Published in final edited form as:

Matern Child Health J. 2016 February ; 20(2): 315–325. doi:10.1007/s10995-015-1831-x.

Differences in Human Papillomavirus Vaccination Among Adolescent Girls in Metropolitan Versus Non-metropolitan Areas: Considering the Moderating Roles of Maternal Socioeconomic Status and Health Care Access

Shannon M. Monnat¹, Danielle C. Rhubart¹, and Sherrie Flynt Wallington²

Shannon M. Monnat: smm67@psu.edu; Danielle C. Rhubart: dcr185@psu.edu; Sherrie Flynt Wallington: slw49@georgetown.edu

¹Department of Agricultural Economics, Sociology, and Education, Penn State University, 110B Armsby Bldg, University Park, PA 16802, USA

²Lombardi Comprehensive Cancer Center, Georgetown University Medical Center, Research Building, W326A, 3970 Reservoir Rd., Washington, DC 20057, USA

Abstract

Objectives—This study is among the first to examine metropolitan status differences in human papillomavirus (HPV) vaccine initiation and completion among United States adolescent girls and is unique in its focus on how maternal socioeconomic status and health care access moderate metropolitan status differences in HPV vaccination.

Methods—Using cross-sectional data from 3573 girls aged 12–17 in the U.S. from the 2008–2010 Behavioral Risk Factor Surveillance System, we estimate main and interaction effects from binary logistic regression models to identify subgroups of girls for which there are metropolitan versus non-metropolitan differences in HPV vaccination.

Results—Overall 34 % of girls initiated vaccination, and 19 % completed all three shots. On average, there were no metropolitan status differences in vaccination odds. However, there were important subgroup differences. Among low-income girls and girls whose mothers did not complete high school, those in non-metropolitan areas had significantly higher probability of vaccine initiation than those in metropolitan areas. Among high-income girls and girls whose mothers completed college, those in metropolitan areas had significantly higher odds of vaccine initiation than those in non-metropolitan areas. Moreover, among girls whose mothers experienced a medical cost barrier, non-metropolitan girls were less likely to initiate vaccination compared to metropolitan girls.

Conclusions—Mothers remain essential targets for public health efforts to increase HPV vaccination and combat cervical cancer. Public health experts who study barriers to HPV vaccination and physicians who come into contact with mothers should be aware of group-specific barriers to vaccination and employ more tailored efforts to increase vaccination.

Correspondence to: Shannon M. Monnat, smm67@psu.edu.

Electronic supplementary material The online version of this article (doi:10.1007/s10995-015-1831-x) contains supplementary material, which is available to authorized users.

Keywords

Human papillomavirus (HPV); Vaccine; Sexually transmitted infections; Cervical cancer; Adolescents; Metropolitan versus non-metropolitan; Mothers; USA

Significance

There are significant metropolitan status disparities in cervical cancer mortality, and widespread use of the HPV vaccine could reduce these disparities. Yet studies on metropolitan status variation in HPV vaccination are limited by their focus on parental acceptability and knowledge or small samples restricted to one state or solely to low-income girls. Though on average, girls in metropolitan and non-metropolitan areas have similar odds of vaccination, the target populations for intervention differ in metropolitan and non-metropolitan areas. Specifically, findings suggest the need to target low-SES mothers in metropolitan areas but high-SES mothers in non-metropolitan areas.

Introduction

The human papillomavirus (HPV) is the most common sexually transmitted infection (STI) in the United States, and virtually all cases of cervical cancer are caused by HPV. It is now widely accepted that HPV vaccination offers tremendous potential for prevention of HPV-related pre-cancers and cancers and could substantially reduce cervical cancer mortality [31]. The U.S. Advisory Committee on Immunization Practices recommends three doses of quadrivalent HPV vaccine be administered to girls starting at ages 11 or 12 [16]. Yet, there is widespread variation in vaccination among adolescent girls, ranging in recent studies from 9 to 37 % for initiation and 2–28 % for completion (CDC 2000; [6, 9, 17, 24, 32, 33]).

One factor that may be an important determinant of variation is metropolitan status. Research has found significant rural disparities in cervical cancer rates and prevention [4, 21, 28]. Unfortunately, most studies examining correlates of HPV vaccination do not disaggregate results by metropolitan status. In one recent study that included both metropolitan and non-metropolitan parents, [24] researchers have found parents' beliefs about HPV vaccination for their daughters were largely consistent across metropolitan status. However, there is a paucity of research identifying factors that influence metropolitan status differences in *actual* HPV vaccination [5]. Studies that have examined these differences have been limited by the use of small data sets restricted to specific samples of girls or one specific geographic area [18, 22, 27].

Using a large sample of adolescent girls living in metropolitan and non-metropolitan areas in nine U.S. states, the current study seeks to identify different conditions under which metropolitan status differences in HPV vaccination may exist. Although non-metropolitan areas have historically been medically underserved in prevention services [34] those disparities have been largely tempered by the introduction of federally funded community health centers [1, 23]. This suggests metropolitan and non-metropolitan girls may have similar access to preventive health services, including the HPV vaccine [27]. In addition, most health insurance providers now cover the HPV vaccination, and most adolescents who

are uninsured, underinsured, or Medicaid-eligible are covered by the federal Free Vaccines for Children Program (VFC) (CDC [7], suggesting that variation in children's insurance coverage across metropolitan and non-metropolitan places should play less of a role in HPV vaccination than in other types of adolescent health service use.

Beyond insurance status, however, it is clear from previous research that mothers and physicians play essential roles in facilitating vaccination. Maternal acceptability of vaccination is among the strongest predictors of adolescent acceptance, interest, and vaccine initiation [25]. Moreover, daughters of women who engage in their own preventive health practices are more likely to get the vaccine than daughters of women who do not engage in these practices [9, 17]. Given the importance of physician recommendation in facilitating vaccination [5, 24], mothers' opportunities to interact with physicians could play a major role in whether their daughters get vaccinated. Therefore, mothers' *own* access to health care and socioeconomic status (SES) may be important factors in eventual physician referral for vaccination and mothers acting on that referral. Although previous research included maternal SES and health care access as predictors of adolescent vaccination [13, 26, 33], the relative significance of these factors were mixed, and no study has examined whether metropolitan versus non-metropolitan differences in vaccination are conditional upon mothers' SES or health care access.

Accordingly, our study aims to advance the literature on understanding predictors of adolescent HPV vaccination by (1) identifying whether there are metropolitan status differences in vaccine initiation and completion among adolescent girls, and (2) determining whether maternal SES and health care access moderate metropolitan status differences in vaccination status.

Methods

Sample

This cross-sectional study used data from the 2008, 2009, and 2010 Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is the world's largest telephone health survey, tracking adult health behaviors, health care use, and health outcomes from all U.S. states and Washington, DC. In 2008–2010, the BRFSS included an adolescent HPV vaccination module as an option for states to include in their annual survey dissemination. Over the 3 years, ten states (Connecticut, Delaware, Kentucky, New York, Oklahoma, Pennsylvania, Texas, West Virginia, Wisconsin, and Wyoming) incorporated the module. The core survey questions and HPV module questions were identical for nine of these states,¹ enabling us to pool the 3 years of data. More information about the BRFSS is available at <http://www.cdc.gov/brfss/>.

One child from each sampled household was randomly selected, and the sampled adult within the household answered questions about the child. Because we were interested in the extent to which maternal SES and health care access moderate metropolitan status

---

¹We excluded respondents from NY because NY excluded the question about number of HPV shots received, disabling us from identifying which girls completed the series.

differences in vaccination, we restricted our analysis to female respondents who served as the maternal figure in the household [i.e., those who identified their relationship as parent (95 %), grandparent (4 %), or foster parent/guardian (1 %)]. For ease, we use the terms ‘mother’ and ‘maternal’ to refer to these groups. We restricted our study to girls aged 12–17 because research suggests that the optimal time for girls to receive the vaccine is age 11 or 12 when their bodies produce the strongest antibody response and because this is an age before most girls become sexually active (CDC [8]). After listwise deletion of cases missing on variables of interest² (7.5 % of eligible cases), our sample size was 3573.

A distribution of our sample of respondents by state is shown in Table 1. Our analyses accounted for the complex sampling design of the BRFSS (strata), and we used post-stratification weights to correct for selection, nonresponse, and telephone coverage bias. This study was exempted from institutional review board review by the lead author’s institution.

Measures

Vaccine Initiation and Completion—Our outcomes were HPV vaccine initiation and completion. Initiation was based on the BRFSS question: “A vaccine to prevent the human papillomavirus or HPV infection is available and is called the cervical cancer vaccine, HPV shot, or GARDASIL. Has the child EVER had the HPV vaccination?” with the options of ‘yes’ versus ‘no’. A follow-up question asked, “How many shots did she receive?” Because the HPV vaccine is administered as a three-shot series, we dichotomized this item to indicate whether the girl had received all three shots.

Metropolitan Status—Our independent variable was metropolitan status. Although the BRFSS provides the county identifier (i.e., FIPs code) for the majority of respondents that would enable us to identify the specific county rural–urban continuum code developed by USDA’s Economic Research Service [30], the BRFSS masks these codes for respondents living in counties with fewer than 50 respondents or 10,000 residents. Rather than exclude these respondents from our analysis and risk systematically excluding residents from the most rural counties, we elected to use the metropolitan status variable provided in the BRFSS rather than the county FIPs codes to identify metropolitan status. The BRFSS places respondents into one of five different categories: center city of a metropolitan statistical area (MSA), outside the center city of an MSA but inside the county containing the center city, inside a suburban county of the MSA, in an MSA that has no center city, and not in an MSA. Due to small sample sizes in some categories, and because we were interested in metropolitan/non-metropolitan differences, we collapsed all respondents living in an MSA into one category identified as ‘metropolitan’ and compared them to respondents who do not live in an MSA (‘non-metropolitan’). Suburban residents are included in the ‘metropolitan’ category. We acknowledge as a limitation our inability to distinguish between those living in large non-metropolitan counties and those living in small, remote rural places.

---

²Rather than excluding respondents who were missing on income (N = 301), we created a dummy variable in order to keep them in our analyses. Excluding these respondents would introduce systematic bias into the results because girls of respondents missing on income were significantly less likely to be vaccinated than those not missing income.

Maternal Socioeconomic Status and Health Care Access—We were interested in the extent to which mother's SES and access to health care condition metropolitan status differences in vaccination. Accordingly, we included household income, educational attainment, health insurance (any form of health insurance vs. none), experience with a medical cost barrier in the past year (mother reported that there was a time in the past year when she needed to see a doctor but could not because of cost), and whether the mother had at least one personal doctor.

Covariates—Based on previous HPV vaccination research, we adjusted our regression models for adolescent age, mother's age, marital status, number of adults and children in the household, employment status, whether the mother received a routine physical health checkup in the past 2 years, whether the mother had a pap test in the past 3 years, and mother's race/ethnicity. Although adolescent race/ethnicity was also available, it was strongly correlated with mother's race/ethnicity. We ran separate models, exchanging adolescent race/ethnicity for mother's race/ethnicity, and the results were unchanged. We included state-level fixed effects to control for unobserved state-level characteristics, including state variation in HPV statutes.

Statistical Analysis

We first present percentages of respondents in each state who indicated daughters initiated and completed the HPV vaccine for the complete sample and by metropolitan status (Table 1). We used adjusted Wald tests to indicate where significant differences exist. We then present descriptive statistics for all variables for the full sample and by metropolitan status (Table 2). We used unadjusted and adjusted binary logistic regression models to calculate odds ratios (ORs) and 95 % confidence intervals (CIs) for vaccine initiation (Table 3). Among those who began the vaccine ($N = 1390$), we used the same regression models to calculate ORs and 95 % CIs for completing the three-shot series (Table 4). Finally, we ran five interaction models for each outcome to determine the extent to which metropolitan status differences in HPV vaccination are conditional on maternal SES and health care access (coefficients available in Appendix). We present average predicted probabilities from significant interactions in Figs. 1, 2, 3 and effect sizes of differences between subgroups in Table 5. We tested for multicollinearity; no problems were detected. Data were analyzed using SAS version 9.4 (SAS Enterprises, Inc., Cary, NC).

Results

Results from Table 1 indicate that although most states have noticeable metropolitan status differences in vaccine initiation and completion, the only difference that is statistically significant (at the $p < 0.05$ level) is for Oklahoma, where initiation was significantly higher among non-metropolitan compared to metropolitan girls.³

---

³Data limitations prevent us from explaining why there are metropolitan status differences in vaccine initiation for Oklahoma but not for other states. We ran the vaccine initiation model on Oklahoma respondents ($N = 233$) using all covariates discussed in the methods section. None of those variables explained away the significantly higher odds of vaccine initiation for non-metropolitan respondents in Oklahoma.

Descriptive statistics for the sample are presented in Table 2. Thirty-four percent of girls started the vaccine, and 55 % of those who initiated vaccination completed all three shots (19 % of all girls). Chi square tests indicated no significant differences in vaccine initiation or completion among girls in metropolitan versus non-metropolitan areas.

Results from unadjusted models for vaccine initiation are shown in the first column of Table 3. Here we found no significant metropolitan status difference in vaccine initiation. The addition of covariates did not change this finding. We found several important maternal-related correlates. Girls in the \$50,000–\$74,999 household income category had significantly lower odds of vaccine initiation compared to those in the highest income category, and girls whose mothers have less than a high school education had significantly lower odds of vaccine initiation than girls whose mothers have a college degree. In addition, mother's access to a personal doctor was associated with 45 % greater odds of vaccine initiation in the adjusted model.

Results from unadjusted and adjusted regression models for vaccine completion (among vaccine initiates) are shown in Table 4. Again we found no significant metropolitan status difference in vaccine completion in either the unadjusted or adjusted models, but unlike with initiation, maternal SES and health care access were not associated with vaccine completion.⁴ Adolescent age was positively associated with both vaccine initiation and completion. Hispanics had significantly greater odds of vaccine initiation than whites, but 'other race' respondents had significantly lower odds of vaccine completion than whites.

We next conducted a series of interaction models where we tested whether metropolitan status differences in vaccine initiation and completion were conditional on mother's SES and health care access (household income, educational attainment, health insurance status, experience with a medical cost barrier in the past year, and whether mother has at least one personal doctor). Coefficients (log-odds) from adjusted models are presented in the Appendix. We present predicted probabilities (Figs. 1, 2, 3) and effect sizes (Table 5) from the models with significant interactions. We found no significant interactions for vaccine completion, but we found three important interactions for vaccine initiation.

First, as shown in Fig. 1, metropolitan status differences were moderated by household income, net of all covariates. Among low-income households, non-metropolitan girls had significantly greater average probability of vaccine initiation than metropolitan girls ($d = -0.340$), but among high-income households, metropolitan girls had significantly greater average probability of vaccine initiation than non-metropolitan girls ($d = 0.781$). Second, as shown in Fig. 2, metropolitan status differences were moderated by mother's educational attainment, net of all covariates. Among girls with low-education mothers, metropolitan girls had significantly lower average probability of vaccine initiation than non-metropolitan girls ($d = -1.325$), but among girls whose mothers have a college degree or more, metropolitan girls had significantly higher average probability of vaccine initiation ($d = 0.893$). Surprisingly, non-metropolitan girls whose mothers have less than high school had

⁴In the unadjusted model for vaccine completion, girls whose mothers had a high school degree had significantly lower odds ($p < 0.05$) of vaccine completion versus girls whose mothers had a college degree. In the adjusted model, that significant difference was eliminated. We found that income alone resulted in the elimination of significance of the high school versus college difference.

the highest average probability of vaccine initiation, holding all else constant. Finally, we found an interaction approaching conventional statistical significance for mother's experience with a medical cost barrier in the past year ($p = 0.056$) (Fig. 3). Among girls whose mothers did not experience a cost barrier in the past year, there were no significant metropolitan status differences in initiation, but among girls whose mothers did experience a cost barrier in the past year, girls living in metropolitan areas were more likely than girls living in non-metropolitan areas to have begun the vaccine; non-metropolitan girls experience a greater penalty when their mothers have a medical cost barrier than do metropolitan girls.

Discussion

Our study is among the first to examine metropolitan status differences in HPV vaccination and is unique in its focus on how maternal SES and health care access condition metropolitan status differences in vaccination. Consistent with other recent research using samples from North Carolina [18] and safety net clinics [27], we found no metropolitan status differences in adolescent vaccination, on average. However, we extend the research in this area by finding important subgroups for which metropolitan status differences are significant and substantial.

First, higher SES facilitates daughter's vaccine initiation, but only in metropolitan areas. Previous studies on the role of parental SES generally find that parents with *lower* levels of education are more likely to accept HPV vaccination for their daughters [5, 26], and to have their daughters vaccinated [33]. Our findings for non-metropolitan girls were in line with these previous studies, suggesting that mother's higher SES is not a facilitator of HPV vaccination for girls living in non-metropolitan areas. Surprisingly, among non-metropolitan girls, those from the lowest income and lowest education households had the highest probability of vaccine initiation. These findings suggest that spatial context plays an important role in the relationship between SES and adolescent vaccination.

There are many potential explanations for these findings. First, it may be that non-metropolitan doctors for low-SES mothers are more likely than doctors of high-SES mothers to view the daughters of these women as having greater risk for contracting HPV due to relatively younger ages at first sexual intercourse and greater likelihood of sexual risk-taking among low-SES girls, especially in rural areas [3, 14]. They may therefore be more likely to recommend vaccination for those girls.

Second, trust in medical authorities is associated with greater likelihood of parental acceptance of the HPV vaccine [19]. It may be that low-SES non-metropolitan mothers have a more traditional patient-doctor relationship, wherein the doctor is viewed as an authority figure and expert. Moreover, research shows physician trust is significantly lower among low-SES urban women [2], and low-SES women in non-metropolitan areas may have more stable and long-term relationships with their physicians than those in metropolitan areas. These relationships may facilitate physician recommendation of vaccination [11, 12, 15]. Given that our SES-interaction findings hold net of controlling for having a personal doctor, the quality of the relationship a woman has with her doctor may be more important in

facilitating daughter's vaccination than simply having a personal provider. Unfortunately, the BRFSS does not ask about physician change or length of time with personal doctors. Future research should examine how differences in continuity of care relate to metropolitan status differences in HPV vaccination.

We also found an interaction for mother's experience with a medical cost barrier in the past year; mother's experience with a medical cost barrier is a disabling factor for girls living in non-metropolitan areas, but not those in metropolitan areas. Because the vaccine is covered by most insurance companies or through the FVC program, we think this finding is not about the cost of the vaccine, but may be related to the barriers low-income non-metropolitan mothers face with actually getting their daughters to the doctor. The cost of transportation in areas where the physician's office is several miles away might be a barrier more commonly faced by non-metropolitan than metropolitan mothers. That this finding holds net of controlling for health insurance also suggests this finding is about more than the cost of the vaccination. Unfortunately, the BRFSS data do not enable us to distinguish type of health insurance or gaps in coverage. Beyond the important role of physicians, our findings may also be explained by factors we are unable to test with the data available. These include differences in religious and cultural beliefs that may influence parents' decisions about vaccination for their children.

It is worrisome that girls from the middle-upper income group (\$50,000–\$75,000) were the least likely to initiate vaccination in both metropolitan and non-metropolitan areas. This 'middle-upper class' group may be increasingly resistant to vaccination in general [29]. It is also possible that this group represents families who are working long hours and are engaged in multiple extramural activities with their children, resulting in time restrictions that may reduce what some parents view as unnecessary visits to physicians.

It is striking that although we found significant interactions for vaccine initiation, these interactions did not hold for vaccine completion. The mechanisms facilitating completion are likely quite different from those facilitating initiation. Whereas initiation can begin during an annual well-child visit or at the time of the girl's first vaginal examination, there may be challenges associated with getting the daughter to an appointment for the second dose at 2 months and third dose at 6 months. New innovations in vaccine delivery, including advances toward a vaccine that could be administered in one dose, would likely increase vaccine completion rates and decrease disparities in completion.

Our results should be considered in light of some limitations. First, only nine states incorporated the optional child HPV module. Thus, our findings are not generalizable to the U.S. population. In particular, our study over-represents Hispanics and underrepresents Blacks. Given that Hispanics were more likely than whites to initiate vaccination, our results may overestimate average vaccine initiation in the population. Still, our percentages for initiation and completion (34 and 19 %) are in line with previous research using similar age groups [9, 10]. Similarly, the BRFSS is a phone survey and likely underrepresents populations without telephones or who refuse to complete surveys via phone. However, we do include the BRFSS design weight in our analyses, which adjusts for probability of selection and phone ownership.

Though the purpose of this study was not to explain state-level variation in vaccination, descriptive results demonstrate state-by-state and within-state differences in vaccination. Some of these may be explained by vaccine mandates. Since 2006, at least 25 states have enacted HPV legislation to require or fund the vaccine or educate school children about HPV, including Texas and Wisconsin, two states included in our sample (NCSL [20]). Vaccination initiation and completion would likely be higher a sample that included respondents from more states that have implemented these statutes. Despite this limitation, our regression models do account for these differences with state fixed effects.

Data limitations also prevented us from including variables that have been found to be important predictors of vaccination in previous research, the most important of which may be physician recommendation. Moreover, we were unable to break down non-metropolitan residence into finer degrees of rurality. There are likely differences between residents of very remote rural areas and those in larger non-metropolitan communities, especially if they are adjacent to urban centers. Relatedly, we were unable to control for contextual conditions, including health care supply and access. The supply of and distance to health care providers, access to public transportation, and local responses (e.g., local deployment of HPV task forces, a rapid response to high incidence of HPV, a particular OBGYN or family physician who is championing the vaccine) may all play a role in explaining spatial variation in vaccination. Data on such contextual predictors of variation are not available, and we encourage researchers to undertake this important data compilation and analysis effort.

Despite these limitations, our study advances research on correlates of adolescent HPV vaccination in important ways. Although not nationally representative, it extends studies restricted to specific states or specific groups (e.g., college students, managed care enrollees) to a more general population of adolescent girls. Further, whereas previous research on metropolitan status differences in parental attitudes or intent to vaccinate have been important in helping to inform interventions for educating parents, our focus on actual vaccine initiation and completion provides insight into the conditions under which metropolitan status differences in *actual* vaccination occur. The finding that vaccine initiation was relatively high among low-SES non-metropolitan girls is encouraging, both because cervical cancer prevalence is higher in non-metropolitan areas [4, 28] and because low-SES is associated with increased incidence of cervical cancer [4]. It may be that doctors are encouraging mothers of these at-risk girls to have their daughters vaccinated. Future research should focus on identifying strategies for increasing continuity of care among metropolitan mothers or finding different mechanisms through which recommendations, reminders, and follow-ups can occur.

Ultimately, one-size-fits-all interventions may be less effective at increasing vaccination than interventions that are more spatially and demographically targeted. In particular, our findings about the divergent role of mother's SES in vaccine initiation for girls in metropolitan versus non-metropolitan areas suggests that future researchers should avoid broad generalizations about the associations between parents' SES and daughters' vaccination status.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors thank the U.S. Centers for Disease Control and Prevention for the Behavioral Risk Factor Surveillance System data. SM and DR acknowledge support from the Population Research Institute at Penn State, which receives center core funding from the National Institute of Child Health and Human Development (R24-HD041025). SFW receives research funding from the National Institutes of Health and the National Cancer Institute, K01CA155417-01A1. SM and SW also acknowledge support from the Robert Wood Johnson Foundation New Connections grant program. Everyone who has contributed to this study has been acknowledged herein. The authors do not have any potential, perceived, or real conflicts of interests. No honorarium, grant, or other form of payment was given to anyone to produce this article.

Abbreviations

BRFSS	Behavioral Risk Factor Surveillance System
CDC	Centers for Disease Control and Prevention
HPV	Human papillomavirus
MSA	Metropolitan statistical area
SES	Socioeconomic status
STI	Sexually transmitted infection

References

1. Adams, SA.; Bellinger, JD.; Gallagher, A.; Probst, JC. Diffusion of preventive innovation: Racial and rural differences in cervical cancer prevention and control practices. South Carolina Rural Health Research Center; 2013. <http://rhr.sph.sc.edu/report/%2810-2%29FullReport.pdf> [Accessed July 19, 2015]
2. Armstrong K, Ravenell KL, McMurphy S, Putt M. Racial/ethnic differences in physician distrust in the United States. American Journal of Public Health. 2007; 97(7):1283–1289. [PubMed: 17538069]
3. Atav, Serdar; Spencer, GA. Health risk behaviors among adolescents attending rural, suburban, and urban schools: A comparative study. Family & Community Health. 2002; 25(2):53–64. [PubMed: 12010115]
4. Bernard VB, Johnson CJ, Thomas TD, et al. Examining the association between socioeconomic status and potential human papillomavirus associated cancers. Cancer. 2008; 113:2910–2918. [PubMed: 18980274]
5. Brewer NT, Fazekas KI. Predictors of HPV vaccine acceptability: A theory-informed, systematic review. Preventative Medicine. 2007; 45(2–3):107–114.
6. Centers for Disease Control and Prevention. Vaccination coverage among adolescents aged 13–17 years- United States. MMWR Morbidity and Mortality Weekly Report. 2008; 57:1100–1103. [PubMed: 18846032]
7. Centers for Disease Control and Prevention (CDC). [Accessed August 22, 2014] Human papillomavirus (HPV). 2012. <http://www.cdc.gov/std/hpv/stdfact-hpv-vaccine-young-women.htm>
8. Centers for Disease Control and Prevention (CDC). [Accessed August 22, 2014] HPV vaccine for preteens and teens. 2014. <http://www.cdc.gov/vaccines/who/teens/vaccines/hpv.html>
9. Chao C, Slezak JM, Coleman KJ, Jacobsen SJ. Papanicolaou screening behavior in mothers and human papillomavirus vaccine uptake in adolescent girls. American Journal of Public Health. 2009; 99(6):1137–1142. [PubMed: 19372507]

10. Chao C, Velicer C, Slezak JM, Jacobsen SJ. Correlates for human papillomavirus vaccination of adolescent girls and young women in a managed care organization. *American Journal of Epidemiology*. 2010; 171:357–367. [PubMed: 20047978]
11. Desjarlais-deKlerk K, Wallace JE. Instrumental and socioemotional communications in doctor-patient interactions in urban and rural clinics. *BMC Health Services Research*. 2013; 13:261. [PubMed: 23835062]
12. Farmer J, Iversen L, Campbell NC, et al. Rural/urban differences in accounts of patients' initial decisions to consult primary care. *Health & Place*. 2006; 12(2):210–221. [PubMed: 16338636]
13. Kester LM, Zimet GD, Fortenberry JD, Kahn JA, Shew ML. A national study of HPV vaccination of adolescent girls: Rates, predictors, and reasons for non-vaccination. *Maternal and Child Health Journal*. 2013; 17(5):879–885. [PubMed: 22729660]
14. Krieger N, Quesenberry C, Peng T, et al. Social class, race/ethnicity, and incidence of breast, cervix, colon, lung, and prostate cancer among Asian, Black, Hispanic, and White residents of the San Francisco Bay Area, 1988–1992 (United States). *Cancer Causes and Control*. 1999; 10:525–537. [PubMed: 10616822]
15. LaRavia, D.; Clavert, J.; Zavala, J.; Smith, OD.; Talley, S.; Gingrich, D., et al. [Accessed July 19, 2015] Keeping physicians in rural practice. 2002. http://www.aafp.org/dam/AAFP/documents/about_us/initiatives/ruralrr.pdf
16. Markowitz LE, Dunne EF, Saraiya M, Lawson HW, Chesson H, Under ER, et al. Quadrivalent human papillomavirus vaccine: Recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recommendations and Reports*. 2007; 56(RR-2):1–24. [PubMed: 17380109]
17. Monnat SM, Wallington SF. Is there an association between maternal pap test use and adolescent human papillomavirus vaccination? *Journal of Adolescent Health*. 2013; 52(2):212–218. [PubMed: 23332487]
18. Moss JL, Gilkey MB, Reiter PL, Brewer NT. Trends in HPV vaccine initiation among adolescent females in North Carolina, 2008–2010. *Cancer Epidemiology, Biomarkers and Prevention*. 2012; 21:1913–1922.
19. Nan X, Zhao X, Briones R. Parental cancer beliefs and trust in health information from medical authorities as predictors of HPV vaccine acceptability. *Journal of Health Communication*. 2014; 19(1):100–114. [PubMed: 24093156]
20. National Conference of State Legislatures. [Accessed July 19, 2015] HPV Vaccine Policies. 2015. <http://www.ncsl.org/research/health/hpv-vaccine-state-legislation-and-statutes.aspx>
21. Newmann SJ, Garner EO. Social inequities along the cervical cancer continuum: a structured review. *Cancer Causes and Control*. 2005; 16(1):63–70. [PubMed: 15750859]
22. Peters SJ, Hansen KA, Quevillon RP. Adolescent human papillomavirus vaccination and contraception in medically rural compared with urban environments. *Obstetrics and Gynecology*. 2013; 123:30S–31S.
23. Regan J, Schempf AH, Yoon J, Politzer RM. The role of federally funded health centers in serving the rural population. *The Journal of Rural Health*. 2003; 19(2):115–124.
24. Reiter PL, Brewer NT, Gottlieb SL, McRee A, Smith JS. Parents' health beliefs and HPV vaccination of their adolescent daughters. *Social Science and Medicine*. 2009; 69(3):475–480. [PubMed: 19540642]
25. Roberts ME, Gerrard M, Reimer R, Gibbons FX. Mother-daughter communication and human papillomavirus vaccination. *Pediatrics*. 2010; 125:982–989. [PubMed: 20385645]
26. Rosenthal SL, Rupp R, Zimet GD, Meza HM, Loza ML, Short MB, et al. Uptake of HPV vaccine: Demographics, sexual history and values, parenting style, and vaccine attitudes. *Journal of Adolescent Health*. 2008; 43(3):239–245. [PubMed: 18710678]
27. Sandri KJ, Verdenius I, Bartley MJ, Else BM, Paynter CA, Rosemergy BE, et al. Urban and rural safety net health care system clinics: no disparity in HPV4 vaccine completion rates. *PLoS One*. 2014; 9(5):10.1371/journal.pone.0096277
28. Singh GK. Rural-urban trends and patterns in cervical cancer mortality, incidence, stage, and survival in the United States, 1950–2008. *Journal of Community Health*. 2012; 37:217–223. [PubMed: 21773819]

29. Smith PJ, Chu SY, Barker LE. Children who have received no vaccines: Who are they and where do they live? *Pediatrics*. 2004; 114(1):187–195. [PubMed: 15231927]
30. United States Department of Agriculture. Economic Research Service. [Accessed July 23, 2014] Rural-urban continuum codes: Documentation. 2013. <http://www.ers.usda.gov/data-products/rural-urban-continuum-codes/documentation.aspx#.U9AfWfldUpq>
31. Van Krieking G, Castellsague X, Cibula D, Demarteau N. Estimation of the potential overall impact of human papillomavirus vaccination on cervical cancer cases and deaths. *Vaccine*. 2014; 32(6):733–739. [PubMed: 24291200]
32. Widdice LE, Bernstein DI, Leonard AC, et al. Adherence of the HPV vaccine dosing intervals and factors associated with completion of 3 doses. *Pediatrics*. 2011; 127:77–84. [PubMed: 21149425]
33. Wong CA, Berkowitz Z, Dorell CG, et al. Human papillomavirus vaccine uptake among 9- to 17-year old girls: National Health Interview Survey, 2008. *Cancer*. 2011; 117(24):5612–5620. [PubMed: 21692069]
34. Yabroff KR, Lawrence WF, King JC, Mangan P, Washington KS, Yi B, et al. Geographic disparities in cervical cancer mortality: What are the roles of risk factor prevalence, screening, and use of recommended treatment? *The Journal of Rural Health*. 2005; 21(2):149–157. [PubMed: 15859052]

Fig. 1.

Top. Average predicted probabilities for HPV vaccine initiation from interaction model by metropolitan status and household income. *Note* Probabilities are calculated from adjusted interaction models with model coefficients available in appendix. Models are adjusted for all control variables and state fixed effects. *Error bars* represent 95 % confidence intervals around the mean predicted probability of vaccine initiation for each subgroup. Overlapping confidence bars indicate no significant difference between subgroups

Fig. 2.

Top. Average predicted probabilities for HPV vaccine initiation by metropolitan status and maternal education. *Note* Probabilities are calculated from adjusted interaction models with model coefficients available in appendix. Models are adjusted for all control variables and state fixed effects. *Error bars* represent 95 % confidence intervals around the mean predicted probability of vaccine initiation for each subgroup. Overlapping confidence bars indicate no significant difference between subgroups

Fig. 3.

Top. Average predicted probabilities for HPV vaccine initiation by metropolitan status and maternal experience with a medical cost barrier in the past year. *Note:* Probabilities are calculated from adjusted interaction models with model coefficients available in appendix. Models are adjusted for all control variables and state fixed effects. *Error bars* represent 95 % confidence intervals around the mean predicted probability of vaccine initiation for each subgroup. Overlapping confidence bars indicate no significant difference between subgroups

Distribution of sample by state and percentage of HPV initiation and completion by metropolitan status

Table 1

State	N	Initiated	Completed	Completed (of initiates)		Initiated		Completed (of initiates)		p	
				Completed	Completed (of initiates)	Metro	Non-metro	Metro	Non-metro		
Connecticut	370	49.1 (3.6)	36.4 (3.5)	74.1 (5.2)		48.3 (3.7)	56.1 (11.8)	0.5284	74.3 (5.6)	73.1 (14.1)	0.9382
Delaware	147	33.7 (5.1)	19.1 (3.7)	56.6 (8.6)		31.1 (5.8)	42.7 (10.3)	0.3270	58.9 (10.4)	50.7 (14.8)	0.6490
Kentucky	234	41.5 (5.2)	27.9 (4.6)	67.3 (7.1)		44.6 (7.3)	37.5 (7.4)	0.4940	70.0 (8.7)	63.6 (12.1)	0.6776
Oklahoma	233	27.2 (3.4)	14.9 (2.8)	54.8 (7.1)		21.0 (3.2)	40.8 (7.7)	0.0170	52.5 (8.0)	57.3 (12.6)	0.7504
Pennsylvania	670	42.0 (2.7)	14.5 (1.8)	34.4 (3.7)		42.5 (3.1)	40.0 (5.1)	0.6723	31.7 (4.1)	47.5 (8.1)	0.0859
Texas	1282	29.4 (2.0)	17.3 (1.6)	58.7 (4.2)		30.4 (2.2)	22.7 (4.5)	0.1213	60.4 (4.5)	44.5 (9.6)	0.1340
West Virginia	210	35.2 (4.2)	23.1 (3.9)	65.7 (6.7)		34.0 (6.1)	36.6 (5.7)	0.7556	76.3 (7.4)	54.2 (9.6)	0.0686
Wisconsin	112	42.4 (6.0)	30.7 (5.6)	72.3 (7.3)		44.5 (8.6)	38.0 (12.7)	0.6756	68.1 (11.7)	82.6 (12.2)	0.3909
Wyoming	315	45.0 (3.5)	31.5 (3.3)	69.9 (4.7)		45.1 (6.8)	45.0 (4.1)	0.9932	78.2 (7.1)	66.8(5.8)	0.2169
Total	3573	34.4 (1.4)	18.9 (1.1)	55.0 (2.4)		34.8 (1.6)	32.6 (2.6)	0.4640	55.1 (2.7)	54.5 (4.7)	0.9145

Unweighted Ns; weighted percentages and standard errors (in parentheses); two-tailed adjusted Wald tests Sample N = 3573; Metropolitan N = 2584; Non-metropolitan N = 989; Initiates N = 1390

Table 2

Sample description for full sample and by metropolitan status [% or mean (SD)]

	Full sample N = 3573	Metro N = 2584	Non-metro N = 989	<i>p</i>
Adolescent started HPV vaccination	34.4 (1.4)	34.8 (1.6)	32.6 (2.6)	0.4640
Adolescent completed HPV vaccination	18.9 (1.1)	19.1 (1.3)	17.7 (1.8)	0.5346
Adolescent completed HPV vaccination (among initiates)	55.0 (2.4)	55.1 (2.7)	54.5 (4.7)	0.9145
<i>Potential maternal moderators of interest</i>				
Household income				0.0001
Income missing	9.5 (1.0)	10.2 (1.1)	6.6 (1.2)	0.0378
Less than \$25,000	22.6 (1.2)	22.4 (1.3)	23.9 (2.5)	0.3143
\$25,000–\$49,999	20.3 (1.2)	18.4 (1.3)	29.0 (2.8)	0.0002
\$50,000–\$74,999	14.1 (1.0)	14.0 (1.1)	14.6 (1.7)	0.7719
\$75,000 or more	33.5 (1.4)	35.1 (1.6)	25.9 (2.7)	0.0049
Mother's education				0.0002
Less than high school	14.0 (1.1)	14.7 (1.3)	10.5 (1.5)	0.0449
High school graduate	55.6 (1.4)	53.2 (1.7)	66.7 (2.7)	<.0001
Four-year college graduate	30.4 (1.3)	32.1 (1.5)	22.8 (2.6)	0.0035
Mother has health insurance	78.1 (1.3)	77.5 (1.5)	80.6 (2.4)	0.2813
Mother experienced medical cost barrier in the past year	22.8 (1.2)	21.8 (1.4)	27.1 (2.7)	0.0701
Mother has at least one personal doctor	82.2 (1.2)	81.6 (1.3)	84.9 (2.2)	0.2167
<i>Control Variables</i>				
Adolescent age	14.6 (.05)	14.6 (.06)	14.6 (.10)	0.7126
Mother's age	41.4 (.36)	41.6 (.42)	40.3 (.69)	0.1131
Mother married	68.7 (1.4)	68.8 (1.5)	68.0 (2.9)	0.8165
Number of adults in household	2.4 (.03)	2.4 (.04)	2.5 (.07)	0.1955
Number of children in household	1.8 (.03)	1.9 (.04)	1.8 (.07)	0.3203
Mother employed	62.7 (1.4)	62.6 (1.6)	63.3 (2.8)	0.8220
Mother race/ethnicity				<.0001
Non-Hispanic white	63.5 (1.4)	59.8 (1.6)	80.6 (2.7)	<.0001
Non-Hispanic black	8.6 (0.8)	10.2 (1.0)	1.6 (0.6)	<.0001
Hispanic	24.3 (2.3)	26.1 (1.4)	16.2 (2.6)	0.0031
Other race	3.6 (0.5)	4.0 (0.6)	1.7 (0.5)	0.0113
Mother had a routine physical health checkup in past 2 years	80.7 (1.2)	81.0 (1.3)	79.4 (2.3)	0.5460
Mother had pap test in past 3 years	89.7 (0.8)	90.4 (1.0)	86.4 (1.7)	0.0307

Weighted; *SD* standard deviation, *p* probability of rejecting null hypothesis of no difference using two-tailed Wald tests for interval-ratio variables and Chi square tests for categorical variables

Table 3

Odds ratios and 95 % confidence intervals from unadjusted and adjusted binary logistic regression models predicting HPV vaccine initiation among adolescent girls aged 12–17 (N = 3573)

	Unadjusted			Adjusted		
	OR	95 % CI	p	OR	95 % CI	p
Non-metropolitan	0.906	0.695–1.181	0.4645	0.849	0.631–1.144	0.2828
Household income						
Missing	0.660	0.414–1.053	0.0815	0.672	0.419–1.077	0.0982
Less than \$25,000	0.859	0.630–1.170	0.3350	0.866	0.568–1.321	0.5055
\$25,000–\$49,999	0.760	0.544–1.061	0.1066	0.745	0.509–1.089	0.1281
\$50,000–\$74,999	0.528	0.371–0.753	0.0004	0.488	0.338–0.705	0.0001
\$75,000 or more (ref)						
Maternal education						
Less than high school	0.611	0.412–0.905	0.0141	0.612	0.378–0.991	0.0456
High school graduate	0.923	0.711–1.199	0.5487	0.952	0.703–1.290	0.7502
Four-year college graduate (ref)						
Mother has health insurance	1.293	0.953–1.754	0.0993	1.156	0.767–1.741	0.4886
Mother experienced medical cost barrier in the past year	0.952	0.718–1.263	0.7344	1.340	0.957–1.877	0.0881
Mother has at least one personal doctor	1.608	1.154–2.241	0.0050	1.453	1.005–2.102	0.0472
Control variables						
Adolescent age	1.078	1.004–1.159	0.0389	1.100	1.027–1.178	0.0063
Mother's age	1.002	0.990–1.015	0.7015	0.999	0.986–1.013	0.9258
Mother married	0.900	0.704–1.151	0.4026	0.888	0.667–1.184	0.4198
Number of adults in household	0.967	0.840–1.113	0.6385	0.939	0.812–1.086	0.3975
Number of children in household	0.998	0.888–1.122	0.9735	1.018	0.898–1.155	0.7767
Mother employed	1.000	0.781–1.280	0.9999	0.907	0.696–1.184	0.4743
Mother's race/ethnicity						
Non-Hispanic white (ref)						
Non-Hispanic black	1.179	0.750–1.853	0.4746	1.269	0.746–2.159	0.3787
Hispanic	1.017	0.755–1.370	0.9125	1.834	1.253–2.686	0.0018
Other race	0.679	0.378–1.218	0.1938	0.748	0.427–1.311	0.3110

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

	Unadjusted			Adjusted		
	OR	95 % CI	p	OR	95 % CI	p
Mother had a routine physical health checkup in past 2 years	1.566	1.124–2.181	0.0080	1.391	0.955–2.204	0.0852
Mother had pap test within past 3 years	1.368	0.930–2.011	0.1118	1.186	0.765–1.839	0.4448

Weighted: adjusted model also controls for state fixed effects; OR odds ratio, CI 95 % confidence interval, p probability of rejecting null hypothesis of no difference

Odds ratios and 95 % confidence intervals from unadjusted and adjusted binary logistic regression models predicting HPV vaccine completion among initiates (N = 1390)

Table 4

	Unadjusted			Adjusted		
	OR	95 % CI	p	OR	95 % CI	p
Non-metropolitan	0.978	0.653–1.465	0.9145	1.019	0.635–1.634	0.9376
Household income						
Missing	1.173	0.527–2.609	0.6964	1.693	0.754–3.800	0.2017
Less than \$25,000	0.755	0.450–1.266	0.2863	0.862	0.417–1.780	0.6878
\$25,000–\$49,999	0.675	0.382–1.191	0.1749	0.747	0.370–1.507	0.4152
\$50,000–\$74,999	0.897	0.482–1.668	0.7314	1.009	0.547–1.860	0.9776
\$75,000 or more (ref)						
Maternal education						
Less than high school	0.684	0.380–1.230	0.2046	0.686	0.336–1.401	0.3009
High school graduate	0.669	0.462–0.970	0.0341	0.780	0.507–1.198	0.2559
Four-year college graduate (ref)						
Mother has health insurance	0.924	0.560–1.522	0.7554	0.771	0.400–1.487	0.4385
Mother experienced medical cost barrier in the past year	0.797	0.504–1.263	0.3344	0.968	0.549–1.709	0.9118
Mother has at least one personal doctor	1.190	0.691–2.048	0.5314	1.176	0.628–2.203	0.6125
Control variables						
Adolescent age	1.107	1.001–1.226	0.0484	1.152	1.034–1.284	0.0104
Mother's age	1.023	1.003–1.043	0.0245	1.022	0.999–1.046	0.0605
Mother married	1.371	0.915–2.054	0.1260	1.082	0.661–1.770	0.7540
Number of adults in household	0.924	0.749–1.140	0.4593	0.955	0.755–1.208	0.7018
Number of children in household	0.992	0.830–1.186	0.9321	1.084	0.880–1.334	0.4498
Mother employed	0.897	0.598–1.346	0.5996	0.781	0.515–1.183	0.2428
Mother's race/ethnicity						
Non-Hispanic white (ref)						
Non-Hispanic black	1.082	0.555–2.108	0.8179	1.271	0.577–2.799	0.5517
Hispanic	0.999	0.631–1.581	0.9977	1.069	0.544–2.099	0.8471
Other race	0.551	0.238–1.278	0.1652	0.361	0.166–0.786	0.0102

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

	Unadjusted			Adjusted		
	OR	95 % CI	p	OR	95 % CI	p
Mother had a routine physical health checkup in past 2 years	1.515	0.929–2.472	0.0960	1.758	0.912–3.390	0.0922
Mother had pap test within past 3 years	1.637	0.834–3.212	0.1521	1.781	0.863–3.675	0.1186

Weighted: adjusted model also controls for state fixed effects; *OR* odds ratio, *CI* 95 % confidence interval, *p* probability of rejecting null hypothesis of no difference

Table 5

Effect sizes for metropolitan versus non-metropolitan status differences in average predicted probabilities of vaccine initiation

	Mean (SE)		Effect Sizes	
	Metro	Nonmetro	Cohen's d	r
Income				
Missing	.296 (.009)	.323 (.016)	−0.196	−0.097
Less than \$25,000	.347 (.007)	.401 (.008)	−0.340	−0.168
\$25,000–\$49,999	.334 (.008)	.317 (.010)	0.107	0.053
\$50,000–\$74,999	.253 (.005)	.264 (.010)	−0.094	−0.047
\$75,000 or more	.408 (.004)	.300 (.010)	0.781	0.364
Maternal education				
Less than high school	.235 (.007)	.441 (.017)	−1.325	−0.552
High school graduate	.355 (.005)	.333 (.006)	0.135	0.068
4-year college graduate	.387 (.004)	.250 (.011)	0.893	0.408
Maternal medical cost barrier				
Medical cost barrier	.358 (.008)	.250 (.010)	0.645	0.307
No medical cost bar	.345 (.004)	.353 (.006)	−0.048	−0.024

r = effect-size correlation. Effect sizes were calculated from adjusted interaction models with model coefficients available in appendix. Models are adjusted for all control variables and state fixed effects