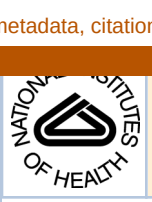

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Organizational correlates of adolescent immunization: Findings of a state-wide study of primary care clinics in North Carolina

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Abstract

Objective—To analyze organization-level correlates of immunization coverage among adolescents served by high-volume primary care providers in North Carolina.

Method—We randomly selected 91 clinics with at least 200 active records for patients ages 11–18 in the North Carolina Immunization Registry. For the 105,121 adolescents served by these clinics, we obtained immunization status for 6 vaccines, including human papillomavirus (HPV) vaccine (females only); meningococcal conjugate; and tetanus, diphtheria, and pertussis booster (Tdap).

Results—Clinics specializing in pediatrics had higher coverage for meningococcal vaccine (OR = 1.79, 95% CI: 1.25–2.55), Tdap vaccine (OR = 1.22, 95% CI: 1.00–1.50), and childhood vaccines. However, pediatric clinics had lower coverage for HPV vaccine initiation (OR = 0.70, 95% CI: 0.52–0.94). Other correlates, which varied by vaccine, included policies related to vaccine documentation and the age at which clinics recommended vaccines.

Conclusion—Overall, adolescents were more likely to receive vaccines, except HPV vaccine, if they attended a pediatric clinic with supportive clinical policies.

Keywords

Adolescent health services; Diphtheria Tetanus acellular Pertussis Vaccine; Meningococcal Vaccine; Human papillomavirus Vaccine; Pediatrics; Family Practice

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Conflict of Interest Statement

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Vaccinating adolescents can reduce morbidity and mortality associated with several infectious diseases. In the United States, guidelines currently recommend administering three vaccines to children ages 11 to 12, with catch-up vaccination throughout adolescence: human papillomavirus (HPV) vaccine; meningococcal conjugate; and tetanus, diphtheria, and pertussis booster (Tdap) [1]. Despite this recommendation, uptake of adolescent vaccines remains uneven. In 2011, initiation of the three-dose HPV vaccine series was 53% for girls ages 13 to 17, and series completion was 35% [2]; initiation and completion for boys was much lower, 4% and < 1% [3]. In the same year, uptake of meningococcal vaccine (for boys and girls) was 71% and uptake of Tdap vaccine was 78% [2]. Improving adolescent vaccination rates even further, particularly for HPV vaccine, is important for achieving population-level protection against vaccine-preventable diseases.

While characteristics of individuals or families, such as income, race, and ethnicity, are associated with uptake of adolescent vaccines, characteristics of healthcare organizations are also important [2,4–6]. For example, clinics with specialties such as pediatrics may be better equipped to stock and administer adolescent vaccines given their focus on younger patients [7–9]. Previous research has demonstrated that vaccine coverage also varies based on characteristics such as clinic size [10], the racial composition of clinics' patient populations [8], and clinics' participation in publicly-funded immunization programs [8,11].

Similarly, vaccination may be supported by organizational practices and policies [6,12]. For example, clinics that send immunizations reminders to patients (or their parents) achieve a 5 to 20 percent increase in vaccination coverage [13]. Having clinic-based systems in place to document vaccination is also associated with increased odds of adolescent vaccination [6,14,15]. Research is needed to better understand the relative importance of these organizational factors, particularly with regard to how the influence of these factors varies, if at all, by vaccine type [6].

We sought to assess the association of clinic characteristics with adolescents' immunization status by analyzing data on vaccine provision in North Carolina clinics. To further probe the importance of provider practices and policies, we also examined how these factors correlated with adolescents' immunization status. By investigating organizational-level correlates of immunization, this study aims to inform healthcare quality improvement efforts to raise vaccine coverage levels among adolescents.

Methods

Participants and Sampling

Using the North Carolina Immunization Registry, we randomly selected 91 primary care clinics that were high-volume adolescent vaccine providers, defined as having active records for at least 200 adolescent patients. We then randomly selected a subset of 61 of these clinics to survey about their practices and policies related to vaccination of adolescents (response rate: 100%). Inclusion criteria for this study included participation in the North Carolina Immunization Program, which includes Vaccines for Children (VFC), a federally-funded program that provides free vaccines to children ages 18 and under who are uninsured, under23 insured, Medicaid-insured, or American Indian/Alaska Native. Around 94% of the approximately 1,300 public and private clinics that participate in the North Carolina Immunization Program use the Immunization Registry [16], which contains information on 54% of the population of adolescents in the state [17].

Measures

Vaccination coverage—The North Carolina Immunization Registry (NCIR) provided data on adolescents' immunization status for the full sample of 91 clinics. We gathered data on the numbers of patients in each clinic who had received: one and three doses of human papillomavirus (HPV) (female patients only); meningococcal conjugate; and tetanus, diphtheria, and pertussis booster (Tdap). We also assessed coverage with childhood vaccines: two doses of measles, mumps, and rubella (MMR); three doses of hepatitis B (HepB); and two doses of varicella.

Clinic characteristics—The Registry also provided data for all 91 clinics on the following organizational characteristics: clinic size, measured as thousands of active adolescent patients (log transformed in analyses); clinic specialty (pediatrics, family medicine, or other); ratio of female to male adolescent patients; and racial/ethnic composition of patient population. We also assessed VFC-participation via a count of instances in which patients qualified for the program because of insurance status or American Indian/Alaska Native ethnicity (log transformed in analyses).

Immunization practices and policies—One author (AD), who coordinates state-wide efforts to increase adolescent vaccination, invited each clinic's vaccine coordinator to complete a web-based survey on immunization practices and policies: use of a reminder/recall system; review of patients' immunization records at each visit; and policies about the age at which clinics recommend each adolescent vaccine (a continuous variable). The survey also assessed the timeliness of vaccination documentation in NCIR (document vaccination during the healthcare visit; at the end of the visit; at the close of business on the day of the visit; or at least every two weeks) and the number of computers available for documentation in the Immunization Registry (one computer per clinic with access to NCIR or more than one computer per clinic).

Data Analysis

We examined characteristics of clinics and their patients using descriptive statistics. To better understand why some immunization records had incomplete data for patient demographics (sex, race, and ethnicity), we correlated clinics' rates of incompleteness with clinic characteristics and policies.

We analyzed clinic-level correlates of vaccination coverage separately for each vaccine. Using the full sample of 91 clinics, we assessed associations between immunization status and clinic characteristics using bivariate logistic regression that adjusted for clustering at the clinic level and weighted vaccination for the number of patients in the clinic. We entered statistically significant correlates into a multivariate logistic regression model, again accounting for clinic level clustering and weighting. For the subset of 61 clinics reporting on immunization practices and policies, we again used bivariate and then multivariate logistic regression to evaluate the association with vaccination. We report odds ratios from bivariate analyses in tables, and odds ratios from multivariate analyses in text. For vaccines that had only one statistically-significant bivariate correlate, the additional multivariate logistic regression was unnecessary.

We conducted a sensitivity analysis by examining correlates of immunization status for the adolescents in the target age range for adolescent vaccines (ages 11–12) and compared the results to those for the full sample (ages 11–18). Because of the lack of variability reported with regard to the practice of performing chart reviews to determine if patients need any immunizations (97% reported doing this at each visit), analyses did not include this variable.

We used Stata Version 12.0 (Statacorp, College Station, TX), and all tests were two-tailed with a critical alpha of .05.

Results

Characteristics of Patients and Clinics

Most adolescent patients were white (47.0%) or African-American (25.0%), and 4.9% were Hispanic (Table 1). Adolescent patients were evenly split between males and females. Clinics had an average of 632 instances in which patients qualified for the VFC program. On average, clinics had 4,745 patients with immunization registry records (almost all would have been children), of whom 1,155 were adolescents ages 11 to 18 (Table 2). Clinic specialties were pediatrics (58%), family medicine (41%), and internal medicine (1%). In analyses, we combined family medicine and internal medicine clinics. There were no differences between pediatric and family medicine clinics on their characteristics or policies, except that on average, pediatric clinics were larger (number of adolescent patients: family medicine, mean = 580, pediatrics, mean = 1,567, $p < .001$).

Most clinics reported not using a reminder/recall system (69%), although having more than one computer with access to NCIR throughout the clinic was the norm (90%) (Table 2). Most clinics had a policy of recommending Tdap and HPV vaccines at 10 years of age or younger, which is earlier than the target age of 11 to 12 years specified by national guidelines (62% and 53%, respectively). The majority of clinics (84%) had a policy of recommending meningococcal conjugate to patients ages 11–12 years old, in accordance with national guidelines.

Clinics with higher rates of incomplete data for sex, race, and ethnicity had fewer patients initiating VFC services and recommended adolescents receive Tdap vaccine at a younger age (all $p < .05$), though there was no association for the other vaccination age policies for HPV and meningitis vaccines. Clinics with higher rates of incomplete data for race and ethnicity had larger patient populations (both $p < .05$). Other correlates did not show any consistent pattern.

Adolescent Vaccines

HPV vaccine—HPV vaccine initiation and completion rates among adolescent females were 47.8% and 27.6%, respectively (Table 2). In multivariate analysis of clinic characteristics, HPV vaccine initiation was higher in clinics with a higher female-to-male adolescent patient ratio (odds ratio [OR] = 1.96, 95% confidence interval [CI]: 1.01–3.80) or with a higher proportion of African-American patients (OR = 2.13, 95% CI: 1.02–4.47). In addition, bivariate analyses found that uptake was higher in family medicine than in pediatric clinics (Table 3) (family medicine clinics: 54.9% coverage, pediatric clinics: 45.9% coverage; Table S1). For the analysis of immunization policies, multivariate analysis found that only age at which practitioners began recommending Tdap vaccine was associated with HPV vaccine initiation, such that the odds of receiving the first dose of HPV vaccine were higher as the age providers began recommending Tdap increased (OR = 1.40, 95% CI: 1.19–1.65). In bivariate analysis, HPV vaccine initiation was also associated with the time to documentation in NCIR (Table 4).

HPV vaccine series completion showed a similar pattern to series initiation. For clinic characteristics, higher female-to-male ratios were associated with higher completion (Table 3). For immunization policies, completion was associated with older ages of Tdap recommendation (OR = 1.22, 95% CI: 1.03–1.44), and time to documentation in NCIR was significant in bivariate but not multivariate analysis (Table 4).

Meningococcal vaccine—The meningococcal conjugate vaccination rate was 60.5%. Uptake of meningococcal vaccine was higher for adolescents attending a pediatric versus a family medicine clinic (family medicine clinics: 49.3% coverage, pediatric clinics: 63.5% coverage; Table S1). In multivariate analysis of immunization policies, uptake was positively associated with having more than one computer with access to NCIR per clinic (OR = 3.42, 95% CI: 1.59–7.38) and negatively associated with older ages of meningococcal conjugate recommendation (OR = 0.80, 95% CI: 0.69–0.93). Additionally, bivariate analysis found that uptake of meningococcal conjugate was associated with time to documentation in NCIR (Table 4).

Tdap—The Tdap vaccination rate was 78.9%. Tdap vaccination was higher for adolescents attending a pediatric versus a family medicine clinic (family medicine clinics: 76.1% coverage, pediatric clinics: 79.6% coverage; Table S1). In addition, multivariate analysis found that uptake of Tdap was negatively associated with older ages of meningococcal conjugate recommendation (OR = 0.92, 95% CI: 0.88–0.97). Bivariate analysis found that Tdap vaccination was also positively related to having more than 1 computer per clinic (Table 4).

Childhood Vaccines

Hepatitis B—The hepatitis B vaccination rate (3 doses) was 81.1%. In multivariate analysis of hepatitis B vaccine, uptake was positively associated with adolescent patient load (OR = 1.38, 95% CI: 1.07–1.76). In bivariate analysis, uptake was negatively associated with proportion of Hispanic patients and positively associated with VFC-participation. Uptake was also higher in pediatric clinics than in family medicine clinics (Table 3) (family medicine clinics: 68.9% coverage, pediatric clinics: 84.3%; Table S1). Hepatitis B vaccination was lower in clinics that took longer to document vaccinations in NCIR (Table 4).

MMR—The MMR vaccination rate (2 doses) was 77.8%. In multivariate analysis, MMR uptake was higher for clinics with more adolescent patients (OR = 1.58, 95% CI: 1.22–2.04). In bivariate analysis of clinic characteristics, MMR vaccination was negatively associated with female-to-male patient ratio and proportion of Hispanic patients. MMR vaccination was positively associated with VFC-participation, and uptake was higher in pediatric clinics than in family medicine clinics (family medicine clinics: 63.7% coverage, pediatric clinics: 81.5%; Table S1). Uptake of MMR vaccine was lower in clinics that took longer to document vaccinations in NCIR (Table 4).

Varicella—The varicella vaccination rate (2 doses) was 54.0%. In multivariate analysis, uptake was higher in clinics with higher female-to-male patient ratios (OR = 0.33, 95% CI: 0.11- 0.99), with more adolescent patients (OR = 1.44, 95% CI: 1.19–1.75), and for pediatric clinics compared to family medicine clinics (OR = 1.52, 95% CI: 1.01–2.28) (family medicine clinics: 35.2% coverage, pediatric clinics: 59.0% coverage, Table S1). In addition, varicella vaccine uptake was lower in clinics that used reminder/recall systems (OR = 0.59, 95% CI: 0.37–0.94) (clinics without reminder/recall systems: 57.0% coverage, clinics with reminder/recall systems: 45.0%, Table S1) and lower in clinics that took longer to document vaccinations in NCIR (compared to documentation during a visit: at the close of business, OR = 0.38, 95% CI: 0.24– 0.61).

Sensitivity Analysis

Bivariate results for adolescents ages 11–12 were similar to those reported for the full sample, except that the percent of African-American patients was positively correlated with vaccination status for each of the childhood vaccines (hepatitis B: OR = 4.67, 95% CI: 1.98–

11.03, $p < .001$; MMR: OR = 2.70, 95% CI: 1.02–7.13, $p < .05$; varicella: OR = 2.03, 95% CI: 0.94–4.38, $p = .07$).

Discussion

Clinic-level correlates of vaccination differed for adolescent and childhood vaccines in our sample of 91 North Carolina clinics that served more than 100,000 adolescents. Uptake of two adolescent vaccines, meningococcal conjugate and Tdap, was higher in pediatric clinics and correlated negatively with older age of meningococcal vaccine recommendation. In contrast, uptake of HPV vaccine was higher in family medicine clinics and correlated positively with age at which clinics begin recommending Tdap. Coverage for childhood vaccines (i.e., hepatitis B; MMR; and varicella vaccines) was higher for clinics with more adolescent patients, those specializing in pediatrics rather than family medicine, and those with policies for more timely documentation of vaccine administration in the North Carolina Immunization Registry.

Clinic specialty was a consistent correlate of vaccination for both childhood and adolescent vaccines. Adolescents were more likely to have received vaccines if they attended pediatric clinics than family medicine clinics, but the relationship reversed for HPV vaccine. In general, pediatric clinics may be better equipped to administer childhood and adolescent vaccines given that they exclusively serve these populations. For example, pediatricians may be more accustomed to and knowledgeable about administering catch-up doses of childhood vaccines than are family practice clinicians [18–20]. Why HPV vaccine might pose an exception to this general trend is unclear, but our findings corroborate previous work showing higher HPV vaccine initiation and completion in family practice versus pediatric clinics [21]. However, two studies [7,8] reported the opposite finding (i.e., rates of HPV vaccination were higher in pediatric clinics than in family medicine clinics). Given that attitudinal research suggests pediatricians are more supportive of HPV vaccination than other specialties [22], additional research is needed to investigate barriers to HPV vaccination that may be disproportionately impacting pediatricians.

Consistent correlates of childhood vaccination rates, but not adolescent vaccination rates, were higher adolescent patient load and more prompt documentation in NCIR. Larger clinics may have better infrastructure supporting routine administration and electronic recordkeeping. More prompt documentation of vaccination (i.e., during the healthcare visit versus at the end of the visit, at the close of business, or at least every two weeks) would support administration of childhood vaccines by enabling record review during each healthcare encounter and possibly leading to increased record completeness.

Policies for age of adolescent vaccination seemed to affect vaccination rates differently. The age at which providers began recommending Tdap and meningococcal vaccines had no relationship with uptake of childhood vaccines but strongly correlated with the uptake of adolescent vaccines. Policies for later administration of meningococcal conjugate were associated with lower odds of vaccination for both that vaccine and Tdap, which is not surprising given that such a policy gives providers less time and, possibly, fewer opportunities to vaccinate patients before age 18. In contrast, HPV vaccination was positively correlated with later recommendation of Tdap. Although routine administration of Tdap is recommended for adolescents ages 11 to 12 years, many of the clinics in this study reported recommending the vaccine before the target age, with some clinics recommending Tdap to children as young as 7 years. Providers who recommend Tdap early likely miss opportunities to concomitantly recommend and provide HPV vaccine. Alternatively, if they do recommend HPV vaccine, parents or children may refuse it given that young age is a common reason for not getting HPV vaccine [23]. Whatever the case, these findings suggest

that Tdap and meningococcal vaccination benefit from policies for younger vaccination, but such policies are a detriment to HPV vaccination. This conflict emphasizes the need for clinic policies that balance the benefits of early and concomitant vaccination, such as the CDC recommendation that practitioners begin administering these vaccines to children at age 11.

Strengths of this study include a large sample size and the assessment of vaccination status using the North Carolina Immunization Registry. Data from electronic databases have shown equivalent or superior results when compared to self-reported data [24,25]. However, some electronic records are likely to reflect recordkeeping rather than actual practices (e.g., doses not recorded), particularly for childhood vaccines that could have been administered years before clinics started using the Registry. Due to the cross-sectional nature of this study, causal inference is not possible. In addition, the clinic-level nature of the data precluded the possibility of investigating personal attributes (e.g., individual race); instead, our analysis focused on the understudied area of clinic composition (e.g., proportion of patients of particular races). Another limitation was missing data on sex, race, and ethnicity for some portion of patients in clinics.

Conclusion

Increasing coverage of catch-up and recommended vaccines during adolescence could reduce morbidity and mortality from vaccine-preventable diseases [1]. National surveys have demonstrated that most vaccination rates are still below the Healthy People 2020 objectives [26], and better understanding of how characteristics of clinics and their populations relate to vaccine uptake may help address these low rates. This investigation of patterns of vaccination among adolescents attending large clinics in North Carolina suggests the importance of clinic specialty, documentation practices, and age recommendations for vaccine administration. Future research and interventions should explore how to maximize adolescent immunization by changing clinic policies around vaccines for this population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Highlights

- For most vaccines, pediatric clinics had higher coverage than family practices.
- However, HPV vaccination was lower in pediatric clinics.
- Vaccination coverage correlated with supportive clinical policies.
- Vaccination was higher in clinics with more frequent documentation.

Table 1

Characteristics of adolescents, ages 11–18.

	n	%
Sex		
Male	50,177	47.7%
Female	49,230	46.8%
Unknown	5,714	5.4%
Race		
White	51,883	47.0%
Unknown	28,165	25.5%
African American or Black	27,551	25.0%
Asian	1,301	1.2%
Other	904	0.8%
American Indian/Alaska Native	405	0.4%
Native Hawaiian/Pacific Islander	102	0.1%
Ethnicity		
Non-Hispanic	65,190	59.1%
Unknown	39,758	36.0%
Hispanic	5,363	4.9%
Insurance type		
Patients who initiated VFC-eligibility, mean (SD)	632 (67)	

Note. The total number of individuals varies due to measurement at two different time points, approximately three months apart.

Table 2

Clinic characteristics and policies.

Characteristics (k = 91)	
Clinic specialty	
Family medicine[a]	42%
Pediatrics	58%
Clinic size	
All patients, mean (SD)	4,745 (419)
Adolescent patients, mean (SD)	1,155 (128)
Policies (k = 61)	
General procedures	
Use a reminder/recall system	31%
Review patient's chart for vaccines at each visit	97%
When practitioners document vaccination administration in NCIR	
During the visit	67%
At the end of the visit	12%
At the close of business	18%
At least every two weeks	3%
Computers per clinic	
1 computer	10%
> 1 computer	90%
Age to start recommending vaccine	
Tdap	
<11 years	62%
11–12 years	38%
>12 years	0%
Meningococcal conjugate	
<11 years	10%
11–12 years	84%
>12 years	7%
HPV vaccine	
<11 years	53%
11–12 years	44%
>12 years	3%

[a] includes 1 internal medicine clinic.

Note. NCIR = North Carolina Immunization Registry; Tdap = tetanus, diphtheria, and pertussis booster; HPV = human papillomavirus.

Table 3

Clinic characteristics as bivariate correlates of vaccine receipt in 91 clinics (n = 105,121).

	Adolescent vaccines				Childhood vaccines		
	HPV, series initiation OR (95% CI)	**HPV, series completion OR (95% CI)**	**Meningococcal conjugate OR (95% CI)**	**Tdap OR (95% CI)**	**Hepatitis B OR (95% CI)**	**MMR OR (95% CI)**	**Varicella OR (95% CI)**
Female:male patient ratio	3.36 (2.08–5.42) ***	2.16 (1.13–4.13) *	0.66 (0.29–1.51)	0.76 (0.55–1.04)	0.42 (0.18–1.03)	0.36 (0.14–0.94) *	0.13 (0.05–0.37) ***
% White patients	0.96 (0.49–1.88)	1.13 (0.70–1.83)	0.54 (0.20–1.46)	1.04 (0.61–1.76)	0.74 (0.32–1.69)	0.55 (0.23–1.32)	0.44 (0.19–1.03)
% African-American patients	2.47 (1.18–5.15) *	1.19 (0.62–2.27)	1.34 (0.56–3.23)	0.82 (0.51–1.29)	1.54 (0.62–3.84)	1.45 (0.55–3.81)	0.83 (0.29–2.42)
% Hispanic patients	5.44 (0.91–32.73)	0.46 (0.13–1.64)	0.68 (0.11–4.42)	0.47 (0.13–1.68)	0.12 (0.02–0.75) *	0.07 (0.01–0.50) **	0.11 (0.01–1.22)
Patients with VFC-eligibility	1.11 (0.97–1.26)	1.05 (0.93–1.18)	1.14 (0.90–1.44)	1.02 (0.93–1.11)	1.50 (1.25–1.82) ***	1.46 (1.19–1.78) ***	1.21 (0.99–1.48)
Adolescent patient load	0.91 (0.80–1.04)	1.01 (0.91–1.12)	1.24 (0.97–1.58)	1.10 (0.94–1.28)	1.71 (1.45–2.01) ***	1.79 (1.51–2.11) ***	1.65 (1.39–1.94) ***
Clinic specialty							
Family medicine	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Pediatrics	0.70 (0.52–0.94) *	0.77 (0.59–1.01)	1.79 (1.25–2.55) **	1.22 (1.00–1.50) *	2.43 (1.69–3.49) ***	2.51 (1.73–3.64) ***	2.65 (1.80–3.91) ***

Note. HPV = human papillomavirus; Tdap = tetanus, diphtheria, and pertussis booster; MMR = measles, mumps, and rubella; OR = odds ratio; 95% CI = 95% confidence interval; VFC = Vaccines for Children;

* $p < .05$,

** $p < .01$,

*** $p < .001$.

HPV vaccination assessed only among girls (n = 49,230). Outcomes for childhood vaccines refer to completion of the vaccine series (i.e., three doses of hepatitis B vaccine, two doses of MMR, and two doses of varicella).

Table 4

Immunization policies as bivariate correlates of vaccine receipt in 61 clinics (n = 70,778).

	Adolescent vaccines				Childhood vaccines		
	HPV, series initiation OR (95% CI)	**HPV, series completion OR (95% CI)**	**Meningococcal conjugate OR (95% CI)**	**Tdap OR (95% CI)**	**Hepatitis B OR (95% CI)**	**MMR OR (95% CI)**	**Varicella OR (95% CI)**
Use reminder/recall system							
No	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Yes	0.86 (0.57–1.29)	1.07 (0.77–1.50)	0.56 (0.30–1.05)	0.90 (0.68–1.18)	0.94 (0.52–1.70)	0.93 (0.51–1.70)	0.60 (0.37–0.99) *
Time to documentation in NCIR							
During the visit	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
At the end of the visit	1.56 (0.97–2.50)	1.11 (0.75–1.65)	1.61 (0.91–2.85)	0.92 (0.71–1.19)	0.74 (0.49–1.12)	0.67 (0.41–1.10)	0.95 (0.65–1.37)
At the close of business	1.52 (0.89–2.59)	1.17 (0.69–2.01)	0.78 (0.45–1.35)	0.77 (0.56–1.06)	0.41 (0.24–0.68) ***	0.39 (0.24–0.64) ***	0.39 (0.21–0.72) **
At least every two weeks	0.59 (0.36–0.98) *	0.49 (0.25–0.94) *	1.53 (1.04–2.26) *	1.06 (0.83–1.36)	0.40 (0.10–1.53)	0.34 (0.08–1.49)	0.54 (0.22–1.29)
Computers per clinic							
1 computer	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
> 1 computer	1.17 (0.87–1.57)	1.07 (0.83–1.39)	4.02 (1.73–9.32) **	1.31 (1.01–1.69) *	0.64 (0.34–1.19)	0.70 (0.35–1.43)	1.55 (0.95–2.53)
Age of vaccine recommendation							
Tdap	1.48 (1.19–1.84) ***	1.22 (1.01–1.47) *	1.06 (0.81–1.39)	0.90 (0.79–1.02)	0.93 (0.73–1.18)	0.86 (0.64–1.16)	0.80 (0.59–1.10)
Meningococcal conjugate	1.00 (0.89–1.13)	0.98 (0.92–1.03)	0.74 (0.58–0.96) *	0.92 (0.86–0.97) **	1.02 (0.86–1.21)	1.02 (0.83–1.24)	0.89 (0.77–1.04)
HPV vaccine	1.04 (0.88–1.23)	1.03 (0.93–1.14)	0.89 (0.66–1.21)	0.97 (0.83–1.12)	1.01 (0.81–1.27)	1.01 (0.79–1.28)	0.90 (0.73–1.11)

Note. NCIR = North Carolina Immunization Registry; HPV = human papillomavirus; Tdap = tetanus, diphtheria, and pertussis booster; MMR = measles, mumps, and rubella; OR = odds ratio; 95% CI = 95% confidence interval;

* $p < .05$,

** $p < .01$,

*** $p < .001$.

HPV vaccination assessed only among girls (n = 33,074). Outcomes for childhood vaccines refer to completion of the vaccine series (i.e., three doses of hepatitis B vaccine, two doses of MMR, and two doses of varicella).