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A multilevel analysis of factors influencing the inaccuracy of parental reports of adolescent HPV vaccination status

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ABSTRACT

Background: Parental reports are commonly used for adolescent HPV vaccination status but may be subjected to bias. Guided by the Socioecological Framework, our study explores potential multilevel factors influencing the inaccuracy of parental reports of adolescent HPV vaccination status.
Methods: Data from parents of 19,683 adolescents with provider-verified data were analyzed using multilevel modeling. Correlates included adolescent characteristics, parent/household factors, number of providers seen, state-level median income, and state-level HPV vaccine policy. Outcomes included inaccuracy in reporting: vaccine initiation (≥1 dose), completion (3 doses), and number of doses.
Results: 24% and 25% of parents reported initiation and completion inaccurately; 28% under-reported and 11% over-reported number of doses. All adolescent characteristics, parent/household factors, and number of healthcare providers seen were associated with the outcomes. Of note, compared to parents of White adolescents, parents of racial/ethnic minority adolescents were more likely to inaccurately report all outcomes (aOR ranges from 1.43 to 1.76 for initiation, 1.45–1.75 for completion, 1.98–2.05 for under-reporting, and 1.17–1.41 for over-reporting). Households with higher maternal education (aOR = 0.70, 0.92, 0.79, and 0.80) and income (aOR = 0.54, 0.62, 0.50, and 0.70) were less likely to inaccurately report initiation, report completion, under-report, and over-report, respectively. Those having seen more providers were less likely to inaccurately report initiation and completion but more likely to over-report number of vaccine doses.
Discussion: Being parents of females, older adolescents, and racial/ethnic minority adolescents, having lower material education, and poverty status were associated with higher odds of inaccurately reporting HPV vaccination status. These results have implications for estimates drawn from self-reports. Future research can examine sources of inaccuracies (e.g., social desirability or health literacy); they could also explore solutions (e.g., access to vaccine records) that can help parents accurately report vaccination status. State policy does not appear to have an impact on report accuracy.

1. Background

Human papillomavirus (HPV) vaccines, available in the United States (U.S.) since 2006, are a safe and effective method for providing close to 100% protection against genital warts and different types of cancers caused by HPV [1]. HPV vaccination is recommended for both sexes and is most effective when administered in early adolescence (age 11 or 12) [2,3]. Currently, the vaccine is underutilized in adolescent males and females [4,5]. Accurate reporting of adolescent HPV vaccination status is essential to identify populations that are under-vaccinated, monitor vaccine coverage, and achieve coverage goals (i.e., 80% of coverage per Healthy People 2020 goals [6]) [7].

A number of different methods of assessing adolescent vaccination status exist. For example, provider-reported HPV vaccine history is often considered the most accurate source of information [7,8]. Unfortunately, obtaining records from providers may require extensive resources and time, especially when adolescent patients have received vaccines from multiple healthcare providers [9]. A less resource-consuming method is parental recall of adolescent HPV vaccination status. However, research has shown that parental reports can be subject to recall bias and social desirability bias,

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thus undermining the accuracy of information about vaccination status [7,9–11]. Little is known about external factors that may influence the accuracy of parental recall.

The Socioecological Framework [12] is useful for understanding the factors that can influence the accuracy of parental reports of adolescent HPV vaccination status. At the individual level, some studies have documented that parents of older children [13] and parents of non-White children (e.g., Black or non-White Hispanic) [9,10,13] are more likely to inaccurately report vaccine initiation status, vaccine completion status, or number of vaccine doses received. Household demographic characteristics, such as lower maternal education, poverty status, or lower household income, have also been shown to be associated with higher inaccuracy in reporting [9,10].

Less research has been done to examine how factors at higher levels of the Socioecological Framework (e.g., institutional-, community-, or policy-level factors) may influence the accuracy of parental reports. In particular, not much is known about the role of educational policy and school-entry mandate legislations around HPV vaccine in promoting parental knowledge of the vaccine and, by extension, the accuracy of their reports. Instead, most research on HPV vaccine policy so far has focused on the relationship between vaccine policy and actual vaccine uptake [14,15]. If there is a potential secondary benefit of HPV vaccine educational requirements on improving awareness and recall of HPV vaccination status, this could lead to reductions in under- or over-vaccination due to lack of knowledge of a child's vaccination status.

The purpose of this study is to understand factors influencing the accuracy of parental reports of HPV vaccination status for their adolescents. We hypothesize that factors at several different levels of the Socioecological Framework [12] can influence the accuracy of parental reports of adolescent HPV vaccination status. These factors include adolescent individual-level characteristics (e.g., the adolescent's race, sex, and age) and parental/household factors (e.g., maternal education and household poverty status). We also assess the number of healthcare providers that the adolescent had seen as a potential interpersonal-level correlate. Additionally, we assess whether community-level factors, such as state-level median household income, also influence the accuracy of reports. In addition, we are interested in whether HPV vaccine-related policy (i.e., a state's policy to mandate vaccine and/or funding and education around vaccine, or a lack thereof) affects the accuracy of parental recall.

2. Methods

2.1. Participants and procedures

The current analyses were conducted using data from NIS-Teen, an annual national survey using random digit dialing administered by the Centers for Disease Control and Prevention (CDC) that collects data and monitors vaccine coverage among adolescents aged 13 to 17 years old in the U.S. [16]. The survey asked parents about adolescents' routine vaccine coverage and verified parental reports with adolescents' healthcare providers. Details for the methodology of the survey have been described elsewhere [17]. The entire NIS-Teen 2016 dataset contains 43,071 participants, of whom 20,475 had complete provider-verified records and resided in the 50 U.S. states and the District of Columbia. Among these 20,475 participants, we excluded 724 participants who had missing data for poverty status. Additionally, we excluded 68 participants who reported having no provider, as the NIS-Teen user's guide did not provide information on how vaccine records were required if the adolescent had not seen any provider. Thus, our final analytic dataset had 19,683 individuals.

2.2. Measures

2.2.1. Dependent variables: Accuracy of parental reports of vaccination status

Both parents and providers were asked to report the number of HPV vaccine shots that adolescents had ever received. If a parent answered "Don't know" (n = 2,412) or "Refused" (n = 7), we coded the number of vaccine shot reported as 0. We based our coding on methods from previous research that examined parental recall of HPV vaccination status. Dorell and colleagues also coded those with "Don't know" responses as "No" (i.e. 0 shot) responses [7]. Parental reports were compared to provider records (i.e., the "accurate" records). Three dependent variables were created for the study. Two binomial dependent variables (assessing the inaccuracy of parental reports of *initiation* and *completion* of vaccine doses) were created with 0 = reporting accurately and 1 = reporting inaccurately. Additionally, a multinomial (3-level) dependent variable was created to indicate whether a parent under-reported, over-reported, or reported accurately the total number of doses that the adolescent received, compared to provider records. We defined vaccine completion as having received 3 doses, since the latest recommendation from the CDC and the Advisory Committee on Immunization Practices indicating that only 2 HPV doses are needed for 11 and 12-year-old adolescents was not issued until mid-October 2016 [18].

2.2.2. Independent variables

Adolescent characteristics included the adolescent's age, race (1 = non-Hispanic White; 2 = non-Hispanic Black; 3 = Hispanic; or 4 = multiple races or other race), and sex (1 = male or 2 = female). The odds ratio obtained is a change by year for adolescent age.

Parental/household factors included maternal education (1 = less than a bachelor's degree or 2 = a bachelor's degree and above) and household poverty status (1 = below poverty line or 2 = above poverty line).

A variable related to *healthcare providers (interpersonal-level factor* in the Socioecological Framework*)* was also included in the analyses. The question used in the NIS-Teen survey was "How many locations have provided vaccinations for [your child] whose birth date is [...]?" We interpret this question as the number of providers seen for the whole time period that the child could have gotten vaccinated. We created a variable capturing the number of providers that the adolescent had seen (1 = 1 provider; 2 = 2 providers; 3 = 3 or more providers).

State-level factors included (1) state-level median household income for 2016, obtained from the U.S. Census Bureau website [19], which was operationalized as a continuous variable (in $1,000 s) (*community-level factor* in the Socioecological Framework); and (2) state-level HPV vaccine policy (*policy-level factor* in the Socioecological Framework). In terms of the latter, specific information on the educational content or vaccine mandate requirements of legislations in each state is provided in Table 1. Data on state-level HPV vaccine policy up to 2015 were collected through the National Conference on State Legislatures website [20] and relevant literature [14,21]. States were categorized as either (1) having a policy mandating HPV vaccine for adolescents entering schools; (2) having a policy to educate the public, parents, or school children about HPV vaccine; or (3) not having policy to mandate, fund, or educate residents about HPV vaccine.

2.3. Statistical analysis

We used SAS 9.4 for all analyses and set an alpha level of 0.05. Weighted descriptive statistics were summarized for each variable using means, standard deviations, and proportions. The multilevel models included two hierarchical levels where parents (level 1)

Table 1
Descriptions of state policy (National Conference on State Legislatures website) regarding educational and informational legislation or school-entry vaccine mandate.

State	Educational/informational legislation or school-entry vaccine mandate legislation
Requiring HPV vaccine mandate for school entry	
District of Columbia	(2007) Mandate the HPV vaccine for girls before the age of 13 and gives parents the right to opt-out their daughter.
Rhode Island	(2015) Requires the HPV vaccine for all seventh-graders.
Virginia	(2008) Requires the HPV vaccine for girls entering sixth grade. Requires the HPV vaccine for girls on or after their 11th birthday and allows parents to exempt their child.
Requiring educational or informational legislation on HPV vaccine	
Colorado	(2007) Includes information on HPV, the link to cervical cancer and the vaccine in sexual education in schools.
Illinois	(2007) Requires the Department of Health to provide all female students who are entering sixth grade and their parents or legal guardians written information about the link between HPV and cervical cancer, and the availability of the vaccine.
Indiana	(2007) Requires the parents of girls entering the sixth grade to receive information about the link between HPV and cervical cancer and the availability of an HPV vaccine.
Iowa	(2007) Requires that educational content for the seventh grade also include information on HPV and the availability of the HPV vaccine.
Louisiana	(2008) Requires schools to provide HPV information and vaccines under certain circumstances.
Maine	(2007) Improves public awareness of the vaccine.
Michigan	(2008) Would require schools to provide HPV information and vaccines under certain circumstances.
Missouri	(2010) Requires the development of a brochure regarding human papillomavirus.
New Jersey	(2007) Requires distributing information about HPV to parents and guardians. Also proposes a public awareness campaign.
North Carolina	(2007) Requires the department of health to distribute information on the HPV and the vaccine through schools to all parents of children in grades five through 12.
North Dakota	(2007) Provides funding for distribution of educational materials on HPV and the HPV vaccine.
Texas	(2007) Requires the Department of Health to develop and distribute educational materials to the public in both English and Spanish.
Utah	(2007) Establishes an awareness campaign on the causes, prevention, and risks of cervical cancer.
Washington	(2007) Provides every parent of sixth grade girls with information on HPV and where they can get the vaccine.

were nested in states (level 2). In the design of the survey, only one adolescent per parent was included. Per the NIS-Teen user's guide, the variable "PROVWT_D" was used for level-1 weighting (i.e., weights for adolescents with provider-verified data living in the U.S., excluding territories). Because a census of states was sampled in the dataset, no level 2 weights were incorporated.

Using PROC GLIMMIX (with maximum likelihood estimation with quadrature approximation) for binomial and multinomial logistic regressions, bivariate analyses were conducted to examine the relationship between covariates and the three dependent variables of interest. For each outcome, model building was conducted separately but in parallel steps. Model 1 included only the dependent variable and no independent variable. From this model, the intraclass correlation (ICC) was calculated in order to understand the variance in the dependent variable at the state level. Guided by our theoretical framework, a series of models with random intercepts were subsequently fitted. Model 2 contained parent-level variables: adolescent's age, adolescent's sex, adolescent's race, maternal education, household poverty level, and the number of providers seen. Model 3 contained state-level variables: HPV vaccine policy and household income. Model 4 contained all parent-level and state-level variables (see Supplement 1 for final model equations). We also conducted sensitivity analyses (SA) examining whether results changed considerably when those who reported "Don't know" (n = 2412) or "Refused" (n = 7) were excluded from analysis.

3. Results

3.1. Sample description

Descriptive characteristics were summarized using weighted data. Adolescents were approximately evenly represented by sex (51.19% male). The majority of adolescents were non-Hispanic White (53.51%), followed by Hispanic (22.28%) and non-Hispanic Black (13.72%) (Table 2). The majority of households had mothers with less than a bachelor's degree (60.02%) and with incomes above the federal poverty level (77.30%). Most parents in the sample (62.20%) resided in states with no HPV vaccine educational or school-entry mandate policy, while 34.82% resided in a state with a policy to educate the public, parents, or school children about HPV vaccine, and 2.98% of parents lived in states with a school-entry mandate for HPV vaccine. Table 2 provides additional information on descriptive characteristics of the sample.

Table 2
Descriptive characteristics of the sample (using weighted data).

Characteristics (N = 19,683)	Mean (SD) or percentage
Adolescent's age	15.00 (0.02)
Adolescent's sex	
Male	51.19%
Female	48.81%
Adolescent's race/ethnicity	
Non-Hispanic White	53.51%
Non-Hispanic Black	13.72%
Hispanic	22.28%
Multiple races or Other race	10.49%
Maternal education	
Below bachelor's degree	60.02%
Bachelor's degree and above	39.98%
Household poverty status	
Below poverty line	22.70%
Above poverty line	77.30%
Number of provider(s) seen	
1 provider	52.53%
2 providers	25.68%
3 and more providers	21.79%
State HPV vaccine policy	
No policy	62.20%
Educational policy	34.82%
School-entry mandate	2.98%
State median household income (in $1,000)	56.29 (0.06)
Reporting vaccine initiation	
Correctly	76.15%
Incorrectly	23.85%
Reporting vaccine completion	
Correctly	75.18%
Incorrectly	24.81%
Reporting the number of vaccine doses	
Under-reported	27.78%
Correctly	60.97%
Over-reported	11.24%

Additionally, in the sample, 76.15% of parents accurately reported vaccine initiation and 75.18% accurately reported vaccine completion (Table 2). Moreover, 60.97% of the sample accurately reported the number of vaccine doses that their children had received, 27.78% under-reported the number of vaccine doses, and 11.24% over-reported the number of vaccine doses.

3.2. Relationships between independent variables and accuracy of parental reports of vaccine initiation and completion

Table 3 shows the bivariate and multivariable associations between the independent variables and the outcomes of inaccuracy in reporting vaccine initiation and completion.

3.2.1. Adolescent's characteristics

Parents of older adolescents were more likely to inaccurately report vaccine initiation and completion (adjusted odd ratio or aOR = 1.03 and 1.10, confidence interval or CI = [1.03–1.03] and [1.10–1.10], respectively). Additionally, compared to parents of males, parents of females were less likely to inaccurately report vaccine initiation (aOR = 0.93, CI = [0.92–0.93]) but more likely to inaccurately report vaccine completion (aOR = 1.38, CI = [1.38–1.38]).

Compared to parents of White adolescents, parents of those who were racial/ethnic minorities were more likely to inaccurately report vaccine initiation and completion. The associations for parents of adolescents who were Black were aOR = 1.56 for reporting initiation and aOR = 1.45 for reporting completion; for parents of adolescents who were Hispanic, aOR = 1.43 and 1.73, respectively; and for parents of adolescents of multiple races, aOR = 1.76 and 1.75, respectively.

3.2.2. Parent/household factors

Compared to households with lower maternal education, households with higher maternal education were less likely to inaccurately report vaccine initiation (aOR = 0.70, CI = [0.70–0.71]) and completion (aOR = 0.92, CI = [0.92–0.91]). Compared to households with income below the poverty line, households with higher income (i.e., non-poverty status) were less likely to inaccurately report vaccine initiation (aOR = 0.54, CI = [0.54–0.55]) and completion (aOR = 0.62, CI = [0.61–0.62]).

3.2.3. Healthcare provider-related factor

Compared to parents of adolescents who had seen only 1 provider, those who had seen more providers were less likely to inaccurately report. For reporting initiation, the association was stronger for parents of those who had seen 3 or more providers (aOR = 0.75, CI = [0.74–0.75]) than for parents of those who had seen 2 providers (aOR = 0.91, CI = [0.90–0.91]). For reporting completion, the associations were similar between the two groups (aOR = 0.86 and 0.86).

3.2.4. State-level factors

In bivariate analyses, compared to those living in states with no HPV vaccine policy, those living in states with school-entry vaccine

Table 3
Multilevel logistic regressions examining predictors of inaccuracy in reporting vaccine initiation and completion.

	Inaccuracy in reporting initiation				Inaccuracy in reporting completion			
	cOR	p (cOR)	aOR	p (aOR)	cOR	p (cOR)	aOR	p (aOR)
Adolescent's age	1.02 (1.02–1.03)	<0.001	1.03 (1.03–1.03)	<0.001	1.09 (1.09–1.09)	<0.001	1.10 (1.10–1.10)	<0.001
Adolescent's sex								
Male	Reference		Reference		Reference		Reference	
Female	0.94 (0.94–0.94)	<0.001	0.93 (0.92–0.93)	<0.001	1.37 (1.37–1.37)	<0.001	1.38 (1.38–1.38)	<0.001
Adolescent's race/ethnicity								
Non-Hispanic White	Reference		Reference		Reference		Reference	
Non-Hispanic Black	1.99 (1.98–2.00)	<0.001	1.56 (1.56–1.57)	<0.001	1.71 (1.70–1.71)	<0.001	1.45 (1.45–1.45)	<0.001
Hispanic	1.87 (1.87–1.88)	<0.001	1.43 (1.43–1.43)	<0.001	2.01 (2.00–2.02)	<0.001	1.73 (1.72–1.73)	<0.001
Multiple races or Other race	1.98 (1.97–1.98)	<0.001	1.76 (1.76–1.77)	<0.001	1.88 (1.88–1.89)	<0.001	1.75 (1.75–1.76)	<0.001
Maternal education								
Below a bachelor's degree	Reference		Reference		Reference		Reference	
Bachelor's degree and above	0.53 (0.53–0.53)	<0.001	0.70 (0.70–0.71)	<0.001	0.70 (0.70–0.70)	<0.001	0.92 (0.92–0.92)	<0.001
Household poverty status								
Below poverty line	Reference		Reference		Reference		Reference	
Above poverty line	0.42 (0.42–0.42)	<0.001	0.54 (0.54–0.55)	<0.001	0.52 (0.52–0.52)	<0.001	0.62 (0.61–0.62)	<0.001
Number of providers seen								
1 provider	Reference		Reference		Reference		Reference	
2 providers	0.88 (0.88–0.88)	<0.001	0.91 (0.90–0.91)	<0.001	0.85 (0.85–0.85)	<0.001	0.86 (0.86–0.86)	<0.001
3 or more providers	0.71 (0.71–0.71)	< 0.001	0.75 (0.74–0.75)	<0.001	0.83 (0.83–0.83)	<0.001	0.86 (0.86–0.86)	<0.001
State HPV vaccine policy								
No policy	Reference		Reference		Reference			
Educational policy	0.88 (0.77–1.00)	0.05	0.89 (0.77–1.04)	0.14	1.01 (0.87–1.18)	0.90	0.94 (0.82–1.09)	0.44
School-entry mandate	1.18 (0.93–1.50)	0.17	0.97 (0.72–1.29)	0.82	1.40 (1.05–1.87)	0.02	1.22 (0.92–1.60)	0.17
State median household income (in $1,000)	1.00 (1.00 – 1.01)	0.28	1.01 (1.00–1.01)	0.13	1.01 (1.00–1.02)	0.05	1.00 (1.00–1.01)	0.24
Variance components								
ICC (null model)			0.0136				0.0197	
Level-2 variance (final model)			0.0170				0.0152	
Proportional reduction in variance (comparing final model to null model)			N/A*				23.51%	
Model fit								
−2LL			20,457,499				20,944,659	
AIC			20,457,527				20,944,687	
BIC			20,457,554				20,944,714	

cOR: crude odd ratios (from bivariate analyses); aOR: adjusted odd ratios (from multivariable analyses).
N/A: proportional reduction was negligble.

mandates were more likely to inaccurately report vaccine completion. However, when adjusted for other covariates, these differences no longer existed. State-level median income was not associated with the inaccuracy of reporting either vaccine initiation or completion.

3.3. Relationships between independent variables and accuracy of parental reports of the number of vaccine doses

Table 4 shows the multivariable associations between the independent variables and the outcome of under-reporting and over-reporting (versus accurately reporting) the number of vaccine doses.

3.3.1. Adolescent's characteristics

Parents of older children were more likely to both under-report (aOR = 1.06, CI = [1.06–1.06]) and over-report (aOR = 1.06, CI = [1.06–1.07]) the number of vaccine doses. Parents of females were more likely to both under-report (aOR = 1.11, CI = [1.11–1.11]) and over-report (aOR = 1.21, CI = [1.21–1.22]) the number of vaccine doses.

Compared to parents of White adolescents, parents of Black adolescents, Hispanic adolescents, and those who were of multiple races or other race were all more likely to both over-report and under-report. The associations were stronger for under-reporting (aOR = 2.05, 2.13, and 1.98 for parents of adolescents who were Black, Hispanic, and of multiple races or other race, respectively) than for over-reporting (aOR = 1.41, 1.17, and 1.38, respectively).

3.3.2. Parent/household factors

Households with higher maternal education were less likely to both under-report (aOR = 0.79, CI = [0.79–0.80]) and over-report (aOR = 0.80, CI = [0.80 – 0.80]) the number of vaccine doses. Households with non-poverty status were less likely to both under-report (aOR = 0.50, CI = [0.49–0.50]) and over-report (aOR = 0.70, CI = [0.70–0.70]) the number of vaccine doses.

3.3.3. Healthcare provider-related factor

Compared to parents of those who had seen 1 provider, parents of those who had seen 2 providers or parents of those who had seen 3 and more providers were less likely to under-report (aOR = 0.78 and 0.69, respectively) but more likely to over-report (aOR = 1.19 and 1.39, respectively).

3.3.4. State-level factors

In bivariate analyses, compared to those living in states with no HPV vaccine policy, those living in states with school-entry vaccine mandates were more likely to under-report the number of vaccine doses. However, when adjusted for other covariates, these differences no longer existed. State-level median income was associated with over-reporting the number of vaccine doses (aOR = 0.98, CI = [0.98–0.99]).

3.4. Sensitivity analyses

We conducted sensitivity analyses (SA) examining whether results changed considerably when those who reported "Don't

Table 4
Multilevel multinomial logistic regression examining predictors of under-reporting and over-reporting number of vaccine doses.

	Underreporting (compared to reporting accurately)		Overreporting (compared to reporting accurately)	
	aOR	p (aOR)	aOR	p (aOR)
Adolescent's age	1.06 (1.06–1.06)	<0.001	1.06 (1.06–1.07)	<0.001
Adolescent's sex				
Male	Reference		Reference	
Female	1.11 (1.11–1.11)	<0.001	1.21 (1.21–1.22)	<0.001
Adolescent's race/ethnicity				
Non-Hispanic White	Reference		Reference	
Non-Hispanic Black	2.05 (2.04–2.05)	<0.001	1.41 (1.40–1.41)	<0.001
Hispanic	2.13 (2.12–2.13)	<0.001	1.17 (1.17–1.18)	<0.001
Multiple races or Other race	1.98 (1.98–1.99)	<0.001	1.38 (1.38–1.39)	<0.001
Maternal education				
Below a bachelor's degree	Reference		Reference	
Bachelor's degree and above	0.79 (0.79–0.80)	<0.001	0.80 (0.80–0.80)	<0.001
Household poverty status				
Below poverty line	Reference		Reference	
Above poverty line	0.50 (0.49–0.50)	<0.001	0.70 (0.70–0.70)	<0.001
Number of providers seen				
1 provider	Reference		Reference	
2 providers	0.78 (0.78–0.78)	<0.001	1.19 (1.18–1.19)	<0.001
3 or more providers	0.69 (0.69–0.69)	<0.001	1.39 (1.38–1.39)	<0.001
State HPV vaccine policy				
No policy	Reference		Reference	
Educational policy	0.87 (0.74–1.01)	0.07	0.93 (0.79–1.07)	0.35
School-entry mandate	1.14 (0.84–1.54)	0.40	1.05 (0.77–1.44)	0.75
State median household income (in $1,000)	1.01 (1.00–1.01)	0.19	0.98 (0.98–0.99)	<0.001
Variance components				
ICC (null model)	0.0261		0.0273	
Level-2 variance	0.0167		0.0195	
Proportional reduction in variance (compared to null model)	31.94%		29.12%	
Model fit				
−2LL	33,436,959			
AIC	33,437,015			
BIC	33,437,070			

know" (n = 2412) or "Refused" (n = 7) were excluded from analysis. In this analysis, parents of females were more likely to inaccurately report vaccine initiation (original model: aOR = 0.93; SA model: aOR = 1.08). Moreover, parents of females were less likely to inaccurately report vaccine completion (original model: aOR = 1.38; SA model: aOR = 0.73). For number of vaccine doses, parents of females were also less likely to both under-report (original model: aOR = 1.11; SA model: OR = 0.90) and over-report (original model: OR = 1.21; SA model: OR = 0.82). All p values were less than 0.001 for these new results obtained from sensitivity analyses. Results obtained for other covariates did not change considerably. Given the differences in the results in regards to adolescent's sex, careful consideration should be taken in how researchers decide to code the responses of "Don't know" and "Refused."

4. Discussion

To our knowledge, this study is the first to use multilevel modeling to examine multilevel factors influencing the accuracy of parental reports of adolescent HPV vaccination status. We found that 76.15% of the sample accurately reported vaccine initiation and 75.18% accurately reported vaccine completion. These findings are in line with other published reports. Past studies using NIS-Teen data over the years have reported a range of accuracy of parental reports from 73% to 79% for HPV vaccine initiation and 64% to 74% for vaccine completion [7,9,10]. We also found that when the number of vaccine doses were considered, 60.97% accurately reported the number of vaccine doses that their children had received, 27.78% under-reported, and 11.24% over-reported. A study using NIS-Teen data from 2008 to 2013 showed that 21.2% and 8.6% of parents in the sample under-reported and over-reported the number of vaccine doses, respectively [13]. Research using parental reports to estimate HPV vaccine coverage should pay attention to these statistics and our findings, as they demonstrate possible magnitudes of the differences between parental reports and actual provider records. It is possible that the disparities in reporting, as shown in our findings, can bias research studies whose data are solely based on parental recalls or reports of adolescents' vaccination status.

Our findings demonstrate that parents of females, older adolescents, adolescents who were of racial/ethnic minorities (i.e., non-Hispanic Black, Hispanic, and multiple or other races), households with lower maternal education, and households living below the poverty line were more likely to inaccurately report vaccination status. These associations have also been observed in past studies examining individual-level or sociodemographic correlates of the accuracy of parental reports of HPV vaccination status [9,10,22,23]. Future studies should examine the sources of the inaccuracy of reports in these groups. For example, lower health literacy could be a reason why parents have not heard of or fully understood about HPV vaccine, and therefore not knew or remembered whether their children had received the vaccine [9,10]. For under-reporting in particular, social desirability bias could play a role. Parents may not want to disclose children's vaccination status for fear of judgment of them condoning adolescents' sexual activity [9,10,24].

We observed that parents of those who had seen more providers were more likely to accurately report vaccine initiation and completion. However, we also found that parents of children who had seen more providers were also more likely to over-report number of vaccine doses received. Having seen more providers may mean increased access to vaccine records or more frequent review of vaccine history, which explains why parents were able to accurately recall vaccine initiation and completion. At the same time, it is possible that, in the absence of clear verification of the number of doses received, parents may have assumed that children were fully vaccinated given a greater number of healthcare encounters. Future research with parents of adolescents experiencing this type of fragmented care will be needed to better understand these factors. While seeing more providers can mean more access to medical history of vaccination, we believe additional tools offered by health systems could also improve parental recalls. For example, vaccine records or passports and records in patient portals may assist parents in accurately reporting vaccinations.

We found that state-level HPV vaccine policy was not associated with any outcome and that increased state-level median household income was associated with a lower odd of over-reporting the number of vaccine doses. Research on policy around HPV vaccine school-entry mandate or education has shown different conclusions. While a study analyzing NIS-Teen data from 2009 to 2013 did not find that state-level HPV vaccine policy was effective in improving actual HPV vaccine uptake [15], another recent paper found that Rhode Island's school-entry HPV vaccination policy was effective in increasing HPV vaccine initiation rate among adolescent boys [25]. We had expected that state-level HPV vaccine policy could have a secondary benefit of improving parental knowledge of their children's HPV vaccination status. We did not find support for this hypothesis. A possible reason could be due to variations in educational requirements as well as differential enforcements and implementations of policy. For example, two out of three states with school-entry mandate have "liberal opt-out" language, allowing parents to exempt their children from vaccination [15,26]. Some states with HPV vaccine education policy also only require information to be provided "under certain circumstances" [20], while some others require information to be available to only parents of female adolescents, and for a few, to all parents of adolescents. Future studies should continue to examine these variations in educational requirements and policy implementation to understand how they may impact parental knowledge of the vaccine as well as their children's vaccination status.

5. Limitations

Limitations of this study include the cross-sectional nature of our data and its restriction in drawing causal claims. As this was a secondary data analysis, it also did not us allow to examine potentially important factors or theoretical constructs that may contribute to variation in the outcome. We also did not consider respondent characteristics (e.g., relationship to the adolescent) that may influence recalls. For example, a study on parental reports of adolescent females' HPV vaccination status in the NIS-Teen data had found that the sensitivity of adult proxy recall was higher when mothers were the adult proxy compared to fathers [22]. In our dataset, it appeared that mothers/female guardians have the lowest proportion of inaccurately reporting vaccine initiation and completion (20.10% and 22.80%, respectively) compared to fathers/male guardians (28.71% and 28.43%, respectively), grandparents (36.70% and 28.65%, respectively), or other family members/friends (44.34% and 31.36%, respectively). Mothers/female guardians also have the highest proportion of accurately reporting the number of vaccine doses (64.20%) compared to fathers/male guardians (56.60%), grandparents (51.16%), or other family members/friends (43.26%). Future research that focuses on the role of respondent characteristics in reporting and recall should take into account these results.

Moreover, the narrow confidence intervals and statistically significant differences observed in our results need to be considered in light of our large sample size. Future research can consider

establishing a guideline for clinical significance for variables similar to those used in our study. Additionally, we restricted our analysis to parents who have provider-verified data in the NIS-Teen. Per the NIS-Teen user's guide, those with inadequate provider data included: (1) those whose parents did not give consent to contact the provider(s), (2) those whose provider(s) did not respond to or return the immunization history questionnaire, or (3) those whose provider(s) did not report any vaccination data despite having returned the immunization history questionnaire. It has been suggested that those with provider-verified data may have higher socioeconomic status [9,10], thus limiting the generalizability of our findings. Parents needed to know the contact information for providers in order for the vaccine records to be verified. This knowledge of the providers' contact information can likely be related to their knowledge of the child's receipt of the HPV vaccine as well as other independent variables. Moreover, while we use provider-verified records as the gold-standard (i.e., the indicator of accurate information), there could be the potential for inaccurate reporting on the providers' ends.

6. Conclusions

Having accurate reporting of vaccination status is crucial for identifying under-vaccinated populations and to monitor vaccine coverage. This study is the first to employ a Socioecological Framework, take advantage of the NIS-Teen design (having parents nested in states), and use multilevel modeling to examine multilevel factors influencing the accuracy of parental reports of adolescent HPV vaccination status. Our study showed that parents with adolescents who were of racial/ethnic minorities, and households with lower maternal education with poverty status were more likely to inaccurately report vaccination status. Future studies should examine the sources of inaccuracy of reports in these groups (e.g., low health literacy, recall or social desirability). Parents of those who had seen more providers were more likely to accurately report vaccine initiation and completion, highlighting the impact of increased access to vaccine records. Our study is the first to examine the impact of different HPV vaccine policy on parental reports to see if state-level HPV vaccine policy could have a secondary benefit of improving parental knowledge of their children's HPV vaccination status. We did not find an impact of state vaccine policy on the accuracy of parental reports, necessitating additional research looking at variations of policy requirements and implementation.

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Conflict of interest

None of the authors have an actual or potential conflict of interest.

Ethics approval

The NIS-Teen dataset version available for public use does not contain identifiable private information and does not meet the criteria for research with human subjects under Emory IRB policies. The project did not require IRB approval.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2018.12.032.

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