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CONCURRENT AND CONCORDANT ORAL AND GENITAL HIGH RISK HUMAN PAPILLOMAVIRUS INFECTIONS IN THE UNITED STATES POPULATION; RESULTS FROM NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY (NHANES)

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Human papillomavirus (HPV) is a common sexually transmitted disease which infects various sites in the body including the genitals, oral cavity, and anal regions. Very little research has assessed the prevalence of concurrent and concordant high risk (HR) HPV oral and genital infections in the general United States population despite the fact that HR HPV oral pharyngeal cancers are on the rise in the US, particularly in men. To further our understanding of HR HPV concurrent and concordant infections we aim to estimate the prevalence of HR HPV concurrent and concordant infections in the U.S. population, and for men and women separately. The next aim is to determine via Monte Carlo simulations, whether HR HPV concurrent and concordant infections happen more than expected by chance, given the population marginal rates of oral and genital infections. Lastly, we characterize predictors of HR HPV concurrent and concordant infections. We use the cross-sectional National Health and Nutrition Examination Survey (NHANES). Participants included women from NHANES 2009-2014 and men from NHANES 2013-2014 who had valid HPV test results. Concurrent infections were identified in 116 (2.5%) individuals in the combined population (65 (4.0%) men and 51 (.76%) women). Simulations showed that the observed prevalence of concurrent infections exceeded the expected prevalence for the combined population, men, and women (1.13%, 4.0%, and .76%, respectively). Similarly, we identified concordant infections in 59 (.99%) of individuals (29 (1.5%) men

and 30 (.47%) women). Simulations showed that the observed prevalence of concordant infections exceeded the expected prevalence for the combined population, men, and women (.15%, .26%, and .05% respectively). Our multivariable analysis for men showed marital status, lifetime number of sexual partners, lifetime number of oral sex partners, recent number of oral sex partners, marijuana use, and sexual orientation were all positively associated with HR HPV concurrent infection, and lifetime number of sex partners, recent number of sex partners, and sexual orientation were positively associated with HR concordant infections. Our multivariable analysis for women showed no predictors were associated with HR HPV concurrent infections, and cigarette use was positively associated with HR HPV concordant infections. Importantly, our analyses show that HR HPV infections between the oral and genital sites are not independent of one another. We further highlight several factors that are important predictors of HR HPV concurrent and concordant infections. These analyses show the importance of the HPV vaccine and suggest its continued recommendation, perhaps more adamantly in boys and men than previously suggested.

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1 Introduction

1.1 Public Health Significance

Human papillomavirus (HPV) is one of the most common sexually transmitted diseases in the United States [1]. The most common anatomical sites for HPV infection are the anogenital and upper aerodigestive tract. There are over 100 types of HPV that are categorized either into high-risk HPV (HR HPV) types, which are known to have oncogenic potential, or low risk types. There are 18 HPV types which are classified as HR and include types 16, 18, 26, 31, 33, 35, 39, 45, 51, 52, 53, 56, 58, 59, 66, 68, 73, and 82 [2]. Persistent HR HPV infection is known to cause cancer at several anatomic sites including cervical, vulvar, vaginal, oropharyngeal, anal, and penile cancers [3]. The causal effect of HPV on cervical cancers is well known and studied. It is estimated that 90-99% of cervical cancer cases are attributable to HPV [4, 5]. Between 2004-2008 and 2008-2012 there has been a decrease in the average rate of cervical carcinoma diagnosed each year in the United States, likely due to improved screening and HPV testing in women; however, the overall rate of HPV-associated cancer has increased during this same time period [6].

A portion of the observed increase in HPV-associated cancers is possibly due to the increasing incidence of HPV positive oropharyngeal cancers (OPC). OPCs include "cancers of the base of the tongue, pharyngeal tonsils, anterior and posterior tonsillar pillars, and glosstonsillar sulci; anterior surface of soft palate and uvula; and lateral and posterior pharyngeal walls" [6]. While oral HPV infections are relatively rare, the incident rate of HPV-associated OPC in women and men is about six and 38 times larger than HPV-associated anal cancer, respectively, and the incidence of HPV-associated OPC in men is 9.5 times larger than penile cancers [3, 6]. Between 1988 and 2004, the incidence of HPV-negative OPC declined by 50%, while the incidence of HPV-positive OPC increased by 225% leading to an overall increase of 28% in the incidence of OPC [7]. It was also estimated that the annual number of HPV-associated

OPC would surpass the annual number of HPV-associated cervical cancers by 2020 if these trends continue; however, this happened between 2008 and 2012 [6, 7]. Another study estimated that the rate of HPV-associated OPC has increased in the United States by 2.5% per year on average between 2002 and 2012 [8]. It is estimated that of all OPC approximately 70% are associated with HPV [7, 5]. Several studies have reported that men are disproportionately infected; rates for OPCs in men is about 4 times higher than that of women [3, 6, 8, 9]. In addition to this, several studies from other countries have also reported increasing incidence of HPV-associated cancers in men including OPC [8].

The high rate of cervical cancers and increasing rates of OPC that are associated with HPV are of concern in light of current HPV vaccine uptake trends, particularly in men. The Advisory Committee on Immunization Practices has recommended vaccination for girls aged 11 or 12 years since 2006, and for boys since 2011 [10]. For vaccinations initiated between ages 9 and 14 years, a two-dose series is recommended, while for those initiated between ages 15 and 26 years, a three-dose series is recommended [10]. All of the available vaccines target HPV 16 and 18, the two most common HPV types found in HPV-associated cancers causing 63% of cases [6]. The bivalent vaccine protects against types 16 and 18, the quadrivalent which adds coverage for types 6 and 11 responsible for most genital warts, and the nine-valent which adds coverage for five additional HR HPV types, 31, 33, 45, 52, and 58. It is estimated that vaccines targeting HPV types 16 and 18 could potentially prevent almost 25,000 cases of cancer annually in the United States and that the nine-valent vaccine could potentially prevent almost an additional 4,000 cases annually [5]. Despite the benefits, the rates of vaccination are relatively low when compared with other 3-dose series vaccinations. In the United States, of females age 13 to 17 years old in 2016, 65.1% received one or more doses, 55.0% received two or more doses, 43.0% received three or more doses, and for males the rates were 56.0%, 43.6%, and 31.5%, respectively [11]. For comparison, in the case of the Hepatitis B vaccine, 94.1% of adolescent males had

received three or more doses [11].

Given the well-known oncogenic potential of HR HPV and the dearth of research on quantifying infections in both the oral and genital cavity, this thesis will quantify and characterize concurrent and concordant HR HPV infections in the U.S. population [12, 13, 2, 6]. Concurrent HPV infection is defined as simultaneous detection of any HR HPV genotype in both the genitals and the oral cavity of a person. Concordant HPV infection is defined as one or more of the same HR HPV genotypes detected in both the genital and the oral cavity of a person. Any HPV infection is defined as an infection with either a low-risk or high-risk HPV type.

1.2 Background

Currently, little is known about HR HPV concurrent and concordant oral and genital HPV infections in the United States' general population. There have been a few studies on concurrent and concordant infections – one for men and one for women in the United States' general population both using the National Health and Nutrition Examination Survey (NHANES) data, and one for men in a rural China population that quantified concurrent and concordant HPV infections with any type (though not specifically HR) [14, 15, 16]. None of these studies performed any further analysis on the HR HPV type subgroup, which are responsible for the majority of cancers described above. Additionally, another study quantified and analyzed concurrent infections in men and women in the United States using NHANES data, but did not necessarily break down those infections by HR and non-HR, perhaps due to small sample sizes [12].

The single study of concurrent and concordant infections with any HPV in U.S. men using NHANES found the prevalence of genital, oral, concurrent, and concordant HPV infection with any type (including low risk) to be 45.3%, 11.2%, 8.8%, and 3.2%, respectively [16]. This study also showed that the prevalence of oral HPV was much higher in men that had a genital infection than among those that had no genital

infection, 19.3% and 4.4%, respectively [16]. The authors also found that lifetime number of any sex (oral, vaginal, or anal) and recent number of any sex partners (number of any sex partners in previous 12 months) was associated with concurrent and concordant infections [16]. One issue with this study, due to sample size, is that not all of the covariates could be included in one multivariable model; therefore, several models were created which all included age, race/ethnicity, smoking status, and one additional covariate based on participant sexual behavior.

The study on concurrent and concordant infections with any HPV in U.S. women using NHANES found the prevalence of genital, oral, concurrent, and concordant HPV infection with any type to be 45.2%, 4.1%, 3.0%, and 1.1%, respectively [15]. The study also showed that the prevalence of concurrent (genital) infection for women with an oral infection was 75.9% and the prevalence of concurrent (oral) infection for women with a genital infection was 6.8%, which is less than that found for men in the aforementioned study [15]. The authors also found age was associated with both concurrent and concordant infections, number of recent oral sex partners is associated with concurrent infection, performing oral sex with a new partner in the past year is associated with concordant infection, and increasing income to poverty ratio was negatively associated with concurrent and concordant infection.

Other studies have also shown a difference in the prevalence of oral HPV infection between men and women, as found in the two previous studies described. In a study of U.S. men and women that focused on oral HPV infections using NHANES, the prevalence of any oral HPV was 11.5% in men and 3.2% in women and the prevalence of HR oral HPV was significantly higher in men than women at 7.3% and 1.4%, respectively [12]. This study also looked at concurrent oral genital infections and found the prevalence of any HPV oral infection among men with any HPV genital infection and HR HPV oral infections among men with any HPV genital infection to be 19.3% and 13.7%, respectively, where the prevalence of any HPV and HR HPV oral infection among men without a genital infection was 4.4% and 3.9%, respectively

[12]. Similarly, the prevalence of any HPV oral infection among women with any HPV genital infection and HR HPV oral infections among women with any HPV genital infection was 5.1% and 3.2%, respectively, where the prevalence among women without a genital infection was 2.1% and 1.1%, respectively [12]. It was also shown that gender, race/ethnicity, cigarette use, and lifetime number of oral sex partners were associated with concurrent HPV infections of any type [12].

The population study on concurrent and concordant HPV infection in men of rural China showed the prevalence of genital, oral, and concurrent HPV77 infection with any type to be 16.9%, 6.7% and 1.9%, respectively, and the prevalence of any oral HPV among men with and without a genital infection was 11.4% and 5.7%, respectively. Among the men that had a concurrent infection, 62.8% also had a concordant infection [14]. This group also performed a Monte-Carlo simulation which showed that the number of observed concordant infections greatly exceeded the expected number. However, since this study population was from rural China, the results are not generalizable as sexual practices in this population are known to be more conservative [14]. While this Chinese study very thoroughly quantified and analyzed concordant and concurrent HR HPV subtypes, it suffers from a small sample size due to the fact that it is not nationally representative of China (the population in this study is a rural one).

The unique opportunity to quantify and analyze concordance and concurrence over multiple years up through 2014 in a nationally representative U.S. sample is the novelty of this thesis. To this end, we aim to fill in the gaps in knowledge that the aforementioned papers could not or did not address; namely, we quantify and analyze HR HPV concurrent and concordant infections in a U.S. representative sample. The distinction between HR HPV and low-risk HPV that some of the prior research did not make (potentially due to small sample sizes for the HR groups) is a lost opportunity. The distinction is incredibly important from a public health standpoint due to the carcinogenic potential of the HR types. Additionally, we determine whether

HR concurrent and concordant HPV infections are occurring more than expected by random chance. We use the NHANES data set (2013-2014 for men and 2009-2014 for women) which is particularly useful for addressing these questions due to it being a nationally representative survey.

1.3 Specific Aims

1.3.1 Characterize the national prevalence of, and predictors of, high-risk HPV concurrent and concordant infections using NHANES, and relevant subgroups of high-risk HPV types

Although there have been several studies of concurrent and concordant oral and genital HPV infections, there is still a gap in the knowledge, presumably due to sample size limitations or non-representativeness of prior studies. For example, none of the previous studies analyzed only the subgroup of HR HPV infections, which are the HPV types that are attributable to HPV-related cancers and thus are the greatest public health burden. Using NHANES years 2013-2014 for men and 2009-2014 for women gave us the statistical power to focus solely on the high-risk subtypes. Using the NHANES study, we estimated the overall prevalence of HR HPV concurrent and concordant infections as well as concurrent and concordant infections for three relevant sub-groupings of HR HPV, i.e., the HR HPV types covered in the 9-valent vaccine, the three most common HPV types in HPV-associated cancers, HPV 16, 18, and 45, and HPV 16 which is the most common type found in HPV-associated cancers. We then built adjusted logistic regression models to determine the predictors that are associated with overall HR HPV concurrent and concordant infections.

1.3.2 Determine whether high risk concurrent and concordant HPV infections are more prevalent than expected by chance

Using the results from Aim 1, we performed Monte-Carlo simulations to determine (a) whether the observed prevalence of overall HR HPV concurrent infections and (b)

whether the three subgroups of HR HPV are greater than that expected by chance. Similarly, we used Monte Carlo simulations to determine whether the observed prevalence of overall HR HPV concordant infections is greater than that expected by chance. Determining whether concurrent and concordant infections are occurring more frequently than expected will clarify the relationship between genital and oral HR HPV infections from an epidemiological perspective. It will also lend insights to the natural history of HPV infections and HPV transmission dynamics.

2 Methods

2.1 Study Design

For this study we used the NHANES data from 2009-2014 (for which oral HPV data are available). NHANES is freely available for public health research through the Centers for Disease Control and Prevention. As the data are public and fully de-identified , its use does not require institutional review board approval. Briefly, NHANES is a series of cross-sectional 2-year surveys that are designed to assess the health and nutrition of children and adults in the United States [1]. NHANES is designed to be nationally representative of the resident, civilian, non-institutionalized United States population living in the 50 states and District of Columbia [1]. Participants of the survey completed questionnaires administered at home as well as completed a standardized health exam in a Mobile Examination Center (MEC) [1]. In order for there to be a sample sufficient for subgroup analysis, certain demographics are over-sampled including persons age 60 years and older, African Americans, Asians, and Hispanics [1]. The NHANES data collection has been approved through the National Center for Health Statistics Ethics Review Board. The survey uses a complex, multistage, probability sampling design with differential probabilities of selection, and all analyses must take the sample design into account using the sampling weights and sampling design parameters [1].

The data were downloaded from the NHANES website. At the time of this study, oral and genital HPV genotypic data were available in the 2013-2014 NHANES cycle for men and in the 2009-2010, 2011-2012, and 2013-2014 NHANES cycles for women. Since we used multiple cycles of NHANES, new sample weights were computed following the methods outlined in the NHANES weighting module [1]. In short, to create new sample weights for data sets using multiple cycles of NHANES, one must divide the provided weights by the number of cycles being used. Since for men there was only one cycle of NHANES that has oral and genital HPV data, we used the provided sample weights. For women, there were three NHANES cycles with oral and genital HPV data available; therefore, six-year sample weights were created by dividing the provided sample weights by three. Where possible, all analyses were performed taking into account the survey weights and the sampling design in accordance the NHANES guidelines, and all variance estimates were calculated using Taylor series linearization. Estimates with a relative standard error less than 30% are considered unstable and should be interpreted with caution. This study was limited to participants in the publicly available NHANES data who also had valid oral and genital HPV test results. Thus, this limited the study population to men and women age 18-59 years old.

2.2 Specimen Collection and Laboratory Methods

The NHANES procedure for collection and laboratory methods are outlined in detail elsewhere [1]. Briefly, oral samples were collected by having participants rinse and gargle with Scope mouthwash [1]. Next, the samples were sent to Ohio State University Gillison Laboratory [1]. Once there, the samples were purified and analyzed for 37 types of HPV using a multiplex polymerase chain-reaction (PCR) assay [1]. Genital samples were collected by using self-collected vaginal and penile swabs collected at the MEC [1]. The samples were processed at the Chronic Viral Diseases Branch of the CDC using a Roche Linear Array HPV Genotyping test for the same 37 types

of HPV as the oral samples [1]. All oral and genital samples that tested positive for β-globin were considered to be of valid quality for analysis [1]. Of the 37 types of HPV tested for, 18 of them are classified as HR HPV types including types 16, 18, 26, 31, 33, 35, 39, 45, 51, 52, 53, 56, 58, 59, 66, 68, 73, and 82 [2]. These 18 types were used to determine the prevalence of overall HR HPV concurrent and concordant infections. Additionally, three other subgroups of HR HPV were considered, HR HPV types which are covered in the 9-valent HPV vaccine (types 16, 18, 31, 33, 45, 52, and 58), the three most common types found in HPV-associated cervical cancers (types 16, 18, and 45), and the most common type in all HPV-associated cancers (HPV 16) [17, 18].

2.3 Methods: Aim 1

2.3.1 Estimate the national prevalence of HR HPV concurrent and concordant infections

In order to estimate the overall prevalence of HR HPV concurrent infections, we first identified subjects with a HR HPV oral infection and those with HR HPV genital infections. Using this information, a two-way table was created using weighed cross tabulation while taking into account the complex survey design. This led to tables of prevalence estimates for HR HPV oral, genital, and concurrent infections. An odds ratio was computed which is interpreted as the odds of a HR HPV oral infection given that an individual has a HR HPV genital infection versus the odds of a HR HPV oral infection given that an individual does not have a HR HPV genital infection. The calculated OR was compared to 1 using McNemar's Chi-square test. Similarly, for the subgroups of HR HPV genotypes outlined above, the same procedure was followed. This resulted in a total of four tables, each of which has the prevalence estimates for oral, genital, and concurrent infections for overall HR HPV, HR 9-valent vaccine type, HPV 16, 18, and 45, and HPV 16. This process was repeated for the combined men and women populations, as well as and the men and women populations

independently, resulting in 12 two-way tables. Calculation of the McNemar's test used the sample weights without the full NHANES design elements (cluster and strata), as there is currently no statistical method available for this.

Similarly, for HR HPV concordant infections, we identified all subjects with a HR HPV oral infection and those with a HR HPV genital infection. Next, we determined which HR types were at the two anatomical locations and compared them. Individuals were defined as having a HR HPV concordant infection if there was at least one HR HPV type in common between the two sites. Once these individuals were identified, the prevalence of HR HPV concordant infection in the population was estimated taking into account the complex survey design and survey weights. In addition to the overall prevalence of HR HPV concordant infection, we also estimated the prevalence of HR HPV concordant infection among individuals who were positive for HR HPV concurrent infection by limiting the analysis to individuals with a HR HPV concurrent infection. We summarized the results in tables of individuals with concordant infections who show complete (oral HR types exactly match genital HR types) and partial (one or more HR types match between oral and genital sites, but not all match) concordance and the HR HPV types at each anatomic site.

2.3.2 Characterize predictors of HR HPV concurrent and concordant infections

2.3.2.1 Demographic and behavioral predictors to be included in analysis

Predictors included in the analysis were based on those previously shown to be associated with concurrent, concordant, oral, or genital infections. Demographic predictors included race/ethnicity, gender, age group, and marital status; behavioral predictors included number of lifetime any sex (oral, vaginal, and anal sex) partners, number of recent (in the previous 12 months) any sex partners, number of lifetime oral sex partners, number of recent oral sex partners, received HPV vaccine, cigarette

use, marijuana use, and sexual orientation [16, 15, 12, 14, 13, 19, 20]. We coded Race/ethnicity as non-Hispanic white, non-Hispanic black, and other race; gender as male and female; age group as 18 to 24, 25 to 39, 40 to 59; marital status as married, no longer married (includes widowed, divorced, and separated), never married, living with partner, and missing; and lifetime number of any sex partners as 0-1, 2-5, 6-10, 11 or more, and missing. Due to a small sample size for men and the fact oral and penile HPV were only recorded in the 2013-2014 cycle, coding of covariates had to reflect categories with reasonable representation. Thus, we combined lifetime sex partners 0-1 and 2-5; in regards to number of recent sex partners, we coded lifetime number of oral sex partners, and number of recent oral sex partners as 0-1, 2-5, 6 or more, and missing; receiving HPV vaccine as yes, no, and missing; cigarette use and marijuana use as never, ever, and missing; sexual orientation as heterosexual, homosexual/bisexual, and other/missing.

2.3.2.2 Demographic and behavioral predictors tables for HR HPV concurrent and concordant infections

We present a table of demographic and behavioral predictors comparing the prevalence of each predictor in those with and without HR HPV concurrent infection. The columns of each predictor sum to 100% so that the distribution of a predictor could be compared between individuals with and without HR HPV concurrent infections. We calculated the prevalence estimates taking into account the full survey design and estimated 95% confidence intervals for the prevalence using the logistic method. This method fits a logistic regression model and computes a Wald-type interval on the log-odds scale, that is then transformed to the probability scale. Additionally, chi-square test statistics were computed for each predictor using the Rao & Scott correction, which adjusts for the Pearson chi-square statistic by a design effect estimate and then compares it to the chi-square distribution it would have under simple random sampling. All chi-square statistics were considered significant if the p-value was less than

.05. Additionally, chi-square statistics with the p-values between (.05, .01], (.01, .005], and those less than .005 were identified separately. Tables for the demographic and behavioral predictors were created using the same methods for HR HPV concordant infections. Lastly, we produced the HR HPV concurrent and concordant infection tables for men and women combined, as well as for men and women separately.

2.3.2.3 Logistic regression models for HR HPV concurrent and concordant infections Survey weighted logistic regression models were constructed for both HR HPV concurrent and concordant infections to test the association between demographic and behavioral predictors within the outcome. All testing was done using a two-sided test with a significance level of .05. All associations were reported using odds ratios and estimates with p-values between (.05, .01], (.01, .005]. Those less than .005 were identified separately. First, we conducted a univariate analysis of demographic and behavioral predictors using survey weighted logistic regression models to account for the complex survey design. This was followed by an adjusted logistic regression analysis. All adjusted models included ethnicity, age, and gender, when appropriate, as well as predictors which had a category in univariate analysis with a p-value less than .15. Since we only used one NHANES cycle for men, we were not able to run one adjusted logistic model because there were not enough degrees of freedom to include all the predictors selected from the univariate model. As a result, multiple models were created for men which included ethnicity, age group, marital status, and one additional predictor at a time, which had a category in univariate analysis with a p-value that was less than .15. The precedent for this approach to analysis with NHANES when there is insufficient data can be found in Patel et al [16].

2.4 Methods: Aim 2

2.4.1 Determine whether HR HPV concurrent infection is more prevalent than expected by chance

Unlike other studies, we hypothesized and tested via simulation that the prevalence of concurrent infections in men and women (separately and combined) would be greater than that expected by chance. In order to determine if HR HPV concurrent infection was more prevalent than expected by chance, the prevalence estimates for HR HPV oral and genital infections from Aim 1 were used in a Monte Carlo simulation holding each prevalence estimate (genital and oral) constant. A population of 10,000 individuals and their HR HPV oral and genital status were simulated. HR HPV oral and genital status were simulated using binomial distributions with the probability of infection equal to the estimated prevalence of HR HPV oral and genital infections in the population, respectively. We calculated the prevalence of HR HPV concurrent infection in the simulated population and compared it to the observed prevalence of HR HPV concurrent infection. This process was repeated 10,000 times, and the expected prevalence was calculated by taking the average of these estimates. The p-values comparing the expected and observed prevalence estimates were calculated by counting the number of simulated HR HPV concurrent infection prevalence estimates which were smaller than the observed prevalence in the population and dividing by the total number of simulations. The simulated proportions were also used to calculate the 95% confidence interval for the simulated proportion by taking the 2.5 and 97.5 percentiles of the simulated proportions. We repeated this for the four groups of HR HPV infection, all HR HPV types, HR 9-valent vaccine types, HPV 16, 18, and 45, and HPV 16, in the combined population as well as for men and women separately.

2.4.2 Determine whether HR HPV concordant infection is more prevalent than expected by chance

To determine if HR HPV concordant infection is more prevalent than expected by chance, we applied a Monte Carlo simulation similar to the above. First, we estimated the prevalence of oral and genital infections for each of the 18 HR HPV types. A population of 10,000 individuals and their HR HPV type specific oral and genital status was simulated. HR HPV Type specific oral and genital status was simulated by binomial distributions where the probability of infection for a specific type at a particular anatomic site is equal to the prevalence of that type in the specified location in the population. The prevalence of HR HPV concordance of the simulated population was calculated by identifying the proportion simulated subjects who had at least one HR HPV type in common between both oral and genital sites. This process was repeated 10,000 times, and a p-values and 95% confidence intervals were calculated in the same way as outlined above. This was done for the combined population of men and women as well as men and women separately.

3 Results

3.1 Aim 1

3.1.1 National prevalence of HR HPV concurrent and concordant infections

The estimated prevalence results for HR HPV concurrent infections are summarized in Table 1. The estimated prevalence of overall HR HPV concurrent infection in the United States total population, men, and women was 2.4% (n=116, 95% CI=(1.7, 3.3)), 4.0% (n=65, 95% CI=(2.7, 5.9)), and 0.76% (n=51, 95% CI=(0.52, 1.1)), respectively. For the combined population, the prevalence of a HR HPV oral infections among individuals with versus without a HR HPV genital infection was 8.7% and

2.4%, respectively, and the prevalence of HR HPV genital infections among individuals with versus without a HR HPV oral infection was 57.2% and 26.0%, respectively. For men, the prevalence of a HR HPV oral infections among men with versus without a HR HPV genital infection was 13.7% and 3.9%, respectively, and the prevalence of HR HPV genital infections among men with versus without a HR HPV oral infection was 59.4% and 27.1%, respectively. For women, the prevalence of a HR HPV oral infections among women with versus without a HR HPV genital infection was 3.0% and 1.1%, respectively, and the prevalence of HR HPV genital infections among individuals with versus without a HR HPV oral infection was 47.9% and 24.9%, respectively. The odds of a HR HPV oral infection for those with versus without a HR HPV genital infection for the total population, men, and women was 3.81 (McNemar p-value $<$ .005), 3.93 (McNemar p-value $<$ .005), and 2.77 (McNemar p-value $<$ .005), respectively. The estimated prevalence of HR 9-valent vaccine type HPV concurrent infection in the United States total population, men, and women was 0.70% (n=33, 95% CI=(0.41, 1.2)), 1.1% (n=17, 95% CI=(0.58, 2.3)), and 0.27% (n=16, 95% CI=(0.15, 0.49)), respectively. The odds of a HR 9-valent vaccine type HPV oral infection for those with versus without a HR 9-valent vaccine type HPV genital infection for the total population, men, and women was 4.79 (McNemar p-value $<$ .005), 4.5 (McNemar p-value $<$ .005), and 5.31 (McNemar p-value $<$ .005), respectively. The estimated prevalence of a concurrent HPV 16, 18, or 45 infection in the United States total population, men, and women was 0.37% (n=23, 95% CI=(0.20, 0.68)), 0.51% (n=11, 95% CI=(0.22, 1.2)), and 0.22% (n=12, 95% CI=(0.10, 0.49)), respectively. The odds of an HPV 16, 18, or 45 oral infection for those with versus without a HPV 16, 18, or 45 genital infection for the total population, men, and women were 5.3 (McNemar p-value $<$ .005), 4.18 (McNemar p-value $<$ .005), and 10.57 (McNemar p-value $<$ .005), respectively. The estimated prevalence of HPV 16 concurrent infection in the United States total population, men, and women was 0.16% (n=12, 95% CI=(0.08, 0.32)), 0.18% (n=6, 95% CI=(0.07, 0.47)), and 0.13%

(n=6, 95% CI=(0.05, 0.35)), respectively. The odds an HPV 16 oral infection for those with versus without an HPV 16 genital infection for the total population, men, and women were 4.28 (McNemar p-value $< .005$), 2.6 (McNemar p-value $< .005$), and 16.16 (McNemar p-value $< .005$), respectively.

The estimated prevalence results for HR HPV concordant infections are summarized in Tables 2 and 3. The estimated prevalence of HR HPV concordant infection in the United States total population, men, and woman was 0.99% (n=59, 95% CI=(0.66, 1.5)), 1.5% (n=29, 95% CI=(0.88, 2.6)), and 0.47% (n=30, 95% CI=(0.31, 0.74)), respectively. The estimated prevalence of HR HPV concordant infection among individuals that have a HR HPV concurrent infection in the United States total population, men, and women was 41.6% (n=59, 95% CI=(31.2, 52.8)), 37.6% (n=29, 95% CI=(25.4, 51.6)), and 62.6% (n=30, 95% CI=(47.2, 75.8)), respectively.

3.1.2 Characterization of demographic and behavioral predictors of HR HPV concurrent and concordant infections

3.1.2.1 Summary of demographic and behavioral predictors HR HPV concurrent infections

Demographic and behavioral characteristics for HR HPV concurrent infections for all three populations are further summarized in Tables 4 through 6. A total of 7010 individuals were tested for both genital and oral HPV infections of which 116 individuals were identified as having a HR HPV concurrent infection. The ethnic distribution of individuals with HR HPV concurrent infection was 59 white (72.7%), 28 black (16.0%), and 29 other (11.3%) and the distribution of those without HR HPV concurrent infection was 2,713 white (62.3%), 1,483 black (12.2%), and 2,698 other (25.5%). Ethnicity showed a significant association with HR HPV concurrent infection with a chi-square p-value $< .005$. The distribution for age group among individuals with a HR HPV concurrent infection was 29 in the 18 to 24 age group (16.2%), 40 in the 25 to 39 age group (35.2%), and 47 in the 40 to 59 age group

(48.7%), and for those without a HR HPV concurrent infection, it was 1,375 in the 18 to 24 age (17.5%), 2,373 in the 25 to 39 age group (34.8%), and 3,146 in the 40 to 59 age group (47.7%). Age group did not show a significant association with HR HPV concurrent infection. Of the participants with a HR HPV concurrent infection and those without there were 65 males (84.0%), and 51 females (16.0%) and 1,618 males (48.9%), and 5,276 females (51.1%), respectively. Gender was shown to be significantly associated with HR HPV concurrent infection with a chi-squared p-value $< .005$.

A total of 1,683 men were tested for both genital and oral HPV infections. The ethnic distribution of men with a HR HPV concurrent infection was 38 white (75.4%), 18 black (16.0%), and 9 other (8.6%) and those without were 653 white (61.7%), 330 black (11.5%), and 635 other (26.8%). For men, ethnicity was also significantly associated with HR HPV concurrent infections with a chi-squared p-value $< .005$. The distribution of age among men with a HR HPV concurrent infection was 14 in the 18 to 24 age group (15.0%), 24 in the 25 to 39 age group (36.1%), and 27 in the 40 to 59 age group (48.9%) and those without was 337 in the 18 to 24 age group (18.3%), 565 in the 25 to 39 age group (35.4%), and 716 in the 40 to 59 age group (46.3%). Age was not significantly associated with HR HPV concurrent infection in men.

A total of 5,327 women were tested for both genital and oral HPV infections. The ethnic distribution of women with a HR HPV concurrent infection was 21 white (58.6%), 10 black (16.2%), and 20 other (25.2%), and those without was 2,060 white (62.9%), 1,153 black (12.9%), and 2,063 other (24.2%). There was not a significant association between HR HPV concurrent infections and ethnicity in women. The distribution of age among women with a HR HPV concurrent infection was 15 in the 18 to 24 age group (22.4%), 16 in the 25 to 39 age group (30.1%), and 20 in the 40 to 59 age group (47.5%). For those without was 1,038 in the 18 to 24 age group (16.7%), 1,808 in the 25 to 39 age group (34.3%), and 2,430 in the 40 to 59 age group (49.0%). There was not a significant association between HR HPV concurrent infection and

age for women.

3.1.2.2 Summary of demographic and behavioral predictors HR HPV concordant infections

Demographic and behavioral characteristics for HR HPV concordant infections for all three populations are further summarized in Tables 4 through 6. A total of 7,010 individuals were tested for both genital and oral HPV infections of which 59 individuals were identified as having a HR HPV concordant infection. The ethnic distribution of individuals with a HR HPV concordant infection was 32 white (71.1%), 12 black (16.5%), and 15 other (12.4%). The distribution of those without HR HPV concordant infection was 2,740 white (62.5%), 1,499 black (12.3%), and 2,712 other (25.3%). There was not a significant association between HR HPV concordant infection and ethnicity. The distribution for age group among individuals with a HR HPV concordant infection was 19 in the 18 to 24 age group (22.8%), 19 in the 25 to 39 age group (41.9%), and 21 in the 40 to 59 age group (35.3%). For those without a HR HPV concordant infection, it was 1,385 in the 18 to 24 age group (17.4%), 2,394 in the 25 to 39 age group (34.7%), and 3,172 in the 40 to 59 age group (47.9%). Age group did not show a significant association with HR HPV concordant infection. Of the participants with a HR HPV concordant infection and those without there were 29 males (75.9%), and 30 females (24.1%), and 1,654 males (49.5%), and 5,297 females (50.5%), respectively. Gender was shown to be significantly associated with HR HPV concordant infection with a chi-squared p-value $< .005$.

The ethnicity distribution of men with a HR HPV concordant infection was 38 white (75.4%), 18 black (16.0%), and 9 other (8.6%) and those without were 653 white (61.7%), 330 black (11.5%), and 635 other (26.8%). For men, ethnicity was significantly associated with HR HPV concordant infections with a chi-squared p-value $< .05$. The distribution of age among men with a HR HPV concordant infection was 8 in the 18 to 24 age group (21.0%), 12 in the 25 to 39 age group (48.5%), and 9

in the 40 to 59 age group (30.5%) and those without was 343 in the 18 to 24 age group (18.2%), 577 in the 25 to 39 age group (35.2%), and 734 in the 40 to 59 (46.7%). Age did not show a significant association with HR HPV concordant infection in men.

The ethnicity distribution of women with a HR HPV concordant infection was 15 white (69.6%), 4 black (8.3%), and 11 other (22.2%) and those without was 2,066 white (62.8%), 1,159 black (13.0%), and 2,072 other (24.2%). There was not a significant association between HR HPV concordant infections and ethnicity in women. The distribution of age among women with a HR HPV concordant infection was 11 in the 18 to 24 age group (28.4%), 7 in the 25 to 39 age group (21.2%), and 12 in the 40 to 59 age group (50.4%) and for those without was 1,042 in the 18 to 24 age group (16.7%), 1,817 in the 25 to 39 age group (34.3%), and 2,438 in the 40 to 59 age group (49.0%). There was not a significant association between HR HPV concordant infection and age for women.

3.1.3 Logistic regression models for HR HPV concurrent and concordant infection

3.1.3.1 Univariable logistic regression models for HR HPV concurrent infection

The results of the univariable logistic regression models for HR HPV concurrent infections for the combined population, men, and women are provided in Tables 7 through 9. Due to issues of singularity in the multivariable models, all participants with missing data for the sexual history questions were removed from the models (n=609). After removing them, there were no longer any participants with HR HPV concurrent or concordant infections in the missing category for marijuana use in the combined population, men, and women, and, thus, this category was removed from analysis as well (n=14). Additionally, there were no longer any women with HR HPV concurrent or concordant infection in the missing category for HPV vaccination status, and this level was dropped from the women models only (n=148).

For the combined population in the univariate logistic models, there were only a few variables (age group, HPV vaccination status, and cigarette use) which showed no statistically significant association with HR HPV concurrent infections. All other predictors had at least one category which showed a significant association with HR HPV concurrent infection. In regards to ethnicity, both white and black individuals showed a significant positive association with HR HPV concurrent infection compared to the other ethnicity. For gender, females showed a significant negative association with HR HPV concurrent infection compared to males. For marital status, no longer married, never married, and living with partner showed a significant positive association with HR HPV concurrent infection compared to married individuals. For lifetime number of sex partners, individuals with 6-10 and 11+ partners showed a significant positive association with HR HPV concurrent infections compared to those with 0-1 partners. For recent number of sex partners, individuals with 2-5 and 6+ partners showed a significant positive association with HR HPV concurrent infection compared to those with 0-1 partners. For lifetime oral sex partners, individuals with 6+ partners showed a significant positive association with HR HPV concurrent infection compared to those with 0-1 partners. For recent number of oral sex partners, individuals with 2-5 and 6+ partners showed significant positive associations with HR HPV concurrent infection compared to those with 0-1 partners. For marijuana use, individuals who had ever used marijuana showed a significant positive association with HR HPV concurrent infections compared to those who had never used marijuana. For sexual orientation, individuals who identified as homosexual or bisexual showed a significant positive association with HR HPV concurrent infection compared to heterosexuals.

Age group, HPV vaccination status, and cigarette use showed no statistically significant association with HR HPV concurrent infections in men. For ethnicity, both white and black men showed a significant positive association with HR HPV concurrent infection compared to the other ethnicity. For marital status, no longer married, never married, and living with partner showed a significant positive association with

HR HPV concurrent infection compared to married men. For lifetime number of sex partners, men with 6-10 and 11+ partners showed a significant positive association with HR HPV concurrent infections compared to those with 0-5 partners. For recent number of sex partners, men with 2-5 and 6+ partners showed a significant positive association with HR HPV concurrent infection compared to those with 0-1 partners. For lifetime oral sex partners, men with 6+ partners showed a significant positive association with HR HPV concurrent infection compared to those with 0-1 partners. For recent number of oral sex partners, men with 2-5 and 6+ partners showed significant positive associations with HR HPV concurrent infection compared to those with 0-1 partners. For marijuana, use men who had ever used marijuana showed a significant positive association with HR HPV concurrent infections compared to those who had never used marijuana. For sexual orientation, men who identified as homosexual or bisexual showed a significant positive association with HR HPV concurrent infection compared to heterosexuals.

Ethnicity, age group, HPV vaccination status, and sexual orientation showed no statistically significant association with HR HPV concurrent infections in women. For marital status, no longer married, never married, and women with missing data showed a significant positive association with HR HPV concurrent infection compared to married women. For lifetime number of sex partners, women with 11+ partners showed a significant positive association with HR HPV concurrent infections compared to those with 0-1 partners. For recent number of sex partners, women with 2-5 and 6+ partners showed a significant positive association with HR HPV concurrent infection compared to those with 0-1 partners. For lifetime oral sex partners, women with 6+ partners showed a significant positive association with HR HPV concurrent infection compared to those with 0-1 partners. For recent number of oral sex partners, women with 2-5 and 6+ partners showed significant positive associations with HR HPV concurrent infection compared to those with 0-1 partners. For cigarette use, women who had ever smoked and those with missing data both showed a significant

positive association with HR HPV concurrent infection compared to those who had never smoked cigarettes. For marijuana use, women who had ever used marijuana showed a significant positive association with HR HPV concurrent infections compared to those who had never used marijuana.

3.1.3.2 Multivariable logistic regression models for HR HPV concurrent infection

The multivariable logistic models were created using covariates that had at least one category which was significant in addition to ethnicity, age group, and gender, where appropriate. For the combined population this included ethnicity, gender, age group, marital status, lifetime number of sex partners, recent number of sex partners, lifetime number oral partners, recent number of oral partners, marijuana use, and sexual orientation. Covariates which were significant in the multivariable logistic regression model of HR HPV concurrent infection for the combined population included gender and lifetime number of sex partners. For gender, females showed a significant negative association with HR HPV concurrent infection compared to males (OR = 0.25; 95% CI = (0.15, 0.42); p-value $<$ .005). For lifetime number of sex partners, the groups 6-10 and 11+ showed a significant positive association with HR HPV concurrent infection compared to individuals with 0-1 partners (OR = 5.5; 95% CI = (1.5, 20.7); p-value $<$ .05, and OR = 16.7; 95% CI = (4.0, 69.9); p-value $<$ .005, respectively).

The covariates used for the multivariable logistic models for men included ethnicity, age group, marital status, lifetime number of sex partners, recent number of sex partners, lifetime number of oral sex partners, recent number of oral sex partners, marijuana use, and sexual orientation. As stated in the methods section, there were not enough degrees of freedom to run a single multivariable model due to a lack of sample size. Therefore, multiple models were run, all of which include ethnicity, age group, marital status in addition to one other covariate. Covariates which were signif-

icant in the multivariable logistic regression models included marital status, lifetime number of sex partners, lifetime number of oral partners, recent oral partners, marijuana use, and sexual orientation. For marital status, men who were never married showed a significant positive association with HR HPV concurrent infection compared to married men (OR = 2.6; 95% CI = (1.3, 5.5); p-value $<$ .05). For lifetime number of sex partners, men with 6-10 and 11+ partners showed a positive association with HR HPV concurrent infection compared to men with 0-5 partners (OR = 5.0; 95% CI = (1.7, 14.6); p-value $<$ .05, and OR = 27.8; 95% CI = (7.8, 98.5); p-value $<$ .005, respectively). For lifetime number of oral partners, men with 6+ partners showed a significant positive association with HR HPV concurrent infection compared to those with 0-1 partners (OR = 10.8; 95% CI = (3.3, 34.9); p-value $<$ .05). For recent number of oral sex partners, men with 2-5 partners showed a significant positive association with HR HPV concurrent infection compared to men with 0-1 partners (OR = 2.8; 95% CI = (1.6, 4.9); p-value $<$ .05). For marijuana use, men who had ever used marijuana showed a significant positive association with HR HPV concurrent infections compared to those who had never used marijuana (OR = 2.8; 95% CI = (1.3, 6.1); p-value $<$ .05). For sexual orientation homosexual and bisexual men showed a significant positive association with HR HPV concurrent infection compared to heterosexuals (OR = 4.2; 95% CI = (1.6, 11.2); p-value $<$ .05).

For women, the multivariable logistic regression model ethnicity, age group, marital status, lifetime number of sex partners, recent number of sex partners, lifetime number of oral sex partners, recent number of oral sex partners, cigarette use, and marijuana use were all included in the model. In this adjusted model, none of the covariates showed a statistically significant association with HR HPV concurrent infections.

3.1.3.3 Univariable logistic regression models for HR HPV concordant infection

The results of the univariable logistic regression models for HR HPV concordant infections for the combined population, men, and women are provided in Tables 7 through 9. For the combined population in the univariable logistic models age group, HPV vaccination status, and marijuana use showed no statistically significant association with HR HPV concordant infections. All other predictors had at least one category which showed a significant association. For ethnicity, black individuals showed a significant positive association with HR HPV concordant infection compared to the other ethnicity. For gender, females showed a significant negative association with HR HPV concordant infection compared to males. For marital status, no longer married and never married showed a significant positive association with HR HPV concordant infection compared to married individuals. For lifetime number of sex partners, individuals with 6-10 and 11+ partners showed a significant positive association with HR HPV concordant infections compared to those with 0-1 partners. For recent number of sex partners, individuals with 2-5 and 6+ partners showed a significant positive association with HR HPV concordant infection compared to those with 0-1 partners. For lifetime oral sex partners, individuals with 6+ partners showed a significant positive association with HR HPV concordant infection compared to those with 0-1 partners. For recent number of oral sex partners, individuals with 2-5 and 6+ partners showed significant positive associations with HR HPV concordant infection compared to those with 0-1 partners. For cigarette use, individuals that had ever smoked cigarettes showed a significant positive association with HR HPV concordant infection compared to those who never smoked cigarettes. For sexual orientation, individuals who identified as homosexual or bisexual showed a significant positive association with HR HPV concordant infection compared to heterosexuals.

For men, age group, HPV vaccination status, cigarette use, and marijuana use showed no statistically significant association with HR HPV concordant infections. For ethnicity, black men showed a significant positive association with HR HPV concordant infection compared to the other ethnicity. For marital, status never married

men showed a significant positive association with HR HPV concordant infection compared to married men. For lifetime number of sex partners, individuals with 11+ partners showed a significant positive association with HR HPV concordant infections compared to those with 0-5 partners. For recent number of sex partners, men with 2-5 and 6+ partners showed a significant positive association with HR HPV concordant infection compared to those with 0-1 partners. For lifetime oral sex partners, men with 6+ partners showed a significant positive association with HR HPV concordant infection compared to those with 0-1 partners. For recent number of oral sex partners, men with 2-5 and 6+ partners showed significant positive associations with HR HPV concordant infection compared to those with 0-1 partners. For sexual orientation, men who identified as homosexual or bisexual showed a significant positive association with HR HPV concordant infection compared to heterosexuals.

For women ethnicity, HPV vaccination status, and sexual orientation showed no statistically significant association with HR HPV concordant infections. Age group 25-39 years showed a significant negative association with HR HPV concordant infections compared to the 18-24 age group. For marital status, women with missing data showed a significant positive association with HR HPV concordant infection compared to married women. For lifetime number of sex partners, women with 11+ partners showed a significant positive association with HR HPV concordant infections compared to those with 0-1 partners. For recent number of sex partners, women with 2-5 and 6+ partners showed a significant positive association with HR HPV concordant infection compared to those with 0-1 partners. For lifetime oral sex partners, women with 6+ partners showed a significant positive association with HR HPV concordant infection compared to those with 0-1 partners. For recent number of oral sex partners, women with 2-5 and 6+ partners showed significant positive associations with HR HPV concordant infection compared to those with 0-1 partners. For cigarette use, women who had ever smoked and those with missing data both showed a significant positive association with HR HPV concordant infection. For marijuana use, women

who had ever used marijuana showed a significant positive association with HR HPV concordant infections compared to those who had never used marijuana.

3.1.3.4 Multivariable logistic regression models for HR HPV concordant infection

The multivariate logistic models for HR HPV concordant infection were created using covariates which had at least one category which was significant in addition to ethnicity, age group, and gender, where appropriate. For the combined population, the covariates included in the model were ethnicity, gender, age group, marital status, lifetime number of sex partners, recent number of sex partners, lifetime number of oral sex partners, recent number of oral sex partners, cigarette use, and sexual orientation. Covariates which were significant in the combined population multivariable model for HR HPV concordant infection were gender and lifetime number of sex partners. For gender, females showed a significant negative association with HR HPV concordant infection compared to males (OR = 0.35; 95% CI = (0.16, 0.78); p-value $<$ .05). For lifetime number of sex partners, the groups 6-10 and 11+ showed a significant positive association with HR HPV concordant infection compared to individuals with 0-1 partners (OR = 5.1; 95% CI = (1.3, 19.9); p-value $<$ .05 and OR = 16.1; 95% CI = (3.4, 75.5); p-value $<$ .005, respectively).

The covariates used for the multivariable logistic models for HR HPV concordant infection in men included ethnicity, age group, marital status, lifetime number of sex partners, recent number of sex partners, lifetime number of oral sex partners, recent number of oral sex partners, and sexual orientation. The same procedures were used to create the HR HPV concordant multivariable models for men as in the HR HPV concurrent multivariable models for men. Covariates which were significant in the multivariable logistic regression models included lifetime number of sex partners, recent number of sex partners, and sexual orientation. For lifetime number of sex partners, men with 11+ partners showed a positive association with HR HPV concor-

dant infection compared to men with 0-5 partners (OR = 11.1; 95% CI = (2.6, 46.6); p-value $< .05$). For recent number of sex partners, men with 2-5 partners showed a significant positive association with HR HPV concordant infection compared to those with 0-1 partners (OR = 2.7; 95% CI = (1.3, 5.6); p-value $< .05$). For sexual orientation, men who identified as homosexual and bisexual showed a significant positive association with HR HPV concordant infection compared to heterosexuals (OR = 8.5; 95% CI = (2.6, 27.2); p-value $< .05$).

The covariates used in the multivariable logistic models for HR HPV concordant infection in women included ethnicity, age group, marital status, lifetime number of sex partners, recent number of sex partners, lifetime number of oral sex partners, recent number of oral sex partners, cigarette use, and marijuana use. Only cigarette use showed a significant association with HR HPV concordant infection. Women who had ever smoked cigarettes showed a positive association with HR HPV concordant infections (OR = 3.3; 95% CI = (1.3, 8.1); p-value $< .05$).

3.2 Aim 2

3.2.1 Determine whether HR HPV concurrent infections are more prevalent than expected by chance

The results for all HR HPV concurrent infections can be found in Figures 1 through 3. The estimated prevalence of any HR HPV in the genital and oral cavity for the combined population was 27.3% (95% CI: 25.9, 28.8) and 4.2% (95% CI: 3.3, 5.3), respectively. These numbers were used to estimate the expected prevalence of any HR HPV concurrent infections at 1.1% (95% CI: .93, 1.35), which were significantly less than the observed prevalence (1.1% vs. 2.4%; p-value = 0). The estimated prevalence of any HR HPV in the genital and oral cavity for men was 29.3% (95% CI: 27.2, 31.6) and 6.7% (95% CI: 4.9, 9.1), respectively. These numbers were used to estimate the expected prevalence of any HR HPV concurrent infections in men at 1.98% (95% CI: 0.0171, 0.0226), significantly less than the observed prevalence (1.98%

vs. 4.0%; p-value = 0). The estimated prevalence of any HR HPV in the genital and oral cavity for women was 25.3% (95% CI: 23.4, 27.3) and 1.6% (95% CI: 1.2, 2.1), respectively. These numbers were used to estimate the expected prevalence of any HR HPV concurrent infections in women at 0.40% (95% CI: 0.0028, 0.0053), significantly less than the observed prevalence (0.40% vs. 0.76%; p-value = 0).

The estimated prevalence of HR 9-valent vaccine types in the genital and oral cavity for the combined population was 12.2% (95% CI: 11.3, 13.2) and 1.8% (95% CI: 1.3, 2.5), respectively. These numbers were used to estimate the expected prevalence of HR 9-valent vaccine type concurrent infections in the combined population at 0.22% (95% CI: 0.0013, 0.0032), significantly less than the observed prevalence (0.22% vs. 0.70%; p-value = 0). The estimated prevalence of HR 9-valent vaccine types in the genital and oral cavity for men was 13.0% (95% CI: 11.6, 14.5) and 3.0% (95% CI: 2.0, 4.4), respectively. These numbers were used to estimate the expected prevalence of HR 9-valent vaccine type concurrent infections in men at 0.39% (95% CI: 0.0027, 0.0052), significantly less than the observed prevalence (0.39% vs. 1.1%; p-value = 0). The estimated prevalence of HR 9-valent vaccine types in the genital and oral cavity for women was 11.4% (95% CI: 10.2, 12.7) and 0.67% (95% CI: 0.43, 1.0), respectively. These numbers were used to estimate the expected prevalence of HR 9-valent vaccine type concurrent infections in women at 0.08% (95% CI: 0.0003, 0.0014), significantly less than the observed prevalence (0.08% vs. 0.27%; p-value = 0).

The estimated prevalence of HPV 16, 18, or 45 in the genital and oral cavity for the combined population was 7.2% (95% CI: 6.4, 8.0) and 1.3% (95% CI: 0.90, 1.9), respectively. These numbers were used to estimate the expected prevalence of HPV 16, 18, or 45 concurrent infections in the combined population at 0.09% (95% CI: 0.0004, 0.0016) and were significantly less than the observed prevalence (0.09% vs. 0.37%; p-value = 0). The estimated prevalence of HPV 16, 18, or 45 in the genital and oral cavity for men was 7.6% (95% CI: 6.4, 9.0) and 2.1% (95% CI: 1.3, 3.3), respectively. These numbers were used to estimate the expected prevalence of HPV 16, 18, or 45

concurrent infections in men at 0.16% (95% CI: 0.0009, 0.0024), significantly less than the observed prevalence (0.16% vs. 0.51%; p-value = 0). The estimated prevalence of HPV 16, 18, or 45 in the genital and oral cavity for women was 6.7% (95% CI: 5.8, 7.8) and 0.51% (95% CI: 0.29, 0.90), respectively. These numbers were used to estimate the expected prevalence of HPV 16, 18, or 45 concurrent infections in women at 0.03% (95% CI: 0.0000, 0.0008) and were significantly less than the observed prevalence (0.03% vs. 0.22%; p-value = 0).

The estimated prevalence of HPV 16 in the genital and oral cavity for the combined population was 4.0% (95% CI: 3.4, 4.8) and 1.0% (95% CI: 0.75, 1.5), respectively. These numbers were used to estimate the expected prevalence of HPV 16 concurrent infections in the combined population at 0.04% (95% CI: 0.0001, 0.0009) and were significantly less than the observed prevalence (0.04% vs. 0.16%; p-value = .0001). The estimated prevalence of HPV 16 in the genital and oral cavity for men was 4.4% (95% CI: 3.3, 5.8) and 1.8% (95% CI: 1.2, 2.6), respectively. These numbers were used to estimate the expected prevalence of HPV 16 concurrent infections in men at 0.08% (95% CI: 0.0003, 0.0014), also significantly less than the observed prevalence (0.08% vs. 0.18%; p-value = .0004). The estimated prevalence of HPV 16 in the genital and oral cavity for women was 3.7% (95% CI: 3.0, 4.5) and 0.34% (95% CI: 0.19, 0.63), respectively. These numbers were used to estimate the expected prevalence of HPV 16 concurrent infections in women at 0.01% (95% CI: 0.0000, 0.0004), significantly less than the observed prevalence (0.01% vs. 0.13%; p-value = 0).

3.2.2 Determine whether HR HPV concordant infections are more prevalent than expected by chance

The estimated prevalence HR HPV of genital and oral infections by HPV subtypes for the combined population can be found in Figure 4. These estimates were used to calculate the expected prevalence of HR HPV concordant infections for the combined population at .15% (95% CI: 0.08, 0.23). The expected prevalence was significantly

less than the observed prevalence (.15% vs. 0.99%; p-value = 0). The estimated prevalence HR HPV of genital and oral infections by HPV subtypes for men can be found in Figure 5. These estimates were used to calculate the expected prevalence of HR HPV concordant infections for men at .26% (95% CI: 0.17, 0.37). The expected prevalence was significantly less than the observed prevalence (.15% vs. 1.5%; p-value = 0). Additionally, the estimated prevalence HR HPV of genital and oral infections by HPV subtypes for women can be found in Figure 6. These estimates were used to calculate the expected prevalence of HR HPV concordant infections for women at .05% (95%CI: 0.01, 0.11). The expected prevalence was significantly less than the observed prevalence (.05% vs. .47%; p-value = 0).

4 Discussion

Currently, research on HPV concurrent and concordant infections is limited, and, to our knowledge, this is the first study to focus solely on HR HPV type concurrent and concordant infections in the general United States population in both men and women. This study estimates that 2.4% of the combined population has a HR HPV concurrent infection and 0.99% have a HR HPV concordant infection. Using the 2010 census population, this equates to an estimated 7.4 million Americans with HR HPV concurrent infections and 3.1 million with HR HPV concordant infections. Based on the estimates of HR HPV concurrent and concordant infections for men, 4.0% and 1.5%, respectively, this is about 6.1 million men with HR HPV concurrent infections and 2.3 million men with HR HPV concordant infections. Similarly, the estimates of HR HPV concurrent and concordant infections for women, .76% and .47%, respectively, equates to 1.2 million women with HR HPV concurrent infections and 700,000 women with HR HPV concordant infections. Also of interest is the number of HR 9-valent vaccine type concurrent infections in the population which have an estimated prevalence of 1.1% and .27% for men and women, respectively.

This amounts to about 1.7 million men and just over 400,000 women who have a HR 9-valent vaccine type concurrent infection that could potentially have been prevented by the HPV 9-valent vaccine.

Several studies have shown that individuals with an infection at one anatomic location are more likely to have an infection at the other site. Kedarisetty et al showed that for any HPV type, 6.8% of women with a vaginal HPV infection had an oral HPV infection while 1.0% of women with no vaginal HPV infection had an oral HPV infection [15]. Similarly, 75.9% of women with an oral HPV infection had a vaginal HPV infection while 42.2% of woman with no oral HPV infection had a vaginal HPV infection [15]. Patel et al found similar results for any HPV type in men with 19.3% of men with a penile HPV infection had an oral HPV infection while 4.4% of men with no penile HPV infection had an oral HPV infection [16]. Additionally, Sonawane et al showed similar associations for oral HPV infections between both men and women with and without genital HPV infections [12]. This is consistent with our results which showed for the combined population, men, and women of individuals with a HR HPV genital infection versus those without are more likely to have a HR HPV oral infection; similarly, those with a HR HPV oral infection are more likely to have a HR HPV genital infection versus those without a HR HPV oral infection.

Additionally, the results of our simulations further support the notion that genital and oral HPV infections are not independent of one another. These simulations show what the expected prevalence of HR HPV concurrent genital and oral infections would be if they were occurring at random given the rates of genital and oral HR HPV infection in the population. For all three populations and four subgroups of HR HPV analyzed, the observed rate of HR HPV concurrent infection was significantly higher than the expected rate. In most cases the observed rate of HR HPV concurrent infections was two to four times higher than the expected rate. Similar results were shown for the rates of HR HPV concordant infections as well, with the observed rate being about 7, 6, and 9 times greater than the expected rate for the

combined population, men, and women, respectively. Despite the fact that HR HPV concurrent infections are relatively rare, the rates of HR HPV concordant infection were quite high particularly in women (41.6%, 37.6%, and 62.6% for the combined population, men, and women, respectively). These simulation results were similar to those in a study of concurrent and concordant infections with any type of HPV in a rural Chinese population [14]. Overall, these results could have important clinical implications and, as suggested by Kedarisetty et al, serve as the basis for increased screening of individuals known to have an HPV infection at 1 anatomic site [15]. Currently there is no protocol for HPV positive OPC screening, and these findings suggest that increased screening for OPC in individuals known to have a HR HPV genital infection is warranted [15]. Conversely, individuals diagnosed with HPV associated OPCs should be more closely monitored for genital infections and cancers, since persons known to have a HR HPV oral infection are much more likely to have a HR HPV genital infection than those without an oral infection [15].

In the United States, rates of any HPV in the genitals are known to be similar for men and women, while for any HPV and HR HPV oral infection rates were higher in men than women 11.5% and 3.2% and 7.3% and 1.4%, respectively [16, 15, 12]. We found similar results, with rates of genital HR HPV infections being similar between men and women for the four groups of HR HPV analyzed, all HR, HR 9-valent vaccine types, HPV 16, 18, and 45, and HPV 16, while the rates of oral infections for these four groupings of HR HPV were four to five times higher in men than in women. It is not known why the rates of oral HPV infection are higher in men than women, but theories include that men have more sexual partners than women, transmission of HPV is more efficient when performing oral sex on infected females compared to infected males, and women may have partial systematic immunity from cervical infections that protect them against oral HPV infections, which men do not [3]. Given that rates of genital HPV infections are similar between men and women and that oral HPV is much more common in men, it is not surprising that rates of concurrent and

concordant HR HPV infections were also higher among men. For all HR HPV types the rate of concurrent infection is significantly different between men and women, approximately 5-fold greater in men. Similar results were seen for the HR 9-valent vaccine types with the rate in men being 4 times that of women. While the rates of concurrent infections for the other groupings of HPV, types 16, 18, or 45, and HPV 16, were higher in men than women, the differences were not statistically significant.

We found a similar result for HR HPV concordant infections with the rate being about 3 times higher in men than in women which was statistically significant. These differences in HR HPV concurrent and concordant infections between men in women are consistent with two studies analyzing any HPV concurrent and concordant infections between men and women separately [16, 15]. In one study of United States men, the prevalence of any HPV concordant infection among those with any HPV concurrent infection (note this includes low and high-risk HPV) was 36.2% [16]. In a study of men in rural China, the same prevalence was 62.8% [14]. Although our population is quite different from that of rural Chinese men, our results showed a prevalence of HR HPV concordant infection among men with a HR HPV concurrent infection of about 38%, i.e., closer to findings in the U.S. study. To our knowledge, this has not been previously examined in women, yet we found a prevalence of HR HPV concordant infection among women with a HR HPV concurrent infection was nearly 63%. A higher rate of HR HPV concordant infections among women with HR HPV concurrent infection is a particularly interesting result considering that HR HPV concurrent and concordant infections are much more common in men; however, this difference was not statistically significant. The three most common HR types detected in HR HPV concordant infections were HPV 16, 59, and 51 for both men and women.

For the combined population many of the predictors showed a significant association with HR HPV concurrent and concordant infections in the univariate analysis with the exception of age, HPV vaccine, and cigarette use (for HR HPV concurrent

infections only). It is not very surprising that HPV vaccination status was not associated with HR HPV concurrent and concordant infections considering that the vaccine has only been recommended since 2006 for women and 2011 for men [10]. Also, HPV vaccination status has been shown to not be associated with any HPV concurrent or concordant infections in women as well as not being associated with oral HPV infections in both men and women [15, 12]. It is a little surprising that age was not associated with HR HPV concurrent or concordant infections since age is associated with genital and oral HPV infection in men and women independently [12, 13, 21]. However, this association might not be apparent given our relatively small sample size. In the adjusted models, the only covariates that remained significant for both HR HPV concurrent and concordant infections were gender and lifetime number of sexual partners. These results are not surprising considering the difference in prevalence of HR HPV concurrent and concordant infections between men and women. Additionally, lifetime number of sex partners is associated with genital and oral HPV infections in men and women; thus, this result is not surprising either [12, 13, 21]. Typically, in HPV studies men and women are analyzed separately; thus, to our knowledge there are no similar results to compare to. However, in light of our small sample size, we feel this analysis could be informative in addition to the results of analyzing men and women separately.

Our analysis of men showed that the lifetime number of sex partners was positively associated with HR HPV concurrent and concordant infections, similar to what has been shown in another study investigating any HPV concurrent and concordant infections [16]. We found homosexual/bisexual men were more likely to have HR HPV concurrent and concordant infections, not surprising since homosexual/bisexual men have been shown to have higher rates of oral HPV infection [12]. We also found positive associations between HR HPV concurrent infections and 6+ lifetime number of oral sex partners and 2-5 recent oral sex partners, also consistent with a prior U.S. study by Patel et al [16]. However, these associations were not present with HR HPV

concordant infections, in contrast to Patel et al, who found an association with any HPV concordant infections [16]. These authors also observed that never married men were more likely to have a HR HPV concurrent infection compared to married men, but this was not observed in rural Chinese men nor in our results of HR HPV concurrent infections [14]. Men who had ever used marijuana showed a positive association with HR HPV concurrent, but not concordant, infection. Marijuana use has also been shown to be associated with oral HPV infection in men [12]. Men with 2-5 recent sex partners showed a positive association with HR HPV concordant infection, similar to what was found in the study by Patel et al. However, we did not find an association with HR HPV concurrent infection and recent number of sex partners as they did [16].

Ethnicity was associated with HR HPV concurrent and concordant infections in the univariate analysis for men. However, this association was attenuated in both of the adjusted models for HR HPV concurrent and concordant infections, similar to that found in Patel et al [16]. Covariates that showed no association with HR HPV concurrent and concordant infections in the univariate analysis for men included age, HPV vaccination status, and cigarette use. Age was still included in the adjusted models and did not show a significant association with HR HPV concurrent or concordant infections similar to the results of the study of any HPV concurrent and concordant infections in men [16]. Cigarette use has been associated with oral HPV infections in men; however, two other studies found no association with HR HPV concurrent infections, one of which also showed cigarette use is not associated with HR HPV concordant infections [16, 12, 14].

Based on our results for men, lifetime number of sex partners, lifetime number of oral sex partners, recent number of oral sex partners, marijuana use, sexual orientation, and marital status play an important role in HR HPV concurrent infections and should be considered when talking with patients about HPV infections. Additionally, lifetime number of sex partners, recent number of sex partners, and sexual orienta-

tion are significant predictors of HR HPV concordant infections and should also be considered when counseling patients.

Results for women revealed that none of our covariates were associated HR HPV concurrent infections in the adjusted model. This differs from what was shown in a previous NHANES study of any HPV concurrent infections in women which showed that age group was associated with any HPV concurrent infection [15]. This discrepancy may be due to our smaller sample size or the fact that their adjusted models were slightly different (e.g., they included poverty ratio, which was associated with any HPV concurrent infections); we did not examine this. [15]. Our results showed that lifetime number of sex partners and recent number of oral sex partners were not associated with HR HPV concurrent infection, consistent with the results found in the study of any HPV concurrent infection in women [15]. Additionally, recent number of any sex partners and lifetime number of oral sex partners were not associated with HR HPV concurrent infection. These results were surprising considering that all four of these covariates were associated with HR HPV concurrent infections in the univariate analysis and are independently associated with oral and genital HPV infections [12, 21]. Covariates associated with HR HPV concurrent infection in the univariate analysis included marital status, cigarette use, and marijuana use, similar to what has been found for oral and genital HPV infections independently, but these associations were also attenuated in the adjusted model [12, 21]. Similar to men, HPV vaccination status was not associated with HR HPV concurrent infections in women, nor were sexual orientation and ethnicity.

In women, a similar pattern was observed for HR HPV concordant and concurrent HR HPV infections, with only cigarette use retaining a significant association with HR HPV concordant infection in the adjusted model. This is different from the previous study on any HPV concordant infection which found associations for age, a recent number of oral sex partners. Again, this could be due to our smaller sample size and different categorization of these variables [15]. Additionally, all of the sexual

history questions showed significant associations with HR HPV concordant infections in the univariate analysis, but were attenuated in the adjusted model. This result is surprising considering that lifetime number of sex partners and recent number of sex partners have been associated with genital and oral HPV infections, and lifetime number of oral sex partners is associated with oral HPV infections [12, 21]. Age group, marital status, and marijuana use were also significant in the univariate, but not multivariate analysis. Age is also known to be associated with oral and genital infections independently [12, 21]. Marital status is known to be associated with HPV genital infections in women, and marijuana use is known to be associated with oral HPV infection in women [12, 21].

HR HPV concurrent and concordant infections are relatively rare in the population, and, thus, one of the major limitations of this study is a lack of sample size. Due to this, many of the estimates in this study have a relative standard error less than 30% which the CDC warns may be unstable [1]. Additionally, with the small number of individuals with HR HPV concurrent and concordant infections, we may not have the statistical power to detect associations which are actually there. Nonetheless, these are the data that are currently available and, to our knowledge, reflect the largest population-based study of HR HPV concurrent and concordant infections to date. This analysis should be repeated as more NHANES cycles become available to provide more stable estimates and build a single multivariate model for men.

Other limitations of this study include the cross-sectional design of NHANES. Therefore, temporal relationships between infections at different anatomic sites cannot be established to further elucidate HPV infection natural history. Furthermore, since there is no follow up, we cannot determine if these infections are incident infections, persistent infections, reinfection, or reactivation from latent infections. We also cannot determine if these infections are clearing or developing into HPV-associated cancers. Longitudinal studies are needed in order to address these types of questions. Additionally, individuals chose to answer sexual history questions, i.e., they

reflect self-report, and are thus prone to reporting bias. Participants also chose to participate in the HPV testing and therefore also subject to selection bias.

Regardless of these limitations, these results may have clinical significance in combating HPV and HPV-associated cancers. They provide a possible foundation that could guide clinicians in screening practices of HPV infections and HPV associated cancers. Additionally, they indirectly highlight the importance of the HPV vaccine, providing support for its continued recommendation, perhaps even more adamantly considering how low the current vaccination rate is, to adolescents and individuals at increased risk of HPV infection. This is especially true of men and boys, who have been shown to have a much lower rate of vaccination rate, than women and girls [11]. The novelty of this study is conducting research that shows HR HPV concurrent and concordant infections are happening more than expected. Additional investigation using longitudinal studies is warranted to further elucidate the reasons.

5 Tables and Figures

Table 1: Two-Way Prevalence Tables of High Risk (HR) Oral and Genital Human Papillomavirus (HPV) for the Four Groups of HR HPV for the Combined Population, Men, and Women. (U.S. National Health and Nutrition Examination Survey, 2013-2014 for Men, 2009-2014 for Women)

	Oral					
	Yes		No		Total	
Genital	n	Percent(95% CI)	n	Percent(95% CI)	n	Percent(95% CI)
Combined						
HR HPV						
Yes	116	2.4(1.7, 3.3)	1863	24.9(23.5, 26.4)	1979	27.3(25.9, 28.8)
No	94	1.8(1.2, 2.6)	4937	70.9(69.1, 72.7)	5031	72.7(71.2, 74.1)
Total	210	4.2(3.3, 5.3)	6800	95.8(94.7, 96.7)	7010	
HR 9V Types						
Yes	33	0.70(0.41, 1.2)	875	11.5(10.6, 12.4)	908	12.2(11.3, 13.2)
No	48	1.1(0.69, 1.8)	6054	86.7(85.7, 87.7)	6102	87.8(86.8, 88.7)
Total	81	1.8(1.3, 2.5)	6929	98.2(97.5, 98.7)	7010	
HPV 16, 18, 45						
Yes	23	0.37(0.20, 0.68)^	504	6.8(6.0, 7.8)	527	7.2(6.4, 8.0)
No	36	0.93(0.62, 1.4)	6447	91.9(91.1, 92.6)	6483	92.8(92.0, 93.6)
Total	59	1.3(0.90, 1.9)	6951	98.7(98.1, 99.1)	7010	
HPV 16						
Yes	12	0.16(0.08, 0.32)^	255	3.9(3.2, 4.7)	267	4.0(3.4, 4.8)
No	31	0.89(0.58, 1.4)	6712	95.1(94.4, 95.7)	6743	96.0(95.2, 96.6)
Total	43	1.0(0.75, 1.5)	6967	99.0(98.5, 99.3)	7010	
Men						
HR HPV						
Yes	65	4.0(2.7, 5.9)	432	25.3(23.3, 27.5)	497	29.3(27.2, 31.6)
No	48	2.7(1.6, 4.5)	1138	67.9(64.7, 71.0)	1186	70.7(68.4, 72.8)
Total	113	6.7(4.9, 9.1)	1570	93.3(90.9, 95.1)	1683	
HR 9V Types						
Yes	17	1.1(0.58, 2.3)^	206	11.9(10.5, 13.3)	223	13.0(11.6, 14.5)
No	25	1.8(1.00, 3.3)	1435	85.2(83.4, 86.7)	1460	87.0(85.5, 88.4)
Total	42	3.0(2.0, 4.4)	1641	97.0(95.6, 98.0)	1683	
HPV 16, 18, 45						
Yes	11	0.51(0.22, 1.2)^	121	7.1(5.8, 8.7)	132	7.6(6.4, 9.0)
No	19	1.6(0.95, 2.6)	1532	90.8(89.6, 91.9)	1551	92.4(91.0, 93.6)
Total	30	2.1(1.3, 3.3)	1653	97.9(96.7, 98.7)	1683	
HPV 16						
Yes	6	0.18(0.07, 0.47)^	65	4.2(3.1, 5.7)	71	4.4(3.3, 5.8)
No	19	1.6(0.95, 2.6)	1593	94.1(92.7, 95.1)	1612	95.6(94.2, 96.7)
Total	25	1.8(1.2, 2.6)	1658	98.2(97.4, 98.8)	1683	
Women						
HR HPV						
Yes	51	0.76(0.52, 1.1)	1431	24.5(22.7, 26.5)	1482	25.3(23.4, 27.3)
No	46	0.82(0.58, 1.2)	3799	73.9(71.9, 75.7)	3845	74.7(72.7, 76.6)
Total	97	1.6(1.2, 2.1)	5230	98.4(97.9, 98.8)	5327	
HR 9V Types						
Yes	16	0.27(0.15, 0.49)^	669	11.1(9.9, 12.4)	685	11.4(10.2, 12.7)
No	23	0.40(0.23, 0.68)	4619	88.2(86.9, 89.4)	4642	88.6(87.3, 89.8)
Total	39	0.67(0.43, 1.0)	5288	99.3(99.0, 99.6)	5327	
HPV 16, 18, 45						
Yes	12	0.22(0.10, 0.49)^	383	6.5(5.6, 7.5)	395	6.7(5.8, 7.8)
No	17	0.29(0.16, 0.56)^	4915	93.0(91.9, 93.9)	4932	93.3(92.2, 94.2)
Total	29	0.51(0.29, 0.90)	5298	99.5(99.1, 99.7)	5327	
HPV 16						
Yes	6	0.13(0.05, 0.35)^	190	3.6(2.9, 4.3)	196	3.7(3.0, 4.5)
No	12	0.22(0.10, 0.46)^	5119	96.1(95.3, 96.8)	5131	96.3(95.5, 97.0)
Total	18	0.34(0.19, 0.63)^	5309	99.7(99.4, 99.8)	5327	

^ The relative standard error of the weighted prevalence estimate was >30%.

Table 2: Estimated Prevalence of High Risk (HR) Concordant Human Papillomavirus (HPV) infections for the Combined Population, Men, and Women (U.S. National Health and Nutrition Examination Survey, 2013-2014 for Men, 2009-2014 for Women)

	Combined		Men		Women	
Concordance	n	Percent(95% CI)	n	Percent(95% CI)	n	Percent(95% CI)
Total Population						
Concordant	59	0.99(0.66, 1.5)	29	1.5(0.88, 2.6)	30	0.47(0.31, 0.74)
Non-Concordant	57	1.4(0.94, 2.0)	36	2.5(1.6, 3.9)	21	0.28(0.18, 0.46)
No Concurrent	6894	97.6(96.7, 98.3)	1618	96.0(94.1, 97.3)	5276	99.2(98.9, 99.5)
Individuals with Concurrent Infection						
Concordant	59	41.6(31.2, 52.8)	29	37.6(25.4, 51.6)	30	62.6(47.2, 75.8)
Non-Concordant	57	58.4(47.2, 68.8)	36	62.4(48.4, 74.6)	21	37.4(24.2, 52.8)

Table 3: : Table of High Risk (HR) Human Papillomavirus (HPV) Types in Complete and Partial HR HPV Concordant Infections (U.S. National Health and Nutrition Examination Survey, 2013-2014 for Men, 2009-2014 for Women)

Concordance Type	Genital Types	Oral Types	Count	Concordance Type	Genital Types	Oral Types	Count
Combined							
Complete	16	16	6	Partial	35	35, 59	1
Complete	18, 51	18, 51	1	Partial	16, 39, 52, 66, 53	39	1
Complete	39, 66	39, 66	1	Partial	39	39, 53	1
Complete	45	45	2	Partial	39, 45	45	1
Complete	45, 68	45, 68	1	Partial	45, 59	45	1
Complete	51	51	3	Partial	51, 53	51	1
Complete	52	52	1	Partial	51, 58	51	1
Complete	53	53	2	Partial	51, 59, 26	51, 26	1
Complete	58	58	1	Partial	52, 53	52	1
Complete	59	59	5	Partial	31, 51, 53	53	1
Complete	68	68	1	Partial	51, 53	53	1
Complete	73	73	4	Partial	16, 35, 39, 51, 59, 66, 53	59	1
Partial	16, 18, 51, 66, 82	16	1	Partial	16, 59	59	1
Partial	16, 31, 51, 52, 56, 66, 53	16	1	Partial	16, 59, 53	59	1
Partial	16, 31, 56, 53	16	1	Partial	18, 51, 56, 59, 68	59	1
Partial	16, 39, 52	16	1	Partial	59, 82	59	1
Partial	16, 53	16	1	Partial	16, 39, 66	66	1
Partial	16, 82	16	1	Partial	18, 51, 66	66	1
Partial	18, 31, 45	18	1	Partial	51, 52, 66	66	1
Partial	16, 18, 51	18, 51	1	Partial	58, 66	66	1
Partial	16, 33, 59	18, 59	1	Partial	59, 73	73	1
Partial	35, 45, 52	35	1	-	-	-	-
Concordance Type	Genital Types	Oral Types	Count	Concordance Type	Genital Types	Oral Types	Count
Men							
Complete	16	16	4	Partial	35	35, 59	1
Complete	45	45	1	Partial	16, 39, 52, 66, 53	39	1
Complete	51	51	2	Partial	39	39, 53	1
Complete	53	53	1	Partial	45, 59	45	1
Complete	59	59	2	Partial	51, 58	51	1
Complete	68	68	1	Partial	16, 35, 39, 51, 59, 66, 53	59	1
Complete	73	73	3	Partial	16, 59, 53	59	1
Partial	16, 31, 51, 52, 56, 66, 53	16	1	Partial	18, 51, 56, 59, 68	59	1
Partial	16, 53	16	1	Partial	16, 39, 66	66	1
Partial	16, 18, 51	18, 51	1	Partial	18, 51, 66	66	1
Partial	16, 33, 59	18, 59	1	Partial	58, 66	66	1
Concordance Type	Genital Types	Oral Types	Count	Concordance Type	Genital Types	Oral Types	Count
Women							
Complete	16	16	2	Partial	16, 82	16	1
Complete	18, 51	18, 51	1	Partial	18, 31, 45	18	1
Complete	39, 66	39, 66	1	Partial	35, 45, 52	35	1
Complete	45	45	1	Partial	39, 45	45	1
Complete	45, 68	45, 68	1	Partial	51, 53	51	1
Complete	51	51	1	Partial	51, 59, 26	51, 26	1
Complete	52	52	1	Partial	52, 53	52	1
Complete	53	53	1	Partial	31, 51, 53	53	1
Complete	58	58	1	Partial	51, 53	53	1
Complete	59	59	3	Partial	16, 59	59	1
Complete	73	73	1	Partial	59, 82	59	1
Partial	16, 18, 51, 66, 82	16	1	Partial	51, 52, 66	66	1
Partial	16, 31, 56, 53	16	1	Partial	59, 73	73	1
Partial	16, 39, 52	16	1	-	-	-	-

Table 4: Distribution of Predictors of High Risk Human Papillomavirus Concurrent and Concordant Infections for Combined Population (U.S. National Health and Nutrition Examination Survey, 2013-2014 for Men, 2009-2014 for Women)

	Concurrent Infection				Concordant Infection			
	Concurrent Infection		No Concurrent Infection		Concordant Infection		No Concordant Infection	
Term	N	Percent(95% CI)	N	Percent(95% CI)	N	Percent(95% CI)	N	Percent(95% CI)
Ethnicity***								
Other	29	11.3(6.3, 19.4)	2698	25.5(21.4, 30.1)	15	12.4(5.0, 27.6)^	2712	25.3(21.2, 29.8)
White	59	72.7(61.1, 81.8)	2713	62.3(57.1, 67.2)	32	71.1(56.0, 82.7)	2740	62.5(57.3, 67.4)
Black	28	16.0(10.2, 24.3)	1483	12.2(9.9, 14.9)	12	16.5(9.2, 27.8)	1499	12.3(9.9, 15.0)
Gender***†††								
Male	65	84.0(76.6, 89.4)	1618	48.9(46.1, 51.8)	29	75.9(61.9, 85.9)	1654	49.5(46.7, 52.4)
Female	51	16.0(10.6, 23.4)	5276	51.1(48.2, 53.9)	30	24.1(14.1, 38.1)	5297	50.5(47.6, 53.3)
Age Group								
18 to 24	29	16.2(9.8, 25.6)	1375	17.5(15.9, 19.2)	19	22.8(13.1, 36.8)	1385	17.4(15.9, 19.1)
25 to 39	40	35.2(21.8, 51.4)	2373	34.8(33.1, 36.6)	19	41.9(21.1, 66.0)	2394	34.7(33.0, 36.6)
40 to 59	47	48.7(32.3, 65.3)	3146	47.7(45.5, 49.9)	21	35.3(17.8, 57.8)	3172	47.9(45.7, 50.0)
Marital Status***††								
Married	24	23.1(13.7, 36.2)	3105	51.3(48.6, 54.1)	12	22.7(9.0, 46.7)^	3117	50.9(48.2, 53.7)
No longer married	24	24.5(12.9, 41.7)	1031	12.7(11.6, 13.9)	12	21.3(9.1, 42.3)^	1043	12.9(11.7, 14.1)
Never married	40	34.7(25.1, 45.9)	1611	22.7(20.5, 24.9)	20	38.6(25.1, 54.2)	1631	22.8(20.6, 25.2)
Living with partner	18	14.6(8.1, 25.1)	634	8.8(7.5, 10.2)	7	11.1(4.8, 23.5)^	645	8.9(7.7, 10.3)
Missing	10	3.1(1.2, 7.4)^	513	4.5(3.9, 5.2)	8	6.3(2.1, 17.2)^	515	4.5(3.9, 5.2)
Lifetime Sex Partners***†††								
0-1	7	1.3(0.50, 3.2)^	1345	16.7(14.1, 19.7)	6	2.2(0.76, 6.4)^	1346	16.5(13.9, 19.4)
2-5	18	7.3(3.2, 15.7)^	2227	30.9(28.9, 32.9)	11	11.7(4.5, 27.1)^	2234	30.5(28.5, 32.6)
6-10	23	11.0(5.9, 19.6)	1360	21.2(19.5, 22.9)	12	12.4(6.2, 23.4)	1371	21.0(19.4, 22.7)
11+	61	72.8(58.8, 83.5)	1360	25.1(22.8, 27.5)	29	71.3(51.3, 85.4)	1392	25.8(23.6, 28.1)
Missing	7	7.6(2.5, 21.2)^	602	6.1(5.4, 7.0)	1	2.3(0.23, 19.7)^	608	6.2(5.5, 7.0)
Recent Sex Partners***†††								
0-1	61	50.6(37.5, 63.7)	5217	78.0(75.7, 80.1)	32	48.5(33.7, 63.5)	5246	77.6(75.4, 79.7)
2-5	38	34.6(24.7, 46.1)	952	13.5(12.2, 14.9)	20	38.6(27.5, 50.9)	970	13.7(12.4, 15.2)
6+	10	7.2(3.6, 13.6)^	123	2.4(1.9, 3.2)	6	10.6(4.1, 24.6)^	127	2.5(1.9, 3.2)
Missing	7	7.6(2.5, 21.2)^	602	6.1(5.4, 7.0)	1	2.3(0.23, 19.7)^	608	6.2(5.5, 7.0)
Lifetime Oral Partners***†††								
0-1	20	7.9(3.8, 15.5)^	2642	32.1(29.3, 35.0)	13	12.0(4.5, 28.2)^	2649	31.7(28.9, 34.6)
2-5	35	18.9(14.3, 24.5)	2573	40.5(38.7, 42.4)	20	27.4(14.5, 45.6)	2588	40.1(38.3, 42.0)
6+	54	65.6(56.7, 73.6)	1080	21.3(19.1, 23.7)	25	58.3(40.2, 74.4)	1109	22.0(19.8, 24.4)
Missing	7	7.6(2.5, 21.2)^	599	6.1(5.3, 7.0)	1	2.3(0.23, 19.7)^	605	6.2(5.5, 7.0)
Recent Oral Partners***†††								
0-1	74	59.5(48.1, 69.9)	5650	84.1(82.5, 85.6)	36	57.3(39.7, 73.1)	5688	83.8(82.3, 85.2)
2-5	27	27.3(19.3, 37.1)	584	8.9(7.9, 10.0)	17	31.8(18.8, 48.4)	594	9.1(8.1, 10.2)
6+	8	5.6(2.2, 13.6)^	61	0.91(0.69, 1.2)	5	8.6(2.6, 25.3)^	64	0.94(0.73, 1.2)
Missing	7	7.6(2.5, 21.2)^	599	6.1(5.3, 7.0)	1	2.3(0.23, 19.7)^	605	6.2(5.5, 7.0)
HPV Vaccine								
Yes	17	6.4(3.2, 12.3)^	663	7.3(6.4, 8.2)	9	7.8(3.0, 18.7)^	671	7.2(6.4, 8.2)
No	97	92.4(85.5, 96.1)	5943	88.1(86.9, 89.2)	48	89.2(75.3, 95.7)	5992	88.2(87.0, 89.3)
Missing	2	1.2(0.25, 5.6)^	288	4.6(3.9, 5.4)	2	2.9(0.53, 14.5)^	288	4.6(3.9, 5.4)
Cigarette Use†††								
Never	50	45.8(32.1, 60.2)	4204	58.2(55.7, 60.6)	22	36.8(21.5, 55.3)	4232	58.1(55.6, 60.5)
Ever	61	52.8(38.3, 66.9)	2464	40.6(38.1, 43.1)	33	60.4(41.4, 76.7)	2492	40.7(38.2, 43.2)
Missing	5	1.3(0.42, 4.2)^	226	1.3(0.98, 1.6)	4	2.8(0.70, 10.6)^	227	1.3(0.97, 1.6)
Marijuana Use***								
Never	23	13.1(6.9, 23.5)	3102	37.9(35.2, 40.7)	14	21.7(9.0, 43.8)^	3111	37.5(34.8, 40.3)
Ever	86	79.3(67.8, 87.4)	3189	55.8(53.0, 58.6)	44	75.9(58.1, 87.8)	3231	56.2(53.4, 59.0)
Missing	7	7.6(2.5, 21.2)^	603	6.3(5.5, 7.1)	1	2.3(0.23, 19.7)^	609	6.3(5.6, 7.1)
Sexual Orientation***†††								
Heterosexual	93	77.0(64.5, 86.0)	5746	87.8(86.5, 89.0)	48	73.5(53.0, 87.2)	5791	87.7(86.4, 88.8)
Homosexual/Bisexual	13	14.7(7.0, 28.2)^	337	4.2(3.6, 4.8)	7	22.4(9.5, 44.2)^	343	4.2(3.6, 4.9)
Other	10	8.3(2.9, 22.0)^	811	8.1(7.0, 9.2)	4	4.1(0.83, 17.9)^	817	8.1(7.2, 9.1)

Concurrent Chi-Squared p-values:*P-Value $< .05$, **P-Value $< .01$, ***P-Value $< .005$; Concordant Chi-Squared p-values:†P-Value $< .05$, ††P-Value $< .01$, †††P-Value $< .005$. ^ The relative standard error of the weighted prevalence estimate was >30%.

Table 5: Distribution of Predictors of High Risk Human Papillomavirus Concurrent and Concordant Infections for Men (U.S. National Health and Nutrition Examination Survey, 2013-2014)

	Concurrent Infection				Concordant Infection			
	Concurrent Infection		No Concurrent Infection		Concordant Infection		No Concordant Infection	
Term	N	Percent(95% CI)	N	Percent(95% CI)	N	Percent(95% CI)	N	Percent(95% CI)
Ethnicity***†								
Other	9	8.6(3.9, 17.9)^	635	26.8(20.6, 34.1)	4	9.3(2.3, 30.4)^	640	26.3(20.2, 33.5)
White	38	75.4(63.2, 84.5)	653	61.7(54.0, 68.9)	17	71.6(54.1, 84.4)	674	62.1(54.5, 69.2)
Black	18	16.0(9.5, 25.6)	330	11.5(8.5, 15.3)	8	19.1(9.9, 33.6)	340	11.6(8.5, 15.5)
Age Group								
18 to 24	14	15.0(8.0, 26.4)	337	18.3(16.1, 20.8)	8	21.0(9.8, 39.4)	343	18.2(16.1, 20.4)
25 to 39	24	36.1(20.5, 55.3)	565	35.4(32.4, 38.5)	12	48.5(22.0, 75.8)	577	35.2(32.2, 38.3)
40 to 59	27	48.9(29.0, 69.1)	716	46.3(43.1, 49.5)	9	30.5(10.1, 63.1)^	734	46.7(43.6, 49.7)
Marital Status***†								
Married	15	23.9(13.3, 39.2)	765	52.4(48.1, 56.6)	5	22.3(7.1, 51.9)^	775	51.7(47.4, 56.0)
No longer married	13	23.8(10.6, 45.0)^	164	9.6(8.0, 11.3)	6	19.4(5.9, 48.0)^	171	10.0(8.3, 12.0)
Never married	22	35.6(23.7, 49.5)	408	24.8(21.4, 28.6)	12	43.1(26.2, 61.7)	418	25.0(21.3, 29.0)
Living with partner	13	15.3(7.8, 27.9)	149	8.4(6.5, 10.8)	5	12.2(4.6, 28.9)^	157	8.6(6.8, 10.9)
Missing	2	1.4(0.23, 8.4)^	132	4.9(3.9, 6.0)	1	3.0(0.25, 27.3)^	133	4.7(3.8, 5.8)
Lifetime Sex Partners***†††								
0-5	4	3.1(0.95, 9.4)^	692	42.2(37.0, 47.5)	4	8.2(2.1, 26.8)^	692	41.1(36.0, 46.4)
6-10	10	8.4(3.7, 18.2)^	314	20.8(18.4, 23.4)	3	7.2(3.0, 16.5)^	321	20.5(18.2, 23.1)
11+	47	80.3(65.7, 89.6)	517	32.6(28.4, 37.1)	21	81.6(62.0, 92.3)	543	33.8(29.7, 38.1)
Missing	4	8.2(2.3, 25.6)^	95	4.4(3.3, 5.8)	1	3.1(0.25, 28.4)^	98	4.6(3.6, 5.9)
Recent Sex Partners***†††								
0-1	34	50.1(35.5, 64.6)	1193	76.4(72.3, 80.1)	14	47.0(30.2, 64.5)	1213	75.8(71.9, 79.3)
2-5	20	34.9(23.8, 48.0)	267	15.2(12.9, 17.8)	10	39.6(26.2, 54.8)	277	15.6(13.4, 18.2)
6+	7	6.8(3.2, 13.7)^	63	4.0(2.7, 5.8)	4	10.3(3.5, 26.8)^	66	4.0(2.8, 5.8)
Missing	4	8.2(2.3, 25.6)^	95	4.4(3.3, 5.8)	1	3.1(0.25, 28.4)^	98	4.6(3.6, 5.9)
Lifetime Oral Partners***†††								
0-1	7	5.6(1.9, 15.3)^	562	29.8(25.4, 34.6)	5	11.6(3.0, 35.3)^	564	29.1(24.8, 33.8)
2-5	14	15.0(9.6, 22.5)	587	39.3(36.4, 42.3)	6	20.9(6.6, 49.7)^	595	38.6(35.7, 41.6)
6+	40	71.3(62.4, 78.8)	374	26.5(23.3, 29.9)	17	64.4(41.0, 82.5)	397	27.7(24.5, 31.2)
Missing	4	8.2(2.3, 25.6)^	95	4.4(3.3, 5.8)	1	3.1(0.25, 28.4)^	98	4.6(3.6, 5.9)
Recent Oral Partners***†††								
0-1	38	57.6(44.3, 69.9)	1336	84.1(81.6, 86.3)	15	54.5(31.0, 76.1)	1359	83.4(81.2, 85.5)
2-5	18	29.2(19.9, 40.8)	167	10.3(8.6, 12.4)	10	34.8(17.8, 56.8)	175	10.7(9.0, 12.7)
6+	5	4.9(1.5, 14.7)^	20	1.2(0.82, 1.8)	3	7.7(1.6, 29.7)^	22	1.2(0.87, 1.8)
Missing	4	8.2(2.3, 25.6)^	95	4.4(3.3, 5.8)	1	3.1(0.25, 28.4)^	98	4.6(3.6, 5.9)
HPV Vaccine								
Yes	5	4.4(1.5, 12.7)^	69	3.8(2.9, 5.0)	3	6.8(1.3, 28.4)^	71	3.8(3.0, 4.9)
No	58	94.1(85.2, 97.8)	1433	89.1(87.4, 90.5)	24	89.3(66.6, 97.2)	1467	89.3(87.6, 90.7)
Missing	2	1.4(0.28, 7.1)^	116	7.1(5.8, 8.6)	2	3.9(0.62, 20.6)^	116	6.9(5.6, 8.4)
Cigarette Use								
Never	29	48.0(31.6, 64.9)	878	54.8(51.0, 58.6)	12	41.3(21.0, 65.0)	895	54.8(51.0, 58.5)
Ever	36	52.0(35.1, 68.4)	740	45.2(41.4, 49.0)	17	58.7(35.0, 79.0)	759	45.2(41.5, 49.0)
Marijuana Use**								
Never	10	11.4(5.0, 24.1)^	604	33.7(29.5, 38.1)	6	22.3(7.4, 50.9)^	608	32.9(28.7, 37.4)
Ever	51	80.4(66.2, 89.5)	916	61.8(57.2, 66.1)	22	74.6(51.9, 88.9)	945	62.3(57.8, 66.6)
Missing	4	8.2(2.3, 25.6)^	98	4.6(3.6, 5.9)	1	3.1(0.25, 28.4)^	101	4.8(3.8, 5.9)
Sexual Orientation***†††								
Heterosexual	51	75.2(60.1, 85.9)	1440	91.0(88.8, 92.8)	22	67.6(43.8, 84.9)	1469	90.7(88.5, 92.5)
Homosexual/Bisexual	9	16.0(7.0, 32.7)^	48	3.0(2.1, 4.1)	5	27.8(11.4, 53.3)^	52	3.1(2.2, 4.5)
Other	5	8.8(2.5, 26.4)^	130	6.0(4.6, 7.8)	2	4.6(0.63, 26.8)^	133	6.2(5.0, 7.7)

Concurrent Chi-Squared p-values:*P-Value $< .05$, **P-Value $< .01$, ***P-Value $< .005$; Concordant Chi-Squared p-values:†P-Value $< .05$, ††P-Value $< .01$, †††P-Value $< .005$. ^ The relative standard error of the weighted prevalence estimate was >30%.

Table 6: Distribution of Predictors of High Risk Human Papillomavirus Concurrent and Concordant Infections for Women (U.S. National Health and Nutrition Examination Survey, 2009-2014)

	Concurrent Infection				Concordant Infection			
	Concurrent Infection		No Concurrent Infection		Concordant Infection		No Concordant Infection	
Term	N	Percent(95% CI)	N	Percent(95% CI)	N	Percent(95% CI)	N	Percent(95% CI)
Ethnicity								
Other	20	25.2(12.6, 44.3)	2063	24.2(20.9, 27.9)	11	22.2(6.1, 55.4)^	2072	24.2(20.9, 27.9)
White	21	58.6(35.2, 78.6)	2060	62.9(58.2, 67.3)	15	69.6(36.3, 90.1)	2066	62.8(58.1, 67.3)
Black	10	16.2(6.8, 33.9)^	1153	12.9(10.7, 15.5)	4	8.3(1.8, 31.2)^	1159	13.0(10.7, 15.6)
Age Group								
18 to 24	15	22.4(13.3, 35.2)	1038	16.7(14.5, 19.1)	11	28.4(12.7, 52.0)	1042	16.7(14.5, 19.1)
25 to 39	16	30.1(16.9, 47.7)	1808	34.3(32.5, 36.0)	7	21.2(6.2, 52.1)^	1817	34.3(32.6, 36.1)
40 to 59	20	47.5(32.0, 63.5)	2430	49.0(46.4, 51.7)	12	50.4(20.8, 79.8)	2438	49.0(46.3, 51.7)
Marital Status***††								
Married	9	18.7(8.1, 37.6)^	2340	50.3(48.0, 52.6)	7	24.2(8.1, 53.5)^	2342	50.2(47.9, 52.5)
No longer married	11	28.4(13.8, 49.6)	867	15.7(14.4, 17.1)	6	27.3(6.5, 66.9)^	872	15.7(14.5, 17.1)
Never married	18	30.4(18.3, 46.1)	1203	20.6(18.4, 23.0)	8	24.4(9.6, 49.6)^	1213	20.7(18.4, 23.1)
Living with partner	5	10.9(3.7, 28.2)^	485	9.2(8.2, 10.2)	2	7.4(1.00, 38.8)^	488	9.2(8.2, 10.3)
Missing	8	11.5(5.0, 24.2)^	381	4.2(3.6, 5.0)	7	16.7(5.3, 42.0)^	382	4.2(3.6, 5.0)
Lifetime Sex Partners								
0-1	7	7.9(2.7, 21.1)^	1064	17.8(16.2, 19.5)	6	9.2(2.2, 31.0)^	1065	17.7(16.1, 19.5)
2-5	14	29.5(10.9, 58.9)^	1816	35.0(33.3, 36.8)	7	23.0(4.4, 66.0)^	1823	35.0(33.3, 36.9)
6-10	13	24.2(10.9, 45.6)^	1046	21.5(19.8, 23.3)	9	28.8(8.2, 64.5)^	1050	21.5(19.8, 23.2)
11+	14	33.8(17.1, 55.9)	843	17.9(16.3, 19.7)	8	39.0(12.7, 73.8)^	849	17.9(16.3, 19.7)
Missing	3	4.5(1.1, 16.5)^	507	7.8(7.0, 8.7)	0	-	510	7.8(7.0, 8.7)
Recent Sex Partners***†††								
0-1	27	53.4(34.8, 71.2)	4024	79.5(77.7, 81.2)	18	53.0(28.1, 76.5)	4033	79.4(77.6, 81.1)
2-5	18	33.1(19.9, 49.7)	685	11.8(10.4, 13.4)	10	35.4(15.7, 61.6)	693	11.8(10.4, 13.4)
6+	3	9.0(1.5, 38.5)^	60	0.94(0.68, 1.3)	2	11.6(0.98, 63.7)^	61	0.95(0.69, 1.3)
Missing	3	4.5(1.1, 16.5)^	507	7.8(7.0, 8.7)	0	-	510	7.8(7.0, 8.7)
Lifetime Oral Partners**†								
0-1	13	20.0(10.7, 34.4)	2080	34.2(32.0, 36.6)	8	13.3(3.9, 37.1)^	2085	34.2(32.0, 36.5)
2-5	21	39.4(23.0, 58.7)	1986	41.7(39.8, 43.7)	14	47.6(17.1, 80.1)	1993	41.7(39.7, 43.6)
6+	14	36.1(18.7, 58.1)	706	16.3(14.3, 18.6)	8	39.0(12.7, 73.8)^	712	16.4(14.4, 18.6)
Missing	3	4.5(1.1, 16.5)^	504	7.7(6.9, 8.6)	0	-	507	7.8(6.9, 8.7)
Recent Oral Partners***†††								
0-1	36	69.3(47.3, 85.0)	4314	84.2(82.8, 85.5)	21	66.0(32.6, 88.7)	4329	84.2(82.8, 85.4)
2-5	9	17.2(7.7, 34.1)^	417	7.4(6.4, 8.6)	7	22.3(6.6, 53.8)^	419	7.4(6.4, 8.6)
6+	3	9.0(1.5, 38.5)^	41	0.63(0.43, 0.94)	2	11.6(0.98, 63.7)^	42	0.64(0.44, 0.95)
Missing	3	4.5(1.1, 16.5)^	504	7.7(6.9, 8.6)	0	-	507	7.8(6.9, 8.7)
HPV Vaccine								
Yes	12	16.6(7.7, 32.2)^	594	10.5(9.2, 12.1)	6	11.1(2.5, 38.2)^	600	10.6(9.2, 12.1)
No	39	83.4(67.8, 92.3)	4510	87.2(85.5, 88.7)	24	88.9(61.8, 97.5)	4525	87.2(85.5, 88.7)
Missing	0	-	172	2.2(1.8, 2.8)	0	-	172	2.2(1.8, 2.8)
Cigarette Use***†††								
Never	21	34.2(18.6, 54.1)	3326	61.3(58.8, 63.8)	10	22.7(8.5, 48.2)^	3337	61.3(58.8, 63.8)
Ever	25	57.5(33.8, 78.1)	1724	36.2(33.6, 38.8)	16	65.6(30.9, 89.1)	1733	36.2(33.6, 38.8)
Missing	5	8.3(2.9, 21.9)^	226	2.5(1.9, 3.2)	4	11.6(2.5, 40.3)^	227	2.5(1.9, 3.2)
Marijuana Use***††								
Never	13	22.1(12.5, 36.0)	2498	42.0(39.6, 44.4)	8	20.0(6.9, 45.7)^	2503	41.9(39.5, 44.4)
Ever	35	73.4(59.3, 84.0)	2273	50.2(47.5, 52.8)	22	80.0(54.3, 93.1)	2286	50.2(47.6, 52.8)
Missing	3	4.5(1.1, 16.5)^	505	7.9(7.0, 8.7)	0	-	508	7.9(7.1, 8.8)
Sexual Orientation								
Heterosexual	42	86.4(72.4, 93.9)	4306	84.7(83.4, 85.9)	26	91.9(70.9, 98.1)	4322	84.7(83.4, 85.9)
Homosexual/Bisexual	4	7.5(2.4, 21.1)^	289	5.3(4.6, 6.2)	2	5.6(0.82, 30.2)^	291	5.3(4.6, 6.2)
Other	5	6.1(1.9, 17.3)^	681	10.0(9.0, 11.1)	2	2.5(0.33, 16.3)^	684	10.0(9.0, 11.1)

Concurrent Chi-Squared p-values:*P-Value $< .05$, **P-Value $< .01$, ***P-Value $< .005$; Concordant Chi-Squared p-values:†P-Value $< .05$, ††P-Value $< .01$, †††P-Value $< .005$. ^ The relative standard error of the weighted prevalence estimate was >30%.

Table 7: Univariable and Adjusted Logistic Models for High Risk Human Papillomavirus Concurrent and Concordant Infections for Combined Population (U.S. National Health and Nutrition Examination Survey), 2013-2014 for Men, 2009-2014 for Women

	Concurrent Infection		Concordant Infection	
	Univariate	Adjusted	Univariate	Adjusted
Term	OR(95% CI)	OR(95% CI)	OR(95% CI)	OR(95% CI)
Ethnicity				
Other	Ref	Ref	Ref	Ref
White	2.4(1.3, 4.4)**^	1.9(0.89, 3.9)^	2.1(0.92, 5.0)^	2.0(0.75, 5.2)^
Black	3.0(1.7, 5.1)***	1.9(0.98, 3.9)^	2.8(1.1, 7.2)*^	1.7(0.54, 5.6)^
Gender				
Male	Ref	Ref	Ref	Ref
Female	0.20(0.12, 0.33)***	0.25(0.15, 0.42)***	0.33(0.17, 0.63)***	0.35(0.16, 0.78)*
Age Group				
18 to 24	Ref	Ref	Ref	Ref
25 to 39	1.2(0.70, 2.2)^	1.1(0.46, 2.4)^	1.1(0.50, 2.2)^	1.1(0.37, 3.6)^
40 to 59	1.1(0.52, 2.4)^	1.1(0.37, 3.3)^	0.64(0.31, 1.4)	0.73(0.19, 2.9)
Marital Status				
Married	Ref	Ref	Ref	Ref
No longer married	3.3(1.4, 8.0)**^	2.1(0.78, 5.5)^	3.7(1.1, 13.1)*^	2.2(0.71, 7.0)^
Never married	3.3(1.9, 5.6)***	2.1(0.94, 4.5)^	3.5(1.4, 8.7)**^	1.6(0.44, 6.0)^
Living with partner	3.5(1.4, 8.3)**^	2.1(0.87, 5.1)^	2.8(0.80, 9.7)^	1.3(0.23, 6.9)^
Missing	1.5(0.47, 4.5)^	2.8(0.57, 14.2)^	3.0(0.79, 11.7)^	2.4(0.19, 31.7)^
Lifetime Sex Partners				
0-1	Ref	Ref	Ref	Ref
2-5	3.1(0.98, 9.9)^	3.8(0.94, 15.8)^	2.8(0.85, 9.5)^	3.9(0.97, 15.9)^
6-10	6.8(2.7, 17.1)***	5.5(1.5, 20.7)*^	4.4(1.6, 12.2)**^	5.1(1.3, 19.9)*^
11+	38.3(14.6, 100.4)***	16.7(4.0, 69.9)***	20.5(7.4, 57.3)***	16.1(3.4, 75.5)***
Recent Sex Partners				
0-1	Ref	Ref	Ref	Ref
2-5	3.9(2.3, 6.7)***	1.2(0.35, 4.3)^	4.5(2.8, 7.3)***	1.1(0.26, 4.7)^
6+	4.5(2.2, 9.2)***	0.45(0.18, 1.1)	6.9(2.8, 17.0)***	0.55(0.13, 2.4)
Lifetime Oral Partners				
0-1	Ref	Ref	Ref	Ref
2-5	1.9(0.87, 4.1)^	0.66(0.28, 1.6)	1.8(0.59, 5.5)^	0.61(0.16, 2.3)
6+	12.5(6.2, 25.0)***	1.4(0.67, 3.1)^	7.0(2.8, 17.3)***	0.68(0.20, 2.3)
Recent Oral Partners				
0-1	Ref	Ref	Ref	Ref
2-5	4.3(2.7, 7.0)***	1.3(0.47, 3.4)^	5.1(2.6, 9.9)***	1.8(0.34, 9.5)^
6+	8.6(3.2, 23.7)***	2.8(0.69, 11.8)^	13.3(4.2, 42.3)***	3.8(0.48, 30.3)^
HPV Vaccine				
Yes	Ref	-	Ref	-
No	1.5(0.69, 3.4)^	-	1.3(0.48, 3.8)^	-
Missing	0.40(0.08, 1.9)	-	0.84(0.17, 4.1)	-
Cigarette Use				
Never	Ref	-	Ref	Ref
Ever	1.8(1.0, 3.3)^	-	2.2(1.2, 4.3)*^	1.3(0.64, 2.4)^
Missing	1.5(0.50, 4.2)^	-	3.4(1.0, 11.0)^	3.8(0.52, 27.9)^
Marijuana Use				
Never	Ref	Ref	Ref	-
Ever	4.1(2.2, 7.7)***	1.2(0.66, 2.3)^	2.3(1.0, 5.4)^	-
Sexual Orientation				
Heterosexual	Ref	Ref	Ref	Ref
Homosexual/Bisexual	4.0(1.9, 8.7)***	2.1(0.92, 4.6)^	6.3(2.5, 15.7)***	3.3(1.0, 10.6)^
Other	0.43(0.08, 2.3)	0.52(0.08, 3.6)	1.1(0.21, 5.8)^	1.2(0.21, 7.3)^

*P-Value $<$ .05, **P-Value $<$ .01, ***P-Value $<$ .005. ^ The relative standard error of the weighted prevalence estimate was $>$ 30%.

Table 8: Univariable and Adjusted Logistic Models for High Risk Human Papillomavirus Concurrent and Concordant Infections for Men (U.S. National Health and Nutrition Examination Survey, 2013-2014)

	Concurrent Infection		Concordant Infection	
	Univariate	Adjusted	Univariate	Adjusted
Term	OR(95% CI)	OR(95% CI)	OR(95% CI)	OR(95% CI)
Ethnicity[a]				
Other	Ref	Ref	Ref	Ref
White	3.3(1.6, 7.0)**^	2.8(1.2, 6.5)^	3.1(0.91, 10.3)^	2.8(0.72, 10.5)^
Black	4.3(2.0, 8.9)***	2.2(0.97, 4.8)^	4.9(1.3, 18.7)*^	2.6(0.61, 11.5)^
Age Group[a]				
18 to 24	Ref	Ref	Ref	Ref
25 to 39	1.5(0.74, 2.9)^	1.1(0.43, 2.7)^	1.4(0.63, 3.2)^	1.1(0.30, 4.2)^
40 to 59	1.3(0.49, 3.6)^	0.97(0.26, 3.7)	0.68(0.22, 2.1)	0.46(0.07, 3.3)
Marital Status[a]				
Married	Ref	Ref	Ref	Ref
No longer married	4.0(1.5, 11.0)*^	2.4(0.90, 6.4)^	4.6(0.93, 22.7)^	2.9(0.61, 14.0)^
Never married	3.0(1.7, 5.5)***	2.6(1.3, 5.5)*^	3.7(1.3, 10.3)*^	2.3(0.45, 11.4)^
Living with partner	3.9(1.4, 10.5)*^	2.4(0.92, 6.5)^	3.4(0.85, 13.3)^	1.5(0.19, 12.1)^
Missing	0.65(0.10, 4.4)	1.5(0.12, 18.3)^	1.4(0.13, 16.4)^	1.8(0.05, 65.5)^
Lifetime Sex Partners[a]				
0-5	Ref	Ref	Ref	Ref
6-10	5.6(2.0, 15.5)**^	5.0(1.7, 14.6)*^	1.8(0.49, 6.4)^	1.6(0.44, 6.1)^
11+	34.1(11.2, 104.1)***	27.8(7.8, 98.9)***	12.2(3.7, 40.1)***	11.1(2.6, 46.6)*^
Recent Sex Partners[b]				
0-1	Ref	Ref	Ref	Ref
2-5	3.5(1.9, 6.5)***	2.6(1.2, 5.6)^	4.1(2.4, 7.0)***	2.7(1.3, 5.6)*^
6+	2.6(1.2, 5.4)*^	1.7(0.78, 3.7)^	4.1(1.5, 11.0)*^	2.5(0.90, 7.0)^
Lifetime Oral Partners[b]				
0-1	Ref	Ref	Ref	Ref
2-5	2.0(0.60, 6.8)^	1.8(0.43, 7.6)^	1.4(0.26, 7.1)^	1.3(0.17, 9.8)^
6+	14.3(5.5, 37.2)***	10.8(3.3, 34.9)*	5.8(1.9, 17.9)**^	4.7(1.1, 21.0)^
Recent Oral Partners[b]				
0-1	Ref	Ref	Ref	Ref
2-5	4.1(2.3, 7.3)***	2.8(1.6, 4.9)*	4.9(2.2, 11.2)***	3.3(1.3, 8.0)^
6+	6.0(1.8, 19.5)*^	3.6(0.90, 14.2)^	9.4(2.3, 38.2)**^	5.1(1.1, 23.2)^
HPV Vaccine[b]				
Yes	Ref	-	Ref	-
No	1.5(0.40, 5.9)^	-	1.0(0.21, 5.1)^	-
Missing	0.31(0.05, 2.1)	-	0.55(0.07, 4.1)	-
Cigarette Use[b]				
Never	Ref	-	Ref	-
Ever	1.5(0.74, 2.9)^	-	1.7(0.75, 3.6)^	-
Marijuana Use[b]				
Never	Ref	Ref	Ref	-
Ever	3.8(1.8, 8.3)***	2.8(1.3, 6.1)*^	1.8(0.66, 4.7)^	-
Sexual Orientation[b]				
Heterosexual	Ref	Ref	Ref	Ref
Homosexual/Bisexual	6.6(2.7, 16.1)***	4.2(1.6, 11.2)*^	11.9(4.2, 34.3)***	8.5(2.6, 27.2)*
Other	0.42(0.04, 5.0)	0.37(0.03, 4.4)	1.3(0.11, 14.4)^	1.3(0.11, 13.8)^

[1] *P-Value $<$ .05, **P-Value $<$ .01, ***P-Value $<$ .005. ^ The relative standard error of the weighted prevalence estimate was $>$ 30%.

[a] Adjusted model included ethnicity, age group, marital status, and lifetime number of sex partners.

[b] Adjusted model included ethnicity, age group, marital status, and the covariate of interest.

Table 9: Univariable and Adjusted Logistic Models for High Risk Human Papillomavirus Concurrent and Concordant Infections for Women (U.S. National Health and Nutrition Examination Survey, 2009-2014)

	Concurrent Infection		Concordant Infection	
	Univariate	Adjusted	Univariate	Adjusted
Term	OR(95% CI)	OR(95% CI)	OR(95% CI)	OR(95% CI)
Ethnicity				
Other	Ref	Ref	Ref	Ref
White	0.87(0.36, 2.1)	0.63(0.21, 1.9)	1.1(0.37, 3.2)^	0.73(0.22, 2.5)
Black	1.3(0.62, 2.7)^	0.86(0.40, 1.8)	0.67(0.19, 2.3)	0.47(0.14, 1.6)
Age Group				
18 to 24	Ref	Ref	Ref	Ref
25 to 39	0.65(0.32, 1.3)	1.5(0.43, 5.1)^	0.38(0.16, 0.89)*	0.88(0.15, 5.2)
40 to 59	0.69(0.38, 1.2)	2.1(0.75, 5.9)^	0.61(0.24, 1.5)	1.9(0.48, 7.6)^
Marital Status				
Married	Ref	Ref	Ref	Ref
No longer married	4.5(1.5, 13.5)**^	2.5(0.73, 8.5)^	3.5(1.0, 12.5)^	1.7(0.48, 6.0)^
Never married	3.8(1.6, 9.1)**^	2.8(0.79, 9.6)^	2.4(0.84, 7.0)^	1.8(0.39, 8.0)^
Living with partner	2.7(0.86, 8.3)^	2.0(0.62, 6.4)^	1.7(0.34, 8.3)^	1.2(0.28, 5.5)^
Missing	7.1(2.4, 20.7)***	5.9(1.0, 34.4)^	8.0(2.5, 25.4)***	6.5(0.95, 44.8)^
Lifetime Sex Partners				
0-1	Ref	Ref	Ref	Ref
2-5	1.9(0.47, 7.3)^	0.99(0.14, 7.1)	1.2(0.23, 6.5)^	0.36(0.06, 2.2)
6-10	2.5(0.89, 6.9)^	0.70(0.16, 3.1)	2.5(0.81, 7.8)^	0.41(0.09, 1.8)
11+	4.1(1.5, 11.6)**^	0.57(0.11, 3.0)	4.1(1.3, 13.3)*^	0.36(0.08, 1.7)
Recent Sex Partners				
0-1	Ref	Ref	Ref	Ref
2-5	4.2(2.2, 7.8)***	3.3(0.87, 12.8)^	4.4(2.1, 9.3)***	3.2(0.45, 23.2)^
6+	14.1(2.6, 75.9)***^	4.2(0.85, 20.3)^	18.2(2.8, 120.2)***^	4.6(0.55, 38.9)^
Lifetime Oral Partners				
0-1	Ref	Ref	Ref	Ref
2-5	1.6(0.81, 3.1)^	1.3(0.44, 3.8)^	2.9(0.96, 8.7)^	3.0(0.75, 12.0)^
6+	3.7(1.5, 9.2)**^	2.1(0.47, 9.6)^	6.0(1.9, 18.6)***^	3.1(0.54, 18.1)^
Recent Oral Partners				
0-1	Ref	Ref	Ref	Ref
2-5	2.8(1.2, 6.3)*^	0.65(0.13, 3.2)	3.8(1.4, 10.4)*^	0.95(0.11, 8.0)
6+	16.8(3.1, 92.5)***^	2.6(0.54, 12.5)^	22.5(3.2, 155.8)***^	3.3(0.41, 26.8)^
HPV Vaccine				
Yes	Ref	-	Ref	-
No	0.59(0.28, 1.2)	-	0.99(0.33, 3.0)	-
Cigarette Use				
Never	Ref	Ref	Ref	Ref
Ever	3.2(1.3, 7.9)*^	2.3(0.81, 6.5)^	4.8(1.8, 12.6)***^	3.3(1.3, 8.1)*^
Missing	6.6(3.3, 13.2)***	1.8(0.31, 11.1)^	12.0(5.3, 27.1)***	1.9(0.27, 13.1)^
Marijuana Use				
Never	Ref	Ref	Ref	Ref
Ever	2.7(1.5, 4.9)***	1.7(0.89, 3.1)^	3.3(1.4, 7.9)*^	1.4(0.70, 2.9)^
Sexual Orientation				
Heterosexual	Ref	-	Ref	-
Homosexual/Bisexual	1.4(0.48, 4.0)^	-	0.98(0.24, 4.0)	-
Other	0.69(0.16, 3.0)	-	1.0(0.24, 4.6)^	-

*P-Value $< .05$, **P-Value $< .01$, ***P-Value $< .005$. ^ The relative standard error of the weighted prevalence estimate was $> 30\%$.

Figure 1: Histograms of Simulated Proportions of High Risk Human Papillomavirus Concurrent Infection for Combined Population (U.S. National Health and Nutrition Examination Survey, 2013-2014 for Men, 2009-2014 for Women)

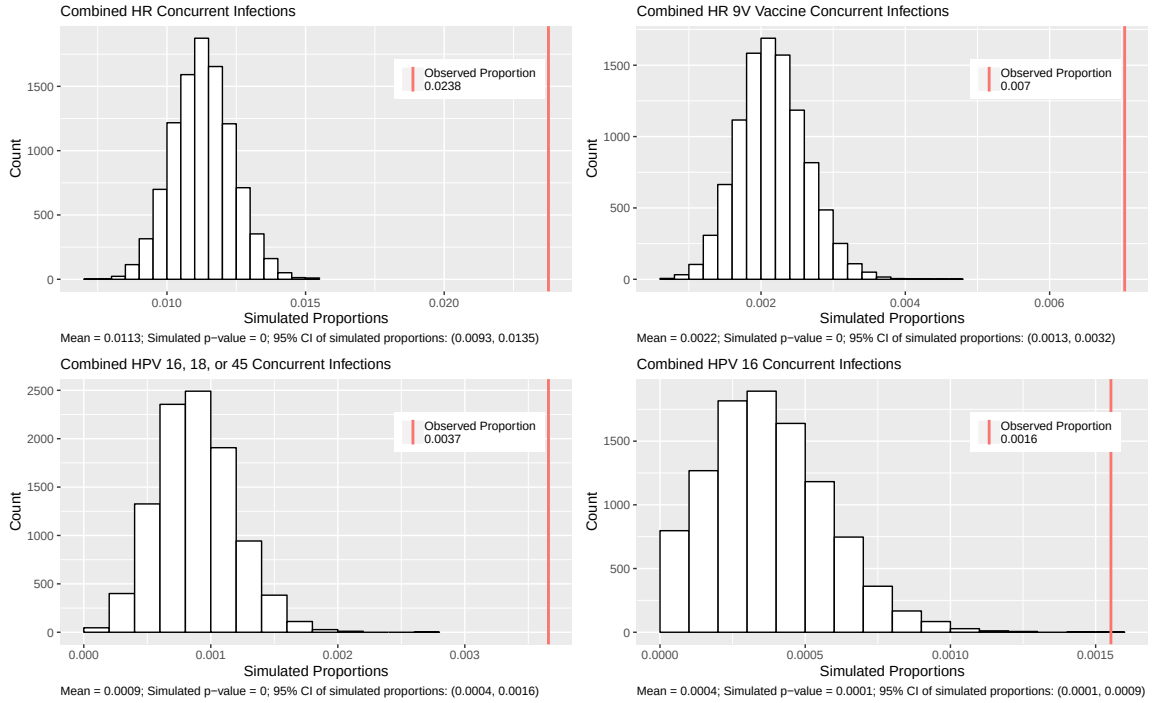


Figure 2: Histograms of Simulated Proportions of High Risk Human Papillomavirus Concurrent Infections for Men (U.S. National Health and Nutrition Examination Survey, 2013-2014)

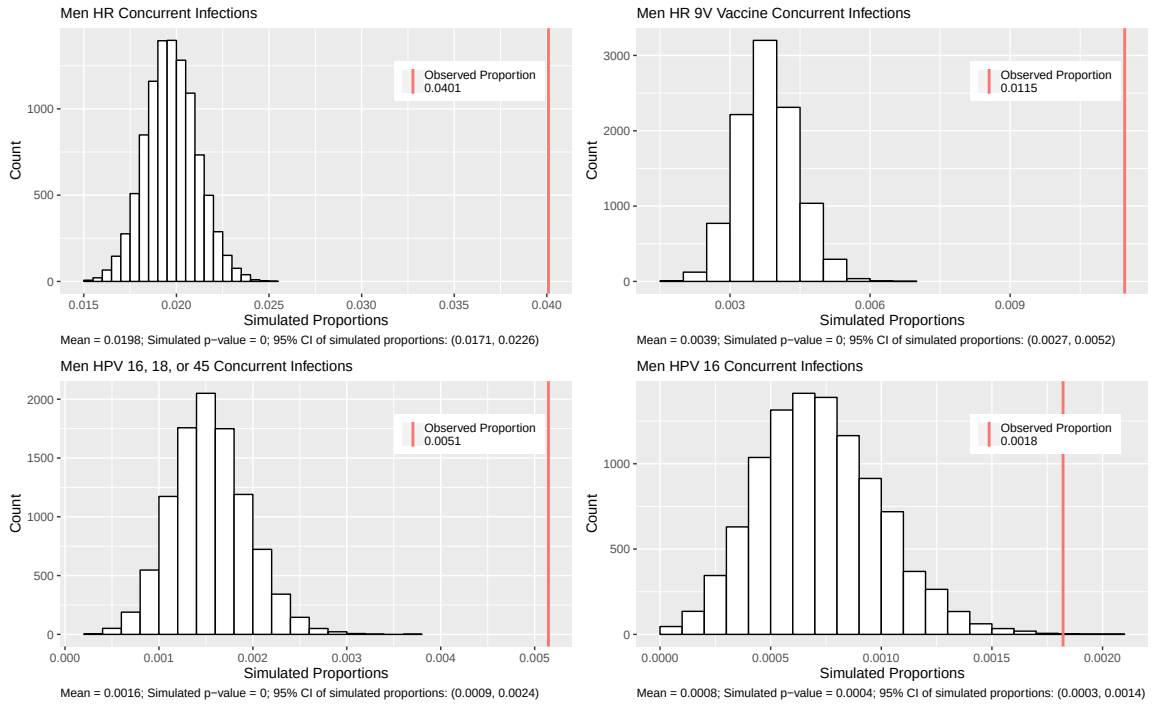


Figure 3: Histograms of Simulated Proportions of High Risk Human Papillomavirus Concurrent Infection for Women (U.S. National Health and Nutrition Examination Survey, 2009-2014)

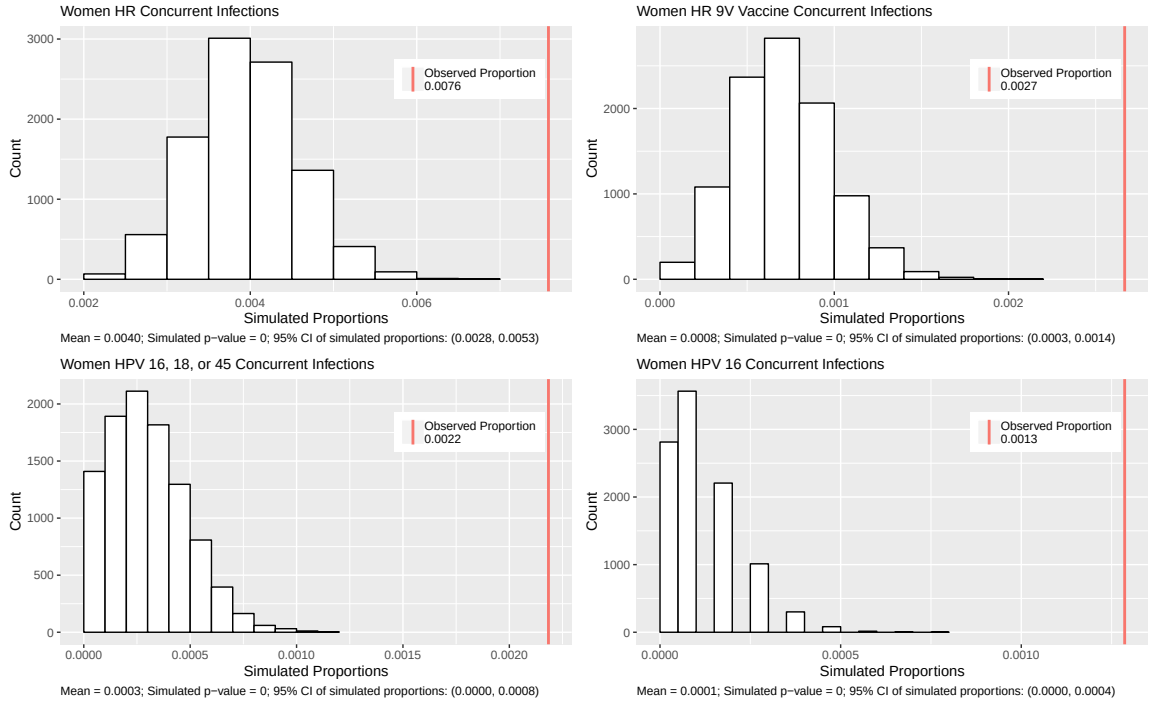


Figure 4: Histograms of Simulated Proportions of High Risk Human Papillomavirus Concordant Infection for Combined Population (U.S. National Health and Nutrition Examination Survey, 2013-2014 for Men, 2009-2014 for Women)

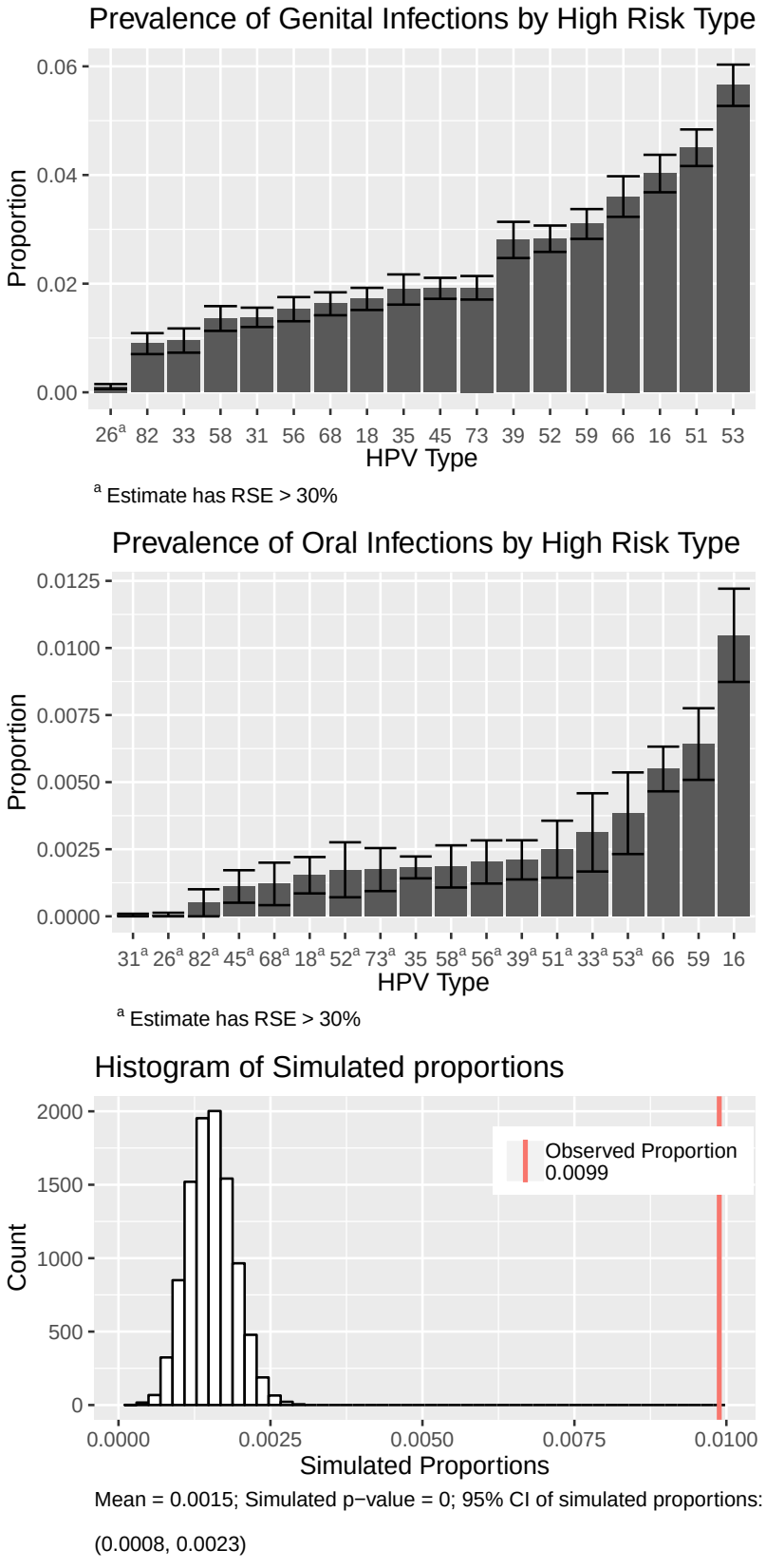


Figure 5: Histograms of Simulated Proportions of High Risk Human Papillomavirus Concordant Infection for Men (U.S. National Health and Nutrition Examination Survey, 2013-2014)

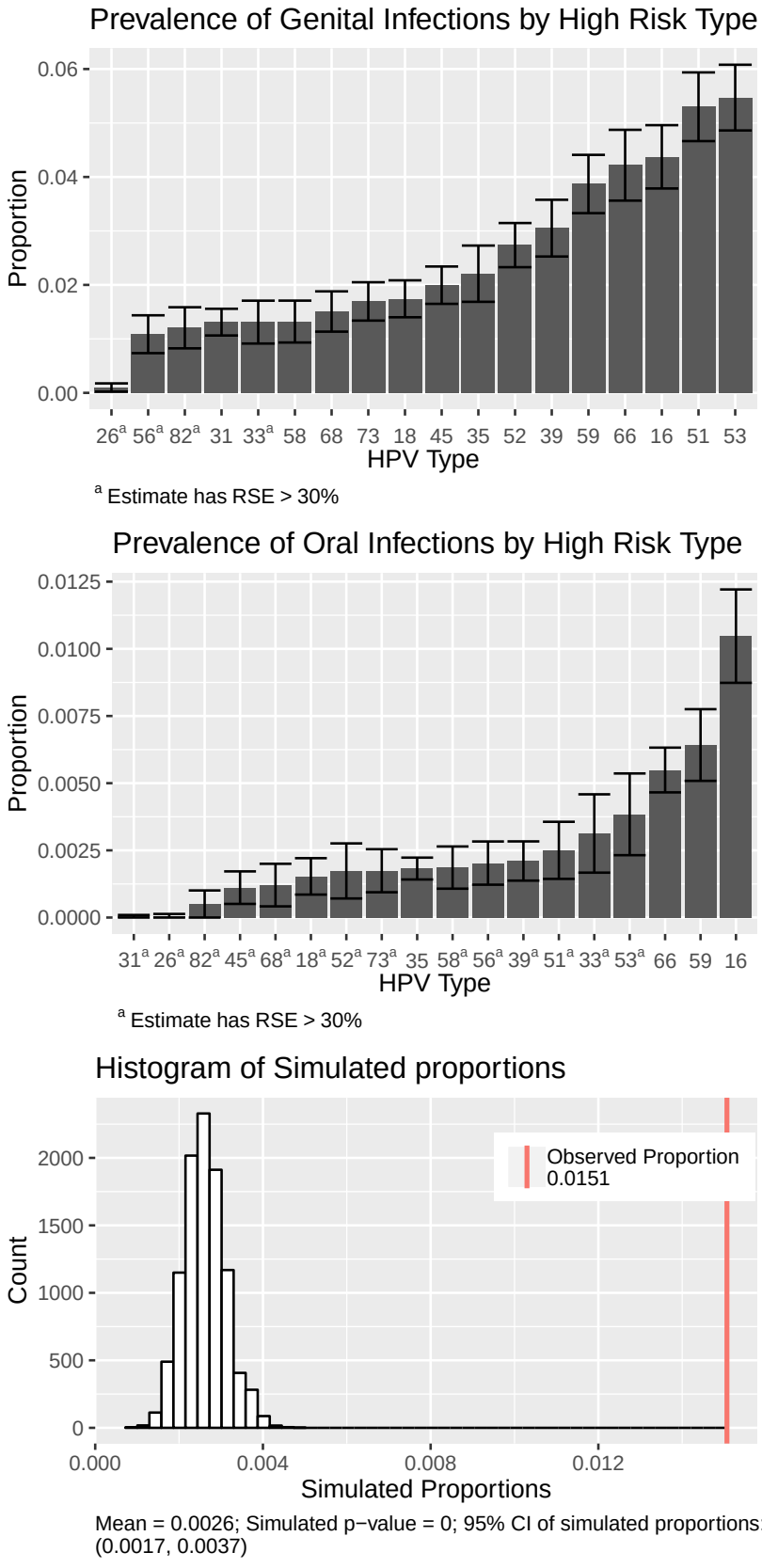
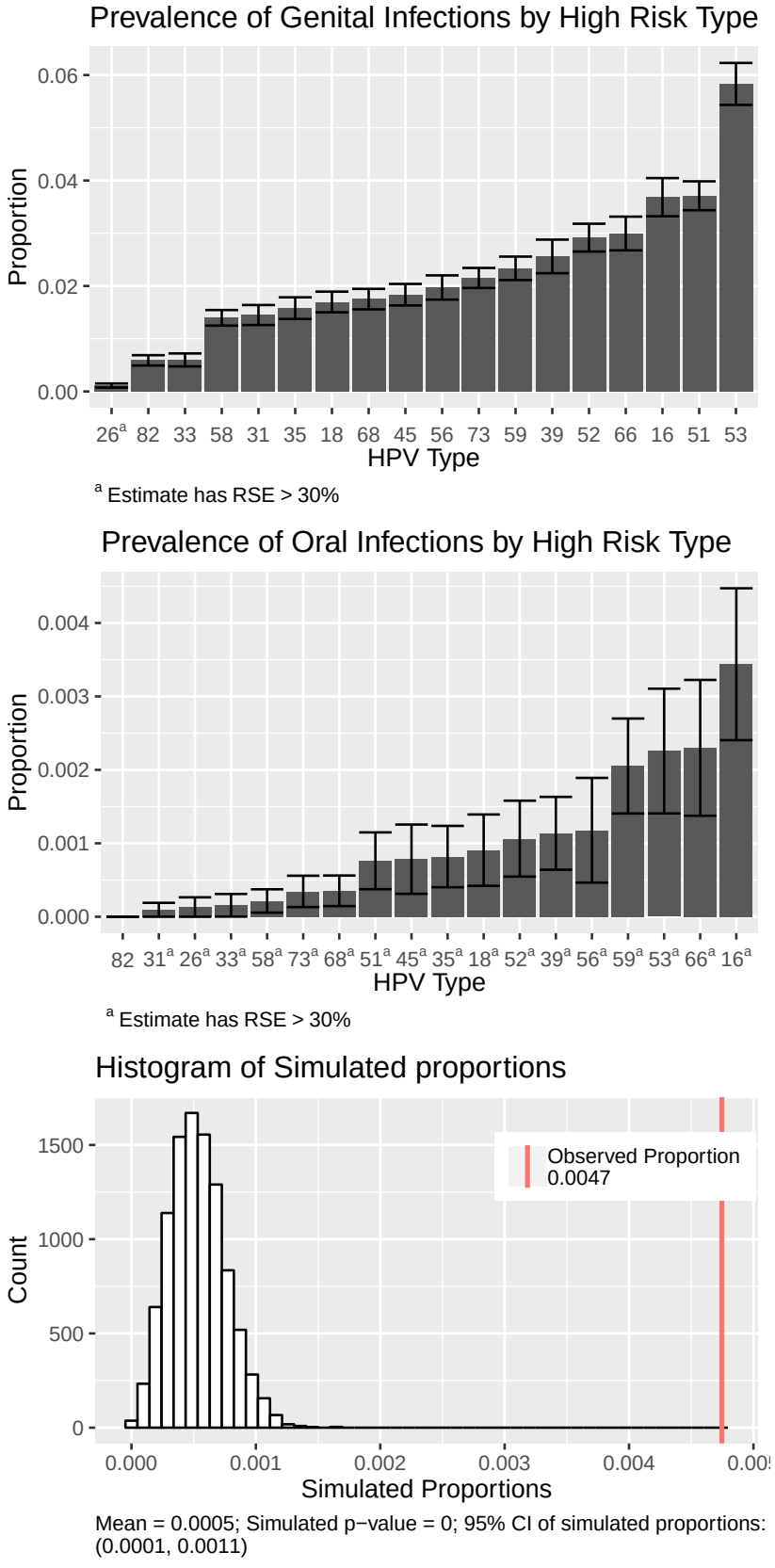


Figure 6: Histograms of Simulated Proportions of High Risk Human Papillomavirus Concordant Infection for Women (U.S. National Health and Nutrition Examination Survey, 2009-2014)



References

[1] Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey; 2018 [cited 18 September 2018]. Available from: https://www.cdc.gov/nchs/nhanes.

[2] Munoz N, Bosch FX, de Sanjose S, Herrero R, Castellsague X, Shah KV, et al. Epidemiologic classification of human papillomavirus types associated with cervical cancer. The New England journal of medicine. 2003 Feb 6;348(6):518–527.

[3] Giuliano AR, Nyitray AG, Kreimer AR, Campbell CMP, Goodman MT, Sudenga SL, et al. EUROGIN 2014 roadmap: differences in human papillomavirus infection natural history, transmission and human papillomavirus-related cancer incidence by gender and anatomic site of infection. International journal of cancer. 2015 Jun 15;136(12):2752–2760.

[4] Walboomers JM, Jacobs MV, Manos MM, Bosch FX, Kummer JA, Shah KV, et al. Human papillomavirus is a necessary cause of invasive cervical cancer worldwide. The Journal of pathology. 1999 Sep;189(1):12–19.

[5] Saraiya M, Unger ER, Thompson TD, Lynch CF, Hernandez BY, Lyu CW, et al. US assessment of HPV types in cancers: implications for current and 9-valent HPV vaccines. Journal of the National Cancer Institute. 2015 Apr 29;107(6):djv086.

[6] Viens LJ, Henley SJ, Watson M, Markowitz LE, Thomas CC, Thompson TD, et al. Human Papillomavirus-Associated Cancers - United States, 2008-2012. MMWRMorbidity and mortality weekly report. 2016 Jul 8;65(26):661–666.

[7] Chaturvedi AK, Engels EA, Pfeiffer RM, Hernandez BY, Xiao W, Kim E, et al. Human papillomavirus and rising oropharyngeal cancer incidence in the United States. Journal of clinical oncology : official journal of the American Society of Clinical Oncology. 2011 Nov 10;29(32):4294–4301.

[8] Mourad M, Jetmore T, Jategaonkar AA, Moubayed S, Moshier E, Urken ML. Epidemiological Trends of Head and Neck Cancer in the United States: A SEER Population Study. Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons. 2017 Dec;75(12):2562–2572. LR: 20180721; CI: Copyright (c) 2017; GR: P30 CA196521/CA/NCI NIH HHS/United States; JID: 8206428; NIHMS968906; 2017/02/27 00:00 [received]; 2017/05/14 00:00 [revised]; 2017/05/14 00:00 [accepted]; 2017/06/16 06:00 [pubmed]; 2017/12/14 06:00 [medline]; 2017/06/16 06:00 [entrez]; ppublish.

[9] Gillison ML, Chaturvedi AK, Anderson WF, Fakhry C. Epidemiology of Human Papillomavirus-Positive Head and Neck Squamous Cell Carcinoma. Journal of clinical oncology : official journal of the American Society of Clinical Oncology. 2015 Oct 10;33(29):3235–3242.

[10] Meites E, Kempe A, Markowitz LE. Use of a 2-Dose Schedule for Human Papillomavirus Vaccination-Updated Recommendations of the Advisory Committee on Immunization Practices. American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons. 2017 Mar;17(3):834–837.

[11] Walker TY, Elam-Evans LD, Singleton JA, Yankey D, Markowitz LE, Fredua B, et al. National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13-17 Years - United States, 2016. MMWRMorbidity and mortality weekly report. 2017 Aug 25;66(33):874–882.

[12] Sonawane K, Suk R, Chiao EY, Chhatwal J, Qiu P, Wilkin T, et al. Oral Human Papillomavirus Infection: Differences in Prevalence Between Sexes and Concordance With Genital Human Papillomavirus Infection, NHANES 2011 to 2014. Annals of Internal Medicine. 2017 Nov 21;167(10):714–724.

[13] Gargano JW, Unger ER, Liu G, Steinau M, Meites E, Dunne E, et al. Prevalence of Genital Human Papillomavirus in Males, United States, 2013-2014. The Journal of infectious diseases. 2017 Apr 1;215(7):1070–1079.

[14] Liu F, Hang D, Deng Q, Liu M, Xi L, He Z, et al. Concurrence of oral and genital human papillomavirus infection in healthy men: a population-based cross-sectional study in rural China. Scientific reports. 2015 Oct 27;5:15637.

[15] Kedarisetty S, Orosco RK, Hecht AS, Chang DC, Weissbrod PA, Coffey CS. Concordant Oral and Vaginal Human Papillomavirus Infection in the United States. JAMA otolaryngology– head & neck surgery. 2016 May 1;142(5):457–465.

[16] Patel EU, Rositch AF, Gravitt PE, Tobian AAR. Concordance of Penile and Oral Human Papillomavirus Infections Among Men in the United States. The Journal of infectious diseases. 2017 Apr 15;215(8):1207–1211.

[17] A WTA, E CD. Don't Forget HPV-45 in Cervical Cancer Screening. American Journal of Clinical Pathology. 2012;137(1):161–163.

[18] Arbyn M, de Sanjose S, Saraiya M, Sideri M, Palefsky J, Lacey C, et al. EUROGIN 2011 roadmap on prevention and treatment of HPV-related disease. International journal of cancer. 2012 Nov 1;131(9):1969–1982.

[19] Chaturvedi AK, Graubard BI, Broutian T, Pickard RK, Tong ZY, Xiao W, et al. NHANES 2009-2012 Findings: Association of Sexual Behaviors with Higher Prevalence of Oral Oncogenic Human Papillomavirus Infections in U.S. Men. Cancer research. 2015 Jun 15;75(12):2468–2477.

[20] D'Souza G, Cullen K, Bowie J, Thorpe R, Fakhry C. Differences in oral sexual behaviors by gender, age, and race explain observed differences in prevalence of oral human papillomavirus infection. PloS one. 2014 Jan 24;9(1):e86023.

[21] Dunne EF, Unger ER, Sternberg M, McQuillan G, Swan DC, Patel SS, et al. Prevalence of HPV infection among females in the United States. Jama. 2007 Feb 28;297(8):813–819. LR: 20161017; JID: 7501160; 0 (DNA, Viral); 0 (Papillomavirus Vaccines); CIN: JAMA. 2007 Jul 4;298(1):38; author reply 38. PMID: 17609486; CIN: JAMA. 2007 Feb 28;297(8):876-8. PMID: 17327531; 2007/03/01 09:00 [pubmed]; 2007/03/06 09:00 [medline]; 2007/03/01 09:00 [entrez]; ppublish.