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Factors associated with human papillomavirus and meningococcal vaccination among adolescents living in rural and urban areas

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ABSTRACT

Background: Studies have shown that adolescent vaccination rates with human papillomavirus (HPV) and quadrivalent meningococcal conjugate (MenACWY) vaccines are lower in rural areas of the U.S. than in urban areas. We sought to determine factors associated with vaccine acceptance in these two settings.
Methods: We conducted a cross-sectional survey of 536 parents or guardians of teens age 13 through 15 years in select rural and urban counties of Minnesota and Wisconsin. We collected information on demographic variables, receipt of adolescent vaccines, and attitudes toward HPV vaccine in particular. Multivariable logistic regression models were used to assess associations between covariates and outcomes of interest (HPV vaccine receipt and MenACWY receipt).
Results: Of the 536 respondents, 267 (50%) resided in a rural county. Most respondents were female (78%) and non-Hispanic White (88%). About half (52%) of teens of the surveyed parents received the three vaccines recommended specifically for adolescents: 90% received tetanus-diphtheria-acellular pertussis (Tdap), 84% received MenACWY, and 60% received one or more doses of HPV vaccine. Rural and urban parents surveyed differed on several covariates relating to teen's health services, parent's demographics, and household characteristics. Parent's perception of the importance that their healthcare providers placed on vaccination with HPV and MenACWY were independently associated with receipt of each of those vaccines (odds ratio [OR] 6.37, 95% confidence interval [CI] 2.90–13.96 and OR 2.15, 95% CI 1.07–4.31, respectively). Parents of vaccinated teens were less likely to report concerns about potential harm from the HPV vaccine or having heard stories about health problems caused by the HPV vaccine.
Conclusion: Teen receipt of HPV vaccine and MenACWY appears to be influenced by parents' perception of vaccine importance, provider recommendations, and concerns regarding potential harm from the HPV vaccine. Continued education of providers and parents of the importance of adolescent vaccinations is warranted.

1. Introduction

In the United States, the primary vaccines recommended in adolescence are tetanus-diphtheria-acellular pertussis (Tdap), human papillomavirus (HPV), quadrivalent meningococcal conjugate (MenACWY), and influenza. Overall, adolescent vaccination rates have increased recently, but for some vaccines such as HPV and MenACWY, national rates among rural adolescents have lagged behind their urban counterparts [1]. Rates for Tdap are similar in rural and urban areas, likely a result of school entry requirements for Tdap vaccination in all states [2]. Comparative data on vaccination for influenza among adolescents in those two settings are not available.

Abbreviations: CDC, Centers for Disease Control and Prevention; CHIAS, Carolina HPV Immunization Attitudes and Beliefs Scale; HPV, human papillomavirus; IIS, immunization information system; IRB, Institutional Review Board; MCRI, Marshfield Clinic Research Institute; MDH, Minnesota Department of Health; MenACWY, quadrivalent meningococcal conjugate vaccine; MIIC, Minnesota Immunization Information Connection; Tdap, tetanus-diphtheria-acellular pertussis vaccine; UIC, Urban Influence Codes; WIR, Wisconsin Immunization Registry.

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Nationally, coverage among adolescents aged 13–17 years with one or more doses of HPV vaccine was 75% in 2020, and the percentage of adolescents who completed the HPV vaccination series was 59%. In contrast, adolescent coverage with one or more doses of MenACWY was 89% in 2020, but only 54% of 17-year-olds received their recommended booster dose. Coverage with one or more doses of Tdap was high at 90% [1]. The percentage of adolescents age 13 through 17 years who received an influenza vaccine during the 2020–2021 season was 51% [3]. With the new Healthy People 2030 objectives to increase the percentage of adolescents who receive recommended doses of HPV vaccine (target 80%) and influenza vaccines (target 70% each season) by 2030, large gaps remain for these vaccines [4]. Additionally, the vaccines with the greatest disparity in coverage between rural and urban adolescents are HPV (68% vs 78%) and MenACWY (86% vs 90%) [1]. In Minnesota and Wisconsin, the rural–urban disparity in coverage with one or more doses of HPV vaccine is among the highest in the U. S., with an average of 13 to 15 percentage points lower coverage among adolescents living in rural areas than those in urban cities during 2016 through 2019 [5]. Similarly, MenACWY coverage in Wisconsin adolescents was on average 15 percentage points lower among rural vs urban adolescents, also among the largest disparities in MenACWY coverage in the U.S. [5]. Of note, MenACWY vaccination has been required for students entering grade 7 since the 2014–2015 school year in Minnesota [6], whereas Wisconsin does not have a MenACWY vaccination requirement for school entry. There is no HPV vaccination requirement for school entry in either state. A previous parent survey in rural and urban areas of North Carolina found that while many of the same parental beliefs were important correlates of HPV vaccine initiation regardless of racial group or urban/rural status, a few differences did exist [7]. We conducted a survey of parents to assess factors associated with—and potential barriers to—adolescent HPV and MenACWY vaccination to better understand determinants of rural–urban differences.

2. Methods

2.1. Design and setting

A cross-sectional survey of parents or guardians of adolescents aged 13 through 15 years in rural and urban counties in Minnesota and Wisconsin was conducted in 2019 by the Minnesota Department of Health (MDH) and the Marshfield Clinic Research Institute (MCRI), respectively. Rurality was based on Urban Influence Codes (UIC) [8]. Rural counties included small urban towns and non-metropolitan areas not adjacent to a metro area and had UIC of 6 through 12 (n = 42 in Minnesota, n = 30 in Wisconsin). Urban counties were large metro areas with more than one million residents and had UIC of 1 (n = 6 in Minnesota, n = 4 in Wisconsin). Small metro areas and those adjacent to a metro area (UIC of 2 through 5) were excluded to ensure representative regional samples with a clear dichotomy between urban and rural populations) (Fig. 1). As described further below, recruitment differed slightly between states, but the survey instrument used was the same for both states unless otherwise noted. Since most respondents reported being a parent of the adolescent surveyed, respondents are referred to as parents in this report.

2.2. Participants

2.2.1. Minnesota

MDH maintains a state immunization information system (IIS), the Minnesota Immunization Information Connection (MIIC, https://www.health.state.mn.us/miic), which contains records of vaccinations as well as demographic information. MIIC was used to identify adolescents aged 13 through 15 years that resided in eligible Minnesota counties as of the sampling date. Stratified random sampling by residency (rural vs urban) and HPV vaccination status (≥1 doses vs 0 doses) was used to create a list for the mailed survey invitation; invitations were addressed to the parent of the identified adolescent.

2.2.2. Wisconsin

Sampling from Wisconsin's IIS, Wisconsin Immunization Registry (WIR, https://www.dhs.wisconsin.gov/immunization/wir.htm), was not feasible for Wisconsin residents due to restrictions on access to data for research. MCRI obtained a list of 6000 households that were believed to have an adolescent aged 13 through 15 years in the eligible Wisconsin counties from a vendor that performs market research and sampling (Marketing Systems Group, Horsham, Pennsylvania). The list was stratified by residency (rural vs urban). Mailed invitations were addressed to the name associated with the phone number.

2.3. Recruitment and survey procedures

Surveys were administered using REDCap electronic data capture tools [9,10]; separate surveys were created and hosted at MDH and MCRI for the corresponding state. Potentially eligible parents were initially invited by mail; the letter included a link to complete the survey online (Supplemental Material). Nonrespondents received a mailed reminder and up to six phone calls from study staff. Most parents reached by phone completed the survey with study staff; some completed the survey online after the call. Parents received a $10 gift card after survey completion. This study was approved by the MCRI Institutional Review Board (IRB). MDH's and the Centers for Disease Control and Prevention (CDC)'s involvement in the study was determined by their respective IRBs as not human subjects research and IRB approval at their institutions was not required.

2.4. Sample size

The sample size calculation was based on the mean difference in the harms sub-factor score from the Carolina HPV Immunization Attitudes and Beliefs Scale (CHIAS) between groups [11]. Our previous research of Wisconsin parents found that baseline CHIAS-harms score was the strongest attitudinal predictor of HPV vaccine series completion and receipt of the next scheduled HPV vaccine dose [12]. Assuming 80 percent power, alpha of 0.05, and a two-sided *t*-test, 512 participants across 8 strata (state, residency, HPV vaccination status) would be needed to detect a 0.3-point difference on the CHIAS-Harms score between two groups.

2.5. Eligibility

Parents confirmed county of residence and that they were the parent or legal guardian of the identified adolescent (Minnesota) or an adolescent aged 13 through 15 years (Wisconsin). If an eligible parent from Wisconsin had more than one adolescent in the age range, they were instructed to complete the survey regarding their youngest adolescent.

2.6. Survey content

2.6.1. Teen, parent, and household information

We collected information on teen and respondent demographics such as sex, age, race/ethnicity, health insurance status, education or school attendance, household size, income, and religious service attendance. Information on general vaccination services

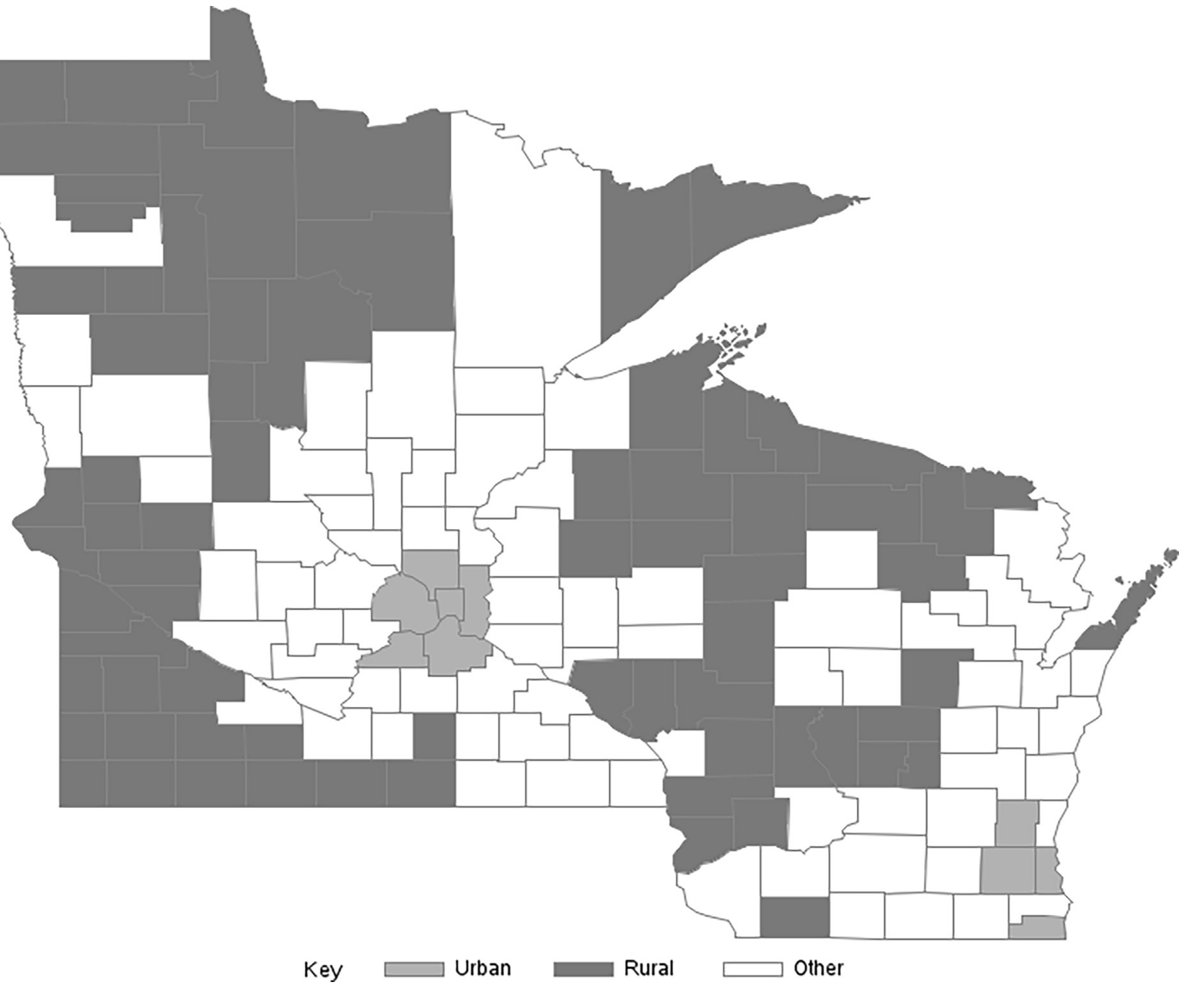

Fig. 1. Rural and urban counties in Minnesota and Wisconsin targeted for survey, 2019.

such as where the teen usually receives vaccinations, usual travel time to get vaccinations, and whether or not the teen had a preventive visit at age 11 or 12 years was also ascertained.

2.6.2. Vaccine receipt, discussion, recommendations, and reminders

Vaccine information included parent report of teen's receipt of recommended adolescent vaccines (Tdap, MenACWY, HPV, and influenza), parent discussion with providers regarding these vaccines, receipt of vaccine recommendations, and receipt of vaccine reminders. Parents who reported discussing vaccinations with providers were asked to rate how important it was to their teen's provider that their teen received each vaccine (very, somewhat, or not important). Parents were also asked how important they thought it was for their teen to be vaccinated with each vaccine. Parents reported whether they received recommendations for or against HPV vaccination for their teen and by whom, and whether they heard stories about health benefits of or health problems caused by the HPV vaccine. Provider discussion and perceived provider importance of each vaccine were combined for analysis (discussed, very important; discussed, somewhat or not important; not discussed; don't know).

2.6.3. General and HPV vaccine attitudes

Attitudes regarding vaccine benefits, HPV vaccine harms, and HPV vaccine effectiveness were assessed with a series of statements. We used the 4-item benefits factor of the Vaccine Confidence Scale, to assess parents' beliefs about vaccination in general [13]. The 4-item benefits factor scale was comparable to the full 8-item scale [13]. Due to space restrictions, only select statements from the CHIAS were included from the harms and effectiveness (modified) factors [11]. In Wisconsin, HPV vaccine effectiveness was assessed with one statement about prevention of cancers related to HPV without specifying sex. In Minnesota, two separate statements were included, one to assess prevention of cancer related to HPV among girls and one to assess prevention of cancer related to HPV among boys because of the interest in responses to gender differences in their state. Each item had a 5-point Likert-scale response, and responses were scored so that higher scores represented more positive attitudes about vaccination. The response scales were labeled "strongly agree," "agree," "neither agree or disagree," "disagree," and "strongly disagree" and were assigned values of 10, 7.5, 5, 2.5, and 0, respectively for all statements except the statements corresponding to HPV vaccine harms, which were assigned values in the reverse order. Items with missing or "don't know or prefer not to answer" responses were imputed with sample mean values [11]. Mean scores were generated for each statement and for the series of statements representing vaccine benefits, HPV vaccine harms, and HPV vaccine effectiveness (Fig. 2). Mean scores were estimated using regression models, responses to individual items were summarized descriptively.

2.7. Vaccination status

Vaccination status was based on IIS records when available or by parent report. Vaccination records, including dates of Tdap,

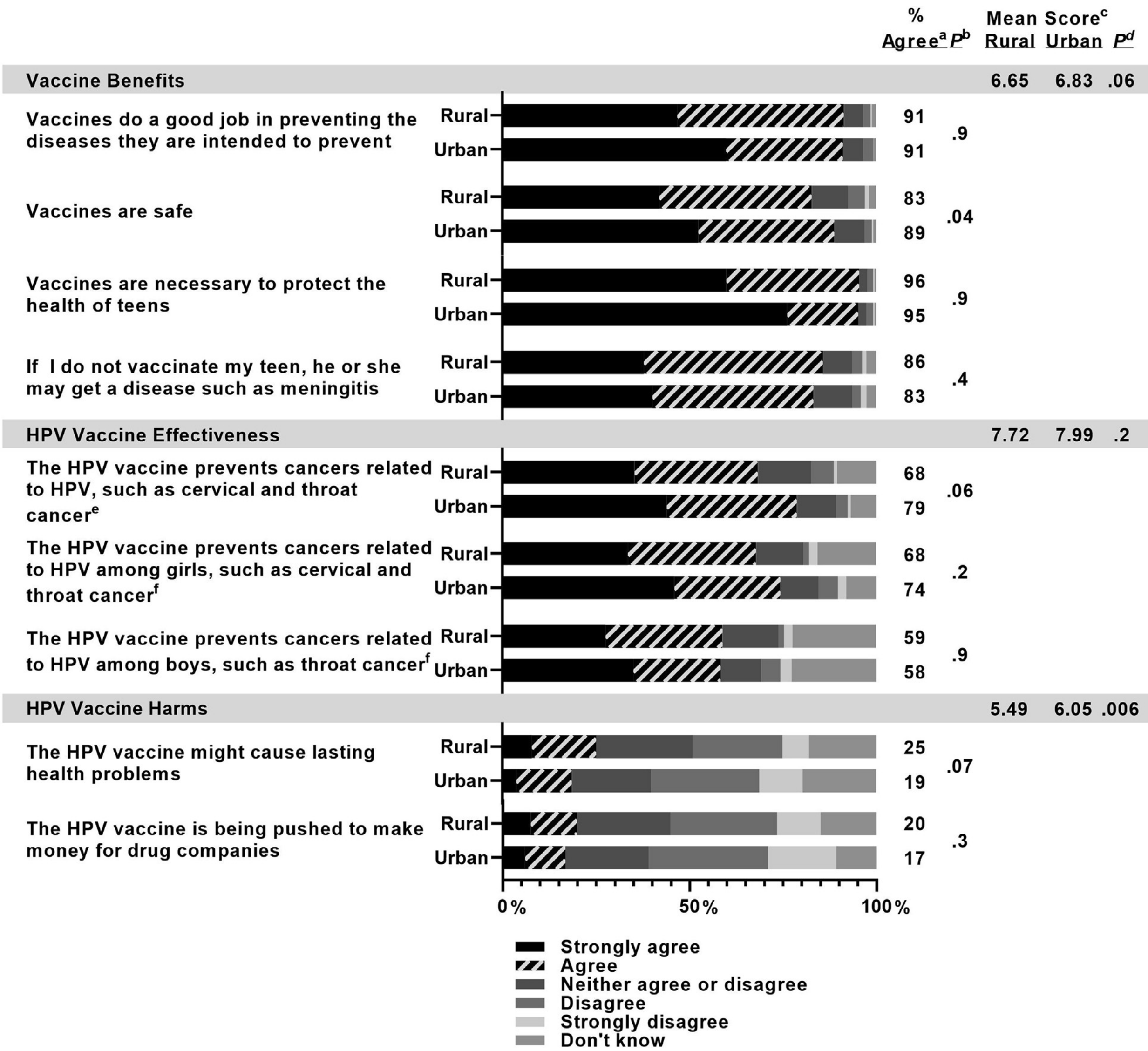

Fig. 2. Reported parent perceptions of vaccine benefits, HPV vaccine effectiveness, and HPV vaccine harms, and mean score in Minnesota and Wisconsin, 2019. Abbreviation: %, percentage; HPV, human papillomavirus. [a]Percentage of parents who strongly agree or agree with the statement. [b]*P* value comparing percent who strongly agree or agree with the statement by residency. [c]Higher mean scores indicate more positive attitudes about vaccination. [d]*P* value comparing mean scores by residency. [e]Among parents of teens living in Wisconsin. [f]Among parents of teens living in Minnesota.

MenACWY, HPV, and influenza vaccination, were available and extracted from MIIC for adolescents in Minnesota. In Wisconsin, vaccination records from WIR were only available for teens whose parents consented to linkage of survey data to their teen's WIR record. Consent was indicated if parents responded "yes" to the statement: "I agree to allow the Wisconsin Immunization Registry to release my adolescent's vaccination record, including vaccine types and dates, to the Marshfield Clinic Research Institute for use in this research study" and provided their adolescent child's name and birth date to allow linkage to the WIR record. WIR records were used if consent was provided and parent report was used for those who did not consent to linkage. Influenza vaccination was assessed as of July 1, 2018.

2.8. Statistical analyses

T-tests and chi-square or Fisher's exact tests were used to compare across groups as appropriate. Multivariable logistic regression models were used to assess associations between covariates and outcomes of interest (HPV vaccine receipt and MenACWY receipt). Covariates used in sampling, state, rural residence, and HPV vaccination status, were included a priori in multivariable models except those with vaccination status as the outcome. Covariates with a *P* value < 0.1 in models that included state, rural residence, and HPV vaccination status (when not the outcome) were included in the initial model to assess associations. Backward elimination with a cutoff of *P* = 0.05 was conducted to determine inclusion in the final reduced model. Analyses were conducted using SAS Version 9.4 (Cary, NC).

3. Results

Invitation letters were sent to 8296 parents (2314 in Minnesota and 5982 in Wisconsin); 538 parents completed the survey, of which 536 (99.6%, 271 from Minnesota, 265 from Wisconsin) were included in analyses. The two exclusions were due to discordance between their reported address (urban/rural residency or county) and address used for sampling. In Minnesota, response rates were similar among rural and urban parents of teens (12%) but higher among parents of teens who received HPV vaccine than teens who had not received HPV vaccine (15% vs 10%). Comparison of respondents and nonrespondents was not possible for Wisconsin because demographic information was not available on the sampled population. By design, the number of rural and urban parents in each state and the number of teens who had and had not received HPV vaccine in Minnesota were approximately equal.

3.1. Parent and teen characteristics

Compared with urban parents, rural parents were younger (<40 years old) (22% vs 10%, $P = 0.0003$), more likely to be non-Hispanic White (92% vs 83%, $P = 0.001$), and less likely to have an advanced degree (18% vs 33%, $P = 0.0002$). Rural households tended to have larger families ($\geq$4 children) (20% vs 6%, $P < 0.0001$) and lower annual household income (<$75,000) (40% vs 22%, $P < 0.0001$) than urban households.

Rural and urban teens of the surveyed parents also differed by race/ethnicity, insurance status, school type and general health services (Table 1). Rural teens were more likely to be non-Hispanic White (89% vs 79%, $P = 0.0006$) and have public health insurance (24% vs 16%, $P = 0.02$) and less likely to attend private school (5% vs 13%, $P = 0.003$) than their urban counterparts. More than 94% of teens received vaccinations at a physician's office or clinic and had a well-child visit at age 11 or 12 years, though rural teens were less likely than urban teens to receive vaccinations at a doctor's office or clinic (93% vs 97%, $P = 0.02$) and have a well-child visit at age 11 or 12 years (91% vs 97%, $P = 0.003$). In addition, rural teens had longer average travel time ($\geq$30 min) to their primary vaccination location than urban teens (20% vs 2%, $P < 0.0001$).

3.2. Vaccine receipt, discussion, recommendations, and reminders

Overall, 52% of teens received at least one dose of the three vaccines recommended specifically for adolescents (34% received all recommended vaccines and influenza vaccine). By vaccine, 90% received Tdap, 84% received MenACWY, 60% received one or more doses of HPV vaccine, and 47% received influenza vaccine in the previous season. Among 429 teens with linked vaccination records, agreement between parent report and IIS records was 90% for Tdap and HPV vaccine, 83% for influenza vaccine, and 71% for MenACWY. Agreement was similar across states for each vaccine, except influenza (78% for Minnesota teens vs 91% for Wisconsin teens, $P = 0.001$). Among teens who received at least one adolescent vaccine and had an IIS record, there was no difference in same day receipt between rural and urban teens: 31% received Tdap, HPV, and MenACWY on the same day, 56% received two adolescent vaccines on the same day, 10% received all vaccinations on different days, and 4% received only one vaccine. However, among teens who received Tdap, HPV, and MenACWY, more rural teens received the three vaccines on the same day than urban teens (62% vs 44%, $P = 0.02$). Parent-reported teen vaccination coverage was lower and parents' vaccine attitudes were less favorable among Wisconsin participants who did not consent to link IIS records to the survey than among participants who provided consent (**Supplemental Table**).

Discussion about adolescent vaccines with a doctor or nurse and vaccination being "very important" for their teen according to their provider was reported by 52% of parents for influenza vaccine, 50% for Tdap and HPV vaccine, and 43% for MenACWY. Significantly more rural parents reported no discussion or recommendation from their provider about giving their teen the influenza vaccine (16% vs 7%, $P = 0.01$) than urban parents (Table 2). Although not significant, fewer rural parents reported discussion with their provider and HPV vaccination as being "very important" for their teen according to their provider (45% vs 54%, $P = 0.08$). Among parents, the percentage who thought it was "very important" for their teen to be vaccinated for each vaccine varied by vaccine type, but not residency. Vaccination of their teen was considered "very important" by 79% of parents with Tdap, 73% with MenACWY, 54% with HPV vaccine, and 39% with influenza vaccine.

With regard to HPV vaccine, 89% of parents reported receipt of a recommendation for HPV vaccine for their teen by a healthcare provider or nurse, 16% by family members or friends, and 6% by community members such as religious leaders, school teachers, or school health staff. Receipt of a recommendation against HPV vaccination for their teen was reported by 28% of parents. More than half (57%) of parents reported hearing stories about the health benefits of the HPV vaccine and 42% heard stories about health problems caused by the HPV vaccine. There were no differences in frequency of recommendations or hearing HPV stories by residency.

Receipt of and preferred method for vaccine reminders did vary by residency. Significantly more rural than urban parents received a vaccine reminder that their teen was due or overdue for a vaccination since their teen's 11th birthday (47% vs 36%, $P = 0.007$) (Table 1). Half (50%) of rural parents preferred to receive vaccine reminders via mail compared to 27% of urban parents. Rural parents were less likely to prefer email (16% vs 30%) and text (12% vs 17%) reminders for vaccinations than urban parents. Fourteen percent of all parents preferred no vaccine reminders.

3.3. Vaccine attitudes and beliefs

In general, urban and rural parents responded similarly to items on individual statements of vaccine benefits, HPV vaccine effectiveness, and HPV vaccine harms (Fig. 2). However, rural parents were less likely to strongly agree or agree to the statement "vaccines are safe" (83% vs 89%, $P = 0.04$). The HPV vaccine harms factor had the lowest mean score (least favorable toward vaccination) among the factors assessed and differed by residency. Mean HPV vaccine harms score was significantly lower among rural parents than urban parents (mean, (standard deviation (SD)): 5.49 (2.32) vs 6.05 (2.35), $P = 0.006$).

3.4. Factors associated with HPV vaccine receipt and MenACWY receipt

In multivariable model adjusted for state and residency, parents of teens who received HPV vaccine were more likely to report teen receipt of other recommended adolescent vaccinations (Tdap, MenACWY, and influenza), always getting a vaccine a provider recommends, the parent's perception of HPV vaccination as very important, more positive attitudes regarding HPV vaccine effectiveness, and discussion of HPV vaccination with providers and perceived importance of HPV vaccination by providers as very important (Table 3). Parents who reported having heard stories about health problems caused by the HPV vaccine and parent's perception of Tdap vaccination as very important were less likely to have HPV-vaccinated teens.

In multivariable model for MenACWY, adjusted for state, residency, and HPV vaccine receipt, teen receipt of Tdap, parent's perception of MenACWY vaccination as very important, discussion of MenACWY vaccination with providers and perceived importance of MenACWY vaccination by providers as very important, and reporting a well-child visit at age 11–12 years were positively associated with teen receipt of MenACWY (Table 4).

4. Discussion

We conducted a cross-sectional survey exploring attitudes regarding adolescent vaccination among rural and urban parents

Table 1
Characteristics of surveyed parents and their teens, and factors by rural residency, Minnesota and Wisconsin, 2019.

	All	**Rural**	**Urban**	***P***[a]
Total	536	267	269	
State				0.9
Minnesota	271 (51)	134 (50)	137 (11)	
Wisconsin	265 (49)	133 (50)	132 (49)	
Parent characteristics				
Parent age[b]				0.0003
<40 years	86 (16)	59 (22)	27 (10)	
40–49 years	303 (58)	147 (56)	156 (59)	
≥50 years	138 (26)	57 (22)	81 (31)	
Parent sex				0.4
Male	120 (22)	56 (21)	64 (24)	
Female	416 (78)	211 (79)	205 (76)	
Parent race/ethnicity[b]				0.001
Non-Hispanic White	462 (88)	242 (92)	220 (83)	
Other	65 (12)	20 (8)	45 (17)	
Parent education[b]				0.0002
High school or less	63 (12)	38 (14)	25 (9)	
Some college/Associate or technical degree/ Bachelor degree	334 (63)	179 (68)	155 (58)	
Graduate or advanced degree	135 (25)	47 (18)	88 (33)	
Parent religious service attendance				0.2
Never	129 (24)	56 (21)	73 (27)	
≥1 time per month	354 (66)	186 (70)	168 (62)	
Missing	53 (10)	25 (9)	28 (10)	
Household characteristics				
Number of children in household[b]				<0.0001
1	142 (27)	66 (25)	76 (28)	
2–3	324 (61)	148 (56)	176 (66)	
≥4	68 (13)	52 (20)	16 (6)	
Household income				<0.0001
<$75,000	166 (31)	108 (40)	58 (22)	
≥$75,000	305 (57)	131 (49)	174 (65)	
Missing	65 (12)	28 (10)	37 (14)	
Teen characteristics				
Age[c]				0.9
13 years	137 (26)	65 (24)	72 (27)	
14 years	189 (35)	95 (36)	94 (35)	
15 years	174 (32)	88 (33)	86 (32)	
16 years	36 (7)	19 (7)	17 (6)	
Sex[b]				0.1
Male	265 (50)	123 (46)	142 (53)	
Female	270 (50)	143 (54)	127 (47)	
Race/Ethnicity[b]				0.0006
Non-Hispanic White	446 (84)	237 (89)	209 (79)	
Other	85 (16)	28 (11)	57 (21)	
Public health insurance[d]				0.02
Yes	106 (20)	64 (24)	42 (16)	
No	430 (80)	203 (76)	227 (84)	
School type[b]				0.003
Public	465 (87)	237 (89)	228 (85)	
Private	48 (9)	14 (5)	34 (13)	
Home school/Online	20 (4)	14 (5)	6 (2)	
Well-child visit at age 11 or 12 years				0.003
Yes	506 (94)	244 (91)	262 (97)	
No	30 (6)	23 (9)	7 (3)	
Primary vaccination location				0.02
Doctor's office or clinic	508 (95)	247 (93)	261 (97)	
Other location or teen does not get vaccinations	28 (5)	20 (7)	8 (3)	
Average travel time to primary vaccination location[b]				<0.0001
<15 min	329 (62)	141 (53)	188 (71)	
15–29 min	143 (27)	71 (27)	72 (27)	
≥30 min	60 (11)	54 (20)	6 (2)	
Teen always gets a vaccine a doctor or nurse recommends				0.08
Yes	247 (46)	113 (42)	134 (50)	
No	289 (54)	154 (58)	135 (50)	
Received vaccine reminder since 11th birthday				0.007
Yes	222 (41)	126 (47)	96 (36)	
No	314 (59)	141 (53)	173 (64)	
Vaccination status[e]				
Received influenza (since July 1, 2018)	254 (47)	121 (45)	133 (49)	0.3
Received all recommended adolescent vaccines (≥1 HPV, MenACWY, and Tdap)	280 (52)	134 (50)	146 (54)	0.3
Received HPV[f]	324 (60)	156 (58)	168 (62)	0.3

Table 1 (*continued*)

	All	Rural	Urban	P[a]
Received MenACWY	450 (84)	232 (87)	218 (81)	0.07
Received Tdap	484 (90)	245 (92)	239 (89)	0.3

Data are no. (%) of respondents. Percentages may not equal 100% due to rounding.
Abbreviations: MenACWY, quadrivalent meningococcal conjugate vaccine; Tdap, tetanus-diphtheria-acellular pertussis vaccine.
[a] T-tests and chi-square or Fisher's exact tests.
[b] Does not include missing responses.
[c] Age at the time of survey completion. All Minnesota teens were aged 13 to 15 years at the time of sampling but some turned 16 years between sampling and survey completion.
[d] Public health insurance status at the time of survey completion.
[e] Vaccination status based on IIS records when available, and parent report.
[f] Sampling of Minnesota residents included HPV vaccination status.

Table 2
Parent experience regarding discussions with providers and parents' perception of the importance of vaccinating teens given by providers and importance of vaccinating teens placed by rural and urban parents, Minnesota and Wisconsin, 2019.

	Rural, n (%)	Urban, n (%)	P[a]
Discussions with provider and parents' perception of importance of vaccination given by providers			
Influenza vaccination			**0.01**
Discussed, very important	134 (50)	144 (54)	
Discussed, somewhat or not important	91 (34)	105 (39)	
Not discussed/not recommended	42 (16)	20 (7)	
HPV vaccination			0.08
Discussed, very important	120 (45)	146 (54)	
Discussed, somewhat or not important	101 (38)	89 (33)	
Not discussed/not recommended	46 (17)	34 (13)	
MenACWY vaccination			0.4
Discussed, very important	124 (46)	109 (41)	
Discussed, somewhat or not important	52 (19)	60 (22)	
Not discussed/not recommended	91 (34)	100 (37)	
Tdap vaccination			0.5
Discussed, very important	139 (52)	129 (48)	
Discussed, somewhat or not important	61 (23)	73 (27)	
Not discussed/not recommended	67 (25)	67 (25)	
Importance of vaccination placed by parents			
Influenza vaccination			0.6
Very important	100 (37)	107 (40)	
Somewhat or not important	95 (36)	100 (37)	
Not important/don't know	72 (27)	62 (23)	
HPV vaccination			0.2
Very important	135 (51)	152 (57)	
Somewhat or not important	58 (22)	60 (22)	
Not important/don't know	74 (28)	57 (21)	
MenACWY vaccination			0.7
Very important	189 (71)	198 (74)	
Somewhat or not important	54 (20)	47 (17)	
Not important/don't know	24 (9)	24 (9)	
Tdap vaccination			0.6
Very important	205 (77)	216 (80)	
Somewhat or not important	40 (15)	35 (13)	
Not important/don't know	22 (8)	18 (7)	

Percentages may not equal 100% due to rounding.
Abbreviations: n, number; %, percentage.
[a] From chi-square test, $p < 0.05$ are bolded, indicating statistical significance.

Table 3
Factors associated with receipt of HPV vaccine among teens in Minnesota and Wisconsin, 2019.

Characteristic	HPV vaccine receipt		OR[a] (95% CI)
	Yes n (row %)	No n (row %)	
Received influenza vaccine (since July 1, 2018)			
Yes	206 (81)	48 (19)	2.58 (1.52, 4.37)
No	118 (42)	164 (58)	Referent
Received MenACWY			
Yes	299 (66)	151 (34)	3.80 (1.74, 8.29)
No	25 (29)	61 (71)	Referent
Received Tdap			
Yes	303 (63)	181 (37)	2.74 (1.08, 6.97)
No	21 (40)	31 (60)	Referent
Frequency of teen receipt of a vaccine a provider recommended			
Always	208 (84)	39 (16)	2.93 (1.65, 5.20)
Usually or sometimes/rarely or never	116 (40)	173 (60)	Referent
Discussions with provider and parents' perception of importance of HPV vaccination given by providers			
Discussed, very important	216 (81)	50 (19)	6.37 (2.90, 13.96)
Discussed, somewhat or not important	83 (44)	107 (56)	2.60 (1.20, 5.63)
Not discussed/Don't know	25 (31)	55 (69)	Referent
Importance of HPV vaccination placed by parents			
Very important	243 (85)	44 (15)	10.69 (4.77, 23.97)
Somewhat important	65 (55)	53 (45)	5.62 (2.65, 11.95)
Not important/Don't know	16 (12)	115 (88)	Referent
Importance of Tdap vaccination placed by parents			
Very important	271 (64)	150 (36)	0.23 (0.08, 0.65)
Somewhat important	35 (47)	40 (53)	0.32 (0.10, 1.07)
Not important/Don't know	18 (45)	22 (55)	Referent
Parent heard stories, in the media or in conversations with other people, about health problems caused by the HPV vaccine			
Yes	112 (50)	114 (50)	0.56 (0.33, 0.97)
No	212 (68)	98 (32)	Referent
Mean HPV vaccine effectiveness score (±SD)[b]	8.7 (1.5)	6.6 (2.5)	1.20 (1.02, 1.42)

Percentages may not equal 100% due to rounding.
Abbreviations: n, number; %, percentage, OR, odds ratio; CI, confidence interval; MenACWY, quadrivalent meningococcal conjugate vaccine; Tdap, tetanus-diphtheria-acellular pertussis vaccine; HPV, human papillomavirus; SD, standard deviation.
[a] Odds ratio of vaccine receipt from multivariable model adjusted for state and residency; odds ratios for sampling variables are not shown.
[b] Higher mean scores indicate more positive attitudes about vaccination.

in Minnesota and Wisconsin. Parent and perceived provider attitudes towards HPV and MenACWY vaccination were among the strongest factors in teen receipt of HPV vaccine and MenACWY.

The importance placed by parents on vaccinating teens and discussions with providers and parents' perception of the importance given by providers for HPV vaccine and MenACWY were associated with teen receipt of those vaccines. Receipt of a healthcare provider recommendation for HPV vaccine has been previously reported in multiple studies as a strong predictor of HPV vaccination [14–20]. In addition, the strength of recommendations for HPV vaccine and MenACWY were also important for teen receipt of those vaccines. In a national study of adolescent parents, a high-quality recommendation was associated with 9 times the odds of HPV vaccine initiation compared with no recommendation [19]. A high-quality recommendation for HPV vaccination was defined as 1) a strong recommendation, 2) one that encouraged same-day vaccination, and 3) one that discussed cancer prevention. Training providers to provide high-quality recommendations for HPV vaccine and

Table 4
Factors associated with receipt of MenACWY among teens in Minnesota and Wisconsin, 2019.

Characteristic	MenACWY receipt		OR[a] (95% CI)
	Yes n (row %)	No n (row %)	
Received Tdap			
Yes	428 (88)	56 (12)	8.80 (4.12, 18.80)
No	22 (42)	30 (58)	Referent
Discussions with provider and parents' perception of importance of MenACWY vaccination given by providers			
Discussed, very important	212 (91)	21 (9)	2.15 (1.07, 4.31)
Discussed, somewhat or not important	96 (86)	16 (14)	2.97 (1.37, 6.44)
Not discussed/Don't know	142 (74)	49 (26)	Referent
Importance of MenACWY vaccination placed by parents			
Very important	350 (90)	37 (10)	2.83 (1.37, 6.44)
Somewhat important	75 (74)	26 (26)	1.06 (0.43, 2.64)
Not important/Don't know	25 (52)	23 (48)	Referent
Well-child visit at age 11 or 12 years			
Yes	434 (86)	72 (14)	3.27 (1.15, 9.30)
No	16 (53)	14 (47)	Referent

Percentages may not equal 100% due to rounding.
Abbreviations: n, number; %, percentage, OR, odds ratio; CI, confidence interval; MenACWY, quadrivalent meningococcal conjugate vaccine; Tdap, tetanus-diphtheria-acellular pertussis vaccine; HPV, human papillomavirus.
[a] Odds ratio of vaccine receipt from multivariable model adjusted for state, residency, and HPV vaccine receipt; odds ratios for sampling variables are not shown.

MenACWY is essential to increasing uptake of these vaccines. In our study, only half of parents reported having a discussion about adolescent vaccination with their provider and perceived that their provider considered vaccination as very important for their teen. Increasing promotion of the importance of these vaccines is central to increasing uptake.

Education of parents that counters unfounded concerns about long-term adverse effects of HPV vaccine might also be needed, especially in rural settings [21]. In our study, parents of teens in rural areas had less positive attitudes regarding HPV vaccine harms than urban parents. Additionally, over 40% of all parents reported having heard stories about health problems caused by the HPV vaccine and over 20% of parents either strongly agreed or agreed with the statement that "The HPV vaccine might cause lasting health problems." Parents who reported hearing about health problems from the HPV vaccine were also more likely to have an adolescent who had not received the HPV vaccine. Additional research is needed to determine the best approach to counter vaccine misinformation and to better understand what factors contribute to parents' perceived importance—or lack of importance—of HPV vaccination, and to understand why misinformation seems to have a stronger impact on rural populations as compared to urban populations.

Receipt of other vaccines routinely recommended for adolescents was independently associated with receipt of both HPV vaccine and MenACWY. However, only 31% of vaccinated teens received Tdap, HPV, and MenACWY vaccines on the same day in our study, suggesting substantial missed opportunities for vaccination. Avoiding missed opportunities by bundling multiple vaccines at a single visit, as recommended by CDC, has been shown to be an effective strategy for promoting adolescent vaccination [22]. The bundled approach may be particularly effective in rural areas. In our study, almost two thirds of rural teens who received all the adolescent vaccines received these vaccines on the same day compared with less than half of urban teens.

Although barriers to vaccination exist for both rural and urban adolescents [23], the specific barriers might be different. Rural participants in our study were more likely than urban participants to live more than 30 min from their primary place of vaccination. They were also more likely to receive vaccines at a site other than a physician's office. An option for adolescent vaccination that may be particularly appealing to rural families is to receive vaccines at local pharmacies [24]. Many experts consider this an underutilized tool to increase vaccination rates. A *meta*-analysis of 36 studies found an increase in vaccine coverage when pharmacists were involved in the immunization process [25]. Although the studies were conducted in adults and focused on influenza and pneumococcal vaccinations, pharmacists could play an important role in increasing vaccinations among adolescents, particularly those living in rural areas for series completion or booster doses. Nearly every state allows administration of vaccines by pharmacists, but some states require a physician to write a prescription, and some restrict pharmacist-administered vaccines based on the patient's age [26].

Another potential setting for adolescent vaccination is school. The best example of school-based vaccination programs in the U. S. is with influenza vaccine [27]. Immunization programs for HPV vaccine have been implemented in some countries, such as Canada, with mixed results [28]. Many of the same barriers to vaccine receipt in the physician's office, particularly for HPV vaccine, also play a role in the school setting. Despite this, a recent study of methods to increase HPV vaccine uptake listed three interventions as cost-effective: quality improvement visits to primary care clinics, a statewide reminder and recall system, and school-based vaccination programs [29]. A multi-component approach involving all key stakeholders may be needed.

Our study had some limitations. Our response rate was low, which could have led to selection bias if those who chose to respond are not representative of the larger population. In Wisconsin, we were unable to utilize the IIS records for sampling and thus were unable to compare the characteristics of respondents and nonrespondents. We had to rely on self-report of most variables, including the vaccination status of 40% of Wisconsin participants. Those who did not consent to have their vaccination data linked had less favorable vaccine attitudes. However, agreement between IIS records and parent report of vaccination was high for HPV vaccine. Finally, the study was conducted in rural and urban areas of Minnesota and Wisconsin, and the results may not be generalizable to areas outside the upper Midwest.

5. Conclusions

In summary, vaccine receipt in both urban and rural areas was associated with a healthcare provider that—by parental perception—considered the vaccine to be very important. Although there are features unique to rural populations that may be barriers to vaccination, attitudes regarding adolescent vaccinations in this study generally were not different between rural and urban parents. Additional studies are needed to identify and understand factors contributing to the urban–rural disparities in coverage for some adolescent vaccines, and particularly HPV vaccine. Continued education of providers and parents of the importance of adolescent vaccinations is warranted.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability Statement

The data that support the study conclusions are not publically available due to privacy or ethical restrictions.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jvacx.2022.100180.

References

[1] Pingali C, Yankey D, Elam-Evans LD, Markowitz LE, Williams CL, Fredua B, et al. National, regional, state, and selected local area vaccination coverage among adolescents aged 13–17 years - United States, 2020. MMWR Morb Mortal Wkly Rep 2021;70(35):1183–90.

[2] Immunization Action Coalition. State laws and mandates by vaccine. 2021 [cited 2022 May 2]; Available from: https://www.immunize.org/laws/.

[3] Centers for Disease Control and Prevention. Flu vaccination coverage, United States, 2020–21 influenza season. 2021 [cited 2022 May 2]; Available from: https://www.cdc.gov/flu/fluvaxview/coverage-2021estimates.htm.

[4] U.S. Department of Health and Human Services. Healthy people 2030: vaccination. 2020 [cited 2021 July 30]; Available from: https://health.gov/healthypeople/objectives-and-data/browse-objectives/vaccination.

[5] Centers for Disease Control and Prevention. TeenVaxView interactive. 2020 [cited 2020 December 1]; Available from: https://www.cdc.gov/vaccines/imz-managers/coverage/teenvaxview/data-reports/index.html.

[6] State of Minnesota. Minnesota adminiatrative rules, chapter 4604, immunization. 2013 [cited 2021 March 22]; Available from: https://www.revisor.mn.gov/rules/4604.1020/.

[7] Reiter PL, Brewer NT, Gottlieb SL, McRee AL, Smith JS. Parents' health beliefs and HPV vaccination of their adolescent daughters. Soc Sci Med 2009;69(3):475–80. https://doi.org/10.1016/j.socscimed.2009.05.024.

[8] United States Department of Agriculture. Urban influence codes. 2019 [cited 2020 11/18]; Available from: https://www.ers.usda.gov/data-products/urban-influence-codes.aspx.

[9] Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: building an international community of software platform partners. J Biomed Inform 2019;95:103208.

[10] Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 2009;42(2):377–81.

[11] McRee AL, Brewer NT, Reiter PL, Gottlieb SL, Smith JS. The Carolina HPV immunization attitudes and beliefs scale (CHIAS): scale development and associations with intentions to vaccinate. Sex Transm Dis 2010;37(4):234–9. https://doi.org/10.1097/OLQ.0b013e3181c37e15.

[12] VanWormer JJ, Bendixsen CG, Vickers ER, Stokley S, McNeil MM, Gee J, et al. Association between parent attitudes and receipt of human papillomavirus vaccine in adolescents. BMC Public Health 2017;17(1). https://doi.org/10.1186/s12889-017-4787-5.

[13] Gilkey MB, Reiter PL, Magnus BE, et al. Validation of the vaccination confidence scale: a brief measure to identify parents at risk for refusing adolescent vaccines. Acad Pediatr 2016;16(1):42–9. https://doi.org/10.1016/j.acap.2015.06.007.

[14] Holman DM, Benard V, Roland KB, Watson M, Liddon N, Stokley S. Barriers to human papillomavirus vaccination among US adolescents: a systematic review of the literature. JAMA Pediatr 2014;168(1):76.

[15] Dempsey AF, Pyrznawoski J, Lockhart S, Barnard J, Campagna EJ, Garrett K, et al. Effect of a health care professional communication training intervention on adolescent human papillomavirus vaccination: a cluster randomized clinical trial. JAMA Pediatr 2018;172(5). https://doi.org/10.1001/jamapediatrics.2018.0016.

[16] Boyd ED, Phillips JM, Schoenberger YM, Simpson T. Barriers and facilitators to HPV vaccination among rural Alabama adolescents and their caregivers. Vaccine 2018;36(28):4126–33. https://doi.org/10.1016/j.vaccine.2018.04.085.

[17] Fu LY, Zimet GD, Latkin CA, Joseph JG. Associations of trust and healthcare provider advice with HPV vaccine acceptance among African American parents. Vaccine 2017;35(5):802–7. https://doi.org/10.1016/j.vaccine.2016.12.045.

[18] Hopfer S, Wright ME, Pellman H, Wasserman R, Fiks AG. HPV vaccine recommendation profiles among a national network of pediatric practitioners: understanding contributors to parental vaccine hesitancy and acceptance. Hum Vaccin Immunother 2019;15(7–8):1776–83. https://doi.org/10.1080/21645515.2018.1560771.

[19] Gilkey MB, Calo WA, Moss JL, Shah PD, Marciniak MW, Brewer NT. Provider communication and HPV vaccination: the impact of recommendation quality. Vaccine 2016;34(9):1187–92.

[20] Radisic G, Chapman J, Flight I, Wilson C. Factors associated with parents' attitudes to the HPV vaccination of their adolescent sons: a systematic review. Prev Med 2017;95:26–37. https://doi.org/10.1016/j.ypmed.2016.11.019.

[21] Ortiz RR, Smith A, Coyne-Beasley T. A systematic literature review to examine the potential for social media to impact HPV vaccine uptake and awareness, knowledge, and attitudes about HPV and HPV vaccination. Hum Vaccin Immunother 2019;15(7–8):1465–75. https://doi.org/10.1080/21645515.2019.1581543.

[22] Farmar A-L, Love-Osborne K, Chichester K, Breslin K, Bronkan K, Hambidge SJ. Achieving high adolescent HPV vaccination coverage. Pediatrics 2016;138(5).

[23] Dempsey AF, Zimet GD. Interventions to improve adolescent vaccination: what may work and what still needs to be tested. Vaccine 2015;33(Suppl 4):D106–13. https://doi.org/10.1016/j.vaccine.2015.09.032.

[24] Fava JP, Colleran J, Bignasci F, Cha R, Kilgore PE. Adolescent human papillomavirus vaccination in the United States: opportunities for integrating pharmacies into the immunization neighborhood. Hum Vaccin Immunother 2017;13(8):1844–55. https://doi.org/10.1080/21645515.2017.1325980.

[25] Isenor JE, Edwards NT, Alia TA, Slayter KL, MacDougall DM, McNeil SA, et al. Impact of pharmacists as immunizers on vaccination rates: a systematic review and meta-analysis. Vaccine 2016;34(47):5708–23.

[26] American Pharmacists Association. Pharmacist-administered immunizations: what does your state allow? 2015 [cited 2020 November 28]; Available from: https://www.pharmacist.com/article/pharmacist-administered-immunizations-what-does-your-state-allow.

[27] Szilagyi PG, Schaffer S, Rand CM, Goldstein NPN, Vincelli P, Hightower AD, et al. School-located influenza vaccinations for adolescents: a randomized controlled trial. J Adolesc Health 2018;62(2):157–63.

[28] Dubé E, Gagnon D, Clément P, Bettinger JA, Comeau JL, Deeks S, et al. Challenges and opportunities of school-based HPV vaccination in Canada. Hum Vaccin Immunother 2019;15(7-8):1650–5.

[29] Spencer JC, Brewer NT, Trogdon JG, Weinberger M, Coyne-Beasley T, Wheeler SB. Cost-effectiveness of interventions to increase HPV vaccine uptake. Pediatrics 2020;146(6). https://doi.org/10.1542/peds.2020-0395.