

The association between Adverse Childhood Experiences and HPV vaccination coverage in US
young adults: a cross-sectional study

Shengruo Zhang

A thesis

submitted in partial fulfillment of the
requirements for the degree of

Master of Science

University of Washington

2022

Committee:

Rachel Winer

Barbra Richardson

Program Authorized to Offer Degree:

Epidemiology

©Copyright 2022
Shengruo Zhang

University of Washington

Abstract

The association between Adverse Childhood Experiences and HPV vaccination coverage in US young adults: a cross-sectional study

Shengruo Zhang

Chair of the Supervisory Committee:

Rachel Winer

Department of Epidemiology

Introduction

Adverse childhood experiences (ACEs) affect more than half of all children in the United States, and people with ACEs are more prone to various unhealthy situations in adulthood. Access to preventive healthcare services, including HPV vaccinations, may help reduce the impact of ACEs on adverse health outcomes. Our objective was to assess the prevalence of ACEs and self-reported HPV vaccination coverage among young adults.

Methods

We included 18–29-year-old respondents to the 2019-2020 Behavioral Risk Factor Surveillance System (BRFSS) ACE and HPV vaccination modules. ACEs were defined as a history of emotional abuse, physical abuse, sexual abuse, intimate partner violence, substance abuse, mental illness, parental separation or divorce, or incarcerated household member. Self-reported HPV vaccination initiation was defined as having ever been vaccinated and completion was defined as reporting at least 3 doses. Data on the timing of vaccination are not available in BRFSS. We used log-binomial regression models to calculate prevalence ratios (PRs) with 95% confidence intervals for the associations between ACEs and HPV vaccination. We evaluated race and ethnicity, urban/rural status, education level, income level, health insurance status, and smoking status as potential confounders. We also evaluated influenza vaccination uptake and the length of time since the last

routine checkup as secondary outcomes, and ever having had an HIV test and recent HIV-related risk behaviors as outcomes in post-hoc analyses.

Results

Among 3450 participants, 2441 (71%) reported at least 1 ACE. 1030 (30%) reported that they had ever been vaccinated, and 489 (14%) completed the HPV vaccination series. We identified several ACEs that were positively associated with HPV vaccine initiation in early adulthood, including emotional abuse (PR for initiation: 1.29, 95% CI:1.17-1.43, PR for completion: 1.20, 95% CI:1.01-1.41), intimate partner violence (PR for initiation: 1.14, 95% CI:1.01-1.30), substance abuse (PR for initiation: 1.20, 95% CI:1.08-1.33, PR for completion: 1.19, 95% CI:1.00-1.41), and mental illness (PR for initiation: 1.35, 95% CI:1.22-1.50, PR for completion: 1.41, 95% CI:1.19-1.68). Conversely, reporting physical abuse, intimate partner violence, substance abuse, parental separation or divorce, and incarcerated household member were each negatively associated with receipt of influenza vaccination in the past year (PRs ranging from 0.72-1.00). Most ACEs were negatively associated with reporting a routine checkup within the past 1-2 years (PRs ranging from 0.92-1.00). There were positive associations between each ACE and report of having ever had an HIV test (PRs ranging from 1.19-1.56) and HIV-related risk behavior (PRs ranging from 1.57-2.07).

Conclusions

Unexpected positive associations between ACEs and HPV vaccination coverage were observed. A possible explanation is that accessing STI/HIV prevention or treatment services provided additional opportunities to receive HPV vaccination in late adolescence or early adulthood. Future studies evaluating associations between ACEs and timely HPV vaccination in early adolescence will be important for informing HPV and HPV-related cancer prevention strategies in individuals with ACEs.

INTRODUCTION

Over half of US children have adverse experiences during childhood [1]. Compared with the general population, individuals with adverse childhood experiences (ACEs) are more vulnerable to various unhealthy situations, such as depression and excessive alcohol use, HIV risk behavior, chronic disease, disability, obesity, and increased risk of sexually transmitted infections (STIs) in adulthood [2]–[5].

Specifically, childhood sexual abuse may lead to increased risk for genital HPV infection [6], [7], a necessary causal agent in uterine cervix cancer and also linked to vagina, anus, vulva, penis, and oropharynx cancers [8]. Childhood sexual abuse has also been linked with reduced uptake of cervical cancer screening in adulthood [9]. The impacts of ACEs on mental health, tobacco smoking, and drinking in adulthood have been evaluated in several studies in the United States, Cambodia, Malawi, Nigeria, and Sweden. Abuse experience in childhood and childhood exposure to intimate partner violence have been shown to have deleterious impacts on individuals' mental health in late adolescence and early adulthood [10], [11]. Childhood parental separation or divorce has been linked to adult tobacco smoking and has also been demonstrated to exacerbate pre-existing unfavorable mental health effects [12], [13]. People living with an incarcerated household member during childhood were more likely to engage in smoking and heavy drinking as adults [14]. ACEs have also been associated with increased engagement in HIV-related risk behaviors, such as infrequent condom use [15].

Accessing health care services may protect those individuals by mitigating the effects of their adverse behaviors and health outcomes, thereby eliminating some of the effects of ACEs [16]. One example is that through discussion with health care providers and their recommendation for administration of the HPV vaccine, people have more opportunities to initiate the HPV vaccination series [17]. However, there is evidence that victims with a history of adverse experiences were less likely to use healthcare [18]. In a study of non-institutionalized adults in the United States, ACEs were negatively associated with having current healthcare insurance and accessing a routine checkup with a clinician in the past year. In addition, exposure to physical and emotional abuse and household dysfunction in childhood were negatively associated with having a personal doctor or health care provider in adulthood [19]. Women who were victims of childhood or adulthood sexual violence were more likely to report not seeing a physician one year before a cancer diagnosis, and not getting a routine comprehensive physical assessment or cancer screening than women without a history of experiencing sexual violence [20]. In a study of a low income population in the southeastern United States, the utilization of breast and cervical cancer screening decreased with higher ACE scores [21].

As preventive care, HPV vaccination can shield people from HPV infection and related disease. Gardasil, which prevents infection with four strains of HPV, including strains 6, 11, 16, and 18, was approved by the FDA for females in 2006 and expanded to include males in 2011 [22]. Eight years later, Gardasil 9 was approved by the FDA in December 2014, which protects against 9 strains of HPV [22]. Since 2017, Gardasil 9 is the only HPV vaccine available in the US [22]. According to the CDC Advisory Committee on Immunization Practices (ACIP) guideline, people can have a 2-dose HPV vaccine schedule if they get the first dose before their 15th birthday, and a 3-dose

schedule if they take the first dose on or after their 15th birthday or are immunocompromised [23]. As a routine vaccination, Gardasil 9 is recommended by the (ACIP) for adolescents at 11 or 12 years old. Catch-up vaccination is also recommended for individuals aged 13 to 26 years who were not previously vaccinated [24]. Although the vaccine is not routinely recommended after the age of 26, approval was extended to people up to the age of 45 in 2019. In the general population, in 2018, HPV vaccination coverage with at least 1 dose was approximately 53% among females and 26% among males aged 19-26 years [25]. To our knowledge, studies have not evaluated HPV vaccine coverage in individuals with ACEs. Data evaluating whether HPV vaccination uptake differs in individuals who report ACEs versus do not report ACEs could be helpful for designing future interventions to reduce health inequities and HPV-related morbidity and mortality in individuals with ACEs.

We examined the associations between ACEs and self-reported HPV vaccination initiation and completion in 18-29-year-old adults in the US, and also examined these associations by age group and assigned sex at birth. In addition, as a comparison with associations with other recent preventive health behaviors, we examined the associations between ACEs and influenza vaccine in the last 12 months and recent health check-ups.

METHODS

Study setting and population

The Behavioral Risk Factor Surveillance System (BRFSS) is a cross-sectional health-related survey of non-institutionalized US adults who are 18 years of age or older. Each year, BRFSS collects more than 400,000 surveys at the state level and reports them to the Centers for Disease Control and Prevention [26]. Consisting of core questions that are asked in each state along with state-added questions and optional modules, the survey samples a diverse population using random digit dialing by both landlines and cell phones. The surveys include weighting methodology designed to represent the health behaviors of the entire US population. BRFSS has become a useful tool for targeting and building health promotion activities.

This study used data from the 2019 and 2020 BRFSS datasets. Individuals who were 18-29 years old, coming from 5 states that administered both the optional ACE and adult HPV vaccine modules were included. In 2019, Mississippi, South Carolina, and Tennessee administered both of the optional ACE and adult HPV vaccination modules. In 2020, Georgia, Mississippi, North Dakota, and South Carolina administered both modules. Individuals were eligible if they answered the HPV vaccination initiation question and at least one question in the ACE module in 2019 or 2020.

Assessment of HPV vaccine uptake

The outcome of interest was self-reported HPV vaccine initiation and completion, using HPV responses to the two questions “Have you ever had an HPV vaccination?” and “How many HPV shots did you receive?” HPV vaccination initiation was dichotomized as “yes” versus “no/don’t know/not sure” based on the response to the first question. For HPV vaccination completion, the outcome “yes” versus “no” was dichotomized based on the reported number of doses. HPV vaccine was recommended on a 3-dose schedule prior to October 2016, and CDC updated the guideline to 2-dose or 3-dose schedules depending on the initiation age [27]. Most people in this study would

not have been eligible for the 2-dose series based on their age, the timing of the guidelines, and the timing of the survey. Therefore, individuals were categorized as completed if they reported 3 or more doses and as not completed if they reported less than 3 doses or do not know the exact number of doses.

Assessment of Adverse Childhood Experiences (ACEs)

The exposure of interest was ACEs, which was defined based on the ACE Module questions from the BRFSS survey. ACEs were categorized into 8 independent exposure variables, including substance abuse in the household, sexual abuse, emotional abuse, physical abuse, intimate partner violence, mental illness, incarcerated household member, and parental separation/divorce. All of the ACE questions specifically refer to the time period when responders were less than 18 years old.

The survey questions about childhood sexual abuse were defined by the type of behavior and responders' and perpetrators' ages and relationships [28]. Emotional abuse, physical abuse, and perpetrated violence questions were based on the Conflicts Tactics Scale [29]. Substance abuse questions were adapted from the 1988 National Health Interview Survey [30].

Substance abuse in the household was defined as a positive response to either of two questions in the survey: if a household member was a problem drinker/alcoholic, or if a household member used illegal street drugs/abused prescription medications [31], [32]. Sexual abuse was defined as a response of either "once" or "more than once" to any of the three questions: has anyone at least 5 years older than the responder or an adult: (1) ever touched the responder sexually, (2) tried to make the responder touch them sexually, or (3) forced the responder to have sex [31], [32]. Emotional abuse was identified by the question: "how often did a parent or adult in your home ever swear at you, insult you, or put you down?" Physical abuse was considered through the question: "Not including spanking, how often did a parent or adult in your home ever hit, beat, kick, or physically hurt you in any way?" Exposure to intimate partner violence was identified by the question: "how often did your parents or adults in your home ever slap, hit, kick, punch or beat each other up?" Exposed to mental illness or not was identified by the question: "did you live with anyone who was depressed, mentally ill, or suicidal?" Incarcerated household members exposure was considered by the question: "did you live with anyone who served time or was sentenced to serve time in a prison, jail, or other correctional facility?" The parental separation or divorce variable was dichotomized as Yes versus No or Parents not married [32]. Respondents with unmarried parents were grouped with the "no" group.

A "don't know or not sure" answer was categorized as a no response [32]. Each self-reported ACE variable was categorized as a dichotomous yes/no variable.

In addition to the eight separate exposure variables, the number of ACE exposures were summed for each individual to obtain an ACE score with a range from 0 to 8. The ACE score was categorized as 0, 1, 2-3, and 4 or more [33], [34].

Statistical analysis

Descriptive statistics were used to assess the sociodemographic characteristics of respondents, including sex assigned at birth, age, race and ethnicity, urban/rural status, education level, income level, and insurance status. Healthcare utilization and risk behaviors were also described, including smoking status, influenza vaccination in the past 12 months, length of time since last routine checkup, ever having been tested for HIV, and HIV-related risk behaviors in the past year. ACEs and HPV vaccination initiation and completion were described by sociodemographic variables. Categorical variables were summarized as frequencies and percentages.

To assess the association between ACEs and vaccination initiation or completion, prevalence ratios (PRs) and 95% confidence intervals (CIs) were estimated using log-binomial regression analysis, with separate models for each ACE variable and for each vaccination outcome. The following potential confounders were evaluated: race and ethnicity (non-Hispanic White/non-Hispanic Black/Hispanic/other, with other including non-Hispanic American Indian or Alaskan Native, non-Hispanic American Asian, non-Hispanic Native Hawaiian or other Pacific Islander, or non-Hispanic Multiracial), urban/rural status (urban/rural), education level (high school graduate or less/some college or technical school/college graduate), income level (less than \$25,000/\$25,000 to less than \$75,000/\$75,000 or more/don't know or not sure), health insurance status (yes/no or don't know or not sure), and smoking status (current smoker/former smoker/never smoked). Each potential confounder was assessed separately by including it in the regression model. A factor was determined to be a confounder if the adjusted PR differed by at least 10% compared with the crude PR. Variables identified as confounders were entered in multivariate models. The same modeling strategy and assessment of confounders was used in all analyses.

To explore effect modification by sex assigned at birth or age on the associations between ACEs and HPV vaccination status, stratified analyses by sex assigned at birth (male vs female) and by age group (18-24 years vs 25-29 years) were conducted [35].

To better understand the results from the primary analysis, as a parallel a priori comparison, analyses to see the associations between the ACEs and influenza vaccination uptake in the past 12 months (yes/no) and length of time since last routine checkup (within past year or past 2 years / within past 5 or more years or never) were conducted.

To explore associations between ACEs and behaviors that may increase likelihood of receiving an HPV vaccination, post hoc analyses for the associations between ACEs and ever having had an HIV test (yes/no) and recent HIV-related risk behaviors (yes/no) were conducted. HIV-related risk behaviors applied if the responders had injected any drug other than those prescribed, had been treated for a sexually transmitted disease (STD), or had given or received money or drugs in exchange for sex in the past year. All the outcomes in the post hoc analyses were binary and PRs were calculated using log-binomial regression.

A significance threshold of 0.05 was used in all analyses. Analyses were performed in RStudio (Version 1.3.1073) and Stata (Version 14.0).

RESULTS

Participant characteristics

The analysis included 3450 individuals who had completed at least one question in the ACE module and the HPV vaccine initiation question (Figure 1). Among the participants, 56.0% were 18-24 years old, 51.3% were female, 60.4% were non-Hispanic White, 24.8% were non-Hispanic Black, and 84.8% lived in an urban region (Table 1). Most participants completed high school or less (38.6%) or some college or technical school (35.0%), had health insurance (75.7%), and an annual household income of more than \$25,000 (56.2%). Less than one-third (29.9%) of the population self-reported that they received the HPV vaccine, with 14.2% receiving three doses. The prevalence of ACEs ranged from 6.1% for sexual abuse to 43.7% for parental separation/divorce. Most (70.8%) had at least 1 ACE and 48.5% had more than 1.

Sociodemographic characteristics by ACEs are shown in Table 2. The frequency of reporting sexual abuse was higher in females than in males (18.3% vs 7.2%) but the frequencies of other ACEs were similar between males and females. Non-Hispanic black individuals were less likely to report ACEs than other individuals, with the exception of parental separation/divorce or incarcerated family member. For most ACEs, frequencies were lower in college graduates than in individuals with less than a college degree. Individuals with household income \geq \$75,000 reported ACEs less frequently than individuals with lower household income. Individuals without health insurance tended to report higher frequencies of ACEs than individuals with health insurance. Never smokers reported lower frequencies of ACEs than current or former smokers.

HPV vaccine initiation and completion were higher in females than in males (initiation: female:39.7% vs male:19.6%, completion: female:21.8% vs male:6.1%, Table 3). Vaccine initiation was slightly higher in younger (31.2%) vs older (28.2%) participants, but similar by age for vaccine completion (13.8% vs 14.6%). Lower HPV vaccine initiation and completion was reported by non-Hispanic black individuals (26.8%, 11.5%) compared with non-Hispanic white (31.3%, 15.5%) and Hispanic (30.9%, 14.5%) individuals. Higher education levels and income levels were associated with higher HPV vaccination initiation and completion. HPV vaccine initiation (33.3% vs 20.4%) and completion (16.2% vs 8.4%) were higher in the population with health insurance than without health insurance.

Prevalence and correlates of HPV vaccination

Participants reporting emotional abuse were more likely to have initiated HPV vaccination than participants who did not report emotional abuse (PR: 1.29, 95% CI:1.17-1.43, Table 4). Similar significant positive associations were seen for intimate partner violence (PR: 1.14, 95% CI:1.01-1.30), substance abuse (PR: 1.20, 95% CI:1.08-1.33), and mental illness (PR: 1.35, 95% CI: 1.22-1.50). Emotional abuse (PR: 1.20, 95% CI:1.01-1.41), substance abuse (PR: 1.19, 95% CI: 1.00-1.41), and mental illness (PR: 1.41, 95% CI:1.19-1.68) were each also positively associated with vaccine completion.

For the ACE score analysis, all ACE score categories greater than 0 (PR: 1.20, 95% CI:1.03-1.40 for 1; PR: 1.21, 95% CI:1.05-1.41 for 2 or 3; PR: 1.38, 95% CI: 1.20-1.59 for 4 or more) were

positively associated with vaccine initiation compared with not reporting any ACEs. However, ACE score was not associated with vaccine completion.

When testing for the candidate confounders, most of the potential confounders evaluated did not appreciably change the crude estimates. In the analysis of the association between reporting an incarcerated household member and HPV vaccine completion, after adjusting for education level, the PR changed from 0.88 to 1.00 (neither the crude nor adjusted estimate was statistically significant). After adjusting for sex assigned at birth, the PR for the association between reporting sexual abuse and HPV vaccine initiation changed from 1.13 to 0.96, although neither the crude nor adjusted estimate was statistically significant. After controlling for sex assigned at birth, the PR for the association between sexual abuse and HPV vaccine completion changed from 1.27 to 0.99, from significantly associated to unassociated.

After stratifying for sex assigned at birth, the association between mental illness and vaccination initiation was stronger in males than in females (PR: 1.67 vs 1.15, respectively; Table 5). Exposure to mental illness also had a stronger relationship with vaccine completion in males (PR: 1.63) than in females (PR: 1.25). In addition, the association between sexual abuse and vaccination completion was stronger in males (PR adjusted for smoking status: 1.37) than in females (crude PR: 0.96).

The associations between substance abuse and vaccine completion were stronger in the 18-24 age group (PR: 1.34) than in the 25-29 age group (PR: 1.02, Table 6). No other appreciable differences in associations between initiation or completion by age group were observed.

Additional Pre-specified Analyses

Reporting physical abuse (PR: 0.86, 95% CI:0.75-0.98), intimate partner violence (PR: 0.81, 95% CI:0.70-0.94), substance abuse (PR: 0.86, 95% CI:0.76-0.96), parental separation or divorce (PR: 0.84, 95% CI:0.75-0.93), and incarcerated household member (PR: 0.72, 95% CI:0.61-0.84) were each negatively associated with receipt of influenza vaccination in the past year. In addition, individuals who reported 4 or more ACEs were less likely to report influenza vaccination than individuals with no ACEs (PR: 0.78, 95% CI:0.68-0.91, Table 7).

With the exception of sexual abuse and parental separation/divorce experience, all other ACEs were negatively associated with reporting a routine checkup within the past 1-2 years (Table 8). Individuals reporting 2-3 ACEs (PR=0.93, 95%CI: 0.89-0.98) or reporting 4 or more ACEs (PR=0.90, 95% CI: 0.86-0.95) were less likely than individuals reporting 0 ACEs to have had a routine check-up in the past 1-2 years.

Post hoc Analyses

There were positive associations between each ACE and report of having ever had an HIV test (Table 9). All the associations were statistically significant, with magnitudes of association ranging from 1.19 for emotional abuse to 1.56 for sexual abuse. All levels of ACE score categories greater than one were associated with HIV test history when compared to 0 ACEs, ranging from 1.32 for an ACE score of 2-3 to 1.71 for an ACE score of more than 4 points.

Individuals reporting emotional abuse were more than twice as likely to report HIV-related risk behavior than individuals who did not report emotional abuse (PR=2.07, 95% CI:1.76-2.44) (Table 10). After adjusting for smoking status, smaller but statistically significant associations were observed for all other ACEs, with PRs adjusted for smoking status ranging from 1.19 for parental separation or divorce to 1.81 for sexual abuse. When adjusting for sex assigned at birth, individuals who had a history of sexual abuse were more likely to report HIV-related risk behavior than individuals without sexual abuse history (PR: 2.24, 95% CI:1.87-2.68).

DISCUSSION

To our knowledge, this is the first quantitative assessment of the relationship between ACEs and HPV vaccine coverage among young adults. We found that more than seventy percent of US young adults surveyed had at least one ACE. Unexpectedly, we identified several ACEs that were positively associated with HPV vaccine coverage in early adulthood, including emotional abuse, intimate partner violence, substance abuse, and mental illness. In addition to describing associations with ACEs and HPV vaccination coverage, an additional goal was to understand the potential mechanisms or barriers to vaccination that can stimulate strategies to improve vaccine uptake in individuals with ACEs, reducing HPV-related morbidity and mortality.

In our assessment of other preventive care seeking behavior among young adults with ACEs, we found a negative association between ACEs and recent influenza vaccination and routine healthcare checkups, which is in the opposite direction from the associations with HPV vaccination. These results were consistent with prior literature showing that not having a personal doctor, not having a checkup in the last 2 years, and not receiving medical care on time due to cost was significantly higher among individuals with at least one versus no ACEs [19],[36]. The findings suggest that the observed positive association between ACEs and HPV vaccination is unlikely to be due to increased general preventive health behaviors or health care. Results suggest that individuals with ACEs were either more likely to get vaccinated in early adolescence than their peers without ACEs (unlikely given that sexual abuse was not one of the ACEs associated with HPV vaccination) or that they were more likely to get vaccinated in late adolescence and early adulthood than their peers without ACEs.

Acknowledging various negative physical and mental health outcomes from ACEs that have been identified in previous studies, our original hypothesis was that individuals who had a history of ACEs were less likely to receive HPV vaccinations than those who had not. On the other hand, in our study, we observed unexpected positive associations between ACEs and HPV vaccination coverage. Because the BRFSS does not capture data on vaccination timing, we hypothesized that these unexpected positive associations could be due to an increased likelihood of vaccination in late adolescence or early adulthood (beyond the target age for vaccination). For example, it is possible that people with ACEs could have additional opportunities for HPV vaccination in late adolescence/early adulthood than people without ACEs if they are more likely to seek HIV/STI testing or treatment. To further explore the potential reasons for these findings, we developed additional post hoc analyses to examine the associations between ACEs and ever having had an HIV test or recent HIV-related risk behavior. We observed that ACEs were positively associated

with behaviors that increase risk for STIs, including HIV, and with ever having had an HIV test, consistent with prior studies showing positive associations between ACEs and STI/HIV risk behaviors and more frequent STI testing [3], [37]–[39]. These results support the theory that the positive associations between ACEs and HPV vaccination could be partly attributable to people receiving HPV vaccination recommendations or incidental HPV vaccination from their healthcare providers when they accessed healthcare for HIV/STI prevention or treatment.

Few differences were observed in associations between ACEs and HPV vaccination when stratifying by sex assigned at birth or age group. Based on evidence in previous studies that sex assigned at birth modifies the association between childhood abuse/neglect and the risk of STDs in early adulthood, we thought that sex assigned at birth might modify associations between ACEs and HPV vaccination [5], [40]–[42]. In addition, we thought the association between ACEs and HPV vaccination uptake might be stronger in the 18-24 vs. 25-29-year-old age group because the ACEs happened more recently.

ACE score was linked to the initiation of HPV vaccination but not to the completion of the HPV vaccination series. Compared with the prevalence ratios for HPV vaccination initiation, the lower prevalence ratios for completion may reflect the possibility that individuals with ACEs who incidentally received a first dose of HPV vaccine while accessing HIV/STI screening or treatment services may not have been as likely to return for a second or third dose.

There are several strengths in our study. The large sample size enhanced power to examine associations. In addition to HPV vaccine coverage, outcomes included additional recent preventive care seeking behaviors and risk behavior, including influenza vaccination uptake, length of time since last routine checkup, ever having an HIV test, and HIV-related risk behavior. Our study provided preliminary data on associations between ACEs and HPV vaccination coverage, which could be useful to inform the design of a future study to explore mechanisms and causal associations between ACE history and HPV vaccination uptake.

Our study was limited by a lack of data on the timing of HPV vaccination. The target population for HPV vaccination is 11-12-year-old adolescents because the vaccine is most effective when administered prior to the onset of sexual activity, and is less beneficial when received in early adulthood. Nevertheless, BRFSS does not ask for age at receiving HPV vaccines, limiting our ability to explore associations with age at vaccine administration. Furthermore, because the BRFSS datasets do not gather data on the timing of ACEs, we were unable to determine whether the ACEs occurred before or after immunization. With these limitations, we were unable to evaluate temporal relationships between ACEs and HPV vaccination in order to reach a conclusion with probable causal inference. In addition, unlike other national surveys like the National Immunization Survey (NIS)-Teen that use documented records to determine vaccination status, the self-reported vaccine status in BRFSS might be subject to recall bias if participants cannot accurately remember previous vaccination experiences [43]. The source population for the BRFSS dataset is non-institutionalized U.S. adults with an active landline or cellular telephone. Since people who do not have an active phone number cannot be included and those who answer their telephones and agree to participate in the survey may be systematically different from those who fail to participate

in the survey, there may be selection bias. Finally, there were only five states that administered both the ACEs and HPV vaccine modules in either 2019 or 2020. The dataset utilized in this analysis only comprised data from five states. Compared with data from the entire national BRFSS dataset in the same time period, HPV vaccine initiation (29.9% vs. 35.3%) and completion (14.2% vs 16.8%) in 18-29-year-olds in these five states was slightly lower. Consequently, the results of our study may not be generalizable to all young adults living in the US.

For the log-binomial regression analyses, we purposely did not use the data weight which was a pre-designed methodology in the BRFSS dataset. The weight method serves as a blanket adjustment for the population that is not surveyed in BRFSS and forces the overall number of cases to equal population estimates for each geographic region [44]. In spite of each state sample design, the final weight in the analysis is used to make generalizations from the study sample to the overall population in the US. However, in our analysis, we only included data from 5 states. We did not think it would be appropriate to use the national weight design when only including 5 states into the analyses.

CONCLUSION AND IMPLICATIONS

While STI/HIV testing or treatment in early adulthood may provide opportunities for individuals with ACEs to be vaccinated and HPV vaccination coverage was slightly higher among people with versus without ACEs, vaccination coverage was still low overall when compared to the Healthy People 2020 national target of 80% completion in adolescents [45]. In addition, we observed reduced access to preventive care (influenza vaccination and recent routine check-ups) in people with versus without ACEs, and increased likelihood of HIV-related risk behavior. Previous research has shown that people with ACEs are less likely to have cervical cancer screening [9]. Given prior studies showing that people with ACEs are at increased risk for STIs, prioritizing vaccination in early adolescence will be important for ensuring the greatest benefit in people with ACEs [5]–[7]. Future evaluations could incorporate national datasets, such as NIS-Teen, which collects vaccination data from teenagers and includes survey questions on reasons for not getting vaccinated [43]. The Community Health Needs Assessment dataset, which includes 11 ACE categories with more granularity than the BRFSS dataset, could also be used for more specificity in examining ACE exposures [46]. Future studies that gather data on timing of HPV vaccination and ACEs could be used to evaluate the temporal associations.

ACKNOWLEDGEMENTS

I would first like to appreciate my committee chair, Dr. Rachel Winer, for her invaluable guidance. I would particularly like to thank my committee member, Dr. Barbra Richardson, for her patient and professional instruction on the statistical analyses.

Reference:

- [1] K. S. Balistreri, "Adverse Childhood Experiences, the Medical Home, and Child Well-Being," *Matern Child Health J*, vol. 19, no. 11, pp. 2492–2500, Nov. 2015, doi: 10.1007/s10995-015-1770-6.
- [2] R. D. Lee and J. Chen, "Adverse childhood experiences, mental health, and excessive alcohol use: Examination of race/ethnicity and sex differences," *Child Abuse Negl*, vol. 69, pp. 40–48, Jul. 2017, doi: 10.1016/j.chiabu.2017.04.004.
- [3] J. A. Campbell, R. J. Walker, and L. E. Egede, "Associations Between Adverse Childhood Experiences, High-Risk Behaviors, and Morbidity in Adulthood," *Am J Prev Med*, vol. 50, no. 3, pp. 344–352, Mar. 2016, doi: 10.1016/j.amepre.2015.07.022.
- [4] D. A. Wiss and T. D. Brewerton, "Adverse Childhood Experiences and Adult Obesity: A Systematic Review of Plausible Mechanisms and Meta-Analysis of Cross-Sectional Studies," *Physiol Behav*, vol. 223, p. 112964, Sep. 2020, doi: 10.1016/j.physbeh.2020.112964.
- [5] A. A. Haydon, J. M. Hussey, and C. T. Halpern, "Childhood abuse and neglect and the risk of STDs in early adulthood," *Perspect Sex Reprod Health*, vol. 43, no. 1, pp. 16–22, Mar. 2011, doi: 10.1363/4301611.
- [6] C. Stevens-Simon, D. Nelligan, P. Breese, C. Jenny, and J. M. Douglas, "The prevalence of genital human papillomavirus infections in abused and nonabused preadolescent girls," *Pediatrics*, vol. 106, no. 4, pp. 645–649, Oct. 2000, doi: 10.1542/peds.106.4.645.
- [7] E. R. Unger *et al.*, "Anogenital human papillomavirus in sexually abused and nonabused children: a multicenter study," *Pediatrics*, vol. 128, no. 3, pp. e658–665, Sep. 2011, doi: 10.1542/peds.2010-2247.
- [8] N. Muñoz, X. Castellsagué, A. Berrington de González, and L. Gissmann, "Chapter 1: HPV in the etiology of human cancer," *Vaccine*, vol. 24 Suppl 3, p. S3/1-10, Aug. 2006, doi: 10.1016/j.vaccine.2006.05.115.
- [9] M. Farley, J. M. Golding, and J. R. Minkoff, "Is a history of trauma associated with a reduced likelihood of cervical cancer screening?," *J Fam Pract*, vol. 51, no. 10, pp. 827–831, Oct. 2002.
- [10] J. Adams, S. Mrug, and D. C. Knight, "Characteristics of child physical and sexual abuse as predictors of psychopathology," *Child Abuse Negl*, vol. 86, pp. 167–177, Dec. 2018, doi: 10.1016/j.chiabu.2018.09.019.
- [11] B. Kieselbach, H. Kress, H. MacMillan, and T. Perneger, "Prevalence of childhood exposure to intimate partner violence and associations with mental distress in Cambodia, Malawi and Nigeria: A cross-sectional study," *Child Abuse Negl*, vol. 111, p. 104807, Jan. 2021, doi: 10.1016/j.chiabu.2020.104807.
- [12] M. Lindström and M. Rosvall, "Parental separation/divorce in childhood and tobacco smoking in adulthood: A population-based study," *Scand J Public Health*, vol. 48, no. 6, pp. 657–666, Aug. 2020, doi: 10.1177/1403494819846724.
- [13] H. Bohman, S. B. Låftman, A. Päären, and U. Jonsson, "Parental separation in childhood as a risk factor for depression in adulthood: a community-based study of adolescents screened for depression and followed up after 15 years," *BMC Psychiatry*, vol. 17, no. 1, p. 117, Mar. 2017, doi: 10.1186/s12888-017-1252-z.
- [14] A. Gjelsvik, D. M. Dumont, and A. Nunn, "Incarceration of a household member and Hispanic health disparities: childhood exposure and adult chronic disease risk behaviors," *Prev Chronic Dis*, vol. 10, p. E69, May 2013, doi: 10.5888/pcd10.120281.
- [15] K. VanderEnde *et al.*, "Adverse Childhood Experiences and HIV Sexual Risk-Taking Behaviors Among Young Adults in Malawi," *J Interpers Violence*, vol. 33, no. 11, pp. 1710–1730, Jun. 2018, doi: 10.1177/0886260517752153.

- [16] E. Smith, K. Milaney, R. I. Henderson, and L. Crowshoe, "Adverse childhood experiences and health among indigenous persons experiencing homelessness," *BMC Public Health*, vol. 21, no. 1, p. 85, Jan. 2021, doi: 10.1186/s12889-020-10091-y.
- [17] P. J. Smith, S. Stokley, R. A. Bednarczyk, W. A. Orenstein, and S. B. Omer, "HPV vaccination coverage of teen girls: the influence of health care providers," *Vaccine*, vol. 34, no. 13, pp. 1604–1610, Mar. 2016, doi: 10.1016/j.vaccine.2016.01.061.
- [18] L. C. Watson-Johnson, J. S. Townsend, K. C. Basile, and L. C. Richardson, "Cancer screening and history of sexual violence victimization among U.S. adults," *J Womens Health (Larchmt)*, vol. 21, no. 1, pp. 17–25, Jan. 2012, doi: 10.1089/jwh.2011.2751.
- [19] H. E. Alcalá, A. Valdez-Dadia, and O. S. von Ehrenstein, "Adverse childhood experiences and access and utilization of health care," *J Public Health (Oxf)*, vol. 40, no. 4, pp. 684–692, Dec. 2018, doi: 10.1093/pubmed/fox155.
- [20] S. C. Modesitt *et al.*, "Adverse impact of a history of violence for women with breast, cervical, endometrial, or ovarian cancer," *Obstet Gynecol*, vol. 107, no. 6, pp. 1330–1336, Jun. 2006, doi: 10.1097/01.AOG.0000217694.18062.91.
- [21] C. P. Mouton, M. K. Hargreaves, J. Liu, S. Fadeyi, and W. J. Blot, "Adult Cancer Risk Behaviors Associated with Adverse Childhood Experiences in a Low Income Population in the Southeastern United States," *J Health Care Poor Underserved*, vol. 27, no. 1, pp. 68–83, Feb. 2016, doi: 10.1353/hpu.2016.0027.
- [22] P. Jul 12 and 2021, "The HPV Vaccine: Access and Use in the U.S.," *KFF*, Jul. 12, 2021. <https://www.kff.org/womens-health-policy/fact-sheet/the-hpv-vaccine-access-and-use-in-the-u-s/> (accessed May 07, 2022).
- [23] "HPV Vaccine Schedule and Dosing | CDC," Dec. 16, 2021. <https://www.cdc.gov/hpv/hcp/schedules-recommendations.html> (accessed May 07, 2022).
- [24] E. Petrosky *et al.*, "Use of 9-valent human papillomavirus (HPV) vaccine: updated HPV vaccination recommendations of the advisory committee on immunization practices," *MMWR Morb Mortal Wkly Rep*, vol. 64, no. 11, pp. 300–304, Mar. 2015.
- [25] P.-J. Lu *et al.*, "Surveillance of Vaccination Coverage Among Adult Populations -United States, 2018," *MMWR Surveill Summ*, vol. 70, no. 3, pp. 1–26, May 2021, doi: 10.15585/mmwr.ss7003a1.
- [26] "CDC - BRFSS," Jan. 05, 2022. <https://www.cdc.gov/brfss/index.html> (accessed Apr. 29, 2022).
- [27] M. L. Johnson Jones *et al.*, "Effectiveness of 1, 2, and 3 Doses of Human Papillomavirus Vaccine Against High-Grade Cervical Lesions Positive for Human Papillomavirus 16 or 18," *Am J Epidemiol*, vol. 189, no. 4, pp. 265–276, Apr. 2020, doi: 10.1093/aje/kwz253.
- [28] G. E. Wyatt, "The sexual abuse of Afro-American and white-American women in childhood," *Child Abuse Negl*, vol. 9, no. 4, pp. 507–519, 1985, doi: 10.1016/0145-2134(85)90060-2.
- [29] "Physical Violence in American Families: Risk Factors and Adaptations to Violence in 8,145 Families | Office of Justice Programs." <https://www.ojp.gov/ncjrs/virtual-library/abstracts/physical-violence-american-families-risk-factors-and-adaptations> (accessed Feb. 06, 2022).
- [30] C. A. Schoenborn, "Exposure to alcoholism in the family: United States, 1988," *Adv Data*, no. 205, pp. 1–13, Sep. 1991.
- [31] V. J. Felitti *et al.*, "Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults. The Adverse Childhood Experiences (ACE) Study," *Am J Prev Med*, vol. 14, no. 4, pp. 245–258, May 1998, doi: 10.1016/s0749-3797(98)00017-8.
- [32] Centers for Disease Control and Prevention (CDC), "Adverse childhood experiences reported by adults --- five states, 2009," *MMWR Morb Mortal Wkly Rep*, vol. 59, no. 49, pp. 1609–1613, Dec. 2010.

- [33] M. T. Merrick, D. C. Ford, K. A. Ports, and A. S. Guinn, "Prevalence of Adverse Childhood Experiences From the 2011-2014 Behavioral Risk Factor Surveillance System in 23 States," *JAMA Pediatr*, vol. 172, no. 11, pp. 1038–1044, Nov. 2018, doi: 10.1001/jamapediatrics.2018.2537.
- [34] S. Sonu, S. Post, and J. Feinglass, "Adverse childhood experiences and the onset of chronic disease in young adulthood," *Prev Med*, vol. 123, pp. 163–170, Jun. 2019, doi: 10.1016/j.ypmed.2019.03.032.
- [35] "Adverse childhood experiences, gender, and HIV risk behaviors: Results from a population-based sample - ClinicalKey." <https://www.clinicalkey.com/#!/content/playContent/1-s2.0-S2211335516300493?returnurl=https%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS2211335516300493%3Fshowall%3Dtrue&referrer=> (accessed May 10, 2022).
- [36] A. Srivastav, C. L. Richard, C. Kipp, and K. White, "Racial/Ethnic Disparities in Health Care Access Are Associated with Adverse Childhood Experiences," *J Racial Ethn Health Disparities*, vol. 7, no. 6, pp. 1225–1233, Dec. 2020, doi: 10.1007/s40615-020-00747-1.
- [37] L. Fang, D.-M. Chuang, and Y. Lee, "Adverse childhood experiences, gender, and HIV risk behaviors: Results from a population-based sample," *Prev Med Rep*, vol. 4, pp. 113–120, Dec. 2016, doi: 10.1016/j.pmedr.2016.05.019.
- [38] T. V. Dyer, R. E. Turpin, D. J. Hawthorne, V. Jain, S. Sayam, and M. Mittal, "Sexual Risk Behavior and Lifetime HIV Testing: The Role of Adverse Childhood Experiences," *Int J Environ Res Public Health*, vol. 19, no. 7, p. 4372, Apr. 2022, doi: 10.3390/ijerph19074372.
- [39] D. F. Bertolino, T. H. Sanchez, M. Zlotorzynska, and P. S. Sullivan, "Adverse childhood experiences and sexual health outcomes and risk behaviors among a nationwide sample of men who have sex with men," *Child Abuse Negl*, vol. 107, p. 104627, Sep. 2020, doi: 10.1016/j.chiabu.2020.104627.
- [40] J. E. Logan, R. T. Leeb, and L. E. Barker, "Gender-specific mental and behavioral outcomes among physically abused high-risk seventh-grade youths," *Public Health Rep*, vol. 124, no. 2, pp. 234–245, Apr. 2009, doi: 10.1177/003335490912400211.
- [41] M. P. Thompson, J. B. Kingree, and S. Desai, "Gender differences in long-term health consequences of physical abuse of children: data from a nationally representative survey," *Am J Public Health*, vol. 94, no. 4, pp. 599–604, Apr. 2004, doi: 10.2105/ajph.94.4.599.
- [42] X. Fang and P. S. Corso, "Gender Differences in the Connections Between Violence Experienced as a Child and Perpetration of Intimate Partner Violence in Young Adulthood," *J Fam Viol*, vol. 23, no. 5, pp. 303–313, Jul. 2008, doi: 10.1007/s10896-008-9152-0.
- [43] "U.S. Vaccination Coverage Reported via NIS-Teen | CDC," Apr. 19, 2021. <https://www.cdc.gov/vaccines/imz-managers/coverage/nis/teen/index.html> (accessed Jun. 05, 2022).
- [44] "Weighting the BRFSS Data." Jun. 05, 2022. [Online]. Available: https://www.cdc.gov/brfss/annual_data/2020/pdf/weighting-2020-508.pdf
- [45] "Healthy-People 2020 - Midcourse Review," Feb. 22, 2019. https://www.cdc.gov/nchs/healthy_people/hp2020/hp2020_midcourse_review.htm (accessed Jun. 05, 2022).
- [46] "CDC - Home - Community Health Assessment - STLT Gateway," Apr. 08, 2019. <https://www.cdc.gov/publichealthgateway/cha/index.html> (accessed Jun. 05, 2022).

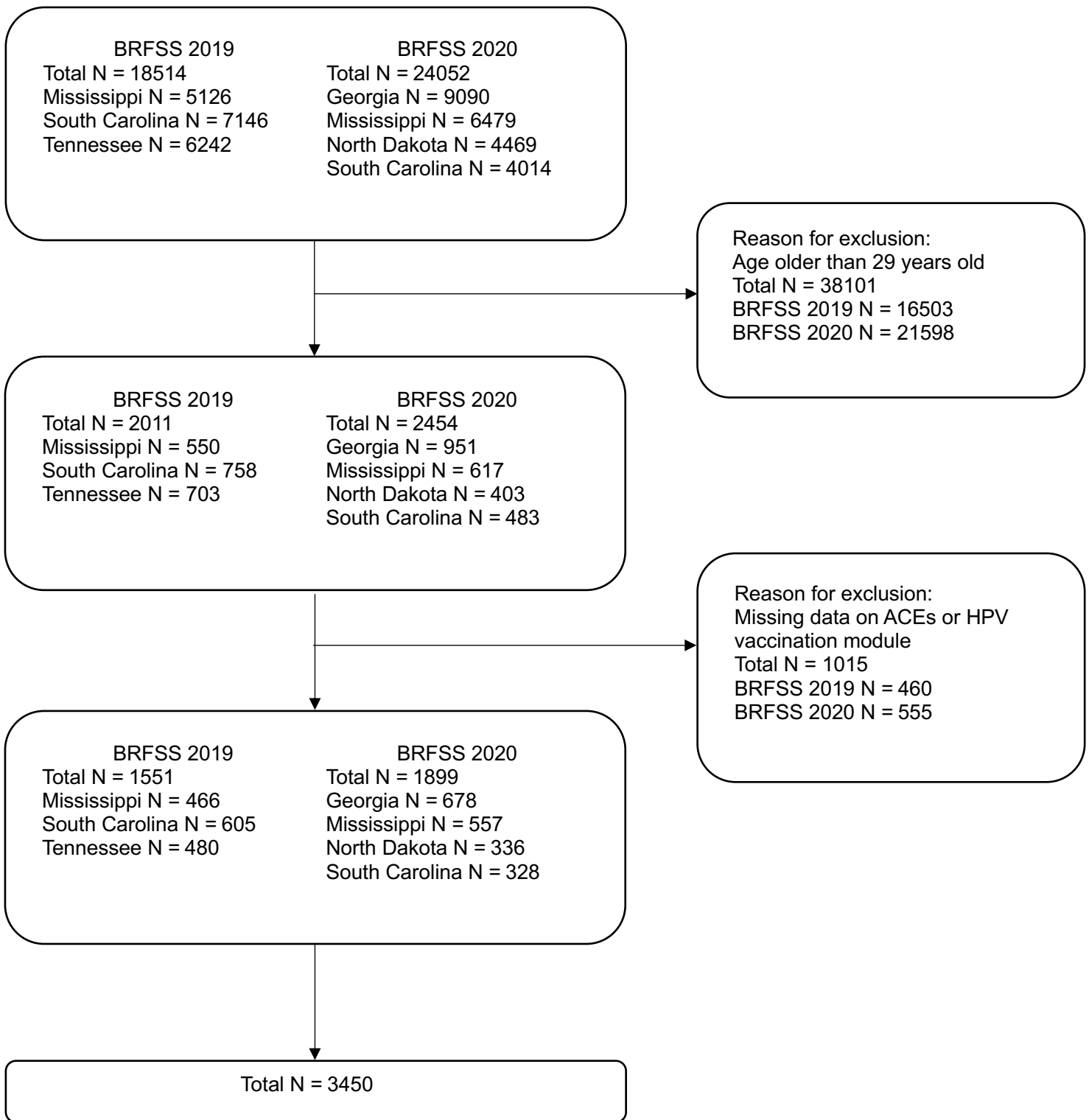


Figure1. Study Sample: Behavioral Risk Factor Surveillance System, 2019-2020

Table 1. Characteristics of 18–29-year-old respondents administered the Adverse Childhood Experiences module and questions on HPV vaccination uptake in the 2019 or 2020 Behavioral Risk Factor Surveillance System (N=3450)

Demographics	n	(%)
Sex		
Male	1681	48.7
Female	1769	51.3
Age, years		
18-24	1931	56.0
25-29	1519	44.0
Race/Ethnicity		
White, non-Hispanic	2085	60.4
Black, non-Hispanic	854	24.8
Hispanic	257	7.5
Other race, non-Hispanic ¹	234	6.8
<i>Don't know/Refused</i> ²	20	0.6
Urban/Rural Status		
Urban	2926	84.8
Rural	524	15.2
Education Level		
High school graduate or less	1329	38.6
Some college or technical school	1206	35.0
College graduate	908	26.4
<i>Refused</i>	7	0.2
Income Level		
Less than \$25,000	836	25.3
\$25,000 to less than \$75,000	1227	37.2
\$75,000 or more	627	19.0
Don't know/Not sure	610	18.5
<i>Refused/Missing</i>	150	4.3
Insurance Status		
Yes	2605	75.7
No	785	22.8
Don't Know/Not Sure	50	1.5
<i>Refused/Missing</i>	10	0.3
Healthcare utilization and risk behaviors	n	(%)
Smoking Status		
Current smoker	497	14.5
Former smoker	342	10.0
Never smoked	2591	75.5
<i>Don't know/Refused/Missing</i> ²	20	0.6

Flu vaccination in the past 12 months		
Yes	1022	29.7
No	2398	69.6
Don't Know/Not Sure	25	0.7
<i>Refused/Missing</i>	5	0.1
Length of time since last routine checkup		
Within past year	2150	62.4
1 to 2 years ago	534	15.5
2 to 5 years ago	357	10.4
5 or more years ago	280	8.1
Never	30	0.9
Don't Know/Not Sure	93	2.7
<i>Refused/Missing</i>	6	0.2
Ever been tested for HIV		
Yes	1350	39.2
No	2004	58.2
Don't Know/Not Sure	90	2.6
<i>Refused/Missing</i>	6	0.2
HIV-related risk behavior in the past year³		
Yes	529	15.4
No	2907	84.5
Don't Know/Not Sure	4	0.1
<i>Refused</i>	10	0.3
HPV vaccination		
Yes	1030	29.9
1 dose	131	3.8
2 doses	190	5.5
3+ doses	489	14.2
Vaccinated - Unknown number of doses	220	6.4
No	1895	55.0
Don't Know/Not Sure	520	15.1
<i>Refused</i>	5	0.1
Adverse Childhood Experiences	n	(%)
Emotional Abuse		
No/Never	1942	58.0
Yes	1395	41.6
Don't Know/Not Sure	14	0.4
<i>Refused/Missing</i>	99	2.9
Physical Abuse		
No/Never	2602	77.6
Yes	735	21.9
Don't Know/Not Sure	14	0.4
<i>Refused/Missing</i>	99	2.9

Sexual Abuse		
No/Never	2970	87.1
Yes	439	12.9
Don't Know/Not Sure	1	0.0
<i>Refused/Missing</i>	40	1.2
Intimate Partner Violence		
No/Never	2730	81.3
Yes	591	17.6
Don't Know/Not Sure	35	1.0
<i>Refused/Missing</i>	94	2.7
Substance Abuse		
Problem drinker		
Yes	868	25.6
No	2507	74.1
Don't Know/Not Sure	10	0.3
<i>Refused/Missing</i>	65	1.9
Illegal drugs		
Yes	648	19.2
No	2720	80.4
Don't Know/Not Sure	14	0.4
<i>Refused/Missing</i>	68	2.0
Mental Illness		
Yes	962	28.4
No	2401	70.9
Don't Know/Not Sure	24	0.7
<i>Refused/Missing</i>	63	1.8
Parental Separation or Divorce		
Yes	1473	43.7
No	1753	52.0
Parents not married	132	3.9
Don't Know/Not Sure	14	0.4
<i>Refused/Missing</i>	78	2.3
Incarcerated Household Member		
Yes	575	17.0
No	2793	82.6
Don't Know/Not Sure	12	0.4
<i>Refused/Missing</i>	70	2.0
ACE Score⁴		
0	1009	29.2
1	769	22.3
2-3	842	24.4
4 or more	830	24.1

¹ Other Race includes non-Hispanic American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific Islander, and Multiracial

² Calculated variable in BRFSS; don't know/not sure and refused are grouped together in the BRFSS codebook

³ Participants were asked if they had injected any drug other than those prescribed, been

treated for a sexually transmitted disease, or given or received money or drugs in exchange for sex in the past year.

⁴ ACE Score was calculated by summing the number of ACE exposures for each participant, with a range from 0 to 8.

Table 2. Frequencies of ACE Types by Sociodemographic Characteristics

	Emotional Abuse	Physical Abuse	Sexual Abuse	Intimate Partner Violence	Substance Abuse	Mental Illness	Parental Separation or Divorce	Incarcerated Household Member
Characteristics	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Sex (%)								
Male (n=1681)	664(40.7)	355(21.8)	119(7.2)	264(16.2)	476(28.5)	422(25.6)	687(41.9)	292(17.8)
Female (n=1769)	731(42.5)	380(22.1)	320(18.3)	327(19.0)	603 (34.3)	540(31.0)	786(45.3)	283(16.3)
Age (%)								
18 to 24 (n=1931)	818(43.4)	418(22.2)	239(12.5)	314(16.7)	604(31.5)	572(30.1)	805(42.5)	340(17.9)
25 to 29 (n=1519)	577(39.3)	317(21.6)	200(13.3)	277(18.8)	475(31.5)	390(26.2)	668(45.2)	235(15.8)
Race/Ethnicity (%)								
White only, non-Hispanic (n=2085)	912(44.8)	458(22.5)	253(12.3)	353(17.3)	723(34.8)	697(34.0)	853(41.7)	315(15.4)
Black only, non-Hispanic (n=854)	257(31.2)	137(16.7)	95(11.3)	122(14.8)	186(22.0)	134(16.1)	399(48.2)	163(19.6)
Hispanic (n=257)	106(42.4)	77(30.8)	42(16.6)	62(24.8)	78(30.6)	56(22.1)	102(40.6)	45(17.9)
Other race, non-Hispanic (n=234) ¹	112(50.0)	61(27.2)	46(20.0)	52(22.9)	85(36.5)	70(30.6)	111(48.7)	49(21.5)
Urban or rural status (%)								
Urban (n=2926)	1206(42.4)	630(22.2)	363(12.5)	493(17.3)	929(31.9)	833(29.0)	1245(43.5)	496(17.3)
Rural (n=524)	189(37.3)	105(20.7)	76(14.7)	98(19.3)	150(28.8)	129(25.0)	228(44.7)	79(15.4)
Education Level (%)								
High school graduate or less (n=1329)	512(39.8)	307(23.8)	191(14.6)	245(19.0)	451(34.2)	375(28.8)	626(48.4)	279(21.5)
Some college or technical school (n=1206)	538(45.9)	274(23.5)	175(14.7)	222(18.9)	388(32.3)	348(29.4)	545(46.2)	210(17.8)
College graduate (n=908)	343(38.7)	154(17.3)	72(8.0)	122(13.7)	23.6(26.1)	236(26.4)	300(33.6)	83(9.3)
Income Level (%)								
Less than \$25,000 (n=836)	356(44.0)	220(27.3)	147(17.8)	182(22.5)	277(33.5)	263(32.2)	404(49.7)	166(20.3)
\$25,000 to less than \$75,000 (n=1227)	527(44.1)	263(22.0)	141(11.6)	215(18.0)	418(34.2)	349(28.9)	558(46.4)	224(18.6)
\$75,000 or more (n=627)	235(38.4)	101(16.4)	65(10.5)	85(13.8)	179(28.7)	160(25.8)	212(34.4)	74(12.0)
Don't know/Not sure (n=610)	237(40.0)	130(21.8)	74(12.3)	96(16.1)	180(29.7)	164(27.5)	251(41.9)	95(15.9)

Insurance Status (%)								
Yes (n=2605)	1043(41.2)	534(21.1)	314(12.2)	411(16.2)	780(30.2)	724(28.3)	1094(42.9)	394(15.5)
No (n=785)	331(43.3)	191(25.0)	123(16.0)	175(23.0)	292(37.3)	229(29.7)	359(46.9)	178(23.1)
Don't Know/Not Sure (n=50)	18(37.5)	9(18.8)	2(4.0)	5(10.4)	6(12.0)	8(16.7)	18(37.5)	3(6.3)
Smoking Status (%)								
Current smoker (n=497)	262(55.3)	171(36.1)	110(22.5)	145(30.6)	250(50.9)	215(44.2)	290(60.3)	139(28.8)
Former smoker (n=342)	182(54.3)	98(29.2)	63(18.9)	79(23.7)	143(42.1)	130(38.3)	174(51.5)	81(24.0)
Never smoked (n=2591)	944(37.4)	462(18.3)	266(10.3)	364(14.4)	680(26.4)	615(24.2)	1001(39.5)	351(13.8)
Don't know/Refused/Missing (n=20)	7(41.2)	4(22.2)	0(0.0)	3(18.8)	6(33.3)	2(11.1)	8(44.4)	4(22.2)

¹ Other Race includes non-Hispanic American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific Islander, and Multiracial

Table 3. Frequencies of HPV vaccination¹ by Sociodemographic Characteristics

	HPV vaccination initiation	HPV vaccination completion
Characteristics	Yes (%)	Yes (%)
Sex (%)		
Male (n=1681)	329(19.6)	103(6.1)
Female (n=1769)	701(39.7)	386(21.8)
Age (%)		
18 to 24 (n=1931)	602(31.2)	267(13.8)
25 to 29 (n=1519)	428(28.2)	222(14.6)
Race/Ethnicity (%)		
White only, non-Hispanic (n=2085)	652(31.3)	323(15.5)
Black only, non-Hispanic (n=854)	228(26.8)	98(11.5)
Hispanic (n=257)	79(30.9)	37(14.5)
Other race, non-Hispanic (n=234) ²	65(27.8)	28(12.0)
Urban or rural status (%)		
Urban (n=2926)	890(30.4)	422(14.4)
Rural (n=524)	140(26.8)	67(12.8)
Education Level (%)		
High school graduate or less (n=481)	315(23.7)	118(8.9)
Some college or technical school (n=476)	385(32.0)	180(15.0)
College graduate (n=560)	329(36.3)	191(21.1)
Income Level (%)		
Less than \$25,000 (n=365)	251(30.1)	117(14.0)
\$25,000 to less than \$75,000 (n=642)	382(31.2)	174(14.2)
\$75,000 or more (n=302)	222(35.5)	117(18.7)
Don't know/Not sure (n=142)	137(22.5)	62(10.2)

Insurance Status (%)		
Yes	865(33.3)	420(16.2)
No	160(20.4)	66(8.4)
Don't Know/Not Sure	5(10.0)	3(6.0)
Smoking Status (%)		
Current smoker (n=497)	140(28.2)	56(11.3)
Former smoker (n=342)	91(26.6)	40(11.7)
Never smoked (n=2591)	796(30.8)	391(15.1)
Don't know/Refused/Missing (n=20)	3(16.7)	2(11.1)

¹ HPV vaccination initiation was defined as ever having had an HPV vaccination; HPV vaccination completion was defined as receiving 3 or more doses.

² Other Race includes non-Hispanic American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific Islander, and Multiracial

Table 4 Association between ACEs and HPV vaccination initiation/completion

ACE		Overall HPV Vaccination Initiation			Overall HPV Vaccination Completion		
		N	Yes (n %)	PR (95% CI)	N	Yes (n %)	PR (95% CI)
Abuse							
Emotional Abuse	No	1954	524(26.8)	1.00	1954	259(13.3)	1.00
	Yes	1395	484(34.7)	1.29(1.17,1.43)	1395	221(15.8)	1.20(1.01,1.41)
Physical Abuse	No	2614	782(29.9)	1.00	2614	371(14.2)	1.00
	Yes	735	222(30.2)	1.01(0.89,1.14)	735	104(14.1)	1.00(0.82,1.22)
Sexual Abuse	No	2969	876(29.5)	1.00	2969	409(13.8)	1.00
	Yes	439	147(33.5)	0.96(0.84,1.11) ¹	439	77(17.5)	0.99(0.79,1.23) ²
Household Challenges							
Intimate Partner Violence	No	2763	811(29.3)	1.00	2763	397(14.4)	1.00
	Yes	591	198(33.5)	1.14(1.01,1.30)	591	83(14.0)	0.98(0.78,1.22)
Substance Abuse	No	2348	664(28.3)	1.00	2348	316(13.5)	1.00
	Yes	1079	365(33.8)	1.20(1.08,1.33)	1079	173(16.0)	1.19(1.00,1.41)
Mental Illness	No	2423	662(27.3)	1.00	2423	310(12.8)	1.00
	Yes	962	356(37.0)	1.35(1.22,1.50)	962	174(18.1)	1.41(1.19,1.68)
Parental Separation or Divorce	No	1898	549(28.9)	1.00	1898	274(14.4)	1.00
	Yes	1472	463(31.4)	1.09(0.98,1.21)	1472	206(14.0)	0.97(0.82,1.15)
Incarcerated Household Member	No	2803	832(29.7)	1.00	2803	408(14.6)	1.00
	Yes	575	183(31.8)	1.07 (0.94,1.22)	575	74(12.9)	1.00(0.80,1.26) ³
ACE Score	0	1005	253(25.1)	1.00	1005	137(13.6)	1.00
	1	768	232(30.2)	1.20(1.03,1.40)	768	105(13.7)	1.00(0.79,1.27)
	2-3	842	257(30.5)	1.21(1.05, 1.41)	842	115(13.7)	1.00(0.80,1.26)
	4 or more	830	288(34.7)	1.38(1.20, 1.59)	830	132(15.9)	1.17(0.94,1.45)

¹ Adjusted for sex assigned at birth. The crude PR is 1.13 (0.98,1.31)² Adjusted for sex assigned at birth. The crude PR is 1.27(1.02,1.59)³ Adjusted for education level. The crude PR is 0.88 (0.70,1.11)

Table 5 Association between ACEs and HPV vaccination initiation/completion by sex assigned at birth

ACE	Vaccination initiation	Male			Female		
		N	Yes (n %)	PR (95% CI)	N	Yes (n %)	PR (95% CI)
Abuse							
Emotional Abuse	No	964	163(16.9)	1.00	990	361(36.5)	1.00
	Yes	664	160(24.1)	1.43(1.17,1.73)	731	324(44.3)	1.22(1.08,1.36)
Physical Abuse	No	1275	249(19.5)	1.00	1339	533(39.8)	1.00
	Yes	355	73(20.6)	1.05(0.83,1.33)	380	149(39.2)	0.99(0.86,1.13)
Sexual Abuse	No	1541	302(19.6)	1.00	1428	574(40.2)	1.00
	Yes	119	26(21.8)	1.11(0.78,1.59)	320	121(37.8)	0.94(0.81,1.10)
Household Challenges							
Intimate Partner Violence	No	1366	264(19.3)	1.00	1397	547(39.2)	1.00
	Yes	264	60(22.7)	1.18 (0.92,1.51)	327	138(42.2)	1.08(0.93,1.24)
Substance Abuse	No	1191	223(18.7)	1.00	1157	441(38.1)	1.00
	Yes	476	105(22.1)	1.18(0.96,1.45)	603	260(43.1)	1.13(1.01,1.27)
Mental Illness	No	1223	206(16.8)	1.00	1200	456(38.0)	1.00
	Yes	422	119(28.2)	1.67(1.38,2.04)	540	237(43.9)	1.15(1.02,1.30)
Parental Separation or Divorce	No	950	182(19.2)	1.00	948	367(38.7)	1.00
	Yes	686	141(20.6)	1.07(0.88,1.31)	786	322(41.0)	1.06(0.94,1.19)
Incarcerated Household Member	No	1348	265(19.7)	1.00	1455	567(39.0)	1.00
	Yes	292	59(20.2)	1.03(0.80,1.32)	283	124(43.8)	1.12(0.97,1.30)
ACE Score	0	523	87(16.6)	1.00	482	166(34.3)	1.00
	1	371	75(20.2)	1.22(0.92,1.61)	397	157(39.5)	1.15(0.97,1.37)
	2-3	427	81(19.0)	1.14(0.87,1.50)	415	176(42.4)	1.23(1.04,1.45)
	4 or more	357	86(24.1)	1.45(1.11,1.89)	473	202(42.7)	1.24(1.06,1.46)

ACE	Vaccination completion	Male			Female		
		N	Yes (n %)	PR (95% CI)	N	Yes (n %)	PR (95% CI)
Abuse							
Emotional Abuse	No	964	58(6.0)	1.00	990	201(20.3)	1.00
	Yes	664	42(6.3)	1.05(0.72,1.54)	731	179(24.5)	1.21(1.01,1.44)
Physical Abuse	No	1275	77(6.0)	1.00	1339	294(22.0)	1.00
	Yes	355	22(6.2)	1.03(0.65,1.62)	380	82(21.6)	0.98(0.79,1.22)
Sexual Abuse	No	1541	94(6.1)	1.00	1428	315(22.1)	1.00
	Yes	119	9(7.6)	1.37(0.71,2.66) ¹	320	68(21.3)	0.96(0.76,1.22)
Household Challenges							
Intimate Partner Violence	No	1366	86(6.3)	1.00	1397	311(22.3)	1.00
	Yes	264	14(5.3)	0.84(0.49,1.46)	327	69(21.1)	0.95(0.75,1.19)
Substance Abuse	No	1191	72(6.0)	1.00	1157	244(21.1)	1.00
	Yes	476	31(6.5)	1.08(0.72,1.62)	603	142(23.5)	1.12(0.93,1.34)
Mental Illness	No	1223	64(5.2)	1.00	1200	246(20.5)	1.00
	Yes	422	36(8.5)	1.63(1.10,2.42)	540	138(25.6)	1.25(1.04,1.50)
Parental Separation or Divorce	No	950	60(6.3)	1.00	948	214(22.6)	1.00
	Yes	686	39(5.7)	0.90(0.61,1.33)	786	167(21.2)	0.94(0.79,1.13)
Incarcerated Household Member	No	1348	86(6.4)	1.00	1455	322(22.1)	1.00
	Yes	292	14(4.8)	0.75 (0.43,1.30)	283	60(21.2)	1.08(0.85,1.37) ²
ACE Score	0	523	40(7.6)	1.00	482	97(20.1)	1.00
	1	371	16(4.3)	0.58(0.33,1.03) ³	397	89(22.4)	1.11(0.86,1.44)
	2-3	427	21(4.9)	0.69(0.41,1.16) ³	415	94(22.7)	1.13(0.88,1.45)
	4 or more	357	26(7.3)	1.06(0.65,1.72) ³	473	106(22.4)	1.11(0.87,1.42)

¹ Adjusted for smoking status. The crude PR is 1.24(0.64,2.39).

² Adjusted for education level. The crude PR is 0.96(0.75,1.22).

³ Adjusted for smoking status. The crude PRs are 0.56(0.32,0.99), 0.64(0.39,1.07), and 0.95(0.59,1.53), separately in 1, 2-3, and 4 or more ACE score categories.

Table 6 Association between ACEs and HPV vaccination uptake/completion by age group

ACE Category	Vaccination uptake	Age (18-24)			Age (25-29)		
		N	Yes (n %)	PR (95% CI)	N	Yes (n %)	PR (95% CI)
Abuse							
Emotional Abuse	No	1063	290(27.2)	1.00	891	234(26.3)	1.00
	Yes	818	302(36.9)	1.35(1.18,1.55)	577	182(31.5)	1.20(1.02,1.41)
Physical Abuse	No	1464	459(31.3)	1.00	1150	323(28.1)	1.00
	Yes	418	131(31.3)	1.00(0.85,1.17)	317	91(28.7)	1.02(0.84,1.24)
Sexual Abuse	No	1666	516(30.9)	1.00	1303	360(27.6)	1.00
	Yes	239	82(34.3)	0.96(0.79,1.16) ¹	200	65(32.5)	0.98(0.79,1.21) ²
Household Challenges							
Intimate Partner Violence	No	1565	478(30.5)	1.00	1198	333(27.8)	1.00
	Yes	314	114(36.3)	1.19(1.01,1.40)	277	84(30.3)	1.09(0.89,1.33)
Substance Abuse	No	1314	382(29.1)	1.00	1034	282(27.3)	1.00
	Yes	604	220(36.4)	1.25(1.09,1.43)	475	145(30.5)	1.12(0.95,1.32)
Mental Illness	No	1327	372(28.0)	1.00	1096	290(26.5)	1.00
	Yes	572	224(39.2)	1.40(1.22,1.60)	390	132(33.8)	1.28(1.08,1.52)
Parental Separation or Divorce	No	1087	325(29.9)	1.00	811	224(27.6)	1.00
	Yes	804	269(33.4)	1.12(0.98,1.28)	668	194(29.0)	1.05(0.89,1.24)
Incarcerated Household Member	No	1553	484(31.2)	1.00	1250	348(27.8)	1.00
	Yes	340	111(32.6)	1.05(0.88,1.24)	235	72(30.6)	1.10(0.89,1.36)
ACE Score	0	558	143(25.6)	1.00	447	110(24.6)	1.00
	1	411	124(30.2)	1.18(0.96,1.44)	357	108(30.3)	1.23(0.98,1.54)
	2-3	484	157(32.4)	1.27(1.05,1.53)	358	100(27.9)	1.14(0.90,1.43)
	4 or more	475	178(37.5)	1.46(1.22,1.76)	355	110(31.0)	1.26(1.01,1.58)

¹ Adjusted for sex assigned at birth. The crude PR is 1.11(0.92,1.34).² Adjusted for sex assigned at birth. The crude PR is 1.18(0.95,1.46).

ACE Category	Vaccination completion	Age (18-24)			Age (25-29)		
		N	Yes (n %)	PR (95% CI)	N	Yes (n %)	PR (95% CI)
Abuse							
Emotional Abuse	No	1063	137(12.9)	1.00	891	122(13.7)	1.00
	Yes	818	126(15.4)	1.20(0.96,1.50)	577	95(16.5)	1.20(0.94,1.54)
Physical Abuse	No	1464	201(13.7)	1.00	1150	170(14.8)	1.00
	Yes	418	59(14.1)	1.03(0.79,1.35)	317	45(14.2)	0.96(0.71,1.30)
Sexual Abuse	No	1666	222(13.3)	1.00	1303	187(14.4)	1.00
	Yes	239	44(18.4)	1.09(0.81,1.46) ¹	200	33(16.5)	0.97(0.70, 1.35) ²
Household Challenges							
Intimate Partner Violence	No	1565	221(14.1)	1.00	1198	176(14.7)	1.00
	Yes	314	43(13.7)	0.97(0.72,1.31)	277	40(14.4)	0.98(0.72,1.35)
Substance Abuse	No	1314	165(12.6)	1.00	1034	151(14.6)	1.00
	Yes	604	102(16.9)	1.34(1.07,1.69)	475	71(14.9)	1.02(0.79,1.33)
Mental Illness	No	1327	164(12.4)	1.00	1096	146(13.3)	1.00
	Yes	572	101(17.7)	1.43(1.14,1.79)	390	73(18.7)	1.41(1.09,1.82)
Parental Separation or Divorce	No	1087	155(14.3)	1.00	811	119(14.7)	1.00
	Yes	804	108(13.4)	0.94(0.75,1.18)	668	98(14.7)	1.14(0.90,1.46) ³
Incarcerated Household Member	No	1553	221(14.2)	1.00	1250	187(15.0)	1.00
	Yes	340	43(12.6)	0.89(0.66,1.21)	235	31(13.2)	1.04(0.73,1.48) ⁴
ACE Score	0	558	74(13.3)	1.00	447	63(14.1)	1.00
	1	411	52(12.7)	0.95(0.69,1.33)	357	53(14.8)	1.06(0.78,1.45) ⁵
	2-3	484	66(13.6)	1.03(0.76,1.40)	358	49(13.7)	1.01(0.73,1.39) ⁵
	4 or more	475	75(15.8)	1.19(0.88,1.60)	355	57(16.1)	1.09(0.80,1.49) ⁵

¹ Adjusted for sex assigned at birth. The crude PR is 1.38(1.03,1.85).

² Adjusted for sex assigned at birth and education level. The crude PR is 1.15(0.82,1.61).

³ Adjusted for education level. The crude PR is 1.00(0.78,1.28).

⁴ Adjusted for education level. The crude PR is 0.88(0.62,1.26).

⁵ Adjusted for sex assigned at birth and education level. The crude PRs are 1.05(0.75,1.48), 0.97(0.69,1.37), and 1.14(0.82,1.58) for the 1, 2-3, and 4 or more ACE score categories, respectively.

Table 7 Association between ACEs and influenza vaccination uptake

ACE		Overall Influenza Vaccination		
		N	Yes (n %)	PR (95% CI)
Abuse				
Emotional Abuse	No	1954	600(30.7)	1.00
	Yes	1395	404(29.0)	0.94(0.85,1.05)
Physical Abuse	No	2614	811(31.0)	1.00
	Yes	735	195(26.5)	0.86(0.75,0.98)
Sexual Abuse	No	2969	899(30.3)	1.00
	Yes	439	116(26.4)	0.87(0.74,1.03)
Household Challenges				
Intimate Partner Violence	No	2763	858(31.1)	1.00
	Yes	591	149(25.2)	0.81(0.70,0.94)
Substance Abuse	No	2348	730(31.1)	1.00
	Yes	1079	288(26.7)	0.86(0.76,0.96)
Mental Illness	No	1970	722(29.8)	1.00
	Yes	820	287(29.8)	1.00(0.32,1.12)
Parental Separation or Divorce	No	1897	609(32.1)	1.00
	Yes	1473	397(27.0)	0.84(0.75,0.93)
Incarcerated Household Member	No	2803	877(31.3)	1.00
	Yes	575	129(22.4)	0.72(0.61,0.84)
ACE Score	0	1004	321(32.0)	1.00
	1	769	236(30.7)	0.96(0.84,1.10)
	2-3	842	257(30.5)	0.95(0.83,1.09)
	4 or more	830	208(25.1)	0.78(0.68,0.91)

Table 8 Association between ACEs and length of time since last routine checkup

ACE		Length of Time Since Last Routine Checkup		
		N	Within past year or past 2 years (n %)	PR (95% CI)
Abuse				
Emotional Abuse	No	1956	1550(79.2)	1.00
	Yes	1395	1048(75.1)	0.95(0.91,0.98)
Physical Abuse	No	2616	2060(78.7)	1.00
	Yes	735	541(73.6)	0.93(0.89,0.98)
Sexual Abuse	No	2971	2323(78.2)	1.00
	Yes	439	331(75.4)	0.96(0.91,1.02)
Household Challenges				
Intimate Partner Violence	No	2765	2173(78.6)	1.00
	Yes	591	432(73.1)	0.93(0.88,0.98)
Substance Abuse	No	2350	1864(79.3)	1.00
	Yes	1079	800(74.1)	0.93(0.90,0.97)
Mental Illness	No	2425	1915(79.0)	1.00
	Yes	962	713(74.1)	0.94(0.90,0.98)
Parental Separation or Divorce	No	1899	1472(77.5)	1.00
	Yes	1473	1144(77.7)	1.00(0.97,1.04)
Incarcerated Household Member	No	2805	2207(78.7)	1.00
	Yes	575	415(72.2)	0.92(0.87,0.97)
ACE Score	0	1009	825(81.8)	1.00
	1	769	606(78.8)	0.96(0.92,1.01)
	2-3	842	641(76.1)	0.93(0.89,0.98)
	4 or more	830	612(73.7)	0.90(0.86,0.95)

Table 9 Association between ACEs and ever having had an HIV test

ACE		Ever Had an HIV Test		
		N	Yes (n %)	PR (95% CI)
Abuse				
Emotional Abuse	No	1953	706(36.1)	1.00
	Yes	1395	600(43.0)	1.19(1.09,1.29)
Physical Abuse	No	2613	954(36.5)	1.00
	Yes	735	350(47.6)	1.30(1.19,1.43)
Sexual Abuse	No	2968	1082(36.5)	1.00
	Yes	439	249(56.7)	1.56(1.42,1.71)
Household Challenges				
Intimate Partner Violence	No	2763	1005(36.4)	1.00
	Yes	591	305(51.6)	1.42(1.29,1.56)
Substance Abuse	No	2348	846(36.0)	1.00
	Yes	1078	495(45.9)	1.27(1.17,1.39)
Mental Illness	No	2422	891(36.8)	1.00
	Yes	962	435(45.2)	1.23(1.13,1.34)
Parental Separation or Divorce	No	1898	635(33.5)	1.00
	Yes	1471	686(46.6)	1.39(1.28,1.52)
Incarcerated Household Member	No	2802	1022(36.5)	1.00
	Yes	575	300(52.2)	1.43(1.30,1.57)
ACE Score	0	1005	298(29.7)	1.00
	1	768	301(39.2)	1.32(1.16,1.50)
	2-3	841	330(39.2)	1.32(1.17,1.50)
	4 or more	830	421(50.7)	1.71(1.52,1.92)

Table 10 Association between ACEs and HIV-related risk behavior¹

ACE		Ever had an HIV test		
		N	Yes (n %)	PR (95% CI)
Abuse				
Emotional Abuse	No	1953	208(10.7)	1.00
	Yes	1392	307(22.1)	2.07(1.76,2.44)
Physical Abuse	No	2611	336(12.9)	1.00
	Yes	733	177(24.1)	1.67(1.42,1.97) ²
Sexual Abuse	No	2965	402(13.6)	1.00
	Yes	439	121(27.6)	2.00(1.67,2.39) ³
Household Challenges				
Intimate Partner Violence	No	2762	370(13.4)	1.00
	Yes	590	142(24.1)	1.57(1.32,1.87) ⁴
Substance Abuse	No	2347	286(12.2)	1.00
	Yes	1075	240(22.3)	1.62(1.38,1.90) ⁵
Mental Illness	No	2419	301(12.4)	1.00
	Yes	961	218(22.7)	1.62(1.38,1.90) ⁶
Parental Separation or Divorce	No	1895	255(13.5)	1.00
	Yes	1470	262(17.8)	1.19(1.01,1.40) ⁷
Incarcerated Household Member	No	2799	378(13.5)	1.00
	Yes	574	140(24.4)	1.61(1.36,1.92) ⁸
ACE Score	0	1004	75(7.5)	1.00
	1	769	96(12.5)	1.61(1.21,2.15) ⁹
	2-3	838	148(17.7)	2.17(1.67,2.83) ⁹
	4 or more	829	210(25.3)	2.96(2.30,3.81) ⁹

¹ Participants were asked if they had injected any drug other than those prescribed, been treated for a sexually transmitted disease, or given or received money or drugs in exchange for sex in the past year.

² Adjusted for smoking status. The crude PR is 1.88(1.59,2.21).

³ Adjusted for sex assigned at birth and smoking status. The crude PR is 2.03(1.70,2.43).

⁴ Adjusted for smoking status. The crude PR is 1.80(1.51,2.13).

⁵ Adjusted for smoking status. The crude PR is 1.83(1.57,2.14).

⁶ Adjusted for smoking status. The crude PR is 1.82(1.56,2.13).

⁷ Adjusted for smoking status. The crude PR is 1.32 (1.13,1.55).

⁸ Adjusted for smoking status. The crude PR is 1.81(1.52,2.14).

⁹ Adjusted for smoking status. The crude PRs are 1.67(1.25,2.23), 2.36(1.82,3.07), and 3.39(2.65,4.34) for 1, 2-3, and 4 or more ACE score categories, respectively.