

RESEARCH ARTICLE

## HPV Vaccine Coverage Among Adolescent Males in Ohio: Results of a Longitudinal Study

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### ABSTRACT

**Background:** Human papillomavirus (HPV) vaccine has been recommended for males in the United States since 2011, yet little is known about vaccine coverage among adolescent males in Ohio. Our longitudinal study examined HPV vaccine coverage among adolescent males in Ohio and identified predictors of vaccination.

**Methods:** The Buckeye Teen Health Study recruited adolescent males aged 11 to 16 years and their parents from 1 urban county and 9 rural counties in Ohio. We report longitudinal vaccination data on 1126 adolescent males, with baseline data from 2015-2016 and follow-up data from 2017-2018. We used multivariable Poisson regression to identify predictors of HPV vaccine initiation that occurred between baseline and follow-up.

**Results:** At baseline, 42.4% of parents reported their sons had initiated the HPV vaccine series. Among parents whose sons were unvaccinated at baseline, 36.3% indicated initiation at follow-up. Initiation at follow-up was more common among sons who had received influenza vaccine (RR = 1.54, 95% CI = 1.08-2.18) or whose parents indicated lack of a recent visit to a doctor as the main reason for not yet vaccinating at baseline (RR = 1.41, 95% CI = 1.02-1.95). Initiation was less common among sons whose parents had an associate degree or some college education (RR = 0.28, 95% CI = 0.46-0.99). Main reasons for not vaccinating changed from baseline to follow-up among parents of unvaccinated sons.

**Conclusion:** Although HPV vaccine initiation increased over time, many adolescent males in Ohio remain unvaccinated. Findings can help guide future strategies for increasing HPV vaccine coverage among this population.

**Keywords:** Adolescent males, HPV vaccine, Parents, Longitudinal

### INTRODUCTION

Human papillomavirus (HPV) is the most common sexually transmitted infection in the United States (US).<sup>1</sup> Data from 2013-2014 National Health and Nutrition Examination Survey (NHANES) show that about 45% of adult men in the US have a genital infection with at least one type of HPV, and about 25% have a genital infection with at least one oncogenic type of HPV.<sup>2</sup> In males, infection with nononcogenic HPV types can cause genital warts, while infection with oncogenic types can cause penile, anal, and oropharyngeal cancers.<sup>3,4</sup> From 1999 to 2015, HPV-associated cancer incidence rates among males increased, particularly for oropharyngeal and anal cancers.<sup>5</sup> In fact, the incidence rate of oropharyngeal cancer among males is expected to be higher than the incidence rate of cervical cancer among females by 2020.<sup>6</sup>

Human papillomavirus vaccine is approved by the Food and Drug Administration (FDA) to prevent HPV-associated cancers and geni-

tal warts in both males and females. The Advisory Committee on Immunization Practices (ACIP) recommends routine HPV vaccination for adolescents aged 11 to 12 years, and recently voted unanimously to support catch-up vaccination for persons through age 26.<sup>7</sup> Prior to this recent update, catch-up vaccination was recommended only for males aged 13 to 21 years, though males aged 22 to 26 years could still be vaccinated.<sup>8</sup> The HPV vaccine series consists of 2 doses if the series is initiated prior to age 15 years and 3 doses if the series is initiated after turning 15.<sup>8</sup> Despite recommendations, recent national data show that only about 63% of adolescent males in the US have received any doses of the HPV vaccine series (ie, vaccine initiation) and only about 44% are up to date with the vaccine series.<sup>9</sup> The HPV vaccine coverage remains much lower than coverage with other vaccines recommended for adolescents (eg, meningococcal and tetanus booster vaccines).<sup>9</sup>

Various parental, adolescent, and health characteristics are associated with HPV vaccination among adolescent males. There are



racial/ethnic differences in parents' intentions to vaccinate,<sup>10</sup> HPV vaccine initiation,<sup>11-15</sup> and completion of the HPV vaccine series<sup>16</sup> among adolescent males. Maternal education level also impacts vaccine initiation among adolescent males.<sup>12,16</sup> Health care providers' recommendation for HPV vaccination increases parents' intention to vaccinate their sons,<sup>10,17</sup> reduces parents' vaccine hesitancy and safety concerns about the vaccine,<sup>18</sup> and increases vaccine initiation.<sup>15</sup> Additional factors associated with HPV vaccination include receipt of other vaccines<sup>13,14,16</sup> as well as the ages of the parents<sup>12,13</sup> and the adolescent.<sup>12</sup> However, much of this evidence is derived from cross-sectional surveys, with only a few longitudinal studies<sup>19,20</sup> examining predictors of HPV vaccine coverage among adolescent males.

Little research has explored HPV vaccine coverage in Ohio. Recent data suggest that HPV vaccine coverage among adolescents in Ohio is slightly lower than the US as a whole.<sup>9</sup> However, there is potentially important variation within the state of Ohio, as vaccine coverage tends to be higher among adolescent males residing in urban and suburban areas compared to those residing in rural areas.<sup>12</sup> One predominantly rural area in Ohio is Appalachian Ohio, a 32-county region in the southern and eastern part of the state. Appalachia has several existing HPV-associated health disparities, including higher incidence rates of multiple HPV-related cancers.<sup>21</sup> Past studies have shown that knowledge about HPV vaccine is low among parents of adolescent males in Appalachian Ohio, though many are willing to vaccinate their sons.<sup>22,23</sup>

In this article, we report longitudinal data on HPV vaccine coverage among adolescent males in Ohio. In doing so, we identify predictors of HPV vaccination, including how vaccination may differ between an urban area of Ohio and a rural area (ie, Appalachian Ohio). We also examine parents' reasons for not vaccinating their sons and their willingness to vaccinate in the future. Findings will be useful for better understanding HPV vaccination among adolescents in Ohio and developing future strategies for increasing vaccine coverage.

## METHODS

### Setting and Design

The Buckeye Teen Health Study was a prospective cohort study that examined the impact of tobacco advertising on adolescent tobacco use in Ohio. As part of this study, data were collected on a range of health behaviors among adolescents, including HPV vaccination. We analyzed the resulting data for the current report.

The methodologies of the Buckeye Teen Health Study have been described elsewhere<sup>24</sup> and briefly here. Both probability and nonprobability sampling methods were used to recruit participants for this study. All recruiting efforts occurred in 1 urban county (Franklin) and 9 Appalachian counties (Brown, Guernsey, Lawrence, Muskingum, Scioto, Clermont, Noble, Morgan, and Washington) in Ohio. For probability sampling, we used address-based sampling of US Postal Service addresses to select house-

holds to contact. A packet with study information and a brief screener was sent to each selected household to determine if there were any eligible adolescents in the household. For nonprobability sampling, we used strategies such as snowball sampling, attending community events, and advertisements in local newspapers and radio to identify potentially eligible households.

### Participants

To be eligible, adolescents had to be male, aged 11 to 16 years, living in a county included in the study, and able to complete study surveys. Data were also collected from parents of the adolescents. Parents included legal guardians and other adults who were involved in the care of the adolescent and living in the same household as the adolescent (hereafter referred to as "parents"). Adolescents who had hearing and vision impairments and parents or adolescents who were unable to speak English were excluded from the study.

### Procedures

The Institutional Review Board at The Ohio State University approved the study protocol. Parents at potentially eligible households were contacted via telephone to confirm eligibility and arrange a baseline interview. Prior to the start of baseline interviews, parents provided consent to participate and adolescents provided assent. Trained interviewers administered the baseline survey to the adolescents, which included both interviewer-administered and audio-administered portions. Parents completed self-administered baseline surveys. Adolescents completed follow-up surveys at months 6, 12, 18 (telephone survey), and 24 (in-person or telephone survey) after baseline. Parents completed follow-up telephone surveys at months 12 and 24 after baseline. We report data from only the baseline and 24-month follow-up surveys of parents since these are the only surveys that assessed HPV vaccination among the adolescents. The HPV vaccination items were asked to the parent in the household that was identified as knowing the most about the adolescent's health. For the remainder of this article, we refer to the 24-month parent survey as the "follow-up survey." Baseline data collection occurred from January 2015 to June 2016, and data collection for the 24-month follow-up survey occurred from January 2017 to August 2018. Parents received a \$10 gift card for the baseline survey and a \$5 gift card for the follow-up survey.

The current study includes HPV vaccination data on a total of 1126 adolescents, as reported by parents. Of the 1126 parents who completed a baseline survey, 817 also completed a follow-up survey.

### Measures

All HPV vaccination items were included on parent surveys at both baseline and follow-up. We assessed parents' reports of whether or not their sons had received at least 1 dose of HPV vaccine (ie, HPV vaccine initiation) at each time point. If parents indicated HPV vaccine initiation, we then assessed the number of HPV vaccine doses the sons had received. Our primary outcome was HPV



vaccine initiation at follow-up among sons who were not vaccinated at baseline, though we report HPV vaccine coverage estimates at both baseline and follow-up.

Among parents of unvaccinated sons (ie, those who had not received any doses of HPV vaccine), the survey assessed their willingness to vaccinate their son if the vaccine was free. This survey item included a 5-point scale with responses of “definitely not willing,” “probably not willing,” “not sure,” “probably willing,” and “definitely willing.” We classified responses into 1 of 3 categories (definitely/probably not willing, not sure, or definitely/probably

willing). The survey also asked parents of unvaccinated sons the main reason why their son had not yet received HPV vaccine. Parents indicated only 1 reason from a predefined list of potential reasons, though parents were provided the option to specify a reason not included in the list.

We collected information on various demographic and health-related characteristics of parents and sons from parent surveys at baseline to examine as potential predictors of HPV vaccine initiation (**Tables 1 and 2**). For county type, “urban” was defined as Franklin County and “rural” was defined as the 9 Appalachian Ohio

**Table 1. Characteristics of Parents and Their Adolescent Sons**

	Baseline Only n=309	Both Baseline and Follow-up n=817	P value
<b>Parent Characteristics</b>			
Gender			
Female	266 (86.6)	710 (87.1)	0.83
Male	41 (13.4)	105 (12.9)	
Age (years)			
Less than 40	135 (43.7)	198 (24.3)	<0.0001
Between 40 and 50	130 (42.7)	430 (52.6)	
Greater than 50	44 (14.2)	189 (23.1)	
Race/ethnicity			
Non-Hispanic white	235 (77.3)	665 (81.8)	0.21
Non-Hispanic black	45 (14.8)	91 (11.2)	
Other	24 (7.9)	57 (7.0)	
Education status			
High school or below	70 (22.7)	111 (13.6)	<0.0001
Associate degree or some college	142 (46.1)	256 (31.4)	
College degree	67 (21.8)	249 (30.5)	
More than a college degree	29 (9.4)	200 (24.5)	
Income			
Less than \$25000	69 (23.5)	100 (12.5)	<0.0001
\$25000 - \$50000	77 (26.3)	135 (16.9)	
More than \$50000	147 (50.2)	563 (70.6)	
Marital status			
Married	193 (63.7)	600 (74.3)	<0.01
Not married	110 (36.3)	208 (25.7)	
County type			
Urban	150 (48.5)	501 (61.3)	<0.0001
Rural	159 (51.5)	316 (38.7)	
<b>Adolescent Male Characteristics</b>			
Age (years)			
11-12	82 (26.5)	264 (32.3)	0.09
13-14	111 (35.9)	294 (36.0)	
15-16	116 (37.6)	259 (31.7)	
Race/ethnicity			
Non-Hispanic white	214 (69.7)	630 (77.4)	0.03
Non-Hispanic black	49 (16.0)	91 (11.2)	
Other	44 (14.3)	93 (11.4)	

Totals may not sum to stated sample size due to missing data. Percentages may not sum to 100% due to rounding. “Baseline Only” includes parents who only completed the baseline survey, and “Both Baseline and Follow-up” includes parents who completed both a baseline and 24-month follow-up survey.



counties. Parents indicated whether their sons had received other vaccines recommended for adolescents (tetanus booster vaccine, influenza vaccine, and meningococcal vaccine).<sup>25</sup>

### Statistical Analysis

We first calculated descriptive statistics (eg, frequencies and percentages for categorical variables) and used chi-square tests to examine potential differences between participants who completed only the baseline survey and those who completed both the baseline and follow-up surveys. We used Poisson regression to identify baseline characteristics associated with HPV vaccine initiation at follow-up among sons who were unvaccinated at baseline. We first identified variables associated with HPV vaccine initiation in bivariate analyses ( $P < 0.10$ ). We then entered these variables into a multivariable model. Poisson regression models produced relative risks (RRs) and 95% confidence intervals (CIs).

We compared baseline and follow-up data on parents' reasons why their sons had not been vaccinated and their willingness to vaccinate their sons. These comparisons were made using McNemar chi-square test for paired data. All analyses were carried out using SAS version 9.4 (SAS Institute Inc., Cary, NC) with an alpha level of 0.05.

## RESULTS

### Participant Characteristics

Parents who completed both the baseline and follow-up surveys were mostly female (87.1%), 40 years of age or older (75.8%), non-Hispanic white (81.8%), married (74.3%), and reported an income of more than \$50,000 (70.6%) (Table 1). Most sons were also non-Hispanic white (77.4%). Compared to parents who completed both surveys, parents who completed only the baseline survey tended to be younger, have less education, report lower incomes, not be married, live in a rural county, and have sons who were not non-Hispanic white (all  $P < 0.05$ ).

### HPV Vaccination

At baseline, parents indicated that 477 of 1126 (42.4%) adolescents had initiated the HPV vaccine series. Among these, 188 of 477 (39.4%) had received 1 dose, 75 of 477 (15.7%) had received 2 doses, 201 of 477 (42.1%) had received 3 doses, and 13 of 477 (2.7%) were not sure about the number of doses received. There was no difference in vaccine initiation at baseline among sons whose parents completed both surveys and sons whose parents completed only the baseline survey (41.1% vs 45.6%,  $P = 0.17$ ). Among sons who were unvaccinated at baseline and whose parents completed a follow-up survey, 166 of 457 (36.3%) had initiated the HPV vaccine series at follow-up. Among these, 69 of 166 (41.6%) had received 1 dose, 42 of 166 (25.3%) had received 2 doses, 54 of 166 (32.5%) had received 3 doses, and 1 of 166 (0.6%) was not sure about the number of doses received.

### Predictors of HPV Vaccine Initiation

Multivariable analyses identified several predictors of HPV vaccine initiation at follow-up among sons who were unvaccinated at baseline. Initiation was lower among sons of parents with an associate degree or some college education compared to parents with a high school degree or less (RR = 0.28, 95% CI = 0.46-0.99) (Table 2; see Supplemental Material for bivariate results). Receipt of other recommended adolescent vaccines also predicted HPV vaccine initiation, albeit in different directions. Sons whose parents indicated they had received influenza vaccine were more likely to initiate the HPV vaccine series (RR = 1.54, 95% CI = 1.08-2.18), while sons whose parents indicated they had received tetanus booster vaccine were less likely to initiate the HPV vaccine series (RR = 0.68, 95% CI = 0.50-0.94). Parents who indicated their sons had not visited a doctor recently as the main reason for not yet vaccinating at baseline were more likely to indicate initiation at follow-up than parents who did not provide this reason at baseline (RR = 1.41, 95% CI = 1.02-1.95). Compared to parents who were definitely or probably willing to vaccinate their sons against HPV at baseline, parents who were not sure (RR = 0.58, 95% CI = 0.43-0.78) or who were definitely or probably not willing to vaccinate (RR = 0.22, 95% CI = 0.11-0.46) were less likely to report initiation at follow-up. No additional variables predicted HPV vaccine initiation, including whether participants resided in an urban or rural county.

### Reasons for Not Vaccinating and Willingness to Vaccinate

The 3 most common reasons given at baseline for why parents had not yet vaccinated their son against HPV were "His doctor did not recommend it" (16.3%, 97 of 595), "I do not know enough about it yet" (12.6%, 75 of 595) and "My son is too young" (10.6%, 63 of 595) (Table 3). At follow-up, the most common reasons were "It might be unsafe" (18.2%, 49 of 270), "His doctor did not recommend it" (15.6%, 42 of 270), and "It is too new" (11.9%, 32 of 270). Reasons more commonly reported at follow-up compared to baseline were "It is too new" and "My son is not having sex yet" (both  $P < 0.05$ ). Conversely, reasons more commonly reported at baseline than follow-up were "I never heard of the vaccine" and "My son is too young" (both  $P < 0.05$ ).

Among parents of unvaccinated sons, willingness to vaccinate their sons against HPV decreased from baseline to follow-up ( $P < 0.01$ ). The percentage of parents who were definitely or probably willing to vaccinate decreased from baseline to follow-up (41.8% vs 30.6%), while the percentage of parents who were definitely or probably not willing to vaccinate increased from baseline to follow-up (21.8% vs 43.0%).

## DISCUSSION

Our longitudinal study provides important insight into HPV vaccine coverage among adolescent males in Ohio. At baseline, just over 40% of adolescent males had initiated the HPV vaccine series. In a similar time period as our study's baseline data



Table 2. Longitudinal Predictors of HPV Vaccine Initiation Among Adolescent Males

	Number of Parents Reporting HPV Vaccine Initiation Among Sons at Follow-up/ Total Number of Parents in the Category (%)	Multivariable RR (95% CI)
<b>Parent Characteristics</b>		
Race/ethnicity		
Non-Hispanic white	129/377 (34.2)	Ref
Non-Hispanic black	25/46 (54.4)	0.68 (0.28-1.69)
Other	11/31 (35.5)	0.55 (0.23-1.29)
Education status		
High school or below	31/70 (44.3)	Ref
Associate degree or some college	48/157 (30.6)	0.28 (0.46-0.99)*
College degree	52/141 (36.9)	0.88 (0.60-1.29)
More than a college degree	35/88 (39.8)	0.84 (0.57-1.25)
<b>Reasons for Not Vaccinating</b>		
I do not know enough about it yet		
Yes	10/52 (19.2)	0.63 (0.35-1.14)
No	134/365 (36.7)	Ref
It might be unsafe		
Yes	4/38 (10.5)	0.72 (0.25-2.04)
No	140/379 (36.9)	Ref
My son is too young		
Yes	25/48 (52.1)	1.09 (0.80-1.50)
No	119/369 (32.3)	Ref
My son has not been to the doctor recently		
Yes	11/16 (68.8)	1.41 (1.02-1.95)*
No	133/401 (33.2)	Ref
Willingness to Vaccinate		
Definitely/Probably willing	101/185 (54.6)	Ref
Not sure	52/164 (31.7)	0.58 (0.43-0.78)**
Definitely/Probably not willing	9/99 (9.1)	0.22 (0.11-0.46)**
<b>Adolescent Male Characteristics</b>		
Age (years)		
11-12	75/176 (42.6)	Ref
13-14	57/163 (35.0)	0.91 (0.69-1.21)
15-16	34/118 (28.8)	0.79 (0.57-1.10)
Son's race/Ethnicity		
Non-Hispanic white	125/363 (34.4)	Ref
Non-Hispanic black	25/45 (55.6)	2.39 (0.99-5.74)
Other	16/48 (33.3)	1.01 (0.51-2.00)
Received influenza vaccine		
Yes	130/306 (42.5)	1.54 (1.08-2.18)*
No	35/150 (23.3)	Ref
Received tetanus booster vaccine		
Yes	131/385 (34.0)	0.68 (0.50-0.94)*
No	35/72 (48.6)	Ref

Note. Predictors were assessed during the baseline survey, and the outcome of HPV vaccine initiation was assessed during the 24-month follow-up survey. Analyses included parents (n = 466) who reported at baseline their sons had not received any doses of HPV vaccine and completed a follow-up survey. Totals may not sum to stated sample size due to missing data.

HPV=human papillomavirus; RR= relative risk; CI=confidence interval; Ref=referent group.

\* P <0.05

\*\* P <0.001



Table 3. Reasons Given by Parents for Their Sons Not Receiving HPV Vaccine

	Baseline % (n=595)	Follow-up % (n=270)
I never heard of the vaccine	7.2	2.6*
I do not know enough about it yet	12.6	10.7
I did not know boys are allowed to get it	9.4	4.1
It is too new	4.7	11.9*
It might be unsafe	9.1	18.2
My son is too young	10.6	4.1*
My son is not having sex yet	5.9	8.5*
My son has not been to the doctor recently	4.5	5.6
His doctor did not recommend it	16.3	15.6

\*  $P < 0.05$ 

collection, national data showed that 56% of adolescent males in the US had initiated the vaccine series.<sup>26</sup> The estimate from our study is likely lower than this national estimate since our study included a younger age range (11 to 16 years) than the national data (13 to 17 years), and HPV vaccination tends to be lower among younger adolescents.<sup>26</sup> Among participants who were unvaccinated at baseline, over one-third initiated the vaccine series by follow-up. The increase between baseline and follow-up is much larger than the 6% increase observed in a past longitudinal study of HPV vaccination among adolescent males in the US from 2010-2011.<sup>19</sup> This may be largely attributable to the follow-up period of this past study being shorter (ie, about a 1 year follow-up period) and that it began before the recommendation for routine HPV vaccination for males in the US was issued in 2011.<sup>27</sup> Despite the increase in HPV vaccination found in our study, it is important to continue to monitor changes in vaccination over time since many adolescent males in Ohio remain unvaccinated.

We found that several variables predicted HPV vaccine initiation between baseline and follow-up. Initiation was higher among participants whose parents had a high school education or less compared to those whose parents had more education, though the only comparison that reached statistical significance involved parents with an associate degree or some college education. This overall pattern is similar to past research where parents with higher educational attainment had sons who tended to be less likely to have initiated the HPV vaccine series.<sup>12,28</sup> Although parents with higher educational attainment know more about the HPV vaccine,<sup>29</sup> they also have expressed more concerns about the effectiveness and safety of HPV vaccine,<sup>30</sup> and this may help explain why vaccination was lower among parents with greater education in our study.

Parents who indicated their sons had not been to the doctor recently as a main reason for not yet vaccinating at baseline were more likely to report initiation among their sons at follow-up. Many of these sons likely had visits to a health care provider between baseline and follow-up, providing opportunities for vac-

ination to occur. The results reiterate the importance of adolescents attending health care visits in order to improve HPV vaccine coverage.<sup>31,32</sup> At visits, it is critical that health care providers offer recommendations for HPV vaccine, as it is a key factor influencing vaccination decisions.<sup>33</sup> Indeed, one of the most common reasons that parents reported for not yet vaccinating was lack of a health care provider recommendation. It is possible that some of these parents forgot receiving a recommendation or misunderstood information about HPV vaccine from a health care provider.<sup>12</sup> Thus, it is important that health care providers are explicit in their messages about adolescent vaccinations.<sup>12</sup> Explicit health care provider recommendations for HPV vaccination may be especially important in Ohio, as Ohio has one of the lowest vaccination rates among adolescent males whose parents have not received a provider recommendation to vaccinate.<sup>12</sup> Further, in addition to health care providers in traditional medical settings, it is important to continue to explore the potential impact that nontraditional settings (eg, pharmacies) can have on increasing HPV vaccine coverage.<sup>34</sup>

We found an association between parents' willingness to vaccinate at baseline and HPV vaccine initiation at follow-up. Interestingly, willingness to vaccinate decreased from baseline to follow-up. This is contrary to a previous study reporting no change in willingness of parents to vaccinate their sons for HPV over a 3-year period, though this was a serial cross-sectional study that included different parents in each data year.<sup>35</sup> In our longitudinal study, parents' willingness was only assessed among those whose sons were unvaccinated at each survey time point. Many parents who indicated a willingness to vaccinate at baseline vaccinated their sons by follow-up (and were therefore not asked about willingness at follow-up), leaving a higher proportion of parents at follow-up who likely had less interest in vaccinating but were still asked about their willingness. This may also help explain the observed changes in parents' reasons for not vaccinating between baseline and follow-up.



Parents were more likely to report HPV vaccine initiation at follow-up if they indicated their son had received influenza vaccine at baseline. These findings are similar to past studies showing that receipt of other recommended adolescent vaccines was correlated with HPV vaccination.<sup>13,16,36,37</sup> This is likely reflective of these parents having greater acceptability of vaccines in general, but it also underscores the potential to increase HPV vaccine coverage by administering the vaccine concomitantly with other recommended vaccines. Indeed, one of the recommendations of the President's Cancer Panel Report is to reduce missed clinical opportunities and provide HPV vaccine during the same health care visit as other adolescent vaccinations.<sup>38</sup> Given that Ohio has mandates currently in place that require tetanus booster and meningococcal vaccination for school entry for adolescents,<sup>39</sup> administering HPV vaccine during the same visits as these other vaccines may be a promising approach for increasing HPV vaccine coverage in the state.

We did not find differences in HPV vaccination initiation across racial/ethnic groups (which is contrary to past studies<sup>12-14,16</sup>) or between the urban (ie, Franklin County) and rural (ie, Appalachian Ohio) counties in our study. The lack of differences between the urban and rural counties is actually encouraging since HPV vaccine coverage has tended to be lower among adolescent males who reside in rural areas.<sup>9,12,40</sup> Moreover, past research has shown that HPV vaccine coverage among adolescent females may be lower in some parts of Appalachia compared to the rest of the US,<sup>41</sup> but our findings suggest this pattern may not be occurring among males in Appalachian Ohio. Further research is needed to better understand how rurality affects vaccine coverage across the entire state of Ohio.

Study strengths include the longitudinal design, large sample size, and assessment of a range of potential predictors. The study also has some limitations. For our primary outcome, we relied on parents' reports of their sons' HPV vaccination status, though most parents are able to accurately remember if their children have received this vaccine.<sup>42</sup> It is also possible that some adolescents went on to receive HPV vaccine after the follow-up data collection period ended. In addition, we did not collect data on the age of the sons when they received the HPV vaccine, which prevented us from examining how many were vaccinated during the ideal age range of 11 to 12 years. We also did not collect data on HPV infection or HPV-associated disease among parents or other family members, which could impact parents' decisions on vaccinating their sons. Participants in our study were from 10 counties in Ohio, though both probability and nonprobability sampling methods were used to increase the generalizability of the sample. Lastly, there were differences between participants who completed both the baseline and follow-up survey and those who completed only the baseline survey, which could have resulted in selective attrition.

## PUBLIC HEALTH IMPLICATIONS

To our knowledge, this is the first longitudinal study of HPV vaccine coverage among adolescent males in Ohio. Despite the observed increases in HPV vaccine coverage during our study's duration, many adolescent males in Ohio remain unvaccinated. Study findings also highlight several key predictors of HPV vaccine initiation and the most common reasons why parents are not vaccinating their sons. We believe this information can be used to guide the development of future strategies and programs to increase HPV vaccine coverage in Ohio.

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