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Determinants of pertussis and tetanus vaccination coverage among foreign-born
adults living in the United States

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Abstract

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Pertussis is a common vaccine-preventable disease worldwide and is endemic in the United States, with an average of 23,000 cases reported annually. The incidence of pertussis among adults has increased steadily, with a fifth of the cases reported in 2013 occurring in persons >20 years old. Up to 55% of cases in infants can be attributed to adult family members. Despite this recognized risk and current Advisory Committee on Immunization Practices (ACIP) recommendations for universal adult tetanus, diphtheria, and acellular pertussis (Tdap) vaccination, reported vaccination coverage among adults remains suboptimal.

The estimated 41.3 million foreign-born individuals living in the United States in 2013 had significantly lower reported coverage for Td and Tdap among adults compared to the U.S-born.

We used data from the 2012 and 2013 National Health Interview Survey (NHIS) to calculate point estimates and 95% confidence intervals of vaccination coverage among foreign born adults. Multivariable logistic regression was conducted to assess Td and Tdap vaccination in relation to migration-related, socio-demographic, and access-to-care variables using prevalence ratios (PR).

Five factors were significantly associated with vaccination status after controlling for all other variables. Age greater than 49 years, having public, or having no health insurance were associated with lower vaccination rates for both vaccines. Having an associate degree or higher education was significantly associated with higher Tdap and Td vaccination coverage. Having at least one visit with a doctor in the previous year was significantly associated with having received each vaccine and there was a general trend towards increased coverage with increasing number of visits; 69.9% of respondents reported at least one such encounter. Tdap coverage was 13.4 % with 10 or more encounters.

Migration-related factors such as region of origin were not associated with lower vaccination rates in this study. Our results suggest that the low coverage rates reported for both foreign born and native born people individuals are most likely due to vaccine system delivery factors that can be modified. Vaccination remains suboptimal even in the face of repeated healthcare encounters. This finding, along with the finding that public insurance is associated with lower vaccination coverage for Tdap and Td, suggests that there may be substantial missed opportunities for vaccination during healthcare encounters, especially for public insurance holders. Opportunities to provide vaccine during health care visits should be taken. Actions might include outreach and education to immigrants and designing vaccine delivery systems to reduce missed opportunities, such as through standing orders.

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Chapter 1. INTRODUCTION

Pertussis is a bacterial respiratory disease caused by *Bordetella pertussis*, and is one of the most common vaccine-preventable diseases worldwide [1]. It is a highly communicable disease and its occurrence is cyclical, with peaks every 3 to 5 years. There are an estimated 50 million pertussis cases and 300,000 deaths globally per year [2]. In 2001 the Global Pertussis Initiative was launched and several vaccination campaigns have been conducted since 2005 [3].

It is endemic in the United States, with an average of approximately 23,000 cases reported annually during the last decade [4]. During 2012, more than 48,000 cases of pertussis were reported to the Centers for Disease Control and Prevention (CDC). That was the largest number of reported cases since 1955 and included 20 pertussis-related deaths [5]. Provisional CDC data show that 28,660 cases were reported in 2014, an 18% increase when compared to corresponding data from 2013 [6]. In 2014 the state of California experienced a pertussis epidemic, with 11,000 cases and 3 infant deaths attributed to the disease [7]. Though considered a childhood disease, the incidence of pertussis among adults has increased steadily in the last decade, with a fifth of the U.S. cases reported in 2013 in persons >20 years old [8].

Infected adults represent an important group for transmission of pertussis to non-immune infants and children who are either too young to be vaccinated or have not received the vaccine for another reason [9-11]. Up to 55% of cases in infants have been attributed to adult family members [12]. Current ACIP recommendations include the administration of a single Tdap dose for all adults aged 19 and older. Pregnant women are recommended to receive a Tdap booster during the third trimester of every pregnancy in order to provide passive immunity to their newborns via maternal antibodies [13].

Despite the recognized risk for transmission from adults to infants and children, and current Advisory Committee on Immunization Practices (ACIP) recommendations for universal adult tetanus, diphtheria, acellular pertussis (Tdap) vaccination [13], pertussis vaccination coverage among adults is not adequate, with reported coverage of 14% in 2012 and 17% in 2013 [14, 15].

Tetanus is a serious disease that, in contrast to pertussis, has become rare in the United States because of effective vaccination. In 2013, 26 cases were reported in the United States [16]. Between 2001 and 2008, an average of 29 cases occurred every year, with a case-fatality of 13%. Of these cases, 90% occurred in adults ≥ 20 years of age. Inadequate vaccination status has been reported as the most important factor associated with tetanus occurrence. Of cases with known vaccination status, 40% had received no doses of tetanus vaccine [17]. In 2012, overall tetanus and diphtheria toxoids (Td) vaccination coverage among adults was estimated as 62%, a small increase compared with the 60% coverage reported in 1999 [18,19]. For non-pregnant adults, Td boosters without the pertussis component should be administered every 10 years, but only after the initial Tdap dose is administered.

Disparities in Td and Tdap vaccination coverage among race and ethnic minorities are well documented [14]. A recent publication also reported significant disparities in coverage for those vaccines among adult foreign-born individuals in the United States when compared to the U.S.-born population [19]. An estimated 41.3 million foreign-born individuals were living in the United States in 2013 (13% of the total population). With immigration projected to increase steadily over time, foreign-born individuals are expected to constitute 18% of the total U.S. population by 2050 [20-22].

In spite of its increasing effect on the size and racial/ethnic diversity of the country, there is little information on factors associated with vaccination among this population. An enhanced understanding of such factors has the potential to inform strategies for targeting and refining vaccine delivery and increasing immunization coverage.

1.1 RESEARCH QUESTIONS

We used data from the 2012 and 2013 National Health Interview Survey (NHIS) to study the effects of migration-related, access-to-care and other factors on Tdap and Td vaccination among foreign-born adults living in the United States and to answer the following questions:

- What are the factors associated with Td and Tdap immunization status among foreign-born persons living in the United States.?
- What is the role of socio-demographic variables, and particularly migration-related factors (region of birth, language spoken, years living in the United States and citizenship status), on the immunization coverage status?

1.2 HYPOTHESES

- Education level is a key determinant of Td and Tdap vaccination coverage among foreign-born people living in the United States, with higher education levels being associated with higher vaccination coverage.
- There are significant differences in vaccination coverage among persons from different regions of birth.
- Limited access to care in the United States (including lack of health insurance) is associated with lower vaccination coverage.
- Non-citizens, recent arrivals to the United States, and those interviewed in a language other than English have lower vaccination coverage.

Chapter 2. METHODS

2.1 STUDY DESIGN, SETTING AND POPULATION

The NHIS is an annual household cross-sectional survey conducted by the National Center for Health Statistics, CDC, which collects health information on the U.S. civilian, non-institutionalized population [23]. The survey is offered in English and Spanish. In the sample adult core, one adult per sampled family in each household was randomly selected to complete questions about vaccination history. The final response rate for the sample adult core was 61.2% in both 2012 and 2013 [23]. The NHIS has routinely collected Td/Tdap vaccination information since 2008 through a series of three questions.

Adult respondents are first asked, “Have you received a tetanus shot in the past 10 years?” If respondents answer “yes” to this question, they are asked, “Was your most recent tetanus shot given in 2005 or later?” Respondents who answer “yes” to this question are then asked, “Thinking back to your most recent tetanus shot, did your health care provider tell you or did the vaccine information sheet say the vaccine included the pertussis or whooping cough vaccine?” In this study, respondents who refused to answer or didn’t know their tetanus vaccination status within the preceding 10 years were excluded from both the Td and Tdap analysis. Respondents who answered “yes” to the first question but refused to answer or didn’t know if the most recent tetanus shot was given in 2005 or later and those who reported tetanus vaccination since 2005 but were not told vaccine type by the provider or did not know vaccine type were excluded from the Tdap analysis.

2.2 EXPOSURES, OUTCOMES, AND COVARIATES

The outcomes of interest were Tdap vaccination status defined as Tdap vaccine received at any time since 2005 and Td vaccination status defined as Td vaccine received in the previous 10 years. The exposures of interest included migration-related factors and health care access-related factors: duration of residence in the United States, U.S. citizenship status, language of interview,

country of birthplace, health insurance status, number of doctor visits in the past year and whether the respondent had a usual source of health care.

In order to preserve statistical reliability, countries of birth were grouped in five geographical regions for the analysis: Mexico/Central America/Caribbean Islands, South America, Europe, Asia, and Other. Covariates of interest included: age, sex, race/ethnicity, marital status, living with an infant aged < 1 year, education, employment status, poverty level, self-reported health status, and region of U.S. residence. Poverty status was defined using 2012 and 2013 poverty thresholds published by the U.S. Census Bureau with “below poverty” defined as a total family income of <\$23,492 or <\$23,834 for a family of four in 2012 and 2013, respectively [24].

2.3 STATISTICAL ANALYSIS

We used SUDAAN statistical software (Research Triangle Institute, Research Triangle Park, NC) to calculate weighted point estimates and 95% confidence intervals of vaccination coverage [25]. Multivariable logistic regression and predictive marginals were conducted to assess Td and Tdap vaccination in relation to variables listed above using prevalence ratios. Statistical significance was defined as $p < 0.05$. The NHIS was approved by Research Ethics Review Board (the ERB number is 2009-16) of the National Center for Health Statistics, CDC.

Chapter 3. RESULTS

The socio-demographic, health access, and migration-related characteristics of the study population are presented in Table 1. There were 13,154 foreign-born adults included in the analysis, with 51.3% females. The largest age subgroup was 18-49 years old, and Hispanics accounted for 49.5% of the population. The most frequent birthplace reported was Mexico/Central America/Caribbean, followed by Asia, Europe and South America.

The majority of subjects had been in the United States for at least 10 years (79.3%) and were U.S. citizens (53%). The interview was conducted in a language other than English for 30.7%. Most subjects were married, employed, and had at least a high school education. More than one-third had an associate degree or higher. Most also had a usual source of health care. More than two-thirds reported having visited a doctor at least once during the previous year.

Vaccination coverage rates for Td were notably and consistently higher than those for Tdap (Table 2). In bivariate analysis, coverage rates for both vaccines were significantly lower among Hispanics compared to non-Hispanic whites and among people living below poverty than among those living at or above poverty. Significantly lower coverage rates for both vaccines were also found among those interviewed in a language different than English than among those interviewed in English, and in those reporting being widowed, divorced, or separated compared with married people.

Having public insurance (e.g., Medicaid) and no insurance were each associated with significantly lower vaccination coverage for Tdap (6.0% with 95% confidence interval (CI) = 4.7%, 7.6%, for public insurance and 5.5% CI = 4.5%, 6.6% for no insurance) when compared with having private insurance (13.3% CI=12.1%, 14.6%). The same result was found for Td vaccination coverage (43.9% CI=41.3%, 46.6% for public insurance and 43.2% CI=41.3%, 45.1% for no insurance) when compared with having private insurance (56.9% CI=55.2%, 58.5%).

Table 1. Socio-demographic and health access characteristics of foreign-born adults ≥ 18 years of age. National Health Interview Survey (NHIS) 2012-2013 – United States

Characteristic	N	Weighted %
Total	13,154	100.0
Age		
18-49 years	8,193	64.0
50-64 years	2,835	22.9
65+ years	2,126	13.1
Sex		
Male	5,976	48.7
Female	7,178	51.3
Race/Ethnicity		
Non-Hispanic white	1,867	19.3
Non-Hispanic black	1,016	7.5
Hispanic	7,013	49.5
Non-Hispanic other	3,258	23.7
Marital status		
Married	6,963	62.6
Widowed/divorced/separated	2,807	14.1
Never married	3,351	23.3
Living with an infant aged <1 year		
Yes	575	4.9
No	12,579	95.1
Education		
Less than high school	4,097	28.2
High school graduate	2,782	22.2
Some college	1,610	12.8
Associate degree	1,014	8.0
Bachelor's degree or higher	3,526	28.8
Employment status		
Employed	8,115	64.1
Unemployed	791	6.0
Not in work force	4,239	29.9
Poverty level*		
At or above poverty	8,739	78.8
Below poverty	3,195	21.2
Health insurance		
Yes, Private	5,665	47.4
Yes, Public	3,233	21.0
Not insured	4,218	31.5
Number of doctor visits in past year		
0	3,943	30.1
1	2,357	19.1
2-3	2,943	23.5
4-9	2,503	18.5
10+	1,194	8.8
Usual source of care		
Yes	9,633	74.5
No	3,420	25.5

Characteristic	N	Weighted %
Self-reported health status		
Excellent/very good	7,378	58.8
Good	3,818	28.2
Fair	1,544	10.2
Poor	407	2.8
Duration of residence		
In U.S. < 5 yrs	1,162	8.4
In U.S. 5 to < 10 yrs	1,574	12.3
In U.S. ≥ 10 yrs	10,283	79.3
Citizenship		
U.S. citizen	6,698	53.0
Not U.S. citizen	6,392	47.0
Language of the interview		
English	8,673	69.3
Not English	4,481	30.7
Birthplace		
Mexico/Central America/Caribbean Islands	6,804	48.2
South America	827	6.2
Europe	1,235	12.5
Asia	3,160	23.2
Others	1,096	9.9
Region of U.S. residence		
Northeast	2,568	21.2
Midwest	1,402	11.2
South	4,254	32.6
West	4,930	34.9

*Poverty level as determined by Federal poverty guidelines

Vaccination coverage rates were significantly higher for both vaccines among adults who had at least some college education than for those persons with less than high school; higher education levels related with higher coverage for both vaccines. Those who had visited a doctor once in the previous year had higher coverage (10.2% CI=8.5%, 12.2% for Tdap and 53.5% CI=51.0%, 56.0% for Td) compared with those who had no visits (5.1% CI=4.3%, 6.2% for Tdap and 40.6% CI=38.5%, 42.6% for Td). There was a trend towards higher coverage rates with more doctor encounters (Table 2).

Those persons who had a usual source of health care had higher Tdap coverage (10.4%) and Td coverage (52.6 %) than did those without such a source (5.9% and 41.8% respectively). The association between birthplace and vaccination coverage was less clear, although those born in Mexico/Central America/Caribbean Islands had the lowest Tdap (6.4%) and Td (48%)

vaccination rates. Non-U.S. citizens had significantly lower vaccination rates for Tdap and Td compared to U.S. citizens. Persons residing in the U.S. for ≥ 10 years had significantly lower vaccination rates for Tdap, but not for Td when compared with more recent arrivals.

Table 2. Tetanus-diphtheria (Td) and tetanus, diphtheria and acellular pertussis (Tdap) vaccination coverage among of foreign-born adults ≥ 18 years of age by socio-demographic and health access characteristics. National Health Interview Survey (NHIS) 2012-2013 -- United States

	Tdap		Td	
	% (95% CI)	p-value	% (95% CI)	p-value
Total	9.1 (8.4-9.9)	--	49.8 (48.7-51.0)	--
Age				
18-49 years*	10.7 (9.7-11.7)	--	51.4 (49.9-52.8)	--
50-64 years	7.1 (5.9-8.7) †	0.00	49.6 (47.1-52.2)	0.24
65+ years	5.3 (3.7-7.4) †	0.00	42.5 (39.7-45.3) †	0.00
Sex				
Male*	8.0 (7.0-9.1)	--	50.1 (48.3-51.9)	--
Female	10.2 (9.3-11.3) †	0.00	49.6 (48.0-51.1)	0.66
Race/Ethnicity				
Non-Hispanic white*	10.5 (8.5-12.8)	--	54.7 (51.4-57.9)	--
Non-Hispanic black	11.7 (8.4-16.0)	0.60	50.1 (45.9-54.3)	0.07
Hispanic	6.5 (5.7-7.5) †	0.00	48.4 (46.7-50.2) †	0.00
Non-Hispanic other	12.6 (10.9-14.5)	0.16	48.6 (46.4-50.9) †	0.00
Marital status				
Married*	9.4 (8.5-10.5)	--	51.4 (49.9-52.8)	--
Widowed/divorced/separated	6.5 (5.3-8.0) †	0.00	45.3 (42.9-47.6) †	0.00
Never married	9.7 (8.2-11.4)	0.80	48.4 (46.0-50.7) †	0.03
Living with an infant aged <1 year				
Yes*	11.5 (8.4-15.7)	--	50.0 (45.3-54.6)	--
No	9.0 (8.3-9.8)	0.19	49.8 (48.6-51.1)	0.96
Education				
Less than high school*	4.8 (3.8-6.0)	--	45.2 (43.1-47.3)	--
High school graduate	6.1 (4.9-7.7)	0.14	43.6 (41.1-46.1)	0.32
Some college	9.2 (7.2-11.7) †	0.00	52.4 (48.9-55.8) †	0.00
Associate degree	13.6 (10.8-16.9) †	0.00	56.2 (52.5-59.9) †	0.00
Bachelor's degree or higher	14.7 (13.2-16.3) †	0.00	56.6 (54.3-58.9) †	0.00
Employment status				
Employed*	9.9 (9.0-10.8)	--	51.8 (50.4-53.2)	--
Unemployed	7.0 (4.9-10.0) †	0.04	46.7 (41.9-51.5) †	0.04
Not in work force	8.0 (6.9-9.4) †	0.02	46.2 (44.1-48.2) †	0.00
Poverty level				
At or above poverty *	10.7 (9.8-11.6)	--	52.6 (51.3-54.0)	--
Below poverty	5.6 (4.4-7.1) †	0.00	42.5 (40.1-45.0) †	0.00
Health insurance				
Yes, Private*	13.3 (12.1-14.6)	--	56.9 (55.2-58.5)	--
Yes, Public	6.0 (4.7-7.6) †	0.00	43.9 (41.3-46.6) †	0.00
Not insured	5.5 (4.5-6.6) †	0.00	43.2 (41.3-45.1) †	0.00

	Tdap		Td	
	% (95% CI)	p-value	% (95% CI)	p-value
Number of doctor visits in past year				
0*	5.1 (4.3-6.2)	--	40.6 (38.5-42.6)	--
1	10.2 (8.5-12.2) †	0.00	53.5 (51.0-56.0) †	0.00
2-3	10.6 (9.0-12.4) †	0.00	51.2 (48.9-53.5) †	0.00
4-9	11.5 (9.8-13.3) †	0.00	56.7 (54.4-59.0) †	0.00
10+	13.4 (10.7-16.5) †	0.00	56.1 (52.4-59.6) †	0.00
Usual source of care				
Yes*	10.4 (9.5-11.2)	--	52.6 (51.3-53.9)	--
No	5.9 (4.7-7.4) †	0.00	41.8 (39.5-44.2) †	0.00
Self-reported health status				
Excellent/very good*	10.7 (9.7-11.8)	--	51.2 (49.7-52.8)	--
Good	7.2 (6.1-8.5) †	0.00	48.1 (46.1-50.0) †	0.01
Fair	6.5 (4.8-8.7) †	0.00	48.3 (44.7-52.0)	0.14
Poor	4.9 (2.8-8.6) †	0.00	43.1 (36.4-50.1) †	0.02
Duration of residence				
In U.S. <5 yrs*	12.1 (9.1-16.0)	--	50.7 (46.7-54.7)	--
In U.S. 5 to <10 yrs	11.5 (9.0-14.4)	0.75	51.8 (48.3-55.3)	0.66
In U.S. ≥ 10 yrs	8.5 (7.7-9.3) †	0.04	49.4 (48.0-50.7)	0.55
Citizenship				
U.S. citizen*	10.2 (9.2-11.2)	--	51.9 (50.3-53.4)	--
Not U.S. citizen	8.0 (7.0-9.2) †	0.01	47.6 (45.8-49.3) †	0.00
Language of the interview				
English*	11.2 (10.3-12.2)	--	51.9 (50.5-53.4)	--
Not English	4.6 (3.7-5.7) †	0.00	45.1 (43.0-47.2) †	0.00
Birthplace				
Mexico/Central America/ Caribbean Islands*	6.4 (5.6-7.4)	--	48.0 (46.2-49.9)	--
South America	8.8 (6.3-12.2)	0.13	49.4 (45.3-53.5)	0.56
Europe	10.5 (8.1-13.4) †	0.00	55.1 (51.5-58.6) †	0.00
Asia	12.1 (10.4-14.0) †	0.00	49.1 (46.8-51.5)	0.51
Others	13.9 (10.7-17.7) †	0.00	54.4 (49.7-59.1) †	0.02
Region of U.S. residence				
Northeast*	7.0 (5.5-8.8)	--	45.4 (43.3-47.6)	--
Midwest	12.7 (10.2-15.7) †	0.00	53.4 (49.8-56.9) †	0.00
South	7.8 (6.7-9.0)	0.43	49.8 (47.9-51.8) †	0.00
West	10.5 (9.4-11.8) †	0.00	51.4 (49.2-53.5) †	0.00

* Reference level.

† p-value by t-test for comparisons for Tdap and Td within each level of each characteristic.

The results of multivariate logistic regression analysis are described in Table 3. Five factors remained significantly associated with vaccination status after controlling for all other variables. Age greater than 49 years was associated with lower coverage for both Tdap and Td. Having

public insurance (e.g., Medicaid) or no health insurance were also associated with lower vaccination rates for both vaccines when compared with having private insurance.

Having an associated degree, a bachelor degree or higher education was significantly associated with higher Tdap vaccination coverage and Td vaccination coverage. Having any visit with a doctor in the previous year was significantly associated with having received each vaccine for each grouping of visits, and there was a general trend towards increased prevalence with increasing number of visits. Migration-related characteristics (i.e., language of the interview, birthplace, citizenship status and duration of residence in the United States) were not associated with Tdap or Td vaccination after adjusting for all other variables in the model. Race/ethnicity, gender, having a usual source of health care and poverty status were also not associated with Tdap or Td vaccination after adjusting for all other variables.

Table 3. Multivariable logistic regression and prevalence ratios of foreign-born adults ≥ 18 years of age who reported Tetanus-diphtheria (Td) or tetanus, diphtheria and acellular pertussis (Tdap) vaccination, by socio-demographic and health access characteristics. National Health Interview Survey (NHIS) 2012-2013 -- United States

	Tdap		Td	
	Adjusted prevalence ratio (PR) (95% CI)	p-value	Adjusted prevalence ratio (PR) (95% CI)	p-value
Age				
18-49 years*	Referent	--	Referent	--
50-64 years	0.65 (0.52, 0.83) †	0.00	0.90 (0.84, 0.96) †	0.00
65+ years	0.54 (0.34, 0.84) †	0.00	0.80 (0.73, 0.88) †	0.00
Sex				
Male*	Referent	--	Referent	--
Female	1.15 (0.96, 1.38)	0.14	0.95 (0.90, 1.00)	0.07
Race/Ethnicity				
Non-Hispanic white*	Referent	--	Referent	--
Non-Hispanic black	1.34 (0.82, 2.21)	0.26	0.97 (0.85, 1.12)	0.70
Hispanic	1.23 (0.73, 2.08)	0.43	1.07 (0.93, 1.22)	0.33
Non-Hispanic other	1.74 (1.00, 3.01)	0.07	0.88 (0.74, 1.05)	0.16
Marital status				
Married*	Referent	--	Referent	--
Widowed/divorced/separated	0.91 (0.71, 1.16)	0.42	0.95 (0.89, 1.02)	0.14
Never married	1.19 (0.96, 1.47)	0.12	1.01 (0.95, 1.07)	0.72
Living with an infant aged <1 year				
Yes*	Referent	--	Referent	--
No	0.88 (0.63, 1.24)	0.49	0.99 (0.89, 1.10)	0.88

	Tdap		Td	
	Adjusted prevalence ratio (PR) (95% CI)	p-value	Adjusted prevalence ratio (PR) (95% CI)	p-value
Education				
Less than high school*	Referent	--	Referent	--
High school graduate	1.06 (0.77, 1.45)	0.73	0.94 (0.87, 1.01)	0.09
Some college	1.23 (0.84, 1.79)	0.29	1.06 (0.97, 1.16)	0.20
Associate degree	1.84 (1.28, 2.63) [†]	0.00	1.17 (1.07, 1.27) [†]	0.00
Bachelor's degree or higher	1.71 (1.23, 2.38) [†]	0.00	1.12 (1.03, 1.23) [†]	0.01
Employment status				
Employed*	Referent	--	Referent	--
Unemployed	0.76 (0.51, 1.12)	0.11	0.96 (0.86, 1.08)	0.51
Not in work force	0.96 (0.77, 1.20)	0.71	0.97 (0.91, 1.03)	0.30
Poverty level				
At or above poverty *	Referent	--	Referent	--
Below poverty	0.82 (0.63, 1.09)	0.14	0.92 (0.87, 0.99) [†]	0.02
Health insurance				
Yes, Private*	Referent	--	Referent	--
Yes, Public	0.67 (0.51, 0.88) [†]	0.00	0.85 (0.78, 0.92) [†]	0.00
Not insured	0.73 (0.54, 0.97) [†]	0.02	0.88 (0.82, 0.95) [†]	0.00
Number of doctor visits in past year				
0*	Referent	--	Referent	--
1	1.61 (1.20, 2.17) [†]	0.00	1.23 (1.14, 1.33) [†]	0.00
2-3	1.74 (1.31, 2.31) [†]	0.00	1.18 (1.09, 1.29) [†]	0.00
4-9	2.21 (1.67, 2.92) [†]	0.00	1.39 (1.28, 1.51) [†]	0.00
10+	2.74 (1.91, 3.94) [†]	0.00	1.40 (1.27, 1.55) [†]	0.00
Usual source of care				
Yes*	Referent	--	Referent	--
No	0.89 (0.66, 1.19)	0.40	0.88 (0.82, 0.95) [†]	0.00
Self-reported health status				
Excellent/very good*	Referent	--	Referent	--
Good	0.88 (0.72, 1.09)	0.23	0.97 (0.92, 1.02)	0.26
Fair	0.89 (0.63, 1.25)	0.46	1.00 (0.91, 1.09)	0.91
Poor	0.88 (0.48, 1.63)	0.67	0.97 (0.84, 1.12)	0.67
Duration of residence				
In U.S. <5 yrs*	Referent	--	Referent	--
In U.S. 5 to <10 yrs	1.06 (0.75, 1.50)	0.74	1.01 (0.91, 1.11)	0.87
In U.S. ≥ 10 yrs	0.73 (0.53, 1.00)	0.09	0.92 (0.84, 1.00)	0.07
Citizenship				
U.S. citizen*	Referent	--	Referent	--
Not U.S. citizen	0.93 (0.75, 1.16)	0.52	0.96 (0.91, 1.02)	0.17
Language of the interview				
English*	Referent	--	Referent	--
Not English	0.79 (0.59, 1.05)	0.08	1.00 (0.93, 1.07)	0.98

	Tdap		Td	
	Adjusted prevalence ratio (PR) (95% CI)	p-value	Adjusted prevalence ratio (PR) (95% CI)	p-value
Birthplace				
Mexico/Central America/ Caribbean Islands*	Referent	--	Referent	--
South America	0.99 (0.69, 1.43)	0.98	0.95 (0.86, 1.05)	0.28
Europe	1.02 (0.63, 1.64)	0.94	1.05 (0.92, 1.21)	0.48
Asia	0.67 (0.38, 1.18)	0.16	1.01 (0.84, 1.21)	0.91
Others	1.30 (0.86, 1.95)	0.22	1.09 (0.95, 1.23)	0.22
Region of U.S. residence				
Northeast*	Referent	--	Referent	--
Midwest	1.56 (1.14, 2.15) [†]	0.01	1.16 (1.07, 1.25) [†]	0.00
South	1.18 (0.90, 1.56)	0.22	1.09 (1.03, 1.16) [†]	0.00
West	1.64 (1.28, 2.10) [†]	0.00	1.12 (1.06, 1.20) [†]	0.00

* Reference level.

[†] p-value <0.05 by t-test within each variable with the indicated reference level.

Chapter 4. DISCUSSION

Attaining optimal vaccination coverage for adult populations continues to be a public health challenge in the United States. In general, coverage for recommended adult vaccines is persistently low among all adult U.S. populations [14,15]. In a previous study using NHIS data, Tdap and Td vaccination coverage were reported as suboptimal for both U.S. born (65% for Td and 15% for Tdap) and foreign-born (50% for Td and 9% for Tdap) adults living in the United States [19]. In that study, disparities in coverage for Tdap and Td vaccines among foreign-born individuals remained after adjusting for race/ethnicity, socio-economic status and access-to-care variables. In this study, we sought to assess the independent effects of migration-related and access-to-care factors that could explain differences in coverage among the foreign-born

Despite recommendations for Tdap since 2005 that included all adults up to age 64 years [13] and implementation of strategies targeting adults who have close contact with newborns (cocooning), coverage have been reported suboptimal even for adults in contact with young infants [14,15,26]. Recommendations for Tdap vaccination of pregnant women were added only in 2012 so they would have no impact on coverage described in this study, but could be important in future assessments. Cost, perception of low personal risk for pertussis, lack of knowledge about the communicability and severity of the disease, and lack of recommendation by health care workers have been associated with low pertussis vaccine uptake among adults in North America [26,27,28]. However, there is limited information on knowledge and attitudes about vaccines among the foreign-born subpopulation.

Pertussis vaccination worldwide is focused on children [29, 30]. For adults, besides the United States, only a few other countries have universal pertussis vaccine booster as part of their recommended vaccines schedules (e.g., Canada, France, and Finland). Most countries include in their recommendations tetanus vaccine booster every 10 years, and pertussis vaccine primarily as part of cocooning strategy, health workers, and high risk sub-populations [31].

In Mexico, the top country of origin for the foreign-born population, tetanus vaccine is included in the recommended schedule for women in fertile age, pregnant women, and men with

occupational risk. Public health professionals have suggested universal use of pertussis booster doses for adults in Mexico, but it has not been included as a national guideline [32, 33].

Given the low availability of pertussis vaccine for adults in the main countries of origin of the foreign-born it should be expected that most adult immigrants are unvaccinated upon arrival to the United States. One important exception would be all foreign-born applying for legal U.S. permanent residence who must receive at least the first dose of each age-appropriate vaccination series (unless medically contraindicated) or have documentation of prior vaccination [34]. These requirements provide an opportunity to reach considerable numbers of foreign-born adults.

We found younger adults to be more likely vaccinated for Td and Tdap than older adults. This finding is consistent with the overall coverage among adult population in the U.S. [14, 15] and has been reported also among other adult sub-populations such as health care providers and parents of young children and adolescents [26, 35]. Education was significantly associated with higher vaccination coverages. We found a trend showing greater vaccination rates at higher levels of education attainment. Associate degree holders were found to be on average 84% more likely to be vaccinated against pertussis and 17% more likely to be vaccinated against tetanus. This association between education and vaccination status might be related with vaccine and disease symptoms awareness.

A physician's or other health care worker's recommendation to their patient to receive a vaccine has been shown to be a powerful determinant for the receipt of several different vaccines among adults and children [26]. Given that such recommendations are provided inconsistently [27], higher educational attainment might result in an adult patient or a pediatric patient's parent being not only more knowledgeable about vaccines that are needed, but also more willing to ask the health care worker to order them. It is important to note that the relationship between education and vaccination status persisted even after adjusting for access to healthcare and socio-demographic factors. In the United States, higher education levels have been reported to be associated with greater coverage for different vaccines, including herpes zoster, pneumococcal vaccine, and pertussis [27, 36, 37]. A similar association has been observed among children in U.S. immigrant families, who are less likely to have insurance coverage, a regular source of care,

to have seen a doctor or dentist in the previous year, and to be in very good or excellent health, if their parents have less educational attainment [38, 39].

Individuals with either public health insurance or no insurance were less likely to be vaccinated for Td and Tdap when compared with individuals privately insured. In 2012, Singer et al reported Tdap vaccine as having the highest full coverage among adult vaccines in private insurance plans [40]. This could partially explain why privately insured individuals were more likely to be vaccinated. Reports of dissatisfaction among primary care physicians with payments for vaccine purchase and third party payers have been reported especially with public insurance [41]. Financial barriers, including lack of health insurance, have been reported previously as a cause for suboptimal vaccination coverage for young children's caregivers, pregnant women, Latino populations, and rural adults in the United States [42-45].

With the introduction of the Patient Protection and Affordable Care Act (ACA) in 2010, all new health insurance plans are required to include ACIP recommended vaccines for adults and children in their covered services, without charging any type of fee [46]. The effect of the ACA in the vaccination coverage among adults, and particularly among the foreign-born, has yet to be determined.

Any number of doctor visits in the past year was significantly associated with vaccination coverage, when compared with individuals who didn't have any visit. The higher the number of visits, the higher the likelihood to be vaccinated for both Td and Tdap vaccines.

It seems intuitive that more exposure to doctors and the health care system would result in a higher likelihood of receiving any type of preventive service, including vaccines.

At the same time, our results indicate that vaccination coverage remains suboptimal in this population even in the face of repeated health encounters, since vaccine coverage among those with 10 or more doctor contacts in the previous year were only 13.4% (95% CI, 10.7%, 16.5%) for Tdap and 56.1% (95% CI, 52.4%, 59.6%) for Td. This finding, along with the finding that public insurance and no insurance are both associated with lower vaccination coverage for Tdap

and Td, suggests that there may be substantial opportunities for vaccination that are being missed for public insurance holders.

In our bivariate analysis we found Hispanics less likely to be vaccinated for Tdap and Td when compared with other racial/ethnic subpopulations. Adjusting for other variables, this difference is no longer significant. The lack of significant association in the multivariate analysis between migration-related factors and Tdap and Td vaccination coverage, suggests that primarily access to care barriers, together with lower education level and poverty are important factors behind vaccination disparities among the foreign-born. Thus for the foreign-born, being a naturalized U.S citizens, being able to speak English well or having lived for decades in this country did not increase the likelihood of having received Tdap or Td vaccines.

Additional exploration of why opportunities for vaccination are being missed, especially for older, lower educated, low income, and those with public insurance foreign-born adults is needed. More information is also needed about vaccination-related knowledge and attitudes among this population. This information would allow interventions to be tightly focused on this population, but also might be applicable to native born persons as pertussis and tetanus are not diseases that exclusively affect immigrants and suboptimal vaccination is not limited to them either. This might include cultural and linguistically appropriate education about the value of vaccination, but also the use of novel approaches to vaccine delivery such as pharmacies, the utilization of newborn doctor visits to vaccinate family members and community health fairs.

We found individuals living in the Northeast region of the United States to be less likely to be vaccinated for Td and Tdap when compared with the other regions of the country. A higher number of immigrants without access to health care services in places like New York and other big cities in the East Coast could explain this finding.

The limitations of our study include the self-reported vaccination status, which can lead to recall bias, especially regarding the contents of the vaccine received. Tdap coverage rates could be then underestimated, although our estimated coverages rates are close to those reported in other industrialized countries such as Switzerland and France [47, 48]. Also, information on birthplace

was only available by world region and thus did not allow to examine differences on vaccination coverage by country of origin.

The findings from this study indicate that disparities in Tdap and Td vaccination coverage among the foreign-born are mainly associated with health care factors, and not with migration-related ones. Addressing such disparities requires thus enhanced access to care for the foreign-born and using all opportunities to educate and provide needed vaccinations when they do contact the health system. To eliminate racial/ethnic disparities in Tdap and Td vaccination coverage, immunization programs also need to implement cultural and linguistically appropriate strategies targeting the foreign-born. This is due to the increasing size of the foreign-born population and the fact that most belong to a racial/ethnic minority. Addressing foreign-born disparities will protect all communities in the United States and help achieve national vaccination goals.

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