



Disparities in Tdap Vaccination and Vaccine Information Needs Among Pregnant Women in the United States

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Abstract

Objectives The Advisory Committee on Immunization Practices (ACIP) and the American College of Obstetricians and Gynecologists (ACOG) recommend that pregnant women receive the Tdap vaccine during every pregnancy. The objectives of this paper are to evaluate disparities in Tdap vaccination among pregnant women in the U.S., and to assess whether race/ethnicity and other characteristics are associated with factors that inform pregnant women's decisions about Tdap vaccination. **Methods** We conducted a nationwide cross-sectional web-based survey of pregnant women in the U.S. during June–July 2014. The primary outcome was self-reported vaccination status with Tdap during pregnancy, categorized as vaccinated, unvaccinated with intent to be vaccinated during the current pregnancy, and unvaccinated with no intent to be vaccinated during the current pregnancy. Secondary outcomes included factors that influenced women's decisions about vaccination and information needs. We used multivariable logistic regression models to estimate odds ratios for associations between race/ethnicity and the outcomes. **Results** Among pregnant women who completed the survey, 41% (95% CI 36–45%) reported that they had received Tdap during the current pregnancy. Among those women in the third trimester at the time of survey, 52% (95% CI 43–60%) had received Tdap during the current pregnancy. Hispanic women had higher Tdap vaccination than white women and black women (53%, $p < 0.05$, compared with 38 and 36%, respectively). In logistic regression models adjusting for maternal age, geographic region, education, and income, Hispanic women were more likely to have been vaccinated with Tdap compared with white women (aOR 2.29, 95% CI 1.20–4.37). Higher income and residing in the western U.S. were also independently associated with Tdap vaccination during pregnancy. Twenty-six percent of surveyed women had not been vaccinated with Tdap yet but intended to receive the vaccine during the current pregnancy; this proportion did not differ significantly by race/ethnicity. The most common factor that influenced women to get vaccinated was a health care provider (HCP) recommendation. The most common reason for not getting vaccinated was a concern about safety of the vaccine. **Conclusions** This study found that some disparities exist in Tdap vaccination among pregnant women in the U.S., and HCPs have an important role in providing information and recommendations about the maternal Tdap recommendation to pregnant women so they can make informed vaccination decisions.

Keywords Tdap · Vaccine · Pregnancy · Pertussis · Whooping cough

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Significance

Current recommendations state that pregnant women should receive the Tdap vaccine during every pregnancy to help prevent pertussis infection in young infants before they develop immunity against pertussis through receipt of their own pertussis vaccine series. This paper evaluates disparities in Tdap vaccination among pregnant women in the U.S., and assesses whether race/ethnicity and other characteristics are associated with factors that inform pregnant women's decisions about Tdap vaccination. Hispanic ethnicity, higher

income, and residing in the western U.S. are associated with Tdap vaccination during pregnancy. A recommendation from a health care provider was the most common factor that influenced women to get vaccinated.

Introduction

The incidence of pertussis and pertussis-related complications and mortality are highest among infants who are too young to be fully vaccinated (Centers for Disease Control and Prevention [CDC] 2002, 2005, 2014; Cortese et al. 2008; Crowcroft et al. 2002; Haberling et al. 2009; Heininger et al. 1997; Murphy et al. 2008; Vitek et al. 2003). In the United States, infants receive their first dose of pertussis vaccine at age 2 months, but do not achieve high levels of protection until their third dose at age 6 months (CDC Immunization Schedule 2018). The tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis (Tdap) vaccine was licensed in 2005 as a booster vaccine. In 2011, the U.S. Advisory Committee on Immunization Practices (ACIP) recommended that women receive Tdap during pregnancy, or immediately after delivery if not received during pregnancy, as a strategy to prevent pertussis infection in young infants before they develop active immunity against pertussis through receipt of their own pertussis vaccine series. In 2012, ACIP extended this recommendation to include Tdap during every pregnancy regardless of a woman's immunization history (Centers for Disease Control and Prevention 2013), and the American College of Obstetricians and Gynecologists (ACOG) made the same recommendation (ACOG Committee on Obstetric Practice 2013). Vaccination is optimally recommended at 27–36 weeks gestation (i.e., third trimester) to maximize antibody response and transfer to the fetus.

Tdap vaccination among pregnant women has increased incrementally in recent years, but coverage estimates remain suboptimal. During 2011–2012, Tdap coverage estimates among pregnant women were 3–16% (Housey et al. 2014; Kharbanda et al. 2014, 2016; Winter et al. 2012). In California, the first U.S. state to recommend Tdap to pregnant women during their 2010 outbreak, 16–30% of pregnant women received Tdap (Kharbanda et al. 2014; Winter et al. 2012). More recent estimates indicate that Tdap coverage has increased: during 2013, 42% of pregnant women at seven Vaccine Safety Datalink sites were vaccinated with Tdap (Kharbanda et al. 2014); 51% of women delivering in Wisconsin in 2014 were vaccinated with Tdap during pregnancy (Koepke et al. 2015); and the proportion of women who received Tdap during pregnancy among a national Internet panel survey increased from 27% in 2014 to 50% in 2017 (Centers for Disease Control and Prevention 2017).

The objectives of this paper were to evaluate disparities in self-reported Tdap vaccination and intent for vaccination during the current pregnancy among pregnant women, and to assess whether race/ethnicity and other characteristics are associated with factors that inform pregnant women's decisions about Tdap vaccination.

Methods

We conducted a nationwide cross-sectional Internet panel survey of pregnant women in the U.S. as part of efforts to inform development of communication materials to increase uptake of the Tdap recommendation among obstetrician-gynecologists (ob-gyns), nurse-midwives, and pregnant women. Survey participants were recruited by a professional recruiting firm (Schlesinger Associates) from their preexisting national, general-population survey panel. Similar survey panels have been used to assess vaccination of pregnant women in the U.S. for several years (Centers for Disease Control and Prevention 2017). Emails inviting women to complete a web-based survey on pertussis and the pertussis vaccine were sent to women ages 18–45 who were members of the survey panel. Out of 2522 individuals who were screened for the survey, 486 met the screening criteria (currently pregnant, 18 years or older, and U.S. resident) and completed the survey. All surveys were completed between June 27, 2014 and July 3, 2014 using NOVI electronic survey software. All study participants were given an information sheet with information about informed consent and whom to contact for more information about the survey; informed consent was obtained electronically at the beginning of the survey. The study protocol was approved by the CDC Institutional Review Board.

The web-based survey was designed to be completed in approximately 10 min, and was conducted in English only. A \$20 gift card was given to survey respondents for their participation. We did not have any additional follow-up with respondents after completion of the survey.

The primary independent variable for this analysis was race/ethnicity, categorized as white non-Hispanic, black non-Hispanic, or Hispanic. The survey asked about other characteristics including maternal age, education, household income, geographic region, health insurance, primigravida, and estimated gestation at time of survey completion. The primary dependent variable for this analysis was Tdap vaccine receipt, which was self-reported and based on the question "Have you gotten the whooping cough vaccine (Tdap) during your current pregnancy?" Responses were categorized as: (1) Received Tdap during current pregnancy; (2) Intended to receive Tdap during current pregnancy but had not yet; and (3) Had not received Tdap during current pregnancy and did not intend to receive

it. Secondary outcomes that were analyzed included factors that influenced women's vaccination decision, Tdap information needs, and sources of information on Tdap.

We used Chi square tests to test differences in proportions, and logistic regression models to estimate odds ratios (ORs) for associations, including polytomous models for the primary outcome which had three nominal categories. We used multivariable models to estimate adjusted ORs, with covariates chosen from variables that were on a causal path with the outcome based on directed acyclic graphs (DAGs) or were associated with the outcome in bivariate analysis at $p < 0.20$. In sensitivity analyses, we weighted our sample using inverse probability weights based on the age and race/ethnicity distribution of all births in the U.S. in 2013 (Martin et al. 2015). SAS

version 9.4 was used for all analyses (SAS Institute, Inc., Cary, NC).

Results

A total of 486 pregnant women completed the survey. Fourteen were excluded from this analysis because of unreported race/ethnicity, and four were excluded because of unreported age. Among respondents, the majority were white ($n = 300$), with smaller numbers of black ($n = 53$), Hispanic ($n = 89$), or 'Other' race/ethnicity ($n = 26$) (Table 1). The 'Other' race/ethnicity category was comprised of women from a variety of racial/ethnic backgrounds including American Indian and Alaska Native, Native Hawaiian and Pacific Islander, and

Table 1 Demographic characteristics of surveyed pregnant women, stratified by race/ethnicity

	Total (n = 442)	White non-Hispanic ^a (n = 300)	Black non-Hispanic (n = 53)		Hispanic (n = 89)	
	n (%)	n (%)	n (%)	p-value ^b	n (%)	p-value
Region^c						
Northeast	103 (24)	75 (26)	9 (18)	0.09	19 (22)	0.06
South	139 (33)	92 (32)	25 (49)		22 (26)	
Midwest	80 (19)	57 (20)	10 (20)		13 (15)	
West	104 (24)	65 (22)	7 (14)		32 (37)	
Age group						
18–29	154 (35)	97 (32)	18 (34)	0.004	39 (44)	0.09
30–39	253 (57)	182 (61)	24 (45)		47 (53)	
40 and older	35 (8)	21 (7)	11 (21)		3 (3)	
Education						
Less than 4-year college degree	184 (42)	112 (37)	34 (64)	0.002	38 (43)	0.53
4-year college degree or more	258 (58)	188 (63)	19 (36)		51 (57)	
Household income						
Less than \$25,000	29 (7)	17 (6)	10 (20)	<0.001	2 (2)	0.21
\$25,000–\$49,999	78 (18)	45 (16)	21 (41)		12 (14)	
\$50,000–\$74,999	111 (26)	73 (25)	8 (16)		30 (36)	
\$75,000 or more	205 (48)	153 (53)	12 (24)		40 (48)	
Health insurance status						
Uninsured	13 (3)	9 (3)	1 (2)	0.70	3 (3)	0.87
Insured	419 (97)	286 (97)	48 (98)		85 (97)	
Primigravida^d						
Yes	186 (43)	124 (42)	15 (29)	0.07	47 (54)	0.05
No	248 (57)	171 (58)	37 (71)		40 (46)	
Gestation at time of survey						
1st trimester	54 (17)	35 (16)	13 (37)	0.008	6 (11)	0.31
2nd trimester	132 (42)	93 (42)	9 (26)		30 (53)	
3rd trimester	128 (41)	94 (42)	13 (37)		21 (37)	

^a26 reported 'Other' race and were excluded from all analyses

^bCompared with 'White non-Hispanic'

^cInformation missing for the following variables (n): region (16), household income (19), health insurance status (10), primigravida (8), gestation (128)

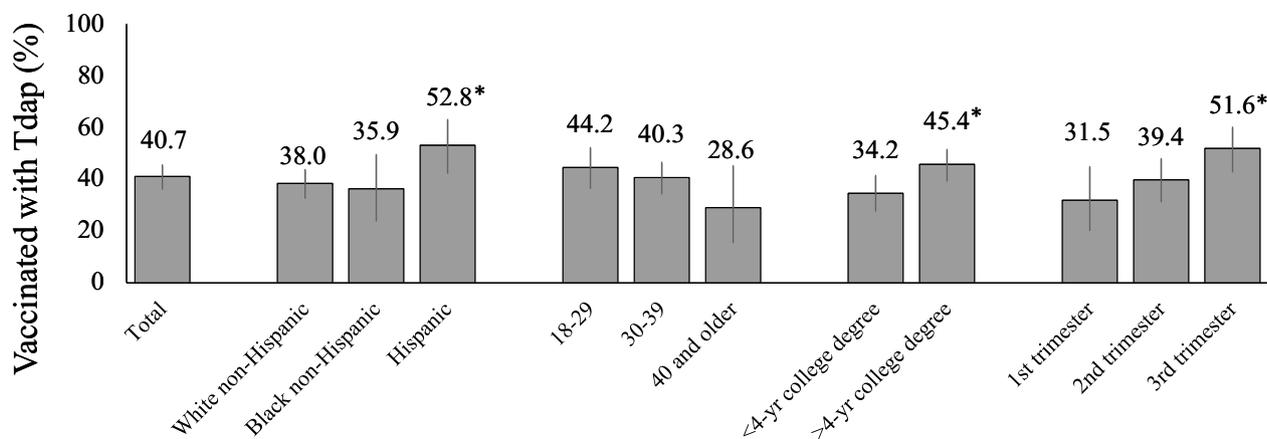
^dCurrent pregnancy is first pregnancy

various multi-racial backgrounds. Because of the heterogeneity in this group and small sample sizes which would likely preclude meaningful conclusions, women in the ‘other’ race/ethnicity were excluded from analyses presented in this paper. Respondents were distributed relatively equally by geographic area, with the largest proportion (33%) in the South, and the smallest proportion (19%) in the Midwest. Majorities of respondents were age 30–39 (57%), had at least a 4-year college degree (58%), and reported a household income of ≥ \$50,000 per year (75%). Just 3% were uninsured, and 43% were primigravid. Most were in their second trimester (42%) or third trimester (41%).

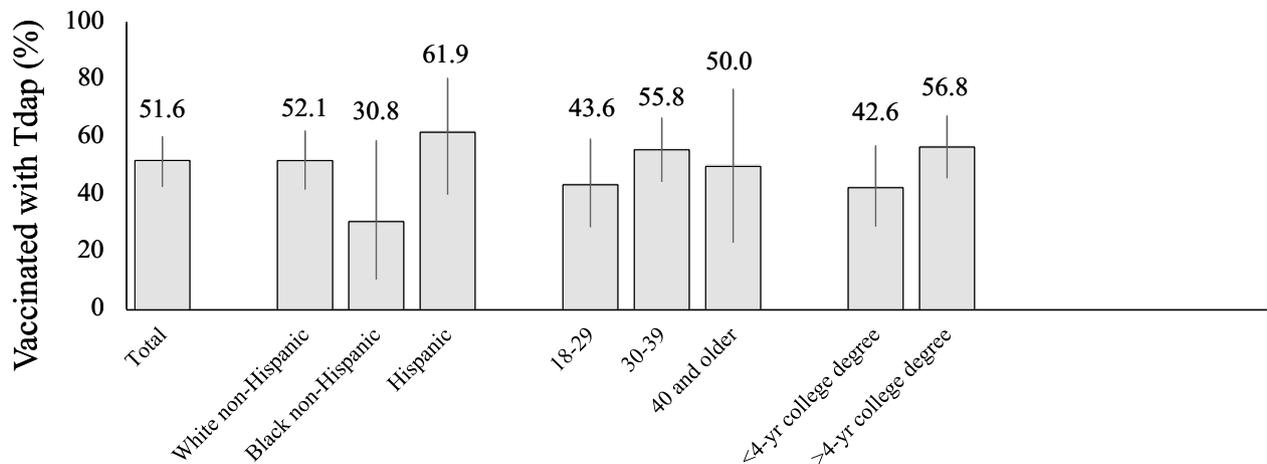
Among all survey respondents, 41% (95% CI 36–45%) reported that they had received Tdap during the current

pregnancy (Fig. 1a; Table 2). Tdap receipt was lowest among women in the first trimester of pregnancy (32%), and increased in the second trimester (39%) and the third trimester (52%) ($p < 0.05$ third compared with first trimester). A higher proportion of Hispanic women had received Tdap during the pregnancy (53%) than white women and black women (38 and 36% respectively, $p < 0.05$). Tdap vaccination was lowest in the South (33%) and highest in the West (53%). Primigravid women were slightly more likely to have received Tdap (45%) compared with non-primigravid women (38%), but not significantly so ($p = 0.06$). When analysis was restricted to women answering the survey during their third trimester (the trimester during which Tdap is recommended to be administered), we found similar patterns

(a) Among pregnant women who completed the survey at any time during their pregnancy^a (n = 442).



(b) Among pregnant women who completed the survey during the third trimester of pregnancy (n = 128).



* $p < 0.05$

^aTrimester is the stage of pregnancy at time of survey, not the time of receipt of Tdap vaccine.

Fig. 1 Receipt of Tdap during the current pregnancy. Proportions of pregnant women who were vaccinated with Tdap vaccine during the current pregnancy, among (a) pregnant women who completed the

survey at any time during their pregnancy, and (b) pregnant women who completed the survey during the third trimester of pregnancy

Table 2 Estimated associations between demographic characteristics and (a) receipt of Tdap vaccine during current pregnancy and (b) intent to receive Tdap vaccine during current pregnancy

	Received Tdap during current pregnancy				Intends to receive Tdap during current pregnancy ^a				
	% (95% CI)	Unadjusted OR (95% CI)	p-value	Adjusted OR ^b (95% CI)	% (95% CI)	Unadjusted OR (95% CI)	p-value	Adjusted OR ^b (95% CI)	p-value
Total	41 (36–45)				26 (22–30)				
Race/ethnicity									
White non-Hispanic	38 (33–44)	Ref		Ref	27 (23–33)	Ref		Ref	
Black non-Hispanic	36 (24–49)	0.79 (0.40–1.54)	0.48	1.54 (0.69–3.41)	23 (13–35)	0.69 (0.32–1.48)	0.34	0.99 (0.42–2.29)	0.97
Hispanic	53 (42–63)	2.04 (1.14–3.64)	0.02	2.29 (1.20–4.37)	24 (16–33)	1.27 (0.65–2.48)	0.49	1.14 (0.54–2.40)	0.73
Region									
Northeast	40 (31–50)	Ref		Ref	23 (16–32)	Ref		Ref	
Midwest	35 (25–46)	0.81 (0.42–1.55)	0.52	0.97 (0.47–2.01)	25 (16–35)	0.92 (0.44–1.92)	0.82	1.16 (0.53–2.54)	0.72
South	33 (26–41)	0.73 (0.41–1.31)	0.29	1.03 (0.54–1.97)	30 (22–38)	1.07 (0.57–2.01)	0.83	1.40 (0.70–2.80)	0.35
West	53 (43–62)	1.88 (0.99–3.54)	0.05	2.08 (1.03–4.20)	24 (17–33)	1.45 (0.70–3.01)	0.32	1.70 (0.77–3.76)	0.19
Age group									
18–29	44 (37–52)	Ref		Ref	26 (20–33)	Ref		Ref	
30–39	40 (34–47)	0.79 (0.50–1.25)	0.31	0.78 (0.46–1.31)	25 (20–31)	0.83 (0.49–1.38)	0.47	0.75 (0.43–1.31)	0.31
40 and older	29 (16–45)	0.46 (0.19–1.11)	0.09	0.68 (0.24–1.97)	34 (20–51)	1.01 (0.43–2.35)	0.99	1.27 (0.47–3.39)	0.64
Education									
< 4-year college degree	34 (28–41)	Ref		Ref	29 (23–36)	Ref		Ref	
≥ 4-year college degree	45 (39–52)	1.66 (1.08–2.57)	0.02	0.93 (0.51–1.70)	24 (19–29)	1.05 (0.65–1.68)	0.85	0.62 (0.33–1.16)	0.13
Household income									
Less than \$25,000	31 (16–49)	Ref		Ref	17 (7–34)	Ref		Ref	
\$25,000–\$49,999	23 (15–33)	0.82 (0.31–2.15)	0.68	0.55 (0.19–1.60)	24 (16–35)	1.55 (0.50–4.78)	0.45	1.19 (0.36–3.90)	0.77
\$50,000–\$74,999	41 (32–50)	2.66 (1.05–6.71)	0.04	2.23 (0.77–6.47)	32 (24–42)	4.04 (1.34–12.16)	0.01	3.86 (1.14–12.99)	0.03
\$75,000 or more	48 (41–55)	3.41 (1.43–8.15)	0.006	2.99 (1.04–8.59)	26 (21–33)	3.46 (1.20–10.01)	0.02	4.00 (1.18–13.53)	0.03
Health insurance status									
Uninsured	15 (3–42)	–	–	–	46 (21–73)	Ref		Ref	
Insured	41 (36–46)	–	–	–	25 (21–30)	0.75 (0.24–2.38)	0.62	0.46 (0.13–1.70)	0.24
Primigravida ^c									
No	38 (32–44)	Ref		Ref	26 (20–33)	Ref		Ref	
Yes	45 (38–52)	1.52 (0.98–2.35)	0.06	1.57 (0.93–2.66)	26 (21–32)	1.21 (0.74–1.96)	0.45	1.48 (0.84–2.60)	0.17

ORs not shown when n < 5

^aBut has not been vaccinated with Tdap yet in current pregnancy

^bAdjusted for race/ethnicity, geographic region, maternal age, education, and household income

^cCurrent pregnancy is first pregnancy

in coverage disparities, although smaller proportions of black women (31%) in the third trimester were vaccinated compared with white women (52%) in the third trimester (Fig. 1b). Only 2.7% ($n=12$) women reported that they were not sure if they received a Tdap vaccination during the current pregnancy.

Polytomous logistic regression models adjusted for maternal age, education, household income, and geographic region; we present both unadjusted and adjusted results (Table 2). In adjusted models black women were slightly more likely than white women to have been vaccinated with Tdap (aOR 1.54, 95% CI 0.69–3.41); black women did not vary from white women in intent to be vaccinated (aOR 0.99, 95% CI 0.42–2.29). Hispanic women were more than twice as likely to have been vaccinated with Tdap compared with white women (aOR 2.29, 95% CI 1.20–4.37), but did not have any differences in intent to be vaccinated (Table 2). Compared with the Northeast (reference group), women residing in the West were more likely to be vaccinated with Tdap (aOR 2.08, 95% CI 1.03–4.20). Women with the highest annual household income ($\geq \$75,000$) were three times more likely to be vaccinated compared with women with low incomes (aOR 2.99, 95% CI 1.04–8.59). In unadjusted models a college degree was associated with Tdap vaccination (OR 1.66, 95% CI 1.08–2.57), but not in adjusted models. Among women who had not yet received Tdap, women with household income \$50,000–\$74,999 and $\geq \$75,000$ were more likely to intend to get vaccinated before the end of pregnancy compared with the lowest income category (aOR 3.86, 95% CI 1.14–12.99, aOR 4.00, 95% CI 1.18–13.53, respectively).

In sensitivity analyses in which we weighted our sample using inverse probability weights based on the age and race/ethnicity distribution of all births in the U.S. in 2013, we found similar results: 43% (95% CI 38–48%) reported Tdap receipt, and 24% (95% CI 20–28%) had not yet been vaccinated but intended to receive Tdap (Supplemental Table 1). Results of multivariable models did not change meaningfully in the weighted analysis, except that in weighted adjusted analysis the aOR for Tdap vaccination among black women was larger and statistically significant (weighted aOR 2.08, 95% CI 1.01–4.28, compared with unweighted aOR 1.54, 95% CI 0.69–3.41). In addition to women with incomes $\geq \$75,000$, women with income \$50,000–\$74,999 were also more likely than low-income women to be vaccinated (weighted aOR 3.60, 95% CI 1.27–10.24).

Among pregnant women who have received Tdap or who intend to receive it during the current pregnancy, the most common factor that influenced their vaccination decision was a recommendation by their doctor, nurse, or midwife (63%) (Table 3), followed by knowledge that babies can die from pertussis (48%) and recommendations from family/friends (43%). Hispanic women were more likely to be

influenced by a commercial (OR 1.93, 95% CI 1.11–3.37) or website (OR 1.76, 95% CI 1.01–3.08) recommending Tdap, but in adjusted models these differences were not significant. Black women were more likely to be influenced by a magazine recommending Tdap (aOR 2.96, 95% CI 1.16–7.58).

A small number of women (7%, $n=31$) said they had not received the Tdap vaccine and did not plan to get it during the current pregnancy. The remainder (31%, $n=135$) were not sure if they would get Tdap during the current pregnancy. Among women who did not plan to receive Tdap, the most common reasons were safety for themselves (48%) or their baby (45%), or not being told about the vaccine by a health care provider (35%) (Table 3).

The majority of respondents (61%) had looked for information on Tdap specifically for pregnant women, and Hispanic women were more likely to have done so (aOR 2.67, 95% CI 1.44–4.93, compared with white women) (Table 4). Among women who looked for information, the most common information looked for was information on vaccine safety (72%), potential side effects (64%), pertussis disease (64%), vaccine effectiveness (63%), when to get Tdap (55%), and who else should get Tdap (52%). The most common places that women looked for information were the Internet/social media (76%), healthcare professionals (63%), friends (45%), and family (41%). The only racial/ethnic difference we found was that Hispanic women were more than twice as likely to look to their insurance company for information about Tdap (aOR 2.13, 95% CI 1.07–4.25, compared with white women).

Discussion

Most estimates of Tdap vaccination among pregnant women are from before or shortly after ACIP first made the recommendation for pregnant women to be vaccinated (Housey et al. 2014; Kharbada et al. 2014, 2016; Koepke et al. 2015; Murphy et al. 2008). More recent estimates have indicated that Tdap coverage is low but improving both among adults and pregnant women (Centers for Disease Control and Prevention; Williams et al. 2017). Few studies have assessed how race/ethnicity and other sources of disparity have contributed to Tdap vaccination among pregnant women. We found that among our survey sample, black and white women did not vary significantly in either self-reported Tdap vaccination or intent to be vaccinated during the current pregnancy, although in both unweighted and weighted analysis, black women were less likely to be vaccinated in unadjusted models, and were more likely to be vaccinated in adjusted models, compared with white women. Because adjusted models control for characteristics that may be intermediates between race/ethnicity and Tdap vaccination (such as education, household income, maternal age), unadjusted

Table 3 Associations between race/ethnicity and factors that influenced pregnant women's decisions about Tdap vaccination

	Total n (%)	White non-Hispanic n (%)	Black non-Hispanic		Hispanic	
			Adjusted OR ^a (95% CI)	p-value	Adjusted OR ^a (95% CI)	p-value
Among women who received Tdap or intend to receive it during current pregnancy: factors that influenced their decision to get vaccinated (n = 294)						
Provider recommendation	184 (63)	125 (64)	1.04 (0.42–2.57)	0.93	0.75 (0.41–1.39)	0.36
Heard babies can die from pertussis	141 (48)	97 (50)	1.62 (0.67–3.90)	0.29	0.64 (0.34–1.19)	0.16
Family or friends recommendation	126 (43)	81 (42)	0.76 (0.30–1.97)	0.58	1.35 (0.72–2.54)	0.35
Prenatal class/hospital tour recommendation	112 (38)	71 (36)	1.32 (0.51–3.45)	0.57	1.50 (0.79–2.85)	0.22
News report recommendation	113 (38)	73 (37)	0.83 (0.32–2.15)	0.70	1.31 (0.70–2.44)	0.40
Cases of pertussis in my state	106 (36)	68 (35)	1.18 (0.46–3.04)	0.73	1.09 (0.58–2.06)	0.79
Commercial recommendation	108 (37)	64 (33)	1.80 (0.72–4.54)	0.21	1.72 (0.93–3.18)	0.09
Website recommendation	106 (36)	63 (32)	2.35 (0.88–6.31)	0.09	1.42 (0.75–2.72)	0.28
Book recommendation	100 (34)	63 (32)	1.46 (0.59–3.59)	0.41	1.28 (0.68–2.41)	0.44
Magazine recommendation	98 (33)	65 (33)	2.96 (1.16–7.58)	0.02	0.72 (0.37–1.42)	0.35
App recommendation	50 (17)	29 (15)	–	–	1.57 (0.74–3.36)	0.24
Among women who did not receive Tdap and do not plan to receive it during current pregnancy: factors that influenced their decision not to get vaccinated (n = 31)						
Unsafe for mother	15 (48)	11 (48)	–	–	–	–
Unsafe for baby	14 (45)	11 (48)	–	–	–	–
No provider recommendation	11 (35)	8 (35)	–	–	–	–
Don't know about the vaccine	9 (29)	7 (30)	–	–	–	–
I'm not likely to get pertussis	9 (29)	8 (35)	–	–	–	–
Got Tdap before I was pregnant	6 (19)	6 (26)	–	–	–	–

ORs not shown when n < 5

Referent group = White non-Hispanic

^aAdjusted for maternal age, education, household income, and geographic region

estimates of association may more accurately represent the total effect of race/ethnicity on Tdap vaccination without adjusting for these intermediate characteristics (Westreich and Greenland 2013). Some other studies have found lower Tdap vaccination among black women during pregnancy compared with white women (Goldfarb et al. 2014; O'Halloran et al. 2016; Williams et al. 2015). We assessed confounding for our primary independent variable (race/ethnicity), but did not assess confounding separately for each of the other independent variables.

Hispanic women in this study were more than twice as likely to be vaccinated with Tdap compared with white women, and this pattern persisted in adjusted models. Previous research on vaccination among Hispanic adults has shown mixed results: data collected through the Pregnancy Risk Assessment Monitoring System (PRAMS) from 16 states and New York City in 2011 found higher Tdap vaccination during pregnancy among Hispanic women (17.1%) compared with white women (7.5%) (Ahluwalia et al. 2015); in contrast, data for adults age 19–64 years from the National Health Interview Survey (NHIS) 2013 found lower Tdap vaccination among Hispanic adults (10.5%) compared with white adults (21.6%) (Williams et al. 2015). Other

demographics that we found to be associated with Tdap vaccination were residence in the western U.S. and household annual income \geq \$75,000; intent to receive Tdap during the current pregnancy was also associated with higher household incomes. Additional studies using the NHIS have suggested some characteristics associated with Tdap vaccination that we did not find in adjusted analysis, including younger maternal age and higher education (Johns et al. 2013). However, the NHIS may not be directly comparable to our study focused solely on pregnant women.

Regardless of race/ethnicity, pregnant women in our study reported that they were most likely to get vaccinated because of a recommendation by their doctor, nurse, or midwife. Previous research has shown that recommendation of vaccination by a medical provider is an important factor in individuals' decisions about vaccination (Centers for Disease Control 1988; Ding et al. 2014; Guerry et al. 2011; Nichol et al. 1996; Sevin et al. 2016; Zimmerman et al. 2003), and we found that this is also true among pregnant women. Evidence from Medicare beneficiaries shows that among individuals who have negative attitudes towards vaccination, a provider recommendation can improve influenza vaccination rates by two to three times compared with women without a

Table 4 Associations between race/ethnicity and information seeking about Tdap for pregnant women

	Total n (%)	White non-Hispanic n (%)	Black non-Hispanic		Hispanic	
			Adjusted OR ^a (95% CI)	p-value	Adjusted OR ^a (95% CI)	p-value
Looked for information on whooping cough vaccine specifically for pregnant women	271 (61)	176 (59%)	1.33 (0.67–2.66)	0.41	2.67 (1.44–4.93)	0.002
Among women who looked for information, type of information they looked for						
Vaccine safety	194 (72)	130 (74)	0.42 (0.17–1.08)	0.07	0.67 (0.34–1.32)	0.24
Side effects	174 (64)	114 (65)	0.71 (0.28–1.82)	0.48	0.98 (0.52–1.87)	0.96
Pertussis disease ^b	173 (64)	112 (64)	1.11 (0.45–2.75)	0.82	1.04 (0.55–1.95)	0.91
Effectiveness	170 (63)	115 (65)	0.61 (0.25–1.49)	0.28	0.68 (0.36–1.26)	0.22
When to get Tdap	150 (55)	98 (56)	1.06 (0.44–2.56)	0.90	0.88 (0.48–1.61)	0.67
Who else should get Tdap	140 (52)	97 (55)	1.17 (0.47–2.92)	0.74	0.51 (0.27–0.96)	0.04
Vaccine ingredients	130 (48)	84 (48)	0.75 (0.30–1.90)	0.55	1.17 (0.63–2.17)	0.61
Insurance coverage for Tdap	117 (43)	74 (42)	1.13 (0.44–2.96)	0.80	0.97 (0.50–1.85)	0.92
Where to get Tdap	113 (42)	75 (43)	0.73 (0.28–1.87)	0.51	0.93 (0.50–1.76)	0.83
Cost of Tdap	110 (41)	71 (40)	0.50 (0.18–1.36)	0.17	1.18 (0.63–2.20)	0.60
Where they looked for this information						
Internet or social media	206 (76)	135 (77)	1.82 (0.55–6.01)	0.33	0.57 (0.28–1.16)	0.12
Healthcare professional ^c	172 (63)	111 (63)	0.75 (0.29–1.92)	0.55	0.98 (0.51–1.87)	0.96
Friends	122 (45)	82 (47)	0.86 (0.32–2.35)	0.77	0.82 (0.43–1.57)	0.54
Family	110 (41)	64 (36)	1.19 (0.46–3.07)	0.72	1.69 (0.90–3.16)	0.10
Pharmacy or pharmacist	94 (35)	60 (34)	1.11 (0.42–2.90)	0.84	1.14 (0.60–2.16)	0.69
Books	92 (34)	62 (35)	1.61 (0.61–4.24)	0.34	0.64 (0.33–1.25)	0.19
Insurance company	91 (34)	55 (31)	–	–	2.13 (1.07–4.25)	0.03
Magazines	83 (31)	54 (31)	2.30 (0.87–6.09)	0.09	0.68 (0.34–1.35)	0.27
Television	81 (30)	48 (27)	1.88 (0.60–5.87)	0.28	1.49 (0.76–2.93)	0.25
Newspapers	60 (22)	47 (27)	–	–	0.47 (0.21–1.03)	0.06
Apps	50 (18)	31 (18)	1.39 (0.43–4.52)	0.58	1.19 (0.56–2.53)	0.65
Radio	40 (15)	24 (14)	–	–	1.56 (0.69–3.56)	0.29

ORs not shown when n < 5

Referent group = White non-Hispanic

^aAdjusted for maternal age, education, household income, and geographic region

^bSuch as symptoms or complications

^cDoctor, nurse, or midwife

provider recommendation, and provider recommendations are especially important for African Americans (Lindley et al. 2006). Conversely, survey respondents in our study reported that not being told about Tdap by a doctor, nurse, or midwife was an important factor in not getting vaccinated.

The results of this study should be considered in light of its limitations. First, respondents to this survey may not be representative of all pregnant women in the U.S. because of the sampling design that was used. The women who were invited to participate in this study had previously agreed to be members of a survey panel, and they may differ from the general U.S. population with respect to some important characteristics. For example, Hispanics in the survey panel had higher socioeconomic status (SES) compared with all Hispanics in the U.S., as measured by educational attainment

and household income (Pew Research Center 2015). We conducted our survey only in English, which may have contributed to the higher SES among Hispanic respondents by excluding non-English speakers. English-speaking Hispanics in the U.S. are likely to have higher SES and also to have less barriers to prenatal care and Tdap vaccination than their non-English-speaking counterparts. Additionally, a larger proportion of the Hispanic respondents (24%) resided in California (which has had several large pertussis outbreaks in recent years), compared with 12% of non-Hispanic women residing in California. Recent localized outbreaks that were heavily covered by the media might have contributed to increased Tdap vaccination among Hispanic respondents living in California. Second, this survey was conducted via the Internet, requiring women to have access to a computer

or mobile device with Internet access; therefore women with lower SES or who live in remote areas may be under-represented in this study sample. We tried to address resulting selection bias by conducting sensitivity analyses using data weighted based on population characteristics, and we did not find significant differences in the weighted analyses compared with the unweighted analyses. However, it is possible that our results may be subject to selection bias even after weighted adjustment if there were unmeasured factors not accounted for by weighting. Additionally, weighted analyses could not account for small subgroups of women who were not in the study population at all. Third, Tdap vaccination status during pregnancy was self-reported by survey respondents, and was not verified by medical record review or vaccine registry, so misclassification of Tdap vaccination status due to inaccurate self-reporting is possible. Some surveyed women may have confused Tdap vaccine with influenza vaccine, since both are recommended during pregnancy. Particularly among women who reported vaccination early in pregnancy, before Tdap is typically recommended, erroneous reporting of an influenza vaccination as Tdap vaccination could have inflated the estimated proportion of women vaccinated with Tdap. Fourth, because women were surveyed at any time during pregnancy, regardless of their current gestation, women answered the survey at a range of gestational ages. Many of the respondents had not yet reached the time in pregnancy when Tdap is recommended (the third trimester). We attempted to address this potential bias by the way we defined Tdap vaccination status. Women who had already been vaccinated were categorized as vaccinated with Tdap during the current pregnancy. Women who were not vaccinated could be categorized as intending to be vaccinated with Tdap during the current pregnancy, which accounts for the fact that women surveyed earlier in pregnancy may intend to be vaccinated even if they have not yet reached the gestational age at which the vaccine is recommended. We observed a surprisingly high proportion of women in the first trimester reporting that they had already been vaccinated with Tdap (32%). Since Tdap vaccination is typically recommended during the third trimester, this high vaccination rate so early in pregnancy was unexpected, and this finding needs further study. Women may receive Tdap at the incorrect time during pregnancy, inaccurately report their Tdap vaccination status, or receive Tdap earlier in their pregnancy because of a pertussis outbreak in their community, in which case it is recommended that they be vaccinated at any time during pregnancy. Fifth, the relatively small sample size in this study resulted in limited power to evaluate differences between race/ethnicity groups. Based on the number of survey participants, there was 87% power to detect a difference in coverage between white non-Hispanics and other race/ethnicities of > 15 percentage points, but power to detect smaller differences in coverage was

reduced, and power to detect differences for Hispanics and black non-Hispanics separately was further reduced. This study indicated that there may be differences in Tdap vaccination by race/ethnicity, but had limited statistical power to detect significant differences; studies with larger sample sizes should further investigate these associations. Finally, we did not follow-up with pregnant women throughout their pregnancies and postpartum periods for this study; there was no further contact after the one-time completion of the survey during pregnancy. Therefore, we were not able to assess if women who reported that they intended to be vaccinated with Tdap actually were vaccinated during this pregnancy, and if women who said they did not intend to be vaccinated with Tdap actually did not get vaccinated. Imperfect correlation between intention to be vaccinated in the future and actual vaccination is likely, particularly among women who were surveyed earlier in pregnancy.

Conclusions

We identified characteristics of pregnant women that are associated with receipt of Tdap during pregnancy. Although we hypothesized that there would be disparities in vaccination by race/ethnicity, we found differences only for Hispanics (higher Tdap coverage) and not for black non-Hispanics when we controlled for other socioeconomic variables. We found disparities in Tdap vaccination related to household income and geographic region. Provider recommendation is one of the most important factors in Tdap vaccination, which has previously been found for Tdap and other vaccines. Accordingly, women's health care providers—including ob-gyns and nurse-midwives—have an important role in providing information and recommendations about the maternal Tdap recommendation to pregnant women so they can make informed vaccination decisions.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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