



Lower human papillomavirus vaccine initiation and completion among Asian American adolescents compared to their peers: National Health and Nutritional Examination Survey 2011–2018

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Received: 30 May 2021 / Accepted: 13 March 2023 / Published online: 27 March 2023
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Abstract

Purpose To compare human papillomavirus (HPV) vaccination initiation and completion between Asian American adolescents and their peers.

Methods HPV vaccine initiation and completion of adolescents aged 9–17 years old were analyzed using the National Health and Nutritional Examination Survey data from 2011 to 2018. The outcomes were HPV vaccine initiation percentage among all adolescents and completion percentage among initiators. Odds ratios for initiation or completion among Hispanics, Blacks, and Asians (referred to as racial/ethnic minorities) versus Whites were compared using logistic regression, adjusted for adolescent's age, annual family income, parent education, and insurance coverage.

Results From 2011 to 2018, overall initiation was less than 40% among U.S. adolescents. The initiation increased among boys (from 10% in 2011–12 to over 30% in 2017–2018) but not among girls. Compared to White girls, Black and Hispanic girls were more likely, while Asian girls were less likely to initiate vaccination. Although not statistically significant, Asian girls had ORs ranging from 0.65 to 0.99 for initiation compared to White girls in each of the four survey cycles. Black and Hispanic boys were more likely to initiate vaccination compared to White boys. Initiation among Asian boys increased to 39% in the 2017–2018 survey cycle. Racial/ethnic minority girls were less likely to complete the series compared to White girls, while the opposite was seen in Black boys.

Conclusion HPV vaccination status varies among racial/ethnic groups. Future efforts should be made to achieve the Healthy People 2020 goal of 80% vaccination among U.S. adolescents and address the gap among Asian American girls.

Keywords Human papillomavirus vaccine · Disparities · Asian American · Race · Ethnicity · Cervical cancer

Introduction

Human papillomavirus (HPV) is the most common sexually transmitted infection in the U.S [1]. Infection with particular HPV types, termed high-risk HPV (hrHPV), is associated with several types of cancers, including cervical, vaginal,

and vulvar cancers in women, penile cancers in men, and anal and oropharyngeal cancers in both men and women [2]. Many of these HPV-associated cancers disproportionately affect racial/ethnic minority groups. For example, the highest incidence rates for vaginal and cervical cancers are among African-American and Hispanic women, respectively [3], and certain Asian American subgroups such as Kam-puchean, Laotian, Samoan, and Vietnamese women have higher cervical cancer incidence than non-Hispanic white women [4].

HPV vaccines, which have been approved for use in the U.S. since 2006, can prevent a significant proportion of many HPV-related cancers, including cervical cancer. Currently approved HPV vaccines target hrHPV types, namely HPV16, 18, 31, 33, 45, 52, and 58, as well as two additional low-risk types, HPV6 and HPV11, that are responsible for approximately 90% of genital warts [5]. Clinical trials have

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demonstrated > 90% vaccine efficacy in preventing cervical HPV infections and cervical intraepithelial neoplasia grade 2 + in females and over 70% efficacy in preventing HPV-associated anal and penile intraepithelial neoplasia in males [6, 7].

In December 2016, the U.S. Advisory Committee on Immunization Practice (ACIP) updated HPV vaccine recommendations and guidelines from the previously recommended three doses to two doses for children between the ages of 11 and 12 years old, informed by evidence of the high efficacy of two-dose HPV vaccination [8, 9]. From 2012 to 2017, HPV vaccine uptake increased from 53.8 to 68.6% and 20.8 to 62.6% among girls and boys, respectively [10, 11]. Despite the increasing trend in HPV vaccination, current levels of uptake remain below the goal of the Department of Health and Human Services, Healthy People 2020 of 80% of U.S. adolescents [11, 12].

In addition to the lower overall uptake, disparities in uptake have been noted based on race/ethnicity [13, 14]. These differences may be due to a variety of factors such as access, knowledge, and cultural beliefs [15, 16]. Of note, given the heterogeneity, in some Asian cultures, vaginal sexual intercourse is only considered appropriate in the context of marriage [17]. These beliefs may affect not only parent-adolescent communication about pre-marital sex but also views and acceptance of vaccines that prevent sexually transmitted infections [18, 19], such as HPV vaccines. Studies that evaluate potential HPV vaccination disparities between racial/ethnic groups, including Asian American adolescents, are necessary to identify and address these disparities.

A limitation of most national health surveys that assess HPV vaccination coverage is that they collapse the racial/ethnic information before releasing the dataset to the public. For example, the most commonly used dataset to assess U.S. adolescent vaccination status, the National Immunization Survey-Teens (NIS-Teens) dataset, collapses the race category of Asian Americans into “other”, limiting insights on the current HPV vaccination status among Asian American adolescents. As a result, few studies have investigated nationwide racial and ethnic disparities, including differences in HPV vaccine uptake between Asian American adolescents and other racial/ethnic groups. The few studies that have included Asian Americans as a distinct race/ethnicity category have not been nationally representative or have inconsistent findings, such that HPV vaccine uptake was higher among Asian American adolescents in some studies but lower in others [14, 20, 21]. Thus, HPV vaccine uptake among Asian American adolescents in relation to their peers remains understudied. The goal of this study was to examine the association between (1) HPV vaccine initiation percentage and race/ethnicity in U.S. adolescents; and (2) HPV vaccine completion percentage among initiators stratified by race/ethnicity using the four most recent survey

cycles of the National Health and Nutritional Examination Survey (NHANES) data from 2011 to 2018.

Methods

Study population

NHANES is a cross-sectional survey conducted by the U.S. Centers for Disease Control and Prevention’s (CDC) National Center for Health Statistics (NCHS) to study the nationwide health and nutritional status of American adults and children [22]. NHANES uses a complex stratified, multistage probability sampling method to enroll a nationally representative sample of individuals over six months of age. NHANES is approved by the CDC’s Institutional Review Board. More details about sampling and data collection are available elsewhere [22–26]. Four cross-sectional survey datasets from NHANES 2011–2012, 2013–14, 2015–16, and 2017–18 were analyzed for this study. We restricted age to 9–17 years old ($n = 1608, 1747, 1689, \text{ and } 1494$ for survey cycle 2011–2012, 2013–2014, 2015–2016, and 2017–2018, respectively) because HPV vaccination can be started as early as age nine. We excluded participants who had missing or unknown data on HPV vaccine status ($n = 488$), annual family income ($n = 224$), parent education level ($n = 250$), and health insurance status ($n = 9$), resulting in 5567 participants for this analysis.

Exposure

Race and ethnicity were self-reported by NHANES participants. Race was determined according to the response to the question, “What race do you consider yourself to be?” Ethnicity was determined according to the response to the question, “Do you consider yourself Hispanic/Latino?” The responses were combined into six categories by NCHS before the release of the data: Mexican American, Other Hispanic, Non-Hispanic Black, Non-Hispanic White, Asian, and other. In this study, race/ethnicity was categorized as non-Hispanic White (reference), Hispanic (i.e., Mexican American and Other Hispanic), [non-Hispanic] Black, Asian, and Other.

Outcome

HPV vaccination status was obtained from participants aged nine years or older from 2011 to 2018. Data were either self-reported for individuals aged eleven or above or provided by parents or guardians if under the age of eleven. Vaccine status was determined according to the response to the question, “How many doses of the vaccine have you/ has screener respondent received?” In this study, HPV vaccine initiation

was dichotomized as yes (if ever received at least one dose of the vaccine) or no (never received vaccine). HPV vaccine completion among those who initiated the vaccination was dichotomized as yes if received two or more doses, or no if only received one dose.

Covariates

We identified covariates of the association between race/ethnicity and HPV vaccination status a priori based on the published literature [15, 16]. The covariates included: biological sex, dichotomized as male or female, child's age at interview (measured as a continuous variable), household reference person's education level, categorized as less than high school (reference), high school graduates, and more than high school, annual family income categorized as < \$20,000 (reference) and \$20,000 and above, insurance coverage, dichotomized as covered (reference) and not covered, and survey cycle, categorized as 2011–2012 (reference), 2013–2014, 2015–2016, and 2017–2018. We used the household reference's education level to infer the parent's education level. Participants with any missing covariates were not included in the analysis to minimize possible bias due to confounding.

Statistical analysis

Stata version 15.1 (StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC.) was used to conduct statistical analyses. The primary analysis examined the association between race/ethnicity and HPV vaccine initiation in all adolescents, and the secondary analysis examined the association between race/ethnicity and HPV vaccine completion among initiators. All analyses used survey sampling weights and adjusted for the complex survey design [23]. Student *t*-tests were used to examine the difference in age between initiators vs. non-initiators and those who completed vs. those who did not complete the vaccine series. Chi-square tests were used to examine differences in categorical variables between initiators vs. non-initiators and those who completed vs. those who did not complete the vaccine series, including annual family income, parent educational attainment, insurance coverage, and survey cycle. Analyses were stratified by biological sex to identify any potential influence of sex on HPV vaccine initiation and/or completion. Statistical tests were two-tailed with a significance level of $\alpha = 0.05$.

The primary analysis was conducted using (1) a combined dataset with four data cycles of the survey (i.e., 2011–2018) and (2) datasets stratified by the survey cycle. To address the change in recommendations regarding doses on HPV vaccine completion in 2016 (i.e., three doses versus two doses), the secondary analysis examining HPV vaccine completion

was conducted using a dataset stratified as before or after 2017.

All analyses were conducted using logistic regression. We estimated the ORs and 95% CIs of initiation and completion associated with race/ethnicity. We present the results using both the predicted prevalence and ORs to ensure a comprehensive interpretation. A significance level of $\alpha = 0.05$ was used based on the Wald Chi-square. The crude model contained race/ethnicity (and survey cycle, if applicable) as the independent variable. The adjusted multivariate model included all the covariates mentioned above. We tested the significance of interactions between race/ethnicity and each of the covariates mentioned above. The prevalence of HPV vaccine initiation and completion and 95% CIs were estimated using the STATA “margins” command for both the crude and the adjusted models.

Results

Demographics

A total of 5,567 U.S. adolescents aged 9–17 years were included in the final dataset, of whom 50.7% were girls ($n = 2,825$). Overall, HPV vaccination initiation was 34.6% in girls and 23.4% in boys (Table 1). The average age of the analytic sample was 13 years for both boys and girls; around 50% had a parent with higher than high school education; about 14% reported an annual family income of less than \$20,000, and over 90% had some insurance coverage.

Initiation

From 2011 to 2012 to 2017 to 2018, initiation increased from 10% to over 30% among boys, but not among girls (39% in 2011–2012, 33% in 2013–2014, 38% in 2015–2016, and 37% in 2017–2018, respectively). In U.S. adolescents, overall race/ethnicity was not associated with HPV vaccine initiation (Table 2, Supplementary Table 1). Within adolescent boys, Black (OR 1.44, 95% CI 1.08–1.94) and Hispanic (OR 1.36, 95% CI 1.00–1.84) boys had significantly higher odds of initiating HPV vaccination compared to non-Hispanic White boys after adjusting for covariates (Table 2). Although not statistically significant, higher odds of initiation were observed among Black (OR 1.32, 95% CI 0.94–1.85) and Hispanic (OR 1.15, 95% CI 0.77–1.70) girls, but not among Asian girls (OR 0.74, 95% CI 0.45–1.21). The survey cycle was significantly associated with initiation within boys ($p < 0.0001$) but not within girls ($p = 0.43$). None of the interactions between race/ethnicity and the covariates were significant.

When stratified by survey cycle (Supplementary Table 1), among adolescent girls, the predicted prevalence of

Table 1 Demographics for adolescent participants age 9–17

Characteristics	Girls <i>n</i> = 2,825				Boys <i>n</i> = 2,742			
	Overall	Dose = 0 <i>n</i> = 1847 (65.4%)	Dose ≥ 1 <i>n</i> = 978 (34.6%)	<i>p</i> -value	Overall	Dose = 0 <i>n</i> = 2,101 (76.6%)	Dose ≥ 1 <i>n</i> = 641 (23.4%)	<i>p</i> -value
Mean age	13.03	12.24	14.39	<0.0001	13.00	12.70	13.92	<0.0001
Education <i>n</i> (row%)				0.42				0.42
< High school	685 (100)	431 (61.75)	254 (38.25)		589 (100)	454 (76.55)	135 (23.45)	
High school graduates	802 (100)	520 (60.78)	282 (39.22)		879 (100)	649 (73.49)	230 (26.51)	
> High School	1338 (100)	896 (64.69)	422 (35.31)		1274 (100)	998 (77.14)	276 (22.86)	
Income <i>n</i> (row%)				0.15				0.42
< \$20,000	530 (100)	334 (59.19)	196 (40.81)		519 (100)	389 (74.07)	130 (25.93)	
≥ \$20,000	2295 (100)	1513 (63.71)	782 (36.29)		2223 (100)	1712 (76.21)	511 (23.79)	
Insurance <i>n</i> (row%)				0.69				0.01
No	232 (100)	156 (65.45)	76 (34.55)		217 (100)	184 (85.87)	33 (14.13)	
Yes	2593 (100)	1691 (62.94)	902 (37.06)		2525 (100)	1917 (75.14)	608 (24.86)	
Race/ethnicity <i>n</i> (row%)				0.05				0.20
White	786 (100)	521 (63.00)	265 (37.00)		789 (100)	623 (77.84)	166 (22.16)	
Hispanic	864 (100)	555 (62.41)	309 (37.59)		792 (100)	590 (73.47)	202 (26.53)	
Black	712 (100)	440 (58.17)	272 (41.83)		713 (100)	540 (72.63)	173 (27.37)	
Asian	268 (100)	185 (67.81)	83 (32.19)		254 (100)	196 (75.61)	58 (24.39)	
Other	195 (100)	146 (76.31)	49 (23.69)		194 (100)	152 (75.66)	42 (24.34)	
Survey Cycle <i>n</i> (row%)				0.38				<0.0001
2011–2012	713 (100)	467 (60.9)	246 (39.10)		685 (100)	615 (90.16)	70 (9.84)	
2013–2014	778 (100)	517 (67.10)	261 (32.90)		755 (100)	588 (77.23)	167 (22.77)	
2015–2016	719 (100)	463 (61.66)	256 (38.34)		698 (100)	481 (67.72)	217 (32.28)	
2017–2018	615 (100)	400 (63.05)	215 (36.95)		604 (100)	417 (69.01)	187 (30.99)	

National Health and Nutritional Examination Surveys (NHANES), 2011–2018

The percentages represented were weighted to account for the complex sampling design

Table 2 Odds ratios and predicted prevalence of Human Papillomavirus vaccine initiation in adolescents age 9–17

		Crude			Adjusted ^b		
		OR (95% CI)	Overall <i>p</i> -value ^d	Prevalence (95% CI)	OR (95% CI)	Overall <i>p</i> -value ^d	Prevalence (95% CI)
Girl ^a <i>n</i> = 2,825	White (reference)	1	0.13	0.37 (0.32, 0.42)	1	0.0589	0.36 (0.31, 0.41)
	Hispanic	1.03 (0.77, 1.39)		0.38 (0.33, 0.42)	1.15 (0.77, 1.70)		0.39 (0.34, 0.44)
	Black	1.24 (0.93, 1.64)		0.42 (0.37, 0.46)	1.32 (0.94, 1.85)		0.42 (0.37, 0.46)
	Asian	0.82 (0.53, 1.25)		0.32 (0.25, 0.40)	0.74 (0.45, 1.21)		0.31 (0.24, 0.38)
Boy ^c <i>n</i> = 2,742	White (reference)	1	0.16	0.22 (0.18, 0.26)	1	0.16	0.22 (0.18, 0.25)
	Hispanic	1.32 (1.02, 1.69)		0.27 (0.23, 0.30)	1.44 (1.08, 1.94)		0.28 (0.24, 0.32)
	Black	1.40 (1.06, 1.86)		0.28 (0.24, 0.32)	1.36 (1.00, 1.84)		0.27 (0.24, 0.30)
	Asian	1.16 (0.79, 1.71)		0.24 (0.19, 0.30)	1.12 (0.76, 1.65)		0.24 (0.19, 0.29)

National Health and Nutritional Examination Surveys (NHANES), 2011–2018

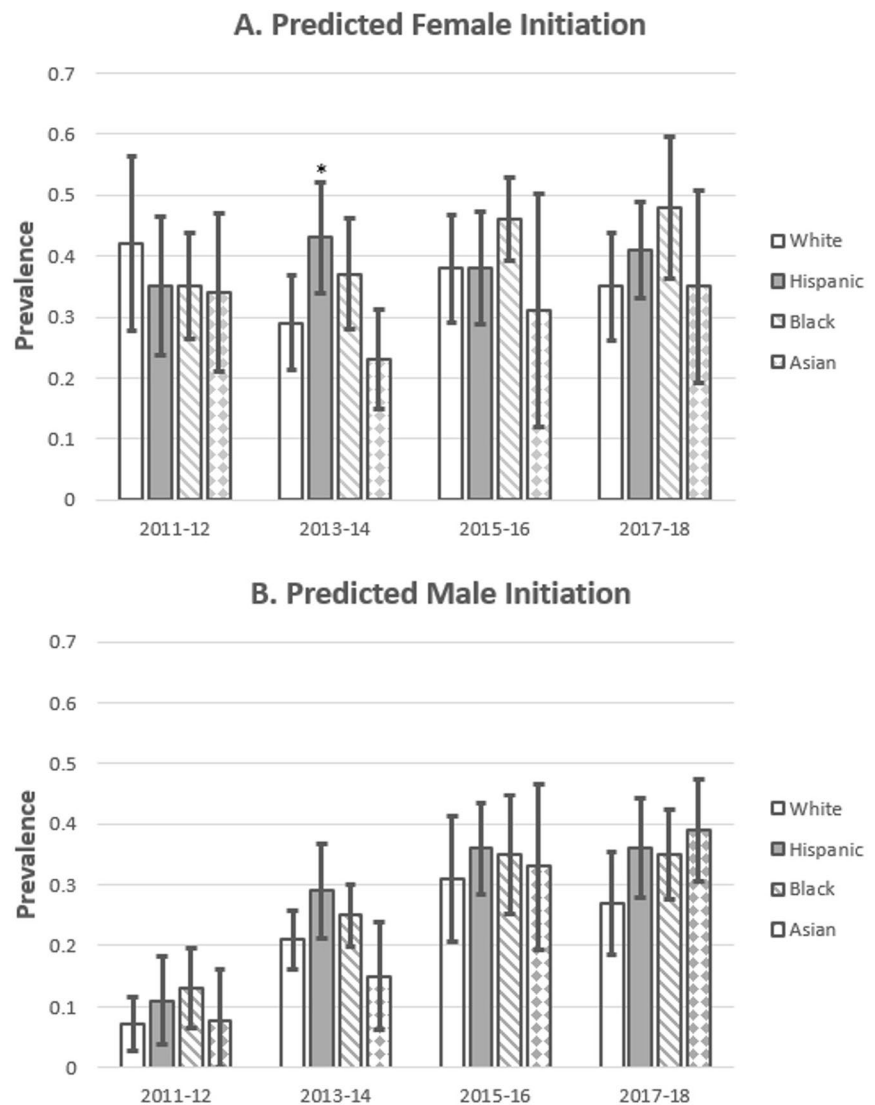
^aAdolescent girls were 713, 778, 719, and 615 for survey cycle 2011–2012, 2013–2014, 2015–2016, and 2017–2018, respectively

^bAdjusted for age (continuous), parent education (less than high school, high school graduates, more than high school-reference), annual household income (less than \$20,000-reference, and ≥ \$20,000), insurance coverage (yes-reference, no), and survey cycle

^cAdolescent boys were 685, 755, 698, and 604 for survey cycle 2011–2012, 2013–2014, 2015–2016, and 2017–2018, respectively

^dThe overall *p*-value of race was based on Wald Chi-square from a logistic regression model

Fig. 1 Predicted prevalence of Human Papillomavirus (HPV) vaccine initiation among U.S. adolescents age 9–17. National Health and Nutritional Examination Surveys (NHANES), 2011–2018



Foot note: * indicate a significant difference compared to the reference group within the survey cycle ($p < 0.05$).

initiation consistently increased for Black girls from 35% in 2011–2012 to 48% in 2017–2018, but not for non-Hispanic White, Hispanic, or Asian girls (Fig. 1A). In the 2013–2014 survey cycle, the odds of initiation for Hispanic girls were significantly higher than those for non-Hispanic White girls (OR 2.02, 95% CI 1.2–3.4). Although not statistically significant, Asian girls had lower initiation compared to their peers, with ORs that ranged from 0.65 in the 2011–2012 survey cycle to 0.99 in the 2017–2018 survey cycle, respectively (Supplementary Table 1).

In adolescent boys, the predicted prevalence of initiation increased for all race/ethnicity groups from 2011–2012 to 2017–2018 (non-Hispanic White: 7% to 27%; Black: 13% to 35%; Hispanic: 11% to 36%; Asian: 8% to 39%). Although not statistically significant, in the earlier three survey cycles,

Asian boys had the lowest odds of initiation among race/ethnicity minority groups, while in 2017–2018, they had the highest initiation (OR 1.83 95% CI 0.91–3.69).

Completion

The demographics of adolescent initiators are presented in Table 3. Overall race/ethnicity was not associated with HPV vaccine completion among initiators (Table 4). Asian girls had significantly lower odds of completion compared to non-Hispanic White girls (OR 0.46, 95% CI 0.22–0.97) before 2017. Moreover, the completion rates decreased for all race/ethnicity groups after the recommended number of doses was reduced to two in 2016 (non-Hispanic White: 81%

Table 3 Demographics for adolescent initiators age 9–17

Characteristics	Girls <i>n</i> = 978			<i>p</i> -value	Boys <i>n</i> = 641			<i>p</i> -value
	Overall	Dose < 2 <i>n</i> = 245 (21.5%)	Dose ≥ 2 <i>n</i> = 686 (74.6%)		Overall	Dose < 2 <i>n</i> = 185 (30.4%)	Dose ≥ 2 <i>n</i> = 409 (63.6%)	
Mean age	14.38	13.56	14.72	<0.0001	13.92	13.68	14.14	0.07
Education <i>n</i> (row%)				0.74				0.95
< High School	254 (100)	60 (19.13)	178 (74.85)		135 (100)	37 (28.66)	86 (64.84)	
High School Graduates	282 (100)	78 (22.07)	193 (74.96)		230 (100)	62 (28.72)	151 (64.75)	
> High School	442 (100)	107 (22.11)	315 (74.26)		276 (100)	86 (32.15)	172 (62.36)	
Income <i>n</i> (row%)				0.61				0.27
< \$20,000	196 (100)	48 (21.87)	136 (72.54)		130 (100)	32 (22.72)	85 (69.45)	
≥ \$20,000	782 (100)	197 (21.42)	550 (74.93)		511 (100)	153 (31.74)	324 (62.56)	
Insurance <i>n</i> (row%)				0.52				0.92
No	76 (100)	25 (28.30)	46 (66.51)		33 (100)	11 (28.98)	19 (63.32)	
Yes	902 (100)	220 (21.04)	640 (75.10)		608 (100)	174 (30.47)	390 (63.60)	
Race/ethnicity <i>n</i> (row%)				0.09				0.35
White	256 (100)	59 (18.01)	193 (78.11)		166 (100)	50 (30.11)	110 (64.69)	
Hispanic	309 (100)	77 (24.79)	223 (72.32)		202 (100)	60 (31.74)	131 (63.66)	
Black	272 (100)	75 (28.85)	178 (65.26)		173 (100)	47 (27.82)	109 (63.56)	
Asian	83 (100)	24 (31.40)	57 (66.12)		58 (100)	14 (26.03)	34 (56.11)	
Other	49 (100)	10 (14.90)	35 (81.09)		42 (100)	14 (37.80)	25 (58.79)	
Survey cycle <i>n</i> (row%)				0.15				0.29
2011–2012	246 (100)	53 (17.96)	182 (79.86)		70 (100)	32 (43.32)	30 (45.73)	
2013–2014	261 (100)	58 (19.07)	188 (75.81)		167 (100)	47 (29.42)	115 (66.66)	
2015–2016	256 (100)	69 (23.07)	179 (74.89)		217 (100)	50 (24.42)	149 (70.14)	
2017–2018	215 (100)	65 (26.00)	137 (66.96)		187 (100)	56 (33.70)	115 (59.65)	

National Health and Nutritional Examination Surveys (NHANES), 2011–2018

The percentages represented were weighted to account for the complex sampling design. The sum of the row percentage is less than 100% due to missing values in the number of doses received

to 77%; Black: 73% to 66%; Hispanic: 74% to 58%; Asian: 67% to 57%).

Within adolescent boys, although not statistically significant, Asian boys were more likely to complete the vaccine series before 2017 (OR 1.69, 95% CI 0.53–5.35). Meanwhile, Black and Hispanic boys had similar odds of completion before 2017 (Black: OR 1.03, 95% CI 0.49–2.17; Hispanic: OR 1.18, 95% CI 0.60–2.32, respectively). Although not supported statistically, after 2017, Hispanic (OR 0.59, 95% CI 0.14–2.53) and Asian (OR 0.61, 95% CI 0.12–3.17) boys were less likely to complete the vaccine series compared to non-Hispanic White boys. After the changes in the recommended number of doses, the predicted completion decreased for Hispanic (69% to 55%) and Asian (76% to 56%) boys but increased slightly for non-Hispanic White (65% to 67%) and

Black (66% to 70%) boys. None of the interactions between race/ethnicity and the covariates were significant.

Discussion

This cross-sectional study of racial/ethnic differences in HPV vaccination utilized the most recent survey cycles of the NHANES data. HPV vaccination status was not significantly associated with race/ethnicity in U.S. adolescents. Previous studies assessing HPV vaccine initiation within boys age 13–17 years old using the NIS-Teens dataset showed initiation increased from 41.7% in 2014 to 62.6% in 2017 [11, 27]. Our results suggested that the overall HPV initiation in boys increased from 10% in 2011–2012

Table 4 Odds ratios and predicted prevalence of Human Papillomavirus vaccine completion among adolescent initiators age 9–17

Girl ^a		Crude			Adjusted ^b		
		OR (95% CI)	Overall <i>p</i> -value ^d	Prevalence (95% CI)	OR (95% CI)	Overall <i>p</i> -value ^d	Prevalence (95% CI)
2011–2016 <i>n</i> =729	White (reference)	1	0.30	0.82 (0.76, 0.89)	1	0.33	0.81 (0.74, 0.88)
	Hispanic	0.65 (0.35, 1.19)		0.75 (0.69, 0.82)	0.63 (0.34, 1.15)		0.73 (0.67, 0.79)
	Black	0.58 (0.29, 1.15)		0.73 (0.65, 0.81)	0.66 (0.32, 1.34)		0.74 (0.65, 0.83)
	Asian	0.45 (0.22, 0.93)		0.68 (0.55, 0.81)	0.46 (0.22, 0.97)		0.67 (0.55, 0.80)
2017–2018 <i>n</i> =202	White (reference)	1	0.14	0.76 (0.65, 0.86)	1	0.20	0.77 (0.68, 0.85)
	Hispanic	0.74 (0.28, 1.95)		0.70 (0.51, 0.89)	0.56 (0.11, 2.74)		0.66 (0.41, 0.92)
	Black	0.46 (0.16, 1.29)		0.59 (0.39, 0.79)	0.37 (0.12, 1.13)		0.58 (0.40, 0.77)
	Asian	0.61 (0.19, 2.01)		0.66 (0.37, 0.94)	0.35 (0.07, 1.83)		0.57 (0.25, 0.90)
Boy ^c		OR (95% CI)	Overall <i>p</i> -value ^d	Prevalence (95% CI)	OR (95% CI)	Overall <i>p</i> -value ^d	Prevalence (95% CI)
2011–2016 <i>N</i> =423	White (reference)	1	0.76	0.64 (0.48, 0.79)	1	0.90	0.65 (0.51, 0.80)
	Hispanic	1.37 (0.71, 2.65)		0.70 (0.61, 0.80)	1.18 (0.60, 2.32)		0.69 (0.59, 0.78)
	Black	1.09 (0.52, 2.27)		0.66 (0.55, 0.77)	1.03 (0.49, 2.17)		0.66 (0.55, 0.76)
	Asian	1.80 (0.56, 5.73)		0.76 (0.57, 0.94)	1.69 (0.53, 5.35)		0.76 (0.58, 0.93)
2017–2018 <i>N</i> =171	White (reference)	1	0.65	0.68 (0.50, 0.86)	1	0.86	0.67 (0.47, 0.87)
	Hispanic	0.51 (0.12, 2.14)		0.52 (0.30, 0.74)	0.59 (0.14, 2.53)		0.55 (0.36, 0.74)
	Black	1.27 (0.44, 3.63)		0.73 (0.55, 0.91)	1.15 (0.40, 3.31)		0.70 (0.52, 0.87)
	Asian	0.58 (0.14, 2.32)		0.55 (0.26, 0.84)	0.61 (0.12, 3.17)		0.56 (0.25, 0.87)

National Health and Nutritional Examination Surveys (NHANES), 2011–2018

^aAdolescent girls were 235, 246, 248, and 202 for survey cycle 2011–2012, 2013–2014, 2015–2016, and 2017–2018, respectively

^bAdjusted for age (continuous), parent education (less than high school, high school graduates, more than high school-reference), annual household income (less than \$20,000–reference, and \geq \$20,000), insurance coverage (yes-reference, no), and survey cycle

^cAdolescent boys were 62, 162, 199, and 171 for survey cycle 2011–2012, 2013–2014, 2015–2016, and 2017–2018, respectively

^dThe overall *p*-value of race was based on Wald χ^2 from a logistic regression model

to 30% in 2017–2018. The initiation in boys in our study is lower compared to previous studies; a similar pattern was observed in adolescent girls. This could be a result of our decision to include adolescents aged 9–12 years in our sample. When restricting the analyses to adolescents age 13–17, initiation increased. For instance, in 2017–2018, initiation was 43% and 53% among boys and girls, respectively. HPV vaccine initiation was higher for Black and Hispanic boys compared to non-Hispanic White boys. In contrast, initiation among Asian boys was lower in earlier cycles of the survey but increased and was the highest compared to other racial/ethnic groups in the most recent survey cycle.

This increasing trend of HPV vaccine initiation with each cycle was not, however, evidenced among adolescent girls. Overall, HPV vaccine initiation among adolescent girls was around 35%. The highest initiation of 39% was observed in the first survey cycle of 2011–2012 and decreased slightly to 38% in the last survey cycle of 2017–2018. Race/ethnicity-specific HPV vaccine initiation increased among Black and Hispanic girls, but not non-Hispanic White or Asian girls. Notably, unlike the

trend observed among Asian boys, initiation among Asian girls was stable and consistently lower than among their non-Asian peers.

In 2017–2018, the overall vaccine completion in our study participants was approximately 67% and 60% among adolescent girls and boys, respectively. Our finding of completion was higher compared to results from NIS-Teen: in 2017, HPV vaccine completion was 53.1% in adolescent girls and 44.3% in adolescent boys, respectively [11]. In addition, our analyses showed a lower completion after the change in the recommended number of doses from 3 to 2, which is inconsistent with findings from NIS-Teens [11]. One possible explanation is that the 2017–2018 survey cycle had relatively smaller sample sizes than previous cycles, which resulted in wider ranges of uncertainty of the point estimates.

Our results suggest initiation differences between adolescent boys and girls. HPV vaccine uptake among boys was lower than girls in 2012–2013 but has continued to increase and, in the most recent cycle, appears to be similar to that of girls. This effect was anticipated because the recommendation by the ACIP differed for girls and boys during the

data collection period. ACIP's recommendation was initially targeted at adolescent girls when the vaccine first became available in 2006 and was not extended to boys until 2011, which explains the low uptake among boys in the earliest survey cycle.

HPV vaccine initiation remains a challenge in U.S. adolescents. The current vaccine coverage is far below the Healthy People 2020 goal of 80% [12]. In addition, in 2020, many parts of the United States issued social distancing measures to contain the spread of SARS-CoV-2, which causes Coronavirus Disease 2019. As a consequence, the vaccination schedule for eligible adolescents has been delayed, with significant decreases in adolescent vaccine coverage [28]. In our analytic sample, Asian adolescent girls tended to have lower HPV vaccine initiation despite the fact that their insurance coverage was significantly higher compared to other racial/ethnic groups ($p < 0.0001$). The reasons for this are complex; one study suggests that in some Asian cultures, the content of parent-adolescent messages about sex to sons promotes sexual exploration and pleasure, but messages to daughters have tended to be prohibitive and emphasize the negative effects of sexual activity [18]. Studies have also shown that Asian American women tend to have lower acceptance and awareness of the HPV vaccine [29]. Although in recent years, the messaging regarding the HPV vaccine has changed from preventing a sexually transmitted disease to preventing cancers, there might still be a perceived link between the HPV vaccine and sexually transmitted diseases that may explain this continued disparity in vaccine uptake [30, 31]. Tailored HPV vaccination promotion programs for Asian adolescents, especially girls, and their parents, are needed. Such programs should aim to increase awareness of the HPV vaccine.

Our results also suggest that Black and Hispanic adolescents have higher initiation rates, especially when compared to Asian adolescents. The reasons for this are unclear. Parental acceptance of vaccines for both genders may be higher in the Black and Hispanic communities. Some of the differences may also be explained by the success of the Vaccines for Children Program (VFC). VFC provides free vaccines for uninsured or underinsured children and has been identified as a factor that has contributed to reduced racial/ethnic disparities in vaccination coverage [32]. A higher proportion of participants in this program are Black or Hispanic than Asian, which suggests that access may also play a role [33].

Our study has several limitations. First, the HPV vaccination status in NHANES is self-reported. However, a previous study of bias resulting from self-reported HPV vaccination status among adults showed approximately 2% over-reporting compared to electronic medical records [34], which suggests that bias from self-reporting may be minimal. The analytical sample size of the current study was approximately 1,500 per survey cycle. The overall sample

size was limited compared to NIS-Teen studies, which typically collect data on over 20,000 U.S. teens. Moreover, the sample size for assessing vaccination completion was small ($n = 1,525$), so we could not stratify by the survey cycle. However, NHANES is the only publicly available nationwide dataset that includes Asian Americans as a distinct race/ethnicity category, thus allowing us to identify HPV vaccination gaps occurring in this population. Finally, due to the limited sample size for Asian American adolescents, we were not able to evaluate potential differences within this group. Future studies will need to examine potential differences within Asian American subgroups, given the marked heterogeneity within this population.

Our study has several strengths. First, the study explored the association between race/ethnicity and HPV vaccination status using the most recent data from NHANES, in which more than 5,500 U.S. adolescents representing a variety of race/ethnicity groups were sampled. As noted, our study included Asian Americans as a distinct category, allowing us to evaluate the HPV vaccination status in this group compared to others. Given the low HPV vaccine initiation among Asian American adolescents, HPV vaccine promotion programs targeting Asian American adolescents and their parents are needed.

Conclusion

HPV vaccination goals for American adolescents have not yet been met. Non-Hispanic White and Asian adolescents were less likely to be vaccinated compared to Black and Hispanic adolescents. Tailored efforts are needed to address significant gaps in vaccination initiation and completion for Asian American girls.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10552-023-01685-z>.

Author contributions RZ: conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing-original draft, writing-review and editing, visualization. AP: methodology, validation, resources, writing-review and editing, visualization. SK: conceptualization, methodology, validation, writing-review and editing.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability The code generated for analyses during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declared that there is no conflict of interest.

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