lakdawalla, D. and D. Goldman, *Understanding Health Disparities Across Education Groups*, 2001, National Bureau of Economic Research, Inc.
67. Park, C. and C. Kang, *Does Education Induce Healthy Lifestyle?* Journal of Health Economics, 2008. **27**(6): p. 1516-1531.
68. Cutler, D.M. and A. Lleras-Muney, *Education and Health: Evaluating Theories and Evidence*, 2006, National Bureau of Economic Research, Inc, NBER Working Papers: 12352.
69. Clements, K.M., et al., *Maternal socio-economic and race/ethnic characteristics associated with early intervention participation.* Matern Child Health J, 2008. **12**(6): p. 708-17.
70. Moon, R.Y., et al., *Parental literacy level and understanding of medical information.* Pediatrics, 1998. **102**(2): p. e25.
71. Kenkel, D.S., *THE DEMAND FOR PREVENTIVE MEDICAL-CARE.* Applied Economics, 1994. **26**(4): p. 313-325.
72. Scott, T.L., et al., *Health literacy and preventive health care use among Medicare enrollees in a managed care organization.* Med Care, 2002. **40**(5): p. 395-404.
73. McPeck, W. *Free Preventive Services - Will Free Make A Big Enough Difference?* National Healthcare Reform Magazine, 2010.
74. Watson, M., et al., *Burden of cervical cancer in the United States, 1998-2003.* Cancer, 2008. **113**(10 Suppl): p. 2855-64.

75. Zimmerman, R.K., *Ethical analysis of HPV vaccine policy options.* Vaccine, 2006. **24**(22): p. 4812-20.
76. National Conference of State Legislatures. *HPV Vaccine: State Legislation and Statutes*. 2011 July, 2011 [cited 2011 8/8/11]; Available from: http://www.ncsl.org/default.aspx?tabid=14381.
77. Pollack, A.E., et al., *Ensuring access to HPV vaccines through integrated services: a reproductive health perspective.* Bull World Health Organ, 2007. **85**(1): p. 57-63.
78. Centers for Disease Control and Prevention, *National, state, and local area vaccination coverage among adolescents aged 13-17 years--United States, 2008.* MMWR Morb Mortal Wkly Rep, 2009. **58**(36): p. 997-1001.
79. Centers for Disease Control and Prevention, *National, state, and local area vaccination coverage among adolescents aged 13-17 years --- United States, 2009.* MMWR Morb Mortal Wkly Rep, 2010. **59**(32): p. 1018-23.
80. Centers for Disease Control and Prevention, *National and state vaccination coverage among adolescents aged 13 through 17 years--United States, 2010.* MMWR Morb Mortal Wkly Rep, 2011. **60**(33): p. 1117-23.
81. Cutler, D.M. and A. Lleras-Muney, *Understanding Differences in Health Behaviors by Education.* Journal of Health Economics, 2010. **29 1**: p. 1-28.
82. SAS Institute Inc., *SAS/STAT 9.2 User's Guide*. 2nd ed2009, Cary, NC: SAS Institute Inc.
83. Fairlie, R.W., *An Extension of the Blinder-Oaxaca Decomposition Technique to Logit and Probit Models.* Journal of Economic and Social Measurement, 2005. **30**(4): p. 305-316.
84. Owen O'Donnell, E.v.D., Adam Wagstaff, Magnus Lindelow, *Ch. 12: Explaining Differences Between Groups: Oaxaca Decomposition*, in *Analyzing Health Equity Using Household Survey Data: A Guide to Techniques and Their Implementation*2008, The International Bank for Reconstruction and Development / The World Bank: Washington, DC.
85. Oaxaca, R.L. and M.R. Ransom, *On discrimination and the decomposition of wage differentials.* Journal of Econometrics, 1994. **61**(1): p. 5-21.
86. Fairlie, R.W., *An extension of the Blinder-Oaxaca decomposition technique to logit and probit models.* Discussion paper no 1917, 2006.
87. Polonijo, A.N. and R.M. Carpiano, *Social inequalities in adolescent human papillomavirus (HPV) vaccination: A test of fundamental cause theory.* Soc Sci Med, 2013. **82**: p. 115-25.
88. Bennett, P. and C. Smith, *Parents attitudinal and social influences on childhood vaccination.* Health Educ Res, 1992. **7**(3): p. 341-8.
89. Bond, L., et al., *Vaccine preventable diseases and immunisations: a qualitative study of mothers' perceptions of severity, susceptibility, benefits and barriers.* Aust N Z J Public Health, 1998. **22**(4): p. 441-6.
90. Gust, D.A., et al., *Underimmunization among children: effects of vaccine safety concerns on immunization status.* Pediatrics, 2004. **114**(1): p. e16-22.
91. National Science Foundation, *Science and Engineering Indicators, 2000*. NSB 00-87 ed2000, Washington, D.C.: National Science Foundation.
92. Prislin, R., et al., *Immunization status and sociodemographic characteristics: the mediating role of beliefs, attitudes, and perceived control.* Am J Public Health, 1998. **88**(12): p. 1821-6.
93. Shawn, D.H. and R. Gold, *Survey of parents' attitudes to the recommended Haemophilus influenzae type b vaccine program.* CMAJ, 1987. **136**(10): p. 1038-40.

94. Kester, L.M., et al., *A National Study of HPV Vaccination of Adolescent Girls: Rates, Predictors, and Reasons for Non-Vaccination.* Matern Child Health J, 2013. **17**(5): p. 879-85.
95. Pruitt, S.L. and M. Schootman, *Geographic disparity, area poverty, and human papillomavirus vaccination.* Am J Prev Med, 2010. **38**(5): p. 525-33.
96. Dorell, C.G., et al., *Human papillomavirus vaccination series initiation and completion, 2008-2009.* Pediatrics, 2011. **128**(5): p. 830-9.
97. Chen, Y. and H. Li, *Mother's Education and Child Health: Is There a Nurturing Effect?* Journal of Health Economics, 2009. **28 2**: p. 413-26.
98. National Center for HIV/AIDS Viral Hepatitis STD and TB Prevention, *Genital HPV Infection - Fact Sheet*, V.H. National Center for HIV/AIDS, STD, and TB Prevention, Division of STD Prevention, Editor 2013, Centers for Disease Control and Prevention: Atlanta, GA. p. 2.
99. National Center for HIV/AIDS Viral Hepatitis STD and TB Prevention, *Incidence, Prevalence, and Cost of Sexually Transmitted Infections in the United States*, in *CDC Fact Sheet*2013: Atlanta, GA. p. 1.
100. Chi, R.C. and K.M. Neuzil, *The association of sociodemographic factors and patient attitudes on influenza vaccination rates in older persons.* Am J Med Sci, 2004. **327**(3): p. 113-7.
101. Bednarczyk, R.A., et al., *Human papillomavirus vaccine uptake and barriers: association with perceived risk, actual risk and race/ethnicity among female students at a New York State university, 2010.* Vaccine, 2011. **29**(17): p. 3138-43.
102. Lau, M., H. Lin, and G. Flores, *Factors associated with human papillomavirus vaccine-series initiation and healthcare provider recommendation in US adolescent females: 2007 National Survey of Children's Health.* Vaccine, 2012. **30**(20): p. 3112-8.
103. Ylitalo, K.R., H. Lee, and N.K. Mehta, *Health care provider recommendation, human papillomavirus vaccination, and race/ethnicity in the US National Immunization Survey.* Am J Public Health, 2013. **103**(1): p. 164-9.
104. Samoff, E., et al., *Predictors of acceptance of hepatitis B vaccination in an urban sexually transmitted diseases clinic.* Sex Transm Dis, 2004. **31**(7): p. 415-20.
105. Dales, L.G., et al., *Measles epidemic from failure to immunize.* West J Med, 1993. **159**(4): p. 455-64.
106. Diseases., N.C.f.I.a.R. *Vaccines for Children Program - VFC About the Program*. 2012 [cited 2013 5/8/2013]; Available from: http://www.cdc.gov/vaccines/programs/vfc/about/index.html.
107. Almeida, C.M., et al., *Evaluating associations between sources of information, knowledge of the human papillomavirus, and human papillomavirus vaccine uptake for adult women in California.* Vaccine, 2012. **30**(19): p. 3003-8.
108. Gold, R., A. Naleway, and K. Riedlinger, *Factors predicting completion of the human papillomavirus vaccine series.* J Adolesc Health, 2013. **52**(4): p. 427-32.
109. Cates, J.R., et al., *How parents hear about human papillomavirus vaccine: implications for uptake.* J Adolesc Health, 2010. **47**(3): p. 305-8.
110. Dorell, C., D. Yankey, and S. Strasser, *Parent-reported reasons for nonreceipt of recommended adolescent vaccinations, national immunization survey: teen, 2009.* Clin Pediatr (Phila), 2011. **50**(12): p. 1116-24.
111. Palli, S.R., S. Mehta, and R.R. Aparasu, *Prevalence and predictors of human papillomavirus vaccination in adolescent girls.* J Am Pharm Assoc (2003), 2012. **52**(1): p. 52-8.

112. Liao, Y., et al., *Surveillance of health status in minority communities - Racial and Ethnic Approaches to Community Health Across the U.S. (REACH U.S.) Risk Factor Survey, United States, 2009.* MMWR Surveill Summ, 2011. **60**(6): p. 1-44.
113. Wong, C.A., et al., *Human papillomavirus vaccine uptake among 9- to 17-year-old girls: National Health Interview Survey, 2008.* Cancer, 2011. **117**(24): p. 5612-20.
114. Ponce, N., et al., *Is there a language divide in pap test use?* Med Care, 2006(44): p. 998–1004.
115. Matthews, B.A., R.C. Anderson, and A.B. Nattinger, *Colorectal cancer screening behavior and health insurance status (United States).* Cancer Causes Control, 2005. **16**(6): p. 735-42.
116. Bhosle, M., et al., *Physician and patient characteristics associated with outpatient breast cancer screening recommendations in the United States: analysis of the National Ambulatory Medical Care Survey Data 1996-2004.* Breast Cancer Res Treat, 2007. **103**(1): p. 53-9.
117. Luo, X., et al., *Children's health insurance status and emergency department utilization in the United States.* Pediatrics, 2003. **112**(2): p. 314-9.
118. DeVoe, J.E., C.J. Tillotson, and L.S. Wallace, *Children's receipt of health care services and family health insurance patterns.* Ann Fam Med, 2009. **7**(5): p. 406-13.
119. Pappano, D., S. Humiston, and J. Goepp, *Efficacy of a pediatric emergency department-based influenza vaccination program.* Arch Pediatr Adolesc Med, 2004. **158**(11): p. 1077-83.
120. Ponce, N.A., et al., *Is there a language divide in pap test use?* Med Care, 2006. **44**(11): p. 998-1004.
121. Kim, G., et al., *Vulnerability of older Latino and Asian immigrants with limited English proficiency.* J Am Geriatr Soc, 2011. **59**(7): p. 1246-52.
122. Haviland, A.M., et al., *Immunization disparities by Hispanic ethnicity and language preference.* Arch Intern Med, 2011. **171**(2): p. 158-65.
123. Gresenz, C.R., J. Rogowski, and J.J. Escarce, *Community demographics and access to health care among U.S. Hispanics.* Health Serv Res, 2009. **44**(5 Pt 1): p. 1542-62.
124. Lees, K.A., P.M. Wortley, and S.S. Coughlin, *Comparison of racial/ethnic disparities in adult immunization and cancer screening.* Am J Prev Med, 2005. **29**(5): p. 404-11.