



Published in final edited form as:

*Cancer Causes Control*. 2016 October ; 27(10): 1187–1196. doi:10.1007/s10552-016-0796-4.

## Sexual orientation identity disparities in human papillomavirus vaccination initiation and completion among young adult US women and men

Madina Agénor<sup>1</sup>, Sarah M. Peitzmeier<sup>2</sup>, Allegra R. Gordon<sup>3,4</sup>, Brittany M. Charlton<sup>3,4</sup>, Sebastien Haneuse<sup>5</sup>, Jennifer Potter<sup>6,7,8</sup>, and S. Bryn Austin<sup>1,3,4</sup>

Madina Agénor: magenor@mail.harvard.edu

<sup>1</sup>Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, 677 Huntington Avenue, Kresge Building, 7th Floor, Boston, MA 02115, USA

<sup>2</sup>Department of Population, Family and Reproductive Health, Johns Hopkins School of Public Health, Baltimore, MD, USA

<sup>3</sup>Division of Adolescent and Young Adult Medicine, Boston Children's Hospital, Boston, MA, USA

<sup>4</sup>Department of Pediatrics, Harvard Medical School, Boston, MA, USA

<sup>5</sup>Department of Biostatistics, Harvard T.H. Chan School of Public Health, Boston, MA, USA

<sup>6</sup>Department of Medicine, Harvard Medical School, Boston, MA, USA

<sup>7</sup>Division of General Medicine and Primary Care, Beth Israel Deaconess Medical Center, Boston, MA, USA

<sup>8</sup>The Fenway Institute, Fenway Health, Boston, MA, USA

### Abstract

**Purpose**—To examine the association between sexual orientation identity and human papillomavirus (HPV) vaccination initiation and completion among both women and men.

**Methods**—Using data from the 2013 and 2014 National Health Interview Survey, we estimated logistic regression models for the association between sexual orientation identity and HPV vaccination initiation (1 dose) and completion (3 doses) among US women and men in relation to sociodemographic and healthcare factors. Analyses were restricted to individuals for whom the HPV vaccine was recommended at some point in their lives, namely women aged 18–34 years ( $n = 9,734$ ) and men aged 18–31 years ( $n = 6,812$ ).

**Results**—Among all women, bisexual women had higher adjusted odds of HPV vaccination initiation [(odds ratio) 1.71; (95 % confidence interval) 1.20–2.45] and completion (1.59; 1.05–2.42) than heterosexual women. No difference was observed in the odds of HPV vaccination initiation or completion between lesbian and heterosexual women. Among women who had initiated HPV vaccination, lesbians had lower adjusted odds of completion than heterosexual women (0.41; 0.19–0.90). Among all men, gay men had higher adjusted odds of initiating (2.07;

1.17–3.52) and completing (3.90; 1.68–9.06) HPV vaccination than heterosexual men. No difference was observed in the odds of HPV vaccination initiation or completion between bisexual and heterosexual men. Among men who had initiated HPV vaccination, gay (4.36; 1.28–14.83) and bisexual (20.92; 2.34–186.73) men had higher adjusted odds of completion than heterosexual men, although these results are unreliable and should be interpreted with caution.

**Conclusions**—Interventions are needed to promote HPV vaccination among all US women and men, regardless of sexual orientation identity.

### Keywords

Human papillomavirus vaccination; Health disparities; Sexual orientation; Gender; Young adults

### Introduction

Human papillomavirus (HPV) is the most common sexually transmitted infection (STI) among women and men in the United States (US) [1, 2], with the highest prevalence occurring among adolescents and young adults [2–4]. An estimated 3.4 million US women aged 15–24 years and 3.5 million US men aged 15–24 years were newly infected with HPV in 2008 [2]. Persistent infection with oncogenic HPV types (e.g., types 16 and 18) is necessary for the development of virtually all cervical cancers and contributes to a substantial proportion of vaginal, vulvar, anal, penile, and oropharyngeal cancers [1, 3, 5]. In the United States, an estimated 26,000 cancers are attributable to HPV infection annually, with 17,000 occurring among women and 9,000 among men [1].

While the HPV vaccine is approved for use starting at age 9 years, the Advisory Committee for Immunization Practices recommends HPV vaccination for girls and boys aged 11 or 12 years to prevent HPV infection and related cancers later in life [1, 6]. Catch-up vaccination is recommended for all girls and women aged 13–26 years, all boys and men aged 13–21 years, and men who have sex with men (MSM) through age 26 years [1, 6]. Uptake of the HPV vaccine has been slow, and, despite recent progress, coverage remains below Healthy People 2020 targets of 80 % for HPV vaccination completion among US adolescents [1, 6–8]. Indeed, in 2014, the prevalence of HPV vaccination initiation and completion among girls aged 13–17 years was only 60.0 and 39.7 %, respectively [9]. HPV vaccination prevalence estimates were even lower among boys aged 13–17 years at 41.7 % for initiation and 21.5 % for completion [9]. Among young adults aged 19–26 years, the prevalence of HPV vaccination initiation was only 40.2 % for women and 8.2 % for men [7].

Sexual minority men and women (i.e., individuals who self-identify as lesbian, gay, or bisexual and/or have same-sex sexual partners or attractions) are at risk of HPV, which can be acquired during sexual contact (e.g., penile–vaginal, penile–anal, genital–oral, digital–genital, genital–sex toy) with partners of any sex or gender [10–16]. Sexual minority women may be at higher risk of cervical cancer than heterosexual women because of a higher prevalence of smoking [17–19] and sexual violence [20, 21], lower prevalence of regular Pap test use [22–26], and higher risk of HPV infection (among bisexual women) [14, 17]. Further, studies have shown that sexual minority men are at higher risk of HPV infection and anal cancer than heterosexual men and men with only female sexual partners [27–29].

Despite this evidence, few studies have investigated HPV vaccine uptake among sexual minority adolescents and young adults [30–34]. In order to address this notable gap in the literature, we recently examined the association between two dimensions of sexual orientation [35], sexual orientation identity and sex of sexual partners, and HPV vaccination initiation among US women and girls using 2006–2010 National Survey of Family Growth (NSFG) data [33, 34]. However, our previous studies did not examine sexual orientation disparities in HPV vaccination completion, which the NSFG did not assess and may be most relevant to the prevention of cervical and other HPV-related cancers. Moreover, no study of which we are aware has examined the relationship between sexual orientation and HPV vaccination initiation or completion among US men and boys using appropriate comparison groups [30–32]. Thus, the present study investigates the association between sexual orientation identity, one of the main dimensions of sexual orientation [35], and both the initiation and completion of the HPV vaccine series among not only women but also men in the United States.

## Methods

### Study participants

We analyzed data from the 2013 and 2014 waves of the National Health Interview Survey (NHIS), which used a stratified multistage sampling design to establish a national probability sample that is representative of the civilian non-institutionalized US population (response rates: 81.7 % in 2013 and 80.5 % in 2014) [36–38]. NHIS collects cross-sectional data on children’s and adults’ health status, health behaviors, and healthcare access and utilization through face-to-face interviews administered by trained US Census Bureau employees using computer-assisted personal interviewing (CAPI) [36]. For this analysis, we used data from 2013 and 2014 NHIS sample adults ( $n = 34,557$  in 2013 and  $n = 36,697$  in 2014)—namely, individuals aged 18–64 years who were randomly selected from each eligible family in the sample [36–38]. We restricted our analytic sample to adult US women and men for whom the HPV vaccine was recommended at some point in their lives. Because the HPV vaccine has been recommended for use among girls and women aged 11–26 years since 2006 and boys and men aged 11–26 years since 2009 [39–41], we restricted our analyses to women aged 18–33 years in 2013 and 18–34 years in 2014 ( $n = 9,734$ ) and men aged 18–30 years in 2013 and 18–31 years in 2014 ( $n = 6,812$ ).

### Measures

The outcomes in our analysis were HPV vaccination initiation and completion. The 2013 and 2014 NHIS assessed HPV vaccination initiation by asking sample adults aged 18–64 years if they had ever received an “HPV shot or vaccine” (coded as yes or no, which included “doctor refused when asked”). The survey also asked sample adults aged 18–64 years who reported having initiated HPV vaccination “how many HPV shots” they received (coded as not having completed HPV vaccination, i.e., received less than three shots, or having completed HPV vaccination, i.e., received at least three shots). The key predictor was sexual orientation identity, which is one of the main dimensions of sexual orientation along with sexual attraction and gender or sex of sexual partners [35]. Respondents were asked whether they thought of themselves as lesbian or gay, bisexual, or “straight, that is, not

lesbian or gay” (i.e., heterosexual). Additional response options included “something else” and “I don’t know the answer.” Women ( $n = 127$ ) and men ( $n = 68$ ) who selected “something else” or “I don’t know the answer” ( $n = 77$  women,  $n = 45$  men) or refused to answer the question on sexual orientation identity ( $n = 50$  women,  $n = 23$  men) were excluded from our analysis due to their small sample numbers in our study.

We used the existing literature and ecosocial theory [42–44], which led us to conceptualize sexual orientation as a dimension of social inequality and investigate the pathways through which inequities related to sexual orientation are embodied in the form of health (biologically) and healthcare (behaviorally) inequities, to guide the choice of covariates potentially acting as confounders or mediators. Covariates, shown with their categorization in Table 1, included sociodemographic factors (i.e., race/ethnicity, nativity, geographic region, relationship status, educational attainment, and employment status), which we conceptualized as potential confounders, and healthcare access and utilization indicators (i.e., health insurance status, usual place of care, and number of healthcare office visits in the past year), which we conceptualized as potential mediators of the association between sexual orientation identity and HPV vaccination initiation and completion among young adult US women and men.

Among women aged 18–34 years who self-identified as heterosexual, bisexual, or lesbian or gay, the proportion of data missing on HPV vaccination initiation and completion was 3.7 % ( $n = 371$ ) and 2.0 % ( $n = 200$ ), respectively. Moreover, 5.0 % ( $n = 353$ ) and 1.3 % ( $n = 95$ ) of men aged 18–31 years who self-identified as heterosexual, bisexual, or lesbian or gay were missing data on HPV vaccination initiation and completion, respectively. The proportion of missing data for covariates was small ( 0.45 % among women and 0.88 % among men).

### Statistical analysis

We first estimated the prevalence of HPV vaccination initiation and completion, sociodemographic factors, and healthcare access and utilization indicators overall and by sexual orientation identity among all women and men and among those who had initiated HPV vaccination. Further, we used multivariable logistic regression to model the association between sexual orientation identity and the odds of HPV vaccination initiation and completion (overall and among initiators only), adjusting for sociodemographic factors (i.e., potential confounders; Model 1). We then entered healthcare access and utilization indicators (i.e., potential mediators) into the models (Model 2). All analyses accounted for the complex survey design using the weights provided by NHIS staff and the “svy” commands in Stata, version 13 (StataCorp, TX).

### Results

Table 1 presents data on the percent distribution of US women aged 18–34 years and men aged 18–31 years in relation to sociodemographic factors and healthcare access and utilization indicators by sexual orientation identity. Compared to heterosexual women, bisexual women were more likely to be white, US born, never married, have visited a healthcare provider’s office 13 or more times in the past year, and initiated HPV vaccination

at the age of 12 years or younger. Lesbians were more likely to be black, US born, never married, and uninsured relative to heterosexual women. Further, they were more likely to have made no visits to a healthcare provider's office in the past year and less likely to have a usual place of care than heterosexual women. Compared to heterosexual men, bisexual men were more likely to be white, US born, never married, and insured and to have acquired some college education, made 6 or more healthcare provider office visits in the past year, and initiated HPV vaccination between the ages of 13 and 26 years. Additionally, gay men were more likely than heterosexual men to be US born, never married, and insured and to have acquired a bachelor's degree or more, have a usual place of care, made at least one healthcare provider office visit in the past year, and initiated HPV vaccination later than 26 years of age (Table 1).

Among women aged 18–34 years, the prevalence of HPV vaccination initiation and completion was 28.9 % and 17.8 % (67.7 % among initiators), respectively (Tables 2 and 3). Among men aged 18–31 years, the prevalence of HPV vaccination initiation and completion was 6.6 % and 1.8 % (35.3 % among initiators), respectively. Among all women, bisexual women were significantly more likely than heterosexual women to have initiated (43.1 % vs. 28.5 %,  $p = 0.0003$ ) but not completed vaccination. Lesbians were no less likely than heterosexual women to have initiated HPV vaccination but were significantly less likely to complete the series compared to their heterosexual counterparts, both overall (13.6 % vs. 17.8 %,  $p = 0.007$ ) and among initiators (47.2 % vs. 68.0 %,  $p = 0.04$ ). Among all men, we observed no statistically significant difference in the prevalence of HPV vaccination initiation or completion between neither bisexual nor gay and heterosexual men (Tables 2 and 3). Among men who had initiated vaccination, bisexual men were significantly more likely than heterosexual men to have completed the series (85.0 % vs. 33.5 %,  $p = 0.0009$ ) (Table 3).

Among all women, bisexual women had significantly higher odds of initiating [(odds ratio) 1.71; (95 % confidence interval) 1.20–2.45] and completing (1.59; 1.05–2.42) HPV vaccination compared to heterosexual women, adjusting for sociodemographic factors (Table 4, Model 1). Including healthcare access and utilization indicators into the models did not appreciably attenuate these odds ratios (Model 2). In contrast, we observed no difference in the adjusted odds of HPV vaccination initiation or completion between lesbian and heterosexual women (Model 1). Among women who had initiated HPV vaccination, bisexual women were no more likely than heterosexual women to have completed the series (Model 1). In contrast, lesbians had significantly lower adjusted odds of completion than their heterosexual counterparts (0.42; 0.19–0.90; Model 1). This odds ratio was not attenuated by the inclusion of healthcare access and utilization indicators in the model (Model 2).

Among all men, we observed no difference in the odds of initiating or completing HPV vaccination between bisexual and heterosexual men, adjusting for sociodemographic factors (Table 3, Model 1). In contrast, gay men had significantly higher adjusted odds of HPV vaccination initiation (2.03; 1.17–3.52) and completion (3.90; 1.68–9.06) compared to heterosexual men (Model 1). Among men who had initiated vaccination, bisexual (20.92; 2.34–186.73) and gay (4.36; 1.28–14.83) men had significantly higher adjusted odds of

completion relative to heterosexual men (Model 1). Including healthcare access and utilization indicators in the models attenuated these odds ratios (Model 2). However, given the small number of bisexual and gay men who initiated and completed the HPV vaccine series in this study, odds ratio estimates for these groups are unreliable and should be interpreted with caution.

## Discussion

This paper presents novel findings pertaining to the association between sexual orientation identity and HPV vaccination initiation as well as completion—which, to our knowledge, had never been assessed and may be particularly relevant to the prevention of cervical cancer among young adult US women. Moreover, by identifying the direction and magnitude of sexual orientation identity disparities in HPV vaccination initiation as well as completion among young adult US men, our study addresses a notable gap in the literature and will help inform future HPV vaccination interventions for boys and men. Specifically, we found that, among all women, bisexual women had significantly higher adjusted odds of HPV vaccination initiation and completion than heterosexual women, whereas no difference was apparent between lesbian and heterosexual women. Among women who had initiated vaccination, lesbians had significantly lower adjusted odds of completing the HPV vaccine series than heterosexual women. Further, gay men had significantly higher adjusted odds of initiating and completing (overall and among initiators) HPV vaccination relative to heterosexual men. Among men who had initiated vaccination, bisexual men had higher adjusted odds of completion than heterosexual men. However, given the small number of bisexual and gay men who initiated and completed HPV vaccination in this study, HPV vaccination completion odds ratio estimates for these groups are unreliable and should be interpreted with caution. In sum, our findings suggest that young adults presumed to only have female sexual partners—namely, lesbian women and heterosexual men—may be less likely to initiate and/or complete the HPV vaccine series relative to those presumed to have male sexual partners—namely, bisexual women and gay and bisexual men.

There are several reasons why bisexual women may have significantly higher adjusted odds of initiating and completing HPV vaccination compared to heterosexual women. Other studies suggest that sexual history factors—such as earlier average age at first sex and a higher average number of sexual partners, including male sexual partners [45]—may contribute to bisexual women taking a more active role than heterosexual women in seeking preventive sexual health services (such as the HPV vaccine) and bisexual women’s caregivers and providers encouraging them more than heterosexual women to obtain such care. Further, it is possible that, because of higher levels of routine sexual and reproductive health services use [22, 45, 47, 48], bisexual women and girls have more opportunities to initiate and complete the HPV vaccine series relative to their heterosexual peers. Moreover, the pervasive societal stereotype that bisexual women are sexually promiscuous [46] may influence healthcare providers’ decision to recommend and provide the HPV vaccine and other STI prevention services [22, 47, 48] to bisexual women more frequently than heterosexual women, regardless of their individual sexual risk.

The present study's finding that lesbians were no less likely to initiate HPV vaccination than heterosexual women differs from that of our prior study, which found that lesbians aged 15–25 years were significantly less likely than their heterosexual counterparts to have initiated HPV vaccination [33]. The two studies' disparate findings may be due to the fact that our prior study used data from the 2006–2010 NSFG, which were collected before the implementation of the Affordable Care Act (ACA). It is possible that the ACA, which requires coverage of the HPV vaccine with no cost sharing and involved the expansion of Medicaid in some states [49–54], may have facilitated access to the HPV vaccine among lesbians, who had a lower prevalence of health insurance and access to health care than heterosexual women [55–57], and thereby reduced HPV vaccination initiation disparities between lesbian and heterosexual women over time. Additional quantitative and qualitative research is needed to elucidate why lesbians who initiated HPV vaccination had significantly lower odds of completing the series than their heterosexual counterparts—especially since healthcare access and utilization indicators did not help explain this difference.

The prevalence of HPV vaccination was very low among men in general and heterosexual men in particular. This is concerning because, contrary to the perceptions of many healthcare providers, adolescents and young adults of all genders and sexual orientations are at risk for HPV infection through a range of penetrative and non-penetrative sexual behaviors with partners of any sex or gender [11, 62]. Other studies suggest that heterosexual men may have especially low levels of HPV vaccination because gender norms (i.e., hegemonic masculinity) may preclude them from obtaining health insurance and seeking health care [58–60], which in turn undermines their ability to receive the HPV vaccine. In the present study, heterosexual men were more likely to be uninsured, have no usual place of care, and not have made a visit to a healthcare provider in the past year compared to gay and bisexual men, which may lead to fewer opportunities to obtain the HPV vaccine among men in this sexual orientation group relative to their sexual minority peers.

The initial HPV vaccination guidelines [61], which did not recommend vaccination for men, and the current set of guidelines, which recommend HPV vaccination up to age 21 years for all men and up to age 26 years for MSM only [6, 41], may have inadvertently promoted the belief, among patients and providers, that men and boys, especially those with female sexual partners, are not at risk for HPV infection and related cancers. However, men and boys can acquire HPV through a range of sexual behaviors, including penile–vaginal, penile–anal, oral–penile, and digital–anal sex, that involve contact with infected skin, mucous membranes, and bodily fluids [62]. Moreover, sexual behavior is fluid and can change throughout the life course, such that men and boys who engage in sex with only female sexual partners or have not yet had sex before age 21 years may engage in same-sex sexual behaviors later in life [35]. Thus, HPV vaccination should be recommended for all men up to age 26 years, regardless of current sexual identity or behavior. Additionally, per current HPV vaccination guidelines, non-MSM may only have until age 21 years before providers stop offering and/or health insurance plans stop covering the HPV vaccine series, which may limit their opportunity to obtain the vaccine. Moreover, gay and bisexual men and other MSM have often been the focus of interventions that promote HIV and STI testing and counseling [63, 64]. Similarly, health education and communication campaigns promoting the prevention of STIs, including HPV vaccination initiatives, have often specifically

targeted sexual minority men [64]. Thus, gay and bisexual men and other MSM may have more opportunities to receive and learn about the HPV vaccine compared to their heterosexual counterparts and peers with only female sexual partners.

Our findings should be interpreted in light of some limitations. First, the number of sexual minority men who had initiated and completed HPV vaccination in our study was small. As a result, estimates of HPV vaccination completion among bisexual and gay men overall and initiators in particular are unreliable and should be interpreted with caution. Second, the 2013 and 2014 NHIS collected data on a single dimension of sexual orientation (i.e., sexual orientation identity) and does not provide information on the gender or sex of individuals' sexual partners [35], which may be discordant with sexual orientation identity and particularly relevant to sexual health care. Third, NHIS does not include measures of several factors that may help explain sexual orientation disparities in HPV vaccination among women and men, such as individuals' sexual history, HPV risk perceptions, and provider recommendation of the HPV vaccine. As a result, we were not able to assess the influence of these potential mediators in our study. Health insurance status, usual source of care, and number of visits to a healthcare provider's office in the past year only helped explain sexual orientation identity disparities among men—and often only partially. Thus, more research should be conducted to identify the factors that underlie sexual orientation identity disparities in HPV vaccine uptake among women and men in order to inform evidence-based interventions that promote initiation and completion of the series among all sexual orientation and gender groups. Lastly, it is important to note that, although the prevalence of HPV vaccination initiation and completion was highest among bisexual women, we had no information on the quality of this group's interactions with healthcare providers when receiving the HPV vaccine; thus, additional research is needed to assess bisexual women's and girls' satisfaction with patient-provider communication during these clinical encounters.

The present study extends existing research by ascertaining the direction and magnitude of sexual orientation identity disparities in not only the initiation but also the completion of the HPV vaccine series among both US women and men using appropriate comparison groups. Our findings show that the prevalence of HPV vaccination initiation and completion was well below Healthy People 2020 targets among young adult women and men overall. Thus, interventions are needed to promote awareness of and access to the HPV vaccine among all adolescents and young adults, regardless of their gender or sexual orientation identity. In particular, targeted efforts that facilitate HPV vaccination initiation and completion among men and boys, who remain especially underserved, are warranted. Additionally, our results suggest that HPV vaccination promotion campaigns should explicitly address sexual orientation disparities in HPV vaccine uptake among both female and male adolescents and young adults. Specifically, programs that facilitate the completion of the HPV vaccine series among lesbians once they initiate vaccination are needed. Moreover, interventions that raise awareness of and access to HPV vaccination among gay and bisexual men continue to be warranted, as are initiatives geared toward the needs and experiences of heterosexual boys and men, who were the least likely group in our study to obtain the vaccine. Lastly, educational programs are needed to ensure that healthcare providers recommend the HPV vaccine to all adolescents and young adults and that parents and caregivers are aware of the critically important role of HPV vaccination in preventing HPV infection in the short term



and HPV-related cancers in the long term. Together, these interventions will help promote HPV vaccine uptake among all US adolescents and young adults while also addressing sexual orientation identity disparities among both women and men—which will in turn ensure that no individual has to live with or die from a preventable HPV-related disease and help reduce unnecessary suffering.

## Acknowledgments

AR Gordon is supported by National Institutes of Health R01HD066963. BM Charlton is supported by National Institutes of Health F32HD084000, Society of Family Planning SHPRF9-18, and the Lesbian Health Fund. S Haneuse is supported by the National Cancer Institute. SB Austin is supported by National Institutes of Health R01HD057368, National Institutes of Health R01HD066963, and Maternal and Child Health Bureau T71MC00009 and T76MC00001. The authors thank National Health Interview Survey participants and staff for the data used in these analyses.

## References

1. Dunne EF, Markowitz LE, Saraiya M, et al. CDC grand rounds: reducing the burden of HPV-associated cancer and disease. *MMWR*. 2014; 63:69–72. [PubMed: 24476977]
2. Satterwhite CL, Torrone E, Meites E, et al. Sexually transmitted infections among US women and men: prevalence and incidence estimates, 2008. *Sex Transm Dis*. 2013; 40:187–193. [PubMed: 23403598]
3. Hariri S, Unger ER, Sternberg M, et al. Prevalence of genital human papillomavirus among females in the United States, the National Health and Nutrition Examination Survey, 2003–2006. *J Infect Dis*. 2011; 204:566–573. [PubMed: 21791659]
4. Markowitz L, Hariri S, Lin C, et al. Reduction in human papillomavirus (HPV) prevalence among young women following HPV vaccine introduction in the United States, National Health and Nutrition Examination Survey, 2003–2010. *J Infect Dis*. 2013; 208:385–393. [PubMed: 23785124]
5. Jemal A, Simard EP, Dorell C, et al. Annual report to the nation on the status of cancer, 1975–2009, featuring the burden and trends in human papillomavirus (HPV)-associated cancers and HPV vaccination coverage levels. *J Natl Cancer Inst*. 2013; 105:175–201. [PubMed: 23297039]
6. Markowitz L, Dunne EF, Saraiya M, et al. Human papillomavirus vaccination: recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR*. 2014; 63:1–30. [PubMed: 25167164]
7. Williams WW, Lu PJ, O'Halloran A, et al. Surveillance of vaccination coverage among adult populations—United States, 2014. *MMWR*. 2016; 65:1–19. [PubMed: 26844596]
8. Centers for Disease Control and Prevention. Immunization and infectious diseases Healthy People 2020. U.S. Department of Health and Human Services; 2015. [www.healthypeople.gov/2020/topics-objectives/topic/immunization-and-infectious-diseases/objectives](http://www.healthypeople.gov/2020/topics-objectives/topic/immunization-and-infectious-diseases/objectives). Accessed 16 Dec 2015
9. Centers for Disease Control and Prevention. National and state vaccination coverage among adolescents aged 13–17 years—United States, 2014. *MMWR*. 2015; 64:784–792. [PubMed: 26225476]
10. Gorgos LM, Marrazzo JM. Sexually transmitted infections among women who have sex with women. *Clin Infect Dis*. 2011; 53:S84–S91. [PubMed: 22080273]
11. Marrazzo JM, Gorgos LM. Emerging sexual health issues among women who have sex with women. *Curr Infect Dis Rep*. 2012; 14:204–211.
12. McNair R. Risks and prevention of sexually transmissible infections among women who have sex with women. *Sex Health*. 2005; 2:209–217. [PubMed: 16402667]
13. Lindley LL, Walsemann KM, Carter JV. Invisible and at risk: STDs among young adult sexual minority women in the United States. *Perspect Sexual Reprod Health*. 2013; 45:66–73.
14. Everett BG. Sexual orientation disparities in sexually transmitted infections: examining the intersection between sexual identity and sexual behavior. *Arch Sex Behav*. 2013; 42:225–236. [PubMed: 22350122]

15. Llata E, Stenger M, Bernstein K, et al. Prevalence of genital warts among sexually transmitted disease clinic patients—sexually transmitted disease surveillance network, United States, January 2010 to December 2011. *Sex Transm Dis.* 2014; 41:89–93. [PubMed: 24413486]
16. Machalek DA, Poynten M, Jin F, et al. Anal human papillomavirus infection and associated neoplastic lesions in men who have sex with men: a systematic review and meta-analysis. *Lancet Oncol.* 2012; 13:487–500. [PubMed: 22445259]
17. Rosario M, Corliss HL, Everett BG, et al. Sexual orientation disparities in cancer-related risk behaviors of tobacco, alcohol, sexual behaviors, and diet and physical activity: pooled Youth Risk Behavior Surveys. *Am J Public Health.* 2014; 104:245–254. [PubMed: 24328632]
18. Boehmer U, Miao X, Linkletter C, et al. Adult health behaviors over the life course by sexual orientation. *Am J Public Health.* 2012; 102:292–300. [PubMed: 22390443]
19. Cochran SD, Mays VM, Bowen D, et al. Cancer-related risk indicators and preventive screening behaviors among lesbians and bisexual women. *Am J Public Health.* 2001; 91:591–597. [PubMed: 11291371]
20. Coker AL, Hopenhayn C, DeSimone CP, et al. Violence against women raises risk of cervical cancer. *J Womens Health.* 2009; 18:1179–1185.
21. McCauley HL, Silverman JG, Decker MR, et al. Sexual and reproductive health indicators and intimate partner violence victimization among female family planning clinic patients who have sex with women and men. *J Womens Health.* 2015; 24:621–628.
22. Agénor M, Krieger N, Austin SB, Hanuse S, Gottlieb BR. Sexual orientation disparities in Papanicolaou test use among US women: the role of sexual and reproductive health services. *Am J Public Health.* 2014; 104:e68–e73. [PubMed: 24328650]
23. Agénor M, Krieger N, Austin SB, Haneuse S, Gottlieb BR. At the intersection of sexual orientation, race/ethnicity, and cervical cancer screening: assessing Pap test use disparities by sex of sexual partners among black, Latina, and white U.S. women. *Soc Sci Med.* 2014; 116:110–118. [PubMed: 24996219]
24. Charlton BM, Corliss HL, Missmer SA, et al. Reproductive health screening disparities and sexual orientation in a cohort study of U.S. adolescent and young adult females. *J Adolesc Health.* 2011; 49:505–510. [PubMed: 22018565]
25. Marrazzo JM, Koutsky LA, Kiviat NB, et al. Papanicolaou test screening and prevalence of genital human papillomavirus among women who have sex with women. *Am J Public Health.* 2001; 91:947–952. [PubMed: 11392939]
26. Tracy JK, Lydecker AD, Ireland L. Barriers to cervical cancer screening among lesbians. *J Women's Health.* 2010; 19:229–237.
27. Daling JR, Madeleine MM, Johnson LG, et al. Human papillomavirus, smoking, and sexual practices in the etiology of anal cancer. *Cancer.* 2004; 101:270–280. [PubMed: 15241823]
28. Dunne EF, Nielson CM, Stone KM, et al. Prevalence of HPV infection among men: a systematic review of the literature. *J Infect Dis.* 2006; 194:1044–1057. [PubMed: 16991079]
29. Goldstone S, Palefsky JM, Giuliano AR, et al. Prevalence of and risk factors for human papillomavirus (HPV) infection among HIV-seronegative men who have sex with men. *J Infect Dis.* 2011; 203:66–74. [PubMed: 21148498]
30. Reiter PL, McRee AL, Katz ML, Paskett ED. Human papillomavirus vaccination among young adult gay and bisexual men in the United States. *Am J Public Health.* 2015; 105:96–102. [PubMed: 25393178]
31. Meites E, Markowitz LE, Paz-Bailey G, Oster AM. HPV vaccine coverage among men who have sex with men—national HIV Behavioral Surveillance System, United States, 2011. *Vaccine.* 2014; 32:6356–6359. [PubMed: 25258097]
32. McRee A, Katz ML, Paskett ED, Reiter PL. HPV vaccination among lesbian and bisexual women: findings from a national survey of young adults. *Vaccine.* 2014; 32:4736–4742. [PubMed: 25038312]
33. Agénor M, Peitzmeier S, Gordon AR, Potter J, Haneuse S, Austin SB. Sexual orientation identity disparities in awareness and initiation of the human papillomavirus vaccine among U.S. women and girls: a national survey. *Ann Intern Med.* 2015; 163:99–106. [PubMed: 25961737]

34. Agénor M, McCauley HL, Peitzmeier SM, Haneuse S, Gordon AR, Potter J, Austin SB. Sex of sexual partners and human papillomavirus vaccination among U.S. girls and women. *Am J Prev Med.* 2016; 50:318–327. [PubMed: 26585049]
35. Sell, RL. Defining and measuring sexual orientation for research. In: Meyer, IH.; Northridge, ME., editors. *The health of sexual minorities: public health perspectives on lesbian, gay, bisexual, and transgender populations.* Springer; New York: 2007. p. 355-374.
36. Parsons VL, Moriarity C, Jonas K, Moore TF, Davis KE, Tompkins L. Design and estimation for the National Health Interview Survey, 2006–2015. *Vital Health Stat Ser 2 Data Eval Methods Res.* 2014; 165:1–53.
37. National Center for Health Statistics. 2013 National Health Interview Survey (NHIS) public use data release survey description. Centers for Disease Control and Prevention; 2014. [ftp://ftp.cdc.gov/pub/Health\\_statistics/NCHS/Dataset\\_Documentation/NHIS/2013/srvydesc.pdf](ftp://ftp.cdc.gov/pub/Health_statistics/NCHS/Dataset_Documentation/NHIS/2013/srvydesc.pdf). Accessed 1 Feb 2016
38. National Center for Health Statistics. 2014 National Health Interview Survey (NHIS) public use data release survey description. Centers for Disease Control and Prevention; 2015. [ftp://ftp.cdc.gov/pub/Health\\_Statistics/NCHS/Dataset\\_Documentation/NHIS/2014/srvydesc.pdf](ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2014/srvydesc.pdf). Accessed 1 Feb 2016
39. Centers for Disease Control and Prevention. FDA licensure of quadrivalent human papillomavirus vaccine (HPV4, Gardasil) for use in males and guidance from the Advisory Committee on Immunization Practices (ACIP). *MMWR.* 2010; 59:630–632. [PubMed: 20508594]
40. Markowitz LE, Dunne EF, Saraiya M, Lawson HW, Harrell Chesson H, Unger ER. Quadrivalent human papillomavirus vaccine: recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR.* 2007; 56:1–24. [PubMed: 17380109]
41. Petrosky E, Bocchini JA Jr, Hariri S, Chesson H, Curtis CR, Saraiya M, Unger ER, Markowitz LE. Use of 9-valent human papillomavirus (HPV) vaccine: updated HPV vaccination recommendations of the Advisory Committee on Immunization Practices. *MMWR.* 2015; 64:300–304. [PubMed: 25811679]
42. Krieger N. A glossary for social epidemiology. *J Epidemiol Commun Health.* 2001; 55:693–700.
43. Krieger N. Theories for social epidemiology in the 21st century: an ecosocial perspective. *Int J Epidemiol.* 2001; 30:668–677. [PubMed: 11511581]
44. Krieger, N. *Epidemiology and the people’s health: theory and context.* Oxford University Press; New York: 2011.
45. Tornello SL, Riskind RG, Patterson CJ. Sexual orientation and sexual and reproductive health among adolescent young women in the United States. *J Adolesc Health.* 2014; 54:160–168. [PubMed: 24157195]
46. Klesse C. Bisexual women, non-monogamy and differentialist anti-promiscuity discourses. *Sexualities.* 2005; 8:445–464.
47. Kerr DL, Ding K, Thompson AJ (2013) A comparison of lesbian, bisexual, and heterosexual female college undergraduate students on selected reproductive health screenings and sexual behaviors. *Women’s Health Issues.* 2013; 23:e347–e355. [PubMed: 24183409]
48. Charlton BM, Corliss HL, Missmer SA, Frazier AL, Rosario M, Kahn JA, et al. Reproductive health screening disparities and sexual orientation in a cohort study of U.S. adolescent and young adult females. *J Adolesc Health.* 2011; 29:505–510. [PubMed: 22018565]
49. Koh HK, Sebelius KG. Promoting prevention through the Affordable Care Act. *N Engl J Med.* 2010; 363:1296–1299. [PubMed: 20879876]
50. Department of Health and Human Services. Preventive services covered under the Affordable Care Act. <http://www.hhs.gov/healthcare/facts/factsheets/2010/07/preventive-services-list.html#CoveredPreventiveServicesforChildren>. Accessed 17 March 2014
51. Durso, LE.; Baker, K.; Cray, A. LGBT communities and the Affordable Care Act: findings from a national survey. Center for American Progress; 2013. <https://cdn.americanprogress.org/wp-content/uploads/2013/10/LGBT-ACAsurvey-brief1.pdf>. Accessed 1 Feb 2016
52. National Conference of State Legislatures. Affordable Care Act Medicaid expansion. 2014. <http://www.ncsl.org/research/health/affordable-care-act-expansion.aspx>. Accessed 22 Sept 2014

53. Sonfield, A.; Frost, JJ.; Gold, RB. Estimating the impact of expanding Medicaid eligibility for family planning services: 2011 update. Guttmacher Institute; 2011. <https://www.guttmacher.org/pubs/Medicaid-Family-Planning-2011.pdf>. Accessed 1 Feb 2016
54. Department of Health and Human Services. The Affordable Care Act and Immunization. 2012. <http://www.hhs.gov/healthcare/facts-and-features/fact-sheets/aca-and-immunization/index.html>. Accessed 2 Feb 2016
55. Ponce NA, Cochran SD, Pizer JC, Mays VM. The effects of unequal access to health insurance for same-sex couples in California. *Health Aff.* 2010; 29:1539–1548.
56. Buchmueller T, Carpenter CS. Disparities in health insurance coverage, access, and outcomes for individuals in same-sex versus different-sex relationships, 2000–2007. *Am J Public Health.* 2010; 100:489–495. [PubMed: 20075319]
57. Gonzales G, Blewett LA. National and state-specific health insurance disparities for adults in same-sex relationships. *Am J Public Health.* 2014; 104:e95–e104. [PubMed: 24328616]
58. Ward BW, Dahlhamer JM, Galinsky AM, Joestl SS. Sexual orientation and health among U.S. adults: National Health Interview Survey, 2013. *Natl Health Stat Rep.* 2013; 77:1–10.
59. Conron KJ, Mimiaga MJ, Landers SJ. A population-based study of sexual orientation identity and gender differences in adult health. *Am J Public Health.* 2010; 100:1953–1960. [PubMed: 20516373]
60. Courtenay WH. Constructions of masculinity and their influence on men’s well-being: a theory of gender and health. *Soc Sci Med.* 2000; 50:1385–1401. [PubMed: 10741575]
61. Markowitz L, Dunne EF, Saraiya M, Lawson HW, Chesson H, Unger ER. Quadrivalent human papillomavirus vaccine: recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR.* 2007; 56:1–24. [PubMed: 17380109]
62. National Cancer Institute. HPV and cancer. About cancer: causes and prevention. 2015. <http://www.cancer.gov/about-cancer/causes-prevention/risk/infectious-agents/hpv-fact-sheet>. Accessed 18 Aug 2015
63. Centers for Disease Control and Prevention. Evolution of HIV/AIDS prevention programs—United States, 1981–2006. *MMWR.* 2006; 55:597–603. [PubMed: 16741496]
64. Centers for Disease Control and Prevention. CDC programs at-a-glance. Gay and bisexual men’s health. 2015. <http://www.cdc.gov/msmhealth/msm-programs.htm>. Accessed 2 Feb 2016

**Table 1**

Percent distribution of young adult US women ( $n = 9,734$ ) and men ( $n = 6,812$ ) by sexual orientation identity in relation to sociodemographic and healthcare factors

Variable (%)	Women (aged 18–34 years)				Men (aged 18–31 years)			
	Total $n = 9,734$	Heterosexual $n = 9,351$ (95.9 %)	Bisexual $n = 209$ (2.2 %)	Lesbian $n = 174$ (1.9 %)	Total $n = 6,812$	Heterosexual $n = 6,599$ (96.6 %)	Bisexual $n = 60$ (0.8 %)	Gay $n = 153$ (2.5 %)
Age (at survey, years)								
18–21	19.2	24.7	23.6	24.7	23.4	23.6	21.9	16.8
22–25	24.7	24.8	23.8	24.8	31.7	31.5	37.2	39.9
26–29	26.9	30.9	30.9	26.3	33.1	33.3	28.8	28.5
30	29.3	21.7	21.7	24.2	11.8	11.7	12.1	14.8
Race/ethnicity								
White	58.3	58.2	67.5	54.5	62.5	62.3	77.1	62.8
Black	15.3	15.1	16.4	24.0	12.2	12.1	8.9	15.4
Latino/a	17.8	18.1	8.8	13.5	17.4	17.5	9.9	14.9
Asian/Asian American	5.9	6.0	0.7	3.7	5.6	5.7	4.2	4.4
Native American	0.6	0.6	0.7	0.6	0.4	0.4	0.0	0.9
Multiracial	2.1	2.0	6.0	3.8	2.0	2.0	0.0	1.6
US born: yes	84.2	83.9	93.1	90.9	84.6	84.3	98.6	93.9
Geographic region								
Northeast	14.6	14.7	16.1	9.1	14.3	14.2	11.7	17.1
Midwest	23.4	23.6	20.9	17.8	25.3	25.3	19.6	26.5
South	39.7	39.6	40.6	45.1	36.8	37.0	24.5	31.8
West	22.3	22.2	22.4	28.0	23.7	23.5	44.2	24.6
Relationship status								
Never married	51.0	50.4	66.2	63.7	66.4	65.9	90.5	77.5
Married	30.8	31.6	12.9	10.6	19.6	20.1	8.3	7.8
Living with a partner	12.0	11.8	13.6	21.6	11.3	11.4	1.2	13.2
Divorced, widowed, or separated	6.1	6.2	7.3	4.1	2.6	2.7	0.0	1.4
Educational attainment								
<High school degree	11.2	11.1	16.6	7.5	10.5	10.7	8.1	6.4
High school diploma or GED	20.4	20.5	17.8	22.3	25.6	26.1	9.9	14.1

Variable (%)	Women (aged 18–34 years)					Men (aged 18–31 years)				
	Total n = 9,734	Heterosexual n = 9,351 (95.9 %)	Bisexual n = 209 (2.2 %)	Lesbian n = 174 (1.9 %)	Total n = 6,812	Heterosexual n = 6,599 (96.6 %)	Bisexual n = 60 (0.8 %)	Gay n = 153 (2.5 %)		
Some college or associate's degree	38.3	38.1	35.7	48.9	37.9	37.7	52.7	40.7		
Bachelor's degree	22.1	22.3	20.0	16.7	20.2	20.1	20.0	26.4		
Graduate or professional degree	8.0	8.0	9.9	4.7	5.8	5.6	9.3	12.4		
Working for pay: yes	66.3	66.4	58.2	68.7	74.6	77.9	66.7	77.9		
Uninsured: yes	19.0	18.9	18.6	25.8	23.6	23.9	10.3	15.3		
Has usual place of care: yes	81.1	81.4	77.3	68.8	65.8	65.5	70.4	74.3		
Number of healthcare office visits in past year										
None	16.9	16.7	13.4	29.4	38.0	38.5	29.7	21.0		
1–5	59.6	59.9	54.7	50.0	54.0	53.6	52.7	69.0		
6–12	15.2	15.1	16.9	13.1	6.0	5.9	12.9	5.4		
13 or more	8.4	8.3	15.0	7.5	2.2	2.1	4.7	4.7		
Age at HPV vaccination initiation (years) <sup>a</sup>										
12	5.0	4.7	13.0	6.4	14.2	15.1	0.0	0.0		
13–17	42.2	42.4	33.0	43.8	33.5	33.7	46.1	25.9		
18–26	49.8	49.7	53.1	49.7	48.8	48.4	53.9	56.5		
>26	3.1	3.2	0.9	0.0	3.4	2.8	0.0	17.6		

All estimates are adjusted for the complex survey design. Percentages may not add to 100 % due to rounding error

Analyses were restricted to US women and men for whom the human papillomavirus (HPV) vaccine was recommended at some point in their lives per HPV vaccination guidelines at the time of the study and identified as heterosexual, bisexual, or lesbian or gay

Percentages are based on distributions that do not include missing data. The proportion of missing data for covariates was small (<1.0 %)

<sup>a</sup>Only applies to those who initiated HPV vaccination (n = 2,536 women, n = 433 men)

**Table 2**  
Percent distribution of human papillomavirus vaccination initiation among young adult US women ( $n = 9,734$ ) and men ( $n = 6,812$ ) in relation to sexual orientation identity

Variable	Total	n	%	95 % CI	<i>p</i> value
<i>US women aged 18–34 years</i>					
Total	9,734	2,536	28.9	27.5, 30.3	
Sexual orientation identity					
Heterosexual	9,351	2,403	28.5	27.1, 29.9	Ref
Bisexual	209	80	43.1	35.3, 51.0	<b>0.0003</b>
Lesbian	174	53	30.5	22.0, 38.9	0.7
<i>US men aged 18–31 years</i>					
Total	6,812	433	6.6	5.8, 7.5	
Sexual orientation identity					
Heterosexual	6,599	407	6.5	5.6, 7.4	Ref
Bisexual	60	7	10.3	1.1, 19.5	0.4
Gay	153	19	11.4	6.3, 16.5	0.06

CI confidence interval, *ref*/reference. All estimates are adjusted for the complex survey design. *p* values were derived from adjusted Wald tests (reference: heterosexual). Bolded *p* values are <0.05. Analyses were restricted to US women and men for whom the HPV vaccine was recommended at some point in their lives per HPV vaccination guidelines at the time of the study and identified as heterosexual, bisexual, or lesbian or gay.

Percentages are based on distributions that do not include missing data

Percent distribution of human papillomavirus vaccination completion among young adult US women and men in relation to sexual orientation identity

**Table 3**

Variable	HPV vaccination completion overall				HPV vaccination completion among initiators					
	Total	n	%	95 % CI	p value	Total	n	%	95 % CI	p value
<i>US women aged 18–34 years</i>										
Total	9,734	1,523	17.8	16.8, 19.0		2,536	1,523	67.7	65.4, 70.0	
Sexual orientation identity										
Heterosexual	9,351	1,451	17.8	16.6, 18.9	Ref	2,403	1,451	68.0	65.6, 70.4	Ref
Bisexual	209	51	28.2	20.7, 35.7	0.27	80	51	71.1	59.3, 82.8	0.6
Lesbian	174	21	13.6	6.0, 21.1	<b>0.007</b>	53	21	47.2	28.1, 66.4	<b>0.04</b>
<i>US men aged 18–31 years</i>										
Total	6,812	121	1.8	1.4, 2.2		433	121	35.3	28.9, 41.7	
Sexual orientation identity										
Heterosexual	6,599	108	1.6	1.2, 2.0	Ref	407	108	33.5	27.0, 40.1	Ref
Bisexual	60	4	7.1	0.0, 15.5	0.2	7	4	85.0	55.5, 114.4	<b>0.0009</b>
Gay	153	9	5.1	1.5, 9.3	0.06	19	9	53.3	27.2, 79.3	0.2

HPV human papillomavirus virus, *ref*/reference. All estimates are adjusted for the complex survey design. *p* values were derived from adjusted Wald tests (reference: heterosexual). Bolded *p* values are <0.05

Analyses were restricted to US women and men for whom the HPV vaccine was recommended at some point in their lives per HPV vaccination guidelines at the time of the study and identified as heterosexual, bisexual, or lesbian or gay

Percentages are based on distributions that do not include missing data

HPV vaccination completion refers to receiving 3 or more doses of the vaccine



**Table 4**

Multivariable logistic regression models for the odds of human papillomavirus vaccination initiation and completion among young adult US women and men in relation to sexual orientation identity

Variable	Women (aged 18–34 years)		Men (aged 18–31 years)	
	Model 1 OR (95 % CI)	Model 2 OR (95 % CI)	Model 1 OR (95 % CI)	Model 2 OR (95 % CI)
<i>HPV vaccination initiation among young adult US women (n = 9,734) and men (n = 6,812)</i>				
Sexual orientation identity				
Heterosexual (ref)	1.00	1.00	1.00	1.00
Bisexual	<b>1.71 (1.20, 2.45)</b>	<b>1.71 (1.19, 2.46)</b>	1.46 (0.47, 4.57)	1.52 (0.49, 4.70)
Lesbian or gay	0.99 (0.66, 1.48)	1.10 (0.73, 1.66)	<b>2.03 (1.17, 3.52)</b>	<b>1.90 (1.09, 3.32)</b>
<i>HPV vaccination completion among young adult US women (n = 9,734) and men (n = 6,812) overall</i>				
Sexual orientation identity				
Heterosexual (ref)	1.00	1.00	1.00	1.00
Bisexual	<b>1.59 (1.05, 2.42)</b>	<b>1.57 (1.02, 2.42)</b>	3.73 (0.79, 17.63)	3.91 (0.81, 18.79)
Lesbian or gay	0.67 (0.37, 1.23)	0.74 (0.41, 1.36)	<b>3.90 (1.68, 9.06)</b>	<b>3.42 (1.45, 8.07)</b>
<i>HPV vaccination completion among young adult US women (n = 2,536) and men (n = 433) who initiated HPV vaccination</i>				
Sexual orientation identity				
Heterosexual (ref)	1.00	1.00	1.00	1.00
Bisexual	1.13 (0.60, 2.15)	1.04 (0.54, 2.01)	<b>20.92 (2.34, 186.73)</b>	<b>15.13 (1.85, 123.47)</b>
Lesbian or gay	<b>0.41 (0.19, 0.90)</b>	<b>0.42 (0.19, 0.92)</b>	<b>4.36 (1.28, 14.83)</b>	<b>4.14 (1.22, 14.09)</b>

HPV human papillomavirus, *ref*reference. Model 1 is adjusted for age at time of survey, race/ethnicity, nativity, geographic region, relationship status, educational attainment, and employment status. Model 2 further includes health insurance status, having a usual source of care, number of healthcare office visits in the past year, and age at HPV vaccination (for HPV vaccination completion among initiators only). Bolded values refer to odds ratios (OR) with 95 % confidence intervals (CI) that exclude 1. All estimates are adjusted for the complex survey design

Analyses were restricted to US women and men for whom the HPV vaccine was recommended at some point in their lives per HPV vaccination guidelines at the time of the study and identified as heterosexual, bisexual, or lesbian or gay

HPV vaccination completion refers to receiving 3 or more doses of the vaccine

Odds ratios are based on distributions that do not include missing data. The proportion of missing data for covariates was small (<1.0 %)