Barriers to up-to-date pertussis immunization in Oregon children

By

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A THESIS

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Abstract

Background: Pertussis, or Whooping cough, is a highly contagious respiratory infection that can cause severe complications in infants and young children. Over half of infected infants under 1 year of age require hospitalization and many will develop apnea or pneumonia[7]. Vaccination is the most effective method to protect children and infants from pertussis. The Advisory Committee on Immunization Practices (ACIP) recommends four doses of pertussis-containing vaccines given at 2, 4, 6, and between 15 and 18 months of age[7]. The national Healthy People 2010 goals aimed for 90% coverage of two year olds up-to-date with recommended childhood vaccines, including pertussis-containing vaccines[24,29]. Unfortunately, Oregon did not meet this goal. *Methods:* Cross-sectional data from the 2007 to 2009 National Immunization Survey (NIS) was used to examine the relationship between sociodemographic factors and up-to-date pertussis immunization in 19-35 month old children in Oregon to identify factors that prevented coverage rates from meeting national goals. *Results:* Children who were up-to-date with pertussis immunizations were older, had fewer gaps in insurance coverage, had fewer siblings younger than 18 years old, were more likely to have their interview conducted in Spanish, and had more educated mothers. *Conclusions:* These results will help inform the development of targeted public health interventions to expand immunization coverage to meet national goals and protect infants and children from a potentially serious and deadly disease.

Specific Aims

In recent years the annual number of reported pertussis cases in children and infants younger than 6 months, the age group in which most pertussis-related deaths occur, has been increasing. In 2010 Oregon had 326 cases and in California there were 9,477 cases reported and ten infant deaths[7,9,24,25]. This increase in reported cases is cause for concern given that in 2009 only 83% of two year olds in Oregon were up to date on their pertussis immunizations (4 doses of pertussis-containing vaccines)[23].

The goal of this study was to identify factors that prevented Oregon from meeting the goal of 90% coverage for pertussis immunization set by Healthy People 2010 and to identify subgroups that had lower vaccination rates. Data for this secondary analysis were drawn from the 2007 to 2009 National Immunization Survey (NIS), a random-digit-dialing telephone-survey followed by a survey of vaccine providers targeting 19-35 month old children living in the United States at the time of interview[26].

This secondary analysis of NIS data had two specific aims:

1) Calculate summary descriptive statistics for children who were up-to-date with pertussis vaccinations (four doses) and children who were not up-to-date.
2) Identify statistically significant predictors of and barriers to up-to-date immunization with pertussis-containing vaccines in Oregon children.

Identifying barriers to pertussis vaccination will enable the development of targeted public health interventions to improve pertussis immunization coverage rates. Improving coverage rates will help us protect young children and infants from a potentially serious, and in some cases deadly, respiratory infection.

Background and Significance

Background

Pertussis, also known as Whooping cough, is a vaccine-preventable disease spread by droplet transmission that is specific to humans[5]. Early symptoms resemble the common cold, with most people developing paroxysms (coughing fits) one to two weeks after symptom onset. The paroxysmal stage can last for up to ten weeks and is followed by a two to three week convalescent period during which coughing fits may continue[7]. The disease gets its name from the characteristic “whoop” sound made while trying to force air into the lungs during a coughing fit. Pertussis infection is usually mild in adults and adolescents but can cause severe complications in infants younger than 1 year of age. Over half of infected infants require hospitalization and many develop apnea, pneumonia, or convulsions. The attack rate for pertussis ranges from 50% to 100% and studies indicate pertussis infection may be the cause of 17% of prolonged cough illness in adults[5]. Although deaths from pertussis are rare in the US, 90% of deaths occur in infants younger than 6 months of age[5].

The source of infant pertussis is often a parent or sibling. One study found that in infant cases with an identifiable source-case, 35% were caused by the mother, 15% by the father, and 20% by siblings[3]. Based on similar results from other studies, the CDC concludes that the best method for protecting infants from pertussis infection is to vaccinate siblings and adults in the household with a TDaP/Td booster and ensure young children are up-to-date with pertussis-containing immunizations. The Advisory Committee on Immunization Practices (ACIP) recommends four doses of pertussis-containing vaccine, with the first three doses given at 2, 4, and 6 months of age and the fourth dose given between 15 and 18 months of age. Due to waning immunity, a booster shot should be given when the child enters school at 4-6 years of age. Since the introduction of the pertussis vaccine in 1940 the number of annual reported cases dropped from an average of 175,000 reported cases per year in the pre-vaccine era to a low of 1000 cases in 1976[5]. However, since 1976 the number of reported cases has increased, with almost 26,000 cases reported nationally in 2004[5] and 17,000 reported in 2009[7]. These numbers are may be underestimates of the true burden of disease since pertussis is commonly misdiagnosed.

Significance

The national Healthy People 2010 goals aimed for 90% coverage of universally recommended childhood vaccines, including pertussis-containing vaccines. By 2009, Oregon had failed to meet this goal. In 2009, 83.3 ± 0.3% of two year olds had received four doses of DTaP, just below the national average of 85.4%[17]. The recent increase in the number of cases combined with low coverage rates provides the potential for an outbreak of pertussis in Oregon, putting young children at risk for serious complications and death. At this time it is important for public health organizations to develop interventions to expand immunization coverage. The purpose of this study is to help guide the development of those interventions.

Previous Studies

The data for this secondary analysis were drawn from the 2007 to 2009 National Immunization Survey (NIS), a nationally-representative, random-digit-dialing survey of 19-35 month old children living in the United States at time of interview. The NIS collects information on sociodemographic variables, vaccination history, and surveys vaccine providers to confirm immunization status. Previous research using NIS data identified gaps in insurance coverage[1,4,10,21], maternal marital status[1], insurance type[4,10,22], race/ethnicity[21,16], poverty[20,21] and access to care[21] as important predictors of immunization status in children.

Several studies found public health insurance was associated with children being up-to-date with recommended vaccinations[4,10,22] and indicate that private health insurance policies may no longer be the “gold standard” for access to vaccinations[4]. In the past, private health insurance was the standard against which other forms of insurance were compared because coverage was assumed to be better under a private insurance plan. However, recent changes in private health insurance such as increases in co-payments and deductibles, rising vaccine costs, reduction of benefits, and removal of dependent coverage may be producing barriers to immunization for children with private health insurance. In multiple studies, children who had gaps in insurance coverage consistently had lower vaccination rates than children with full-year private or public health insurance coverage [4,10,22].

Previous studies have shown mixed results for factors such as income level and race/ethnicity. Some studies found these variables to be statistically significant barriers to vaccination[1,21] while others found these factors to no longer be significant when included in a multivariate model[9]. These results can partially be explained by parental opinions about vaccine safety and opinions about their child’s risk of infection with vaccine-preventable diseases. In a study conducted in San Diego county[9] the gap in vaccination coverage normally seen between Hispanic and non-Hispanic populations was not observed. In fact, coverage rates for the 4:3:1:3:3:1 series (the series of recommended childhood vaccines: 4 DTaP, 3 Polio, 1 MMR, 3 *Haemophilus influenzae*, 3 Hep B, 1 Varicella) were lower for non-Hispanic white children than Hispanic children, a result that is traditionally reversed[9]. The authors suggested these results may be due to parental opinions on vaccine safety. Their conclusions are supported by a study conducted in Colorado that examined parental vaccine refusal rates and found the majority of parents who refused vaccines for their children were white and of a higher socioeconomic status[11]. In a review article, Omer et al also found that unvaccinated children were more likely to be white, belong to households with higher incomes, have married mothers with a college education and were intentionally unvaccinated by their parents [18]. That review article found that parents who refused vaccines thought their children had a low risk of infection with the disease (58%), the severity of the disease was low (51%), and the safety of the vaccines was low (60%)[18]. The most frequent reason for non-vaccination was found to be the parent’s concern that the vaccine would cause harm (69%)[18]. While it is beyond the scope of the current study to examine the effect that opinions about vaccine safety have on immunization rates in Oregon, results from previous studies are important to consider when examining barriers to vaccination given that some counties in Oregon have high non-medical exemption rates for required childhood immunizations.

Results from previous research vary from state to state and most studies identified different predictors and barriers to immunization in children. There is little research assessing the relationship between sociodemographic factors and immunization status in Oregon using NIS data. Given the low vaccination rates for pertussis-containing vaccines in Oregon, the increasing number of reported pertussis cases, and the recent pertussis epidemic in California, such an analysis would be informative in developing targeted public health interventions to expand immunization coverage.

Methods

Overview

The purpose of this study was to identify important factors that prevented Oregon from meeting the Healthy People 2010 goal of vaccinating 90% of two-year olds with pertussis-containing vaccines. Data were drawn from the 2007 to 2009 National Immunization Survey (NIS), a random-digit-dialing telephone-survey followed by a survey of vaccine providers targeting 19-35 month old children living in the United States at the time of interview[26]. The NIS began collecting data in 1994 to monitor childhood immunization coverage and is conducted jointly by the National Center for Immunizations and Respiratory Diseases (NCIRD) and the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention[26].

NIS Study Population

The NIS target population is children aged 19 to 35 months living in the United States at the time of interview. Households with age-eligible children were selected through a random-digit-dialing telephone survey. Data on the child's vaccination history were gathered through interviews with the adult most knowledgeable about the child's vaccination status and, if parental consent was given, the child's health care provider(s) were contacted by mail to request confirmatory immunization records.

NIS Selection Criteria and Sample Design: Household Interview and Provider Survey

Telephone numbers were drawn independently during each calendar quarter within set geographic strata consisting of urban city/county areas, entire state or "rest of state" areas[26]. Beginning in 2007, state immunization programs could select city/county areas of particular interest to be oversampled. The 2007 survey included 56 geographic strata[27]. The 2008 survey consisted of 67 geographic strata: 11 city/county areas specifically selected to be oversampled, 50 state or "rest of state" areas, and 6 grantee urban areas (areas receiving federal Section 317 immunization grants)[26]. The 2009 survey included 64 estimation areas: 56 geographic strata, 7 specific city/county areas, and the US Virgin Islands[28]. The sampling area for Oregon was the same across all years included in the current study, though different telephone numbers were sampled each year. Telephone numbers from the defined geographic strata were identified through a four step process[26]:

1. Statistical models predicted the number of sample telephone numbers needed in each geographic stratum to meet precision requirements.
2. The samples from each geographic stratum were divided into sub-samples so these sub-samples could be spread evenly across the entire calendar quarter.
3. An automated procedure eliminated a portion of non-working and non-residential telephone numbers from the samples before interviews were conducted.
4. The sample telephone numbers were matched against a national database of residential phone numbers to obtain mailing addresses.

If a phone number was identified as a residential phone number a letter was sent to the corresponding mailing address approximately two weeks prior to the household phone interview in an attempt to increase participation[26]. Table 1 gives the results of the random-digit-dialing telephone survey from 2007 to 2009.

Table 1: Results of Random-Digit-Dialing Telephone Survey from 2007 to 2009[26,27,28]

	2007		2008		2009	
Key Indicator	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Total selected telephone numbers	4,539,367		5,710,803		6,310,629	
Phone numbers released for interviewing	2,551,732	56.22%	3,216,959	56.33%	3,376,031	53.49%
Advance letters mailed	1,469,436	57.6%	1,760,771	54.7%	1,579,190	46.8%
Households identified	974,586		1,108,491		1,114,670	
Households successfully screened for presence of age-eligible children	879,207	90.2%	1,000,840	90.3%	1,030,376	92.4%
Households with no age-eligible children	851,400	96.8%	971,162	97.0%	1,001,463	97.2%
Households with age-eligible children	27,807	3.16%	29,678	2.97%	28,913	2.81%
Households with age-eligible children with completed household interview	24,133	86.8%	25,257	85.1%	24,068	83.2%
Age-eligible children with completed household interviews	24,807		25,948		24,809	
Children with adequate provider data	18,430 (includes 151 unvaccinated children)	71.0%	17,017 (includes 128 unvaccinated children)	68.6%	17,053 (includes 172 unvaccinated children)	68.7%

For the provider survey, a request was made for consent to contact the child's health care provider(s) at the end of the household phone interview[26]. When oral consent was obtained from the parents a questionnaire was mailed to the child's vaccine provider(s). If no reply was received after two weeks, a reminder letter was sent to the provider. If after five weeks a reply had still not been received a second questionnaire was mailed[26]. At seven weeks with no response, a telephone call was made to the provider(s) to remind and encourage them to fill out the questionnaire or to offer to fill out the questionnaire over the phone.

A complete description of the sample design can be found in the 2007 to 2009 NIS Public-Use Data File User's Guides at: http://www.cdc.gov/nchs/nis/data_files.htm#09dug

NIS Inclusion and Exclusion Criteria

Eligible children were 19-35 months of age (for example, in 2009 eligible children were born between January 2006 and July 2008) and lived in the United States at the time of the household telephone interview[26]. A child was considered to have adequate provider data if either the vaccination history obtained from the provider(s) was sufficient to determine if the child was up-to-date with the recommended vaccination schedule set by ACIP, or the child was unvaccinated. Unvaccinated children were defined as those who were reported during the household interview to have received no vaccinations and had no immunization provider(s), or those for whom the child's provider(s) reported administering no vaccinations. A lack of adequate provider data was defined as the provider(s) not having medical records for the child or consent to contact provider(s) was not given. A child was ineligible if they were outside of the age range (younger than 19 months or older than 35 months) or if the child did not have a completed household interview. A completed household interview is defined as having answered up to Section C of the questionnaire. In 2009 there were 25,241 respondents of which 17,313 (68.5%) had adequate provider data[28]. In 2008 there were 25,948 respondents from all 50 states and the District of Columbia, of which 18,430 (71.03%) had adequate provider data[26]. In 2007 there were 24,807 respondents of which 17,017 (68.59%) had adequate provider data[27].

Secondary Analysis Selection Criteria

For this secondary analysis, children who lived in Oregon at the time of interview from 2007 to 2009 and had adequate provider data were selected for inclusion in this study. Parental reports of vaccination status, whether from memory recall or shot cards, were not used in this analysis. Children without adequate provider data were excluded for three reasons: 1) using medical records to confirm immunization status eliminates the potential for recall bias; 2) the exact number of doses of pertussis-containing vaccines received is an important outcome variable in this study; and 3) to get the most accurate immunization history available.

Data Collection: Phone interview and Provider Survey

The household phone interview was conducted using a computer-assisted telephone interview (CATI) questionnaire consisting of two sections[26]. First, a screener identified households with children ages 19 to 35 months and explained the purpose of the survey. The second section consisted of the interview. Before the interview was conducted the respondent was asked if he/she was the most knowledgeable person about the child's vaccination history[26]. If that person was unavailable, a callback date and time was scheduled. The questionnaire was translated into

Spanish and several other languages using Language Line Services. Information about the child's vaccination history was obtained from shot cards or memory recall[26]. Sociodemographic information was obtained from all respondents who completed the first portion of the interview pertaining to the child's vaccination history. The questionnaire given to providers requested the child's name, date of birth, gender, and contained a shot grid and a list of websites that could be visited to obtain more information about the NIS[26].

Data Collection: Variables

For a complete list of variables included in the NIS see the 2007, 2008 and 2009 NIS User's Guide for Public-Use Data Files at: http://www.cdc.gov/nchs/nis/data_files.htm#09dug.

The data from the household interview and the provider survey were weighted to account for screener non-response, interview non-response, non-resolution of telephone numbers, multiple telephones, households without a landline, and provider non-response.

Variables Included in Secondary Analysis

Table 2: Variables from NIS Included in Secondary Analysis

Variable Name	Variable Label	Response Categories
AGEGRP	age category of child	19-23 months, 24-29 months, 30-35 months
RACEETHK	race/ethnicity of child	Hispanic, White (non-Hispanic), Black (non-Hispanic), All other races and multi-racial (non-Hispanic)
RACE_K	Race of child	White only, Black only, Other/multiple races
I_HISP_K	Hispanic origin of child	Hispanic, Non-Hispanic
LANGUAGE	Language in which the interview was conducted	English, Spanish, Other
SEX	gender of child	Male, Female
EDUC1	education of mother	<12 yrs, 12 yrs, >12 yrs (not a college graduate), College graduate
MARITAL2	marital status of mother	Widowed/divorced/separated/deceased/never married, currently married
M_AGEGRP	age category of mother	≤29 yrs, ≥30 yrs
FRSTBRN	first born status of child	No, Yes
INCQ298A	Family income level in 2006	$0-20000, $20001-40000, $40001-60000, $60001-75000+, Don't Know/Refused
INS_1	insurance through employer or union	Yes, No, Missing
INS_2	Medicaid coverage	Yes, No, Missing
INS_3	S-CHIP coverage	Yes, No, Missing
INS_4_5	covered by Indian Health Service, Military health care, TRICARE, CHAMPUS, CHAMP-VA	Yes, No, Missing

INS_6	Any other health insurance or health care plan	Yes, No, Missing
INS_11	Anytime when the child was not covered by health insurance	Yes, No, Missing
SEQNUMC	Unique child identifier	(number)
SEQNUMHH	Unique household identifier	(number)
STATE	State FIPS code	41 (Oregon)
CWIC_01	Child ever participated in WIC	Yes, No
CWIC_02	Child currently participating in WIC	Yes, No, Missing
P_UTDTP3	UTD for 3+ DT-containing shots from provider info	UTD, Not UTD
P_UTDTP4	UTD for 4+ DT-containing shots from provider info	UTD, Not UTD
PDAT	Child has adequate provider information	Yes, No
PROV_FAC	Provider facility type	All public facilities, all hospital facilities, all private facilities, all military/other/mixed facilities, unknown
D6R	Number of vaccination providers identified	0, 1, 2, 3+
N_PRVR	Number of providers responding with vaccination data for child	0, 1 or more
RDDWT RDDWTNEW	Household-phase weight	(value)
PROVWT PROVWTNEW	Provider-phase weight	(value)

Statistical Analysis

The specific aims of the current study were to: (1) calculate summary descriptive statistics for children up-to-date with pertussis-containing vaccines and children who were not up-to-date; and (2) identify statistically significant predictors of and barriers to complete immunization with pertussis-containing vaccines using logistic regression. Data from the 2007 to 2009 NIS were combined to obtain larger sample sizes than were available for Oregon from any single year. Statistical analysis was carried out using SAS v.9.2 to handle the complex sampling design and weighting methods used in the NIS. Additional analysis was also conducted in Excel 2010 and STATA 11. The NIS recommended method for combining multiple years of data was utilized.

To achieve the first specific aim sociodemographic summary statistics were calculated for two different comparison groups: first, children who had adequate provider information or were unvaccinated were compared to children who did not have adequate provider information, and second, children up-to-date with pertussis-containing vaccinations (four doses) were compared to children not up-to-date (three doses or less) with pertussis-containing vaccinations. Wald chi-square tests were used to test for a relationship between sociodemographic factors and the outcome variable (up-to-date pertussis immunization) and to identify which factors varied significantly between the two groups (up-to-date and not up-to-date). The Wald chi-square test in PROC SURVEYFREQ tests for independence of row and column variables based on the difference between the observed and expected weighted cell frequencies and takes into account the weighting and complex survey design.

To analyze the age effect noted during the sociodemographic analysis of up-to-date and not up-to-date children, the mean age at each shot for both up-to-date and not up-to-date children were compared using the General Linear Models procedure for repeated measures ANOVA. Winsorized means were used to reduce the effect from outliers by truncating outliers to the 95th percentile.

To achieve the second specific aim I generated a multivariate regression model using up-to-date pertussis vaccination status (four doses vs. three or less doses) as the outcome to examine the magnitude of the effect of sociodemographic factors identified from the first specific aim. Univariate analysis was used to analyze the relationship between pertussis-containing vaccinations and various independent sociodemographic variables. Variables with a significance level of $p<0.25$ from univariate analysis were entered into a multivariate logistic regression model. A higher cut-off point of 0.25 was used to prevent variables from being removed from the model prematurely. Variables with a significance level of $p<0.05$ in multivariate analysis were kept in the final model. Finally, stepwise variable selection was used to ensure the most parsimonious model was selected. These steps produced crude and adjusted odds ratios and 95% confidence intervals for each independent variable tested. Comparing the crude and adjusted odds ratios for a difference of at least 10% identified no confounding variables. There are no known interaction terms to include in this analysis. Collinearity of variables was assessed using estimated correlation matrixes to identify any unnecessary variables to remove from the final model and ensure the best fit. Weighting was accounted for in the regression model building process.

Quality Control and Data Management

Data from the household interview were entered electronically at time of interview using the CATI system, which allowed interviewers to reconcile errors while the respondent was on the phone. Data from the provider's survey were entered manually with quality assurance checks performed after entry. Specifics on data editing and cleaning can be found at: http://www.cdc.gov/nchs/nhis.htm. Quality assurance checks were conducted after the provider survey was received to ensure the provider filled out the questionnaire for the correct child. Data from the provider's survey were independently re-entered for verification[26]. A complete description of data cleaning and editing can be found in the 2008 NIS User's Guide (http://www.cdc.gov/nchs/nis/data_files.htm).

After obtaining the 2007 to 2009 data sets from the NIS website, the data were cleaned to remove unnecessary variables; new weight and identification variables were generated to enable merging of three years of data; and some variables were merged or categories were collapsed to make variables uniform across the three data sets. After this the three data sets were merged and data for Oregon only was extracted. Six observations were dropped from this final data set because there were too few observations in certain categories to be useful in analysis. Variables were re-coded into numerical categories to make regression analysis easier. There were four observations categorized as not having adequate provider information that had one provider respond to the survey. These children had no immunizations listed so the providers identified in the household interview most likely had no medical records for these four children. Since these four observations do not appear to be misclassified they were left in the "does not have adequate provider information" category. The final data set consisted of 1006 observations and 55 variables.

Human Subject Protections

Informed consent was obtained from each participant before the interview was conducted and before the child's vaccination provider(s) was contacted. Any information collected by the NIS was done so confidentially and can only be used for research[26]. To prevent participant identification composite variables were created, certain items from the interview were not included in the public-use data files, and variables were re-coded or had their categories collapsed.

Results

Comparison of the summary statistics for children with adequate provider information (n=752) and children without adequate provider information (n=254) identified only one variable that was statistically significantly different between the two groups: the number of children less than 18 years of age in the household (p=0.0231). Households with a child who did not have adequate provider information tended to have fewer children under 18 years of age than households whose child was up-to-date. Insurance variables could not be compared between the two groups due to the large numbers of missing observations from children without adequate provider information (see Appendix B1). For the variables that could be compared the two groups differed only in regards to the number of children in the household less than 18 years of age, indicating the results from the analysis of children with adequate provider information can be generalized to children without adequate provider information, though conclusions regarding insurance status should be interpreted with caution.

The demographic summary statistics of children who are up-to-date with pertussis immunizations (n=627) versus children who are not up-to-date (n=125) identified six statistically significant differences ($p<0.05$) between the two groups. Children who were up-to-date tended to be older, had fewer siblings less than 18 years old in the household, a smaller proportion had ever received WIC benefits, they came from more educated households, had fewer gaps in insurance coverage, and were more likely to have their interview conducted in Spanish. While these were the only statistically significant differences between the two groups, all variables analyzed were carried over into univariate analysis because of their potential as confounders.

Table 3: Summary demographic statistics for Oregon children aged 19-35 months who are up-to-date (4 shots) with pertussis vaccinations versus children who are not up-to-date (3 shots or less) with pertussis vaccinations for the years 2007-2009. Data are drawn only from children with adequate provider data (n=752; counts are un-weighted, proportions are weighted).

Characteristic (Variable)	Up-To-Date (4 shots) pertussis immunization (UTD) N (%)	Not Up-To-Date (≤ 3 shots) pertussis immunization (NOT UTD) N (%)	p-Value[1]
Age group: 19-23 months	159 (25.94)	61 (48.14)	
24-29 months	231 (34.69)	36 (32.21)	<0.0001
30-35 months	237 (39.37)	28 (19.65)	
Number of children less than 18 years old in the household:			
1	150 (23.16)	14 (11.09)	0.0029
2 or 3	401 (63.54)	82 (62.78)	
4+	76 (13.30)	29 (26.14)	
Child ever received WIC benefits: Yes	253 (52.50)	64 (63.74)	0.0491
No	374 (47.49)	61 (36.26)	
Child currently receiving WIC benefits: Yes	178 (36.70)	34 (36.32)	0.0596
No	75 (15.80)	30 (27.42)	
Missing	374 (47.49)	61 (36.26)	
Education level of the mother:			
<12 years	78 (21.72)	16 (20.11)	0.0203
12 years	92 (26.72)	33 (44.65)	
>12 years, non-college grad	171 (19.98)	33 (15.25)	
College grad	286 (31.58)	43 (19.98)	
First born status of child:			
Yes	294 (46.27)	44 (39.23)	0.2310
No	333 (53.73)	81 (60.77)	
Hispanic origin of child:			
Hispanic	130 (25.84)	22 (18.00)	0.0825
Non-Hispanic	497 (74.17)	103 (81.99)	
Family income:			
$0-20,000	99 (22.14)	22 (29.99)	
$20,001-40,000	121 (21.42)	27 (20.48)	0.2941
$40,001-60,000	107 (17.96)	32 (21.59)	
$60,001-75,000+	275 (34.20)	40 (24.60)	
Don't Know/Refused	25 (04.55)	4 (03.33)	
Language in which the interview was conducted:			0.0057
English	539 (81.25)	113 (88.95)	
Spanish	82 (17.22)	8 (07.08)	
Other	6 (01.53)	4 (03.97)	
Maternal age group: 20-29 yrs	208 (42.64)	46 (46.60)	
≥30yrs	419 (57.36)	79 (53.39)	0.5116
Marital status of mother:			
Married	524 (79.62)	104 (76.65)	
Never married/ widowed/divorced/ separated/deceased	103 (20.38)	21 (23.35)	0.5805

[1] Obtained from Wald Chi-Square tests.

Race of child: White only Black only Other + Multiple Race	539 (83.85) 12 (02.24) 76 (13.91)	110 (88.14) 2 (02.12) 13 (09.74)	0.4853
Race/ethnicity of child: Hispanic Non-Hispanic White only Non-Hispanic Black only Non-Hisp other /multi Race	 130 (25.83) 425 (60.94) 9 (01.68) 63 (11.55)	 22 (18.00) 89 (70.87) 2 (02.12) 12 (09.00)	0.2654
Sex of child: Male Female	 336 (51.52) 291 (48.48)	 62 (51.36) 63 (48.64)	0.9777
Number of vaccination providers identified by respondent:* 1 2 *Frequency missing: 37	 437 (71.88) 161 (28.12)	 79 (62.56) 38 (37.44)	0.1304
Consent to obtain child's immunization records for providers: Yes	627	125	--
Number of providers responding with vaccination data for the child: 0 or 1 2 *Frequency missing: 15	 511 (81.59) 101 (18.41)	 109 (83.15) 16 (16.85)	0.7491
Provider facility type: All public facilities All hospital facilities All private facilities Military/other/mixed Unknown	 62 (12.35) 45 (06.29) 407 (59.96) 86 (15.54) 27 (05.85)	 20 (16.89) 12 (10.19) 63 (46.15) 16 (15.49) 14 (11.27)	0.1737
Child covered by union or employer provided health insurance: Yes No Missing	 392 (55.19) 229 (43.86) 6 (00.94)	 66 (43.98) 57 (54.20) 2 (01.82)	0.1591
Child covered by any Medicaid plan: Yes No Missing	163 (33.94) 459 (64.96) 5 (01.11)	30 (36.33) 93 (61.85) 2 (01.82)	0.8046
Child covered by S-CHIP: Yes No Missing	 26 (06.17) 572 (87.51) 29 (06.32)	 5 (08.58) 113 (83.61) 7 (07.82)	0.7266
Child covered by IHS, Military health care, Tricare, CHAMPUS, CHAMP-VA: Yes No Missing	 12 (01.89) 605 (96.27) 10 (01.84)	 2 (01.24) 121 (96.94) 2 (01.82)	0.8352
Child covered by any other health insurance or health care			

plan: Yes	67 (09.03)	15 (12.29)	0.5583
No	555 (90.09)	108 (85.89)	
Missing	5 (00.87)	2 (01.82)	
Any time when the child was not covered by health insurance:			0.0029
Yes	54 (09.14)	15 (15.00)	
No	533 (82.37)	85 (62.37)	
Missing	40 (08.48)	25 (22.63)	
Total number of children	627 (80.09)	125 (19.91)	

Univariate analysis identified age group, number of children less than 18 years of age in the household, child had ever received WIC benefits, child currently receiving WIC benefits, education of the mother, first born status of the child, Hispanic origin of the child, language in which the interview was conducted, number of vaccine providers identified, provider facility type, health insurance through employer or union, and gaps in insurance coverage as being significant at the $p \leq 0.25$ level (see Appendix B2). Despite not being statistically significant, all other variables were carried over into the multivariate model because of their potential as confounders indicated by previous studies.

Analysis of confounding using age group as the main predictor identified two possible confounders (defined as a change of ≥10% between the crude and adjusted odds ratio): the number of children less than 18 years of age in the household and gaps in insurance coverage. No other variables led to a substantial (≥10%) change in the adjusted odds ratio of the main predictor. Given results from previous studies all variables were carried through to multivariate analysis (see Appendix B3).

Stepwise variable selection generated the following final model:

Table 4: Final model. Includes the age group of child at time of interview, any time when the child was not covered by health insurance, the number of children less than 18 years of age in the household, the language in which the survey was conducted and the education of the mother.

Variable	Estimate	Standard error	OR	95% CI	p-value
Age group					
24 to 29 mo	0.89	0.29	2.43	1.39, 4.26	<0.0001
30 to 35 mo	1.55	0.35	4.69	2.38, 9.27	
Gaps in insurance					
Yes	-1.23	0.39	0.29	0.14, 0.64	0.0003
Missing	-1.16	0.37	0.31	0.15, 0.65	
Child <18 yrs old					
2 or 3	-1.04	0.39	0.35	0.16, 0.76	0.0005
4 or more	-1.82	0.47	0.16	0.07, 0.41	

Interview language					
Spanish	1.52	0.52	4.58	1.66, 12.6	0.0078
Other	-0.79	0.89	0.46	0.08, 2.65	
Maternal education					
12yrs	-0.40	0.42	0.67	0.29, 1.53	
>12 yrs, no college	0.49	0.42	1.62	0.71, 3.71	0.0207
College grad	0.45	0.44	1.56	0.67, 3.67	

Assessment of collinearity did not identify any collinear variables in the final model.

Given the age affect indicated by the demographic summary (statistical significance of the age group variable) and the continued significance of the age group variable in the final model, further analysis of the age difference between the two groups (up-to-date and not up-to-date) was conducted by analyzing the distribution of the ages at which each of the four vaccinations were received. Five children (4.03%) in the not up-to-date group were found to have provider-reported ages at fourth shot. These five children were moved into the up-to-date group for the age group analysis. Moving these children did not substantially change the results of the age group analysis and the misclassification error is small enough that it is unlikely to have had any major effects on previous analysis. The following tables provide summary statistics of the age distribution at each shot for the two groups. The NIS provided up to nine spots for reporting pertussis vaccinations in the provider survey. The observations seen in the columns beyond shot 4 are most likely children who were over-immunized due to confusion over their immunization status at the time of contact with the provider.

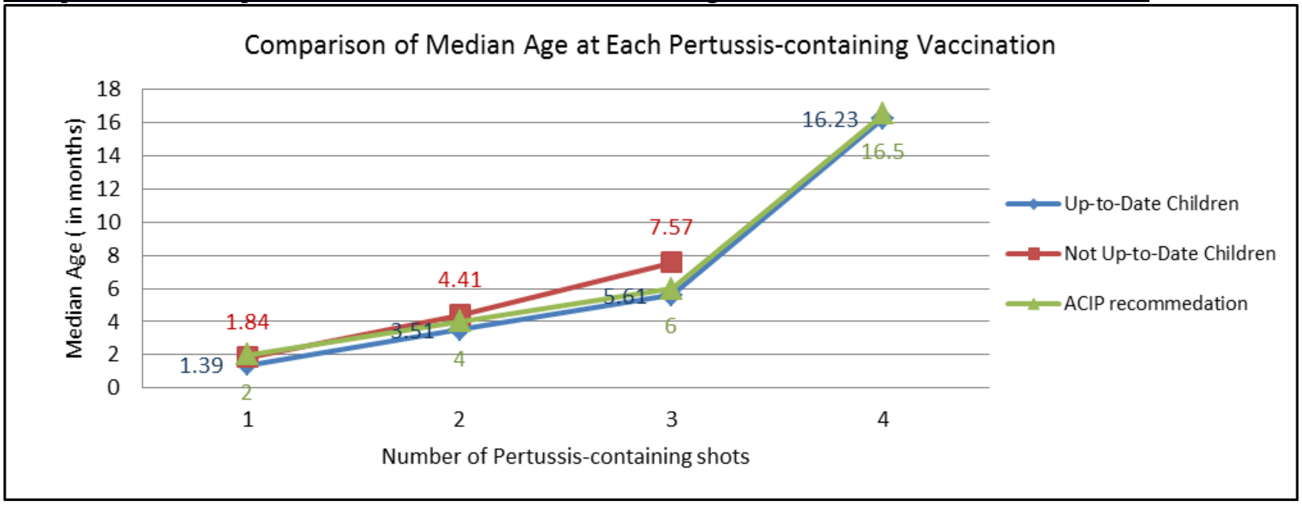
Table 5: Age distribution by shot number for up-to-date children including the 5 children who had an age at fourth shot listed but were categorized as not-up-to-date (weighted data reported).

	Shot Number						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Age ± s.e. (in months)	1.97±0.07	4.19±0.08	6.56±0.09	16.79±0.15			
Median	1.39	3.51	5.61	16.23			
ACIP recommended age	2	4	6	15-18			
Range	1-18	2-22	3-23	6-35	10-25	12-15	13
n	632	632	632	632	10	2	1
n missing	0	0	0	0	622	630	631

Table 6: Age distribution by shot number for not up-to-date children who have adequate provider information without the 5 children who had an age at fourth shot listed but were categorized as not up-to-date (weighted data reported).

	Shot Number				
	1	**2**	**3**	**4**	**5**
Age ± s.e. (in months)	4.57±0.78	8.31±0.98	12.89±1.31		
Median	1.84	4.41	7.57		
ACIP recommended age	2	4	6	15-18	
Range	1-27	3-31	6-37		
n	99	90	81	0	0
n missing	20	29	38	119	119

Figure 1: Comparison of the median age at receipt of each pertussis-containing vaccine for children who are up-to-date, not up-to-date and the ACIP recommended age for administration of each vaccine.



The medians for up-to-date children were close to the ACIP recommended ages for receipt of each pertussis-containing vaccination, while the median ages for not up-to-date children were slightly older than the ACIP recommended age (see Figure 1 above).

Comparison of the mean ages (not weighted) at receipt of each shot found the mean ages for up-to-date children and not up-to-date children differed significantly from each other for all three pertussis-containing vaccines (mean ages were not compared to the ACIP recommended age). The data in table 7 indicate the groups are different with regards to the age at which children receive their pertussis immunizations, with not up-to-date children receiving immunizations at an older age than up-to-date children.

Table 7: Comparison of mean age (in months) at each pertussis-containing vaccine for up-to-date children and not up-to-date children (no comparison was possible for age at fourth shot since not up-to-date children did not receive a fourth vaccine; means are not weighted).

Shot number	Overall Mean	Least Squares Mean	Overall F-value	p-value
1 (dtp1_age)	2.184		107.19	<0.0001
UTD		1.902		
Not UTD		3.886		
2 (dtp2_age)	4.528		153.40	<0.0001
UTD		4.115		
Not UTD		7.256		
3 (dtp3_age)	7.051		226.04	<0.0001
UTD		6.435		
Not UTD		11.545		

See Appendix B4 and B5 for graphs depicting the distribution of age at each pertussis-containing vaccine for up-to-date and not up-to-date children.

Discussion

The results from the initial sociodemographic analysis indicate children who do not have adequate provider data come from households with fewer children less than 18 years of age in the household, but were similar to children with adequate provider information with regards to the other variables examined. Comparison of the insurance variables between these two groups was not possible due to the large number of households that did not respond (had a response of 'missing') to the insurance questions. Overall, results from the analysis of children who have adequate provider information can be generalized to children without adequate provider information because there were no significant differences between the variables for which comparison was possible. However, conclusions regarding the effect of insurance status on vaccination status should be interpreted with caution since the results for these variables may not be generalizable to the entire population due to the number of missing responses from the children without adequate provider information (see Appendix B1).

The sociodemographic analysis of children who are up-to-date and those who are not up-to-date concluded that children who are up-to-date with the recommended pertussis immunizations are older, had fewer siblings less than 18 years old in the household, a smaller proportion had ever received WIC benefits, they came from more educated households, had fewer gaps in insurance coverage, and were more likely to have their interview conducted in Spanish. When these sociodemographic variables were carried over into multivariate analysis, the final model identified the age group of child at time of interview, any time when the child was not covered by health insurance, the number of children less than 18 years of age in the household, the language in which the survey was conducted and the education level of the mother as significant predictors of a child being up-to-date with pertussis-containing immunizations.

Age group of child at time of interview

An age effect was seen when comparing up-to-date and not up-to-date children. Children who were 24-29 months of age were 2.43 (95% CI: 1.39-4.26) times more likely to be up-to-date than children who were 19-23 months of age, and children who were 30-35 months of age were 4.69 (95% CI: 2.38, 9.27) times more likely to be up-to-date than children who were 19-23 months of age. This result was expected and is frequently seen in vaccine studies. Further analysis of this age effect found that the median age of receipt of pertussis-containing vaccinations were close to the ACIP recommended age in the up-to-date group, but the not up-to-date group received their immunizations at a slightly older age (see tables 5 and 6). Comparison of the means found that the mean age at receipt of each pertussis-containing vaccine differed significantly between the up-to-date and not up-to-date groups (see table 7).

The range of ages for each shot was wide for both groups, and overall the children who were not up-to-date tended to receive their immunizations after the ACIP recommended age while children who were up-to-date received their shots close to the ACIP recommended age (see table 5 and 6). Results from analysis using means should be interpreted with caution due to the large age ranges for each vaccination (see Appendix B4 and B5). Even after truncating outliers to the 95^{th} percentile the not up-to-date mean ages were still significantly higher than the mean ages for up-to-date children. However, the effect of outliers on these results should not be ignored. Medians are a more robust and stable measure of when children are receiving their vaccinations, but no non-parametric statistical test for comparing weighted medians from survey data was known to the author, so no comparison test was conducted.

Gaps in insurance coverage

Children who had experienced gaps in insurance coverage were 70.7% less likely (OR: 0.293, 95% CI: 0.135, 0.636) to be up-to-date than children who had not experienced gaps in insurance coverage. While this result cannot be generalized to the entire population due to missing information from the children who do not have adequate provider information, it can be concluded that among children with adequate provider information gaps in insurance coverage significantly decrease the likelihood that a child will be up-to-date with pertussis immunizations. This association has been seen in several other studies[4,10,22].

Number of children less than 18 years old in the household

As the number of children less than 18 years old in the household increased the less likely a child was to be up-to-date with pertussis-containing immunizations (OR: 0.352, 95% CI: 0.163, 0.761 for households with 2 or 3 children less than 18 years old; OR: 0.162, 95% CI: 0.065, 0.406 for households with 4 or more children less than 18 years old). This makes sense given the increased cost of vaccinating multiple children, and the added burden of finding child care for the other children to enable the parent to take their younger child to the doctor for immunizations.

Language in which the interview was conducted

Children whose household interview was conducted in Spanish were 4.58 (95% CI: 1.66, 12.63) times more likely to be up-to-date with pertussis-containing vaccinations than children who had their household interview conducted in English. Children whose household interview was conducted in a language other than English or Spanish were about 55% less likely to be up-to-date with pertussis-containing vaccines than children who had their interview conducted in English (OR: 0.46, 95% CI: 0.08, 2.65). This reversal of the traditional gap between Hispanic and non-Hispanic populations has also been seen in California[9] and Colorado[11]. It can be explained in part by the high non-medical vaccination exemption rates in Oregon and refusal by some parents to vaccinate their children due to anxiety about the safety and efficacy of vaccines.

Education level of the mother

Education level of the mother had mixed results. It was expected that as education level of the mother increased the odds of a child being up-to-date would also increase. However, children whose mothers had 12 years of schooling were less likely (OR: 0.67, 95% CI: 0.29, 1.53) to be up-to-date than children whose mothers had received less than 12 years of schooling, and while any education beyond high school increased the likelihood that the child would be up-to-date with pertussis vaccines (OR: 1.62, 95% CI: 0.71, 3.71 for >12 years, non-college graduates; OR: 1.56, 95% CI: 0.66, 3.67 for college graduates) the increase was not consistent. Some studies[11,18] have found that children whose mothers are more educated are increasingly being unvaccinated, potentially due to fears about vaccine safety. The non-linear results seen in the current study could be an indicator that this phenomenon is occurring in Oregon as well. Overall, however, it appears that children who are up-to-date have mothers who are more educated than mothers of children who are not up-to-date.

Strengths and Limitations

There are a few limitations to using this data set to assess the specific aims of the current study. The most important of these is the lack of data on county of residence. Coverage levels for childhood vaccinations differ greatly from county to county in Oregon (see Appendix A). Without knowing the distribution of households in the various counties it is difficult to discern if the data are representative of children from all counties and it is impossible to identify which counties are underrepresented. For example, the coverage rate for four doses of DTaP in two year olds in Multnomah County in 2008 was 85.9% ± 0.8% while in Lane County it was 76.3% ± 1.4%[23]. If Lane County was not sampled equally with Multnomah County then these results cannot be generalized to children in both counties. Secondly, there are no data on parental refusal rates, use of Dr. Bob's schedules, or opinions concerning vaccine safety. These factors all play a significant role in a parent's decision to vaccinate their child[9,11,13,18]. For example, if a parent refuses a specific vaccine for fear of adverse events (say, MMR or DTaP) but does not refuse other vaccines, the available data in the NIS will not reflect that decision making process and thus will not identify an important barrier to immunization with specific vaccines.

Despite these limitations, the study has several strengths. The NIS covered a wide range of known confounders and important predictor variables that influence vaccination status. Detailed information was collected on the number of doses of each vaccine, the type of provider that administered the vaccine, the type of insurance coverage the child had, the type of vaccine that was administered (combination or monovalent), maternal education, poverty level, poverty ratio, age of child (in months), race/ethnicity and other demographic factors. A large portion of respondents (68.5% in 2009[28], 71.0% in 2008[26], 68.6% in 2007[27]) had adequate provider information to confirm the immunization history obtained from the household interview. The data from the household interview and the provider survey were weighted to account for screener non-response, interview non-response, non-resolution of telephone numbers, multiple telephones, households without a landline, and provider non-response. This weighting adjusts the data to accurately reflect coverage rates in the general population and makes results generalizable to all two year old children in Oregon and makes point estimates more conservative. Finally, this study is one of the first of its kind done in Oregon and its results are important for developing interventions to expand vaccination coverage in Oregon.

Future Studies

An avenue for future research that would further shed light on the issue of vaccine coverage rates in Oregon would be to obtain data on opinions about vaccines, the occurrence of adverse events, the utilization of Dr. Bob schedules, and parent refusal rates and link that data with a data set like the NIS to analyze the magnitude of the effect these factors have on immunization rates. This would be an especially important study in Oregon given the variation in coverage rates from county to county (see Appendix A). Studies indicate parental opinions on vaccine safety and adverse events associated with immunizations play an important role in their decision to vaccinate their child[9,11,13,18]. Many parents have not experienced vaccine-preventable diseases and are not knowledgeable about the risks associated with diseases like pertussis, so the risk of adverse events outweighs the perceived risk to their children from vaccine-preventable diseases. Some parents refuse vaccines because they believe the risk from the vaccine is greater than the risk of being infected with the disease itself. These beliefs are one reason areas like Lane county consistently have some of the highest vaccine exemptions rates in the country and are among the counties with the lowest coverage rates in Oregon (see Appendix A). By quantifying the effect these decisions have on vaccination rates, we can better understand why Oregon is not meeting national goals for immunization coverage. It does not appear that a study linking a data set like the NIS to a data set detailing opinions on vaccine safety in Oregon has been done. Addressing issues such as vaccine refusal by parents and opinions about vaccine safety could significantly improve vaccine coverage rates in Oregon and the US.

Another avenue for research is examining the utilization of alternative vaccination locations[15], such as workplaces and retail clinics, to identify who is using them and if they are a viable option for reaching populations who do not interact with the traditional health care system either because they choose not to or because it is inaccessible to them. Studies such as this could identify interventions that would expand immunization coverage to populations that current interventions are missing. Finally, further research examining the effect that vaccinating adults and adolescents has on preventing pertussis infection in infants should be conducted to explore this as a method for protecting young children who have not yet completed the pertussis immunization series[12]. Since immunity wanes over time, boosters will reduce pertussis infection in adult and adolescent populations, which will in turn reduce infant pertussis cases since parents and siblings are the primary source of infection in infants[3].

Recommendations

Based on the results of this study I have the following recommendations for future interventions to address current barriers to up-to-date pertussis immunization.

First, the ACIP recommended immunization schedule should be better communicated to parents and physicians. By giving parents a schedule to take home at the birth of their child and by continuing to offer copies of the schedule at each vaccination visit we can keep parents informed of when recommended childhood immunizations should be received. Many parents aren't familiar with the complicated immunization schedule set by ACIP[14]. Clearer communication of the ACIP immunization schedule would help reduce missed immunization opportunities by keeping parents aware of when their child should be receiving each vaccine. Physicians and non-physician staff should also be supported so they can stay up to date with the current immunization schedule. One study in California found that some physician and non-physician staff felt they did not have sufficient knowledge about the vaccine schedule or contraindications for vaccination[14]. Keeping medical personnel informed will enable them to keep parents informed as well.

Second, better communication is needed between parents and physicians regarding vaccine safety and efficacy. Physicians are critical in the flow of information about vaccines to parents[14]. They are frequently the source from which misinformation can be replaced with facts about vaccines. If parents feel that their physician listens to their questions and is willing to discuss their concerns they may be more likely to vaccinate their child than if they feel they cannot make an informed decision because they lack critical information about vaccines[14].

Third, increasing awareness among parents and physicians of the symptoms of pertussis would help reduce misdiagnosis of pertussis and help prevent young children from being exposed by parents and siblings. Pertussis has no known animal vector or reservoir, so if we can improve diagnosis and increase the number of people receiving treatment for pertussis we could reduce the transmission of pertussis from parents to their young children. This is especially important for parents whose children are not old enough to have completed the pertussis series.

Fourth, improving the recall and reminder system used by ALERT (Oregon's immunization reporting system) could help reduce missed opportunities and reduce the number of children who are overdue for vaccines by keeping kids on schedule[14,19]. With the increased use of electronic health records during office visits we could also set up a reminder system that would place a message on the computer screen during a physician encounter with a patient. This system could inform physicians of the child's overdue vaccines and vaccines that should be received in the near future and prompt physicians to initiate that conversation with parents. By keeping parents and physicians up-to-date with the child's immunization status we could prevent over-immunization and reduce missed opportunities to vaccinate during office visits.

Conclusions

Pertussis, or Whooping Cough, is a highly contagious respiratory infection that can cause severe complications in infants and young children; over half of infected infants under 1 year of age require hospitalization and many will develop apnea or pneumonia[7]. Immunization with pertussis-containing vaccines has proven to be the most effective method of protection for young children and infants from pertussis infection. While Oregon has not meet national goals for immunization coverage, the results of this study have helped to identify factors that prevented Oregon from meeting those goals and have identified areas for future interventions.

The current study found that children who were older, had fewer siblings younger than 18 years old in the household, had fewer gaps in insurance coverage, had their interview conducted in Spanish, and had more educated mothers were more likely to be up-to-date with pertussis immunizations. Some traditional barriers, such as gaps in insurance coverage, were found in Oregon children and some newer trends, such as the reversal of the gap between Hispanic and non-Hispanic children and a reduction in vaccinations in more educated households, were also found. Identifying these barriers to pertussis immunization will enable the development of targeted public health interventions in Oregon and help public health agencies to expand immunization coverage to meet national goals and protect infants and children from a potentially serious and deadly disease.

References

1. Allred NJ, Wooten KG, Kong Y. The association of health insurance and continuous primary care in the medical home on vaccination coverage for 19- to 35-month-old children. *Pediatrics*. 2007;119(1). doi:10.1542/peds.2006-2089C.
2. American Academy of Pediatrics. Committee on Practice and Ambulatory Medicine and Council on Community Pediatrics. Policy statement: increasing immunization coverage. *Pediatrics*. 2010;125(6):1295-1303.
3. Bisgard KM, Pascual FB, Ehresmann KR, Miller CA, Cianfrini C, Jennings CE, Rebmann CA, Gabel J, Schauer SL, Lett SM. Infant pertussis: who was the source? *The Pediatric Infectious Disease Journal*. 2004;23(11):985-989
4. Blewett LA, Davidson G, Bramlett MD, Rodin H, Messonnier ML. The impact of gaps in health insurance coverage on immunization status for young children. *HSR: Health Services Research.* 2008;43(5):1619-1633.
5. Brooks DA, Clover RC. Pertussis infection in the United States: role for vaccination of adolescents and adults. *J Am Board Fam Med*. 2006;19:603-611.
6. Brown KF, Kroll JS, Hudson MJ, Ramsay M, Green J, Long S, Vincent CA, Fraser G, Sevdalis N. Factors underlying parental decisions about combination childhood vaccinations including MMR: a systematic review. *Vaccine.* 2010; 28: 4235-4248.
7. Centers for Disease Control and Prevention. National Center for Immunization and Respiratory Diseases. Division of Bacterial Diseases. Pertussis (Whopping Cough). http://www.cdc.gov/pertussis/index.html. Updated August 26, 2010. Accessed November 26, 2010.
8. Centers for Disease Control and Prevention. *Morbidity and Mortality Weekly Report*. 2011; 59(52): 1704-1717.

http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5952md.htm?s_cid=mm5952md_w. Accessed June 3, 2011.

9. Davila JC, Wang W, Gustafson KW, Smith PJ. The San Diego immunization survey: a model for local vaccination coverage assessment. *Public Health Reports*. 2008;123:39-44.
10. Ghosh TS, Patnaik JL, Bennett A, Trefren L, Vogt RL. Assessment of missing immunizations and immunization-related barriers among WIC populations at the local level. *Public Health Reports*. 2007;122:602-606.
11. Glanz JM, McClure DL, Magid DJ, Daley MF, France EK, Salmon DA, Hambidge SJ. Parental refusal of pertussis vaccination is associated with an increased risk of pertussis infection in children. *Pediatrics*. 2009;123:1446-1451.
12. Halperin SA. The control of pertussis: 2007 and beyond. *The New England Journal of Medicine*. 2007;356(2):110-113.
13. Heininger U. An internet-based survey of parental attitudes towards immunization. *Vaccine*. 2006;24:6351-6355.
14. Kimmel SR, Burns IT, Wolfe RM, Zimmerman RK. Addressing immunization barriers, benefits, and risks. *The Journal of Family Practice*. 2007; 56(2): 61-69.
15. Lee BY, Mehrotra A, Burns RM, Harris KM. Alternative vaccination locations: who uses them and can they increase flu vaccination rates? *Vaccine*. 2009;27(32):4252-4256. doi:10.1916/j.vaccine.2009.04.055.
16. McElliott JT, Darden PM. Are patient-held vaccination records associated with improved vaccination coverage rates? *Pediatrics*. 2010;125(3). dio:10.1542/peds.2009-0835.
17. National Committee for Quality Assurance. The State of Health Care Quality. Reform, The Quality Agenda and Resource Use. 2010. http://www.ncqa.org/portals/0/state%20of%20health%20care/2010/sohc%202010%20-%20full2.pdf . Accessed June 2, 2011.
18. Omer SB, Salmon DA, Orenstein WA, deHart P, Halsey N. Vaccine refusal, mandatory immunization, and the risks of vaccine-preventable diseases. *New England Journal of Medicine*. 2009;360:1981-8.
19. Poehling KA, Fairbrother G, Zhu Y, Donauer S, Ambrose S, Edwards KM, Staat MA, Prill MM, Finelli L, Allred NJ, Bardenheier B, Szilagyi PG. Practice and child characteristics associated with influenza vaccine uptake in young children. *Pediatrics*. 2010; 126: 665-673.
20. Smith PJ, Jain N, Stevenson J, Männikkö N, Molinari NA. Progress in timely vaccination coverage among children living in low-income households. *Arch Pediatr Adolesc Med*. 2009;163(5):462-468.
21. Smith PJ, Singleton JA. Vaccination coverage estimates for selected counties: achievement of Healthy People 2010 goals and association with indices of access to care, economic conditions, and demographic composition. *Public Health Reports*. 2008;123:155-171.
22. Smith PJ, Stevenson J, Chu SY. Associations between childhood vaccination coverage, insurance type, and breaks in health insurance coverage. *Pediatrics*. 2006;117(6):1972-1978.
23. State of Oregon. Immunization Program. Research and Evaluation. http://www.oregon.gov/DHS/ph/imm/Research/index.shtml. Accessed November 12, 2010.

24. State of Oregon. Acute and Communicable Disease Prevention Program. Office of Disease Prevention and Epidemiology. Selected Reportable Communicable Disease Summary: 2007 State of Oregon. http://www.oregon.gov/DHS/ph/acd/arpt/arpt07/index.shtml. Accessed November 26, 2010.
25. State of Oregon. Immunization Program. Whooping Cough: An Oregon family's story. 2010. http://www.oregon.gov/DHS/ph/imm/docs/PertussisStory.pdf. Updated August 13, 2010. Accessed November 26, 2010.
26. US Department of Health and Human Services. National Center for Health Statistics. The 2008 National Immunization Survey. Hyattsville, MD: Centers for Disease Control and Prevention, 2009. http://www.cdc.gov/nis/datafiles.htm. Accessed November 26, 2010.
27. US Department of Health and Human Services. National Center for Health Statistics. The 2007 National Immunization Survey. Hyattsville, MD: Centers for Disease Control and Prevention, 2008. http://www.cdc.gov/nis/datafiles.htm. Accessed November 26, 2010.
28. US Department of Health and Human Services. National Center for Health Statistics. The 2009 National Immunization Survey. Hyattsville, MD: Centers for Disease Control and Prevention, 2010. http://www.cdc.gov/nchs/nis/data_files.htm#09dug. Accessed December 20, 2010.
29. US Department of Health and Human Services. Office of Disease Prevention and Health Promotion. Healthy People 2010. http://www.healthypeople.gov/default.htm. Accessed November 26, 2010.

Appendix A: Comparison of pertussis infections rates and immunization coverage rates in Oregon by county in 2007

County	Population (2007)[2]	Coverage rates for 4 doses of DTaP in 2 yr olds (2007) (%±95%CI)[3]	# of Pertussis cases (2007)[4]	Rate per 100,000 people*1 yr (2007)[5]
(Statewide)	3,745,455	80.7±0.4	124	3.31
Baker	16,435	92.7±4.2	0	0.00
Benton	86,300	75.1±3.2	1	1.16
Clackamas	372,270	81.0±1.2	4	1.07
Clatsop	37,440	76.5±4.1	0	0.00
Columbia	47,565	81.2 ±3.6	0	0.00
Coos	63,050	77.1±3.4	0	0.00
Crook	25,885	77.1±5.7	0	0.00
Curry	21,475	75.1±7.7	0	0.00
Deschutes	160,810	85.6±1.6	1	0.62
Douglas	104,675	72.1±2.8	1	0.96
Gilliam	1,885	82.8±4.4	0	0.00
Grant	7,580	No info	0	0.00
Harney	7,680	78.1±9.7	8	104.2
Hood River	21,470	86.2±4.0	0	0.00
Jackson	202,310	80.9±1.6	5	2.47
Jefferson	22,030	85.3±3.7	0	0.00
Josephine	82,390	82.8±2.7	0	0.00
Klamath	65,815	84.3±2.5	0	0.00
Lake	7,565	92.6±6.3	0	0.00
Lane	343,140	74.3±1.5	13	3.79
Lincoln	44,630	80.7±3.8	4	8.96
Linn	109,320	74.9±2.3	14	12.8
Malheur	31,620	78.9±3.7	0	0.00
Marion	311,070	80.0±1.2	5	1.61
Morrow	12,335	76.7±6.9	0	0.00
Multnomah	710,025	82.6±0.8	21	2.96
Polk	67,505	77.1±2.6	2	2.96
Sherman	1,855	82.8±4.4	0	0.00
Tillamook	25,485	84.0±4.5	0	0.00
Umatilla	72,245	81.0±2.4	0	0.00
Union	25,250	64.9±5.4	22	87.3
Wallowa	7,130	80.1±9.6	0	0.00
Wasco	24,125	82.8±4.4	0	0.00
Washington	511,075	83.2±0.8	18	3.52
Wheeler	1,570	No info	0	0.00
Yamhill	93,085	81.0±2.3	5	5.37

[2] Proehl RS. 2007 Oregon Population Report. Population Research Center, College of Urban and Public Affairs, Portland State University. March 2008. http://www.pdx.edu/sites/www.pdx.edu/prc/files/media_assets/PRC_2007_Population_Report2_rev.pdf

[3] Oregon Department of Human Services, Immunization Program: Research and Evaluation. Oregon Population-based rates. http://www.oregon.gov/DHS/ph/imm/Research/index.shtml

[4] Oregon Department of Human Services, Acute and Communicable Disease Prevention. Case counts by county of residence. Selected reportable communicable disease summary: 2007 State of Oregon. www.oregon.gov/DHS/ph/acd/arpt/arpt07/index.shtml

[5] Calculation: $\left(\frac{\text{number of pertussis cases in 2007}}{\text{county population in 2007}}\right) * 100{,}000$

Appendix B

<u>**B1:** Summary demographic statistics for Oregon children aged 19-35 months who have adequate provider information versus children who do not have adequate provider information for the years 2007-2009 (proportions are weighted, counts are not weighted).</u>

	Has Adequate Provider Information	Does Not Have Adequate Provider Information	
Characteristic (Variable)	**N (%)**	**N (%)**	**P-Value**
Age group (AGEGRP)			
19-23 months	220 (30.35)	72 (29.20)	
24-29 months	267 (34.20)	100 (36.43)	0.8657
30-35 months	265 (35.44)	82 (34.38)	
Number of children less than 18 years of age in household (CHILDNM)			
1	164 (20.76)	87 (30.85)	0.0231
2 or 3	483 (63.39)	138 (54.61)	
4+	105 (15.86)	29 (14.54)	
Child ever received WIC benefits (CWIC_01)			
Yes	317 (54.74)	100 (49.91)	0.2581
No	435 (45.26)	154 (50.09)	
Child currently receiving WIC benefits (CWIC_02)			
Yes	212 (36.63)	72 (36.82)	0.2748
No	105 (18.11)	28 (13.09)	
Missing	435 (45.26)	154 (50.09)	
Education of mother (EDUC1)			
<12 years	94 (21.40)	28 (18.38)	
12 years	125 (30.29)	45 (32.54)	0.6253
>12 years, non-college grad	204 (19.04)	73 (21.77)	
College grad	329 (29.27)	108 (27.31)	
First born status of child (FRSTBRN)			
Yes	338 (44.87)	131 (47.79)	0.4961
No	414 (55.13)	123 (52.20)	
Hispanic origin of child (I_HISP_K)			
Hispanic	152 (24.28)	53 (23.91)	0.9181
Non-Hispanic	600 (75.72)	201 (76.09)	
Family income (INCQ298A)			
$0-20,000	121 (23.71)	46 (24.14)	
$20,001-40,000	148 (21.23)	41 (18.19)	0.2235
$40,001-60,000	139 (18.47)	52 (19.22)	
$60,001-75,000+	315 (32.29)	91 (29.19)	
Don’t Know/Refused	29 (4.303)	24 (9.261)	
Language in which the interview was conducted			

(LANGUAGE)			
English	652 (82.79)	220 (81.52)	0.5543
Spanish	90 (15.20)	28 (13.99)	
Other	10 (2.011)	6 (4.485)	
Maternal age group (M_AGEGRP)			
≤ 29 yrs	254 (43.43)	93 (43.54)	0.9803
≥ 30yrs	498 (56.57)	161 (56.46)	
Marital status of mother (MARITAL2)			
Married	628 (79.03)	201 (71.37)	0.0691
Never married/ widowed/divorced/ separated/deceased	124 (20.97)	53 (28.63)	
Race of child (RACE_K)			
White only	649 (84.71)	214 (81.19)	0.3816
Black only	14 (02.22)	8 (05.81)	
Other + Multiple Race	89 (13.08)	32 (12.99)	
Race/ethnicity of child (RACEETHK)			
Hispanic	152 (24.28)	53 (23.91)	
Non-Hispanic White only	514 (62.92)	166 (59.28)	0.5145
Non-Hispanic Black only	11 (01.76)	7 (05.59)	
Non-Hispanic other + Multiple Race	75 (11.05)	28 (11.22)	
Gender of child (SEX)			
Male	398 (51.49)	130 (50.42)	0.8055
Female	354 (48.51)	124 (49.58)	
Number of vaccination providers identified by respondent (D6R)*			
1	516 (70.05)	164 (75.91)	0.1656
2	199 (29.95)	49 (24.09)	
*Frequency missing: 78			
Consent to obtain child's immunization records from providers (D7)			
Yes	752 (100.0)	83 (39.58)	--
No	0	5 (01.38)	
Missing	0	166 (59.04)	
Number of providers responding with vaccination data for child (N_PRVR)*			
0	8 (01.27)[6]	250 (98.90)	<0.0001
1 or more	729 (98.73)	4 (01.09)	
*Frequency missing: 15			
Provider facility type (PROV_FAC)			

[6] These 8 children were reported as having zero vaccinations and are considered by the NIS to have adequate provider information.

All public facilities	82 (13.25)	1 (00.31)	--
All hospital facilities	57 (07.07)	0	
All private facilities	470 (57.21)	0	
Military/other/mixed	102 (15.54)	3 (00.78)	
Unknown/missing	41 (06.93)	250 (98.91)	
Child covered by health insurance provided through employer or union?(INS_1)			--
Yes	458 (52.96)	62 (21.41)	
No	286 (45.92)	40 (23.03)	
Missing	8 (01.12)	152 (55.57)	
Child covered by any Medicaid plan (INS_2)			
Yes	193 (34.41)	26 (16.86)	--
No	552 (64.34)	74 (26.62)	
Missing	7 (01.25)	154 (56.52)	
Child covered by S-CHIP (INS_3)			
Yes	31 (06.65)	9 (05.39)	--
No	685 (86.74)	91 (36.55)	
Missing	36 (06.62)	154 (58.06)	
Child covered by IHS, Military health care, Tricare, CHAMPUS, or CHAMP-VA (INS_4_5)			--
Yes	14 (01.77)	4 (02.29)	
No	726 (96.40)	99 (42.36)	
Missing	12 (01.84)	151 (55.35)	
Child covered by any other health insurance or health care plan (INS_6)			
Yes	82 (09.68)	8 (02.63)	--
No	663 (89.26)	95 (42.03)	
Missing	7 (01.06)	151 (55.35)	
Any time when the child was not covered by any health insurance (INS_11)			
Yes	69 (10.31)	10 (04.13)	--
No	618 (78.39)	84 (36.25)	
Missing	65 (11.29)	160 (59.62)	
Total number of children (PDAT)	752 (75.41)	254 (24.59)	

* Children whose parent/guardian did not give permission to contact their vaccine providers (variable D7) were not asked questions about the child's insurance status. Statistical analysis of these variables does not make sense due to the large number of observations that will be missing for those without adequate provider information.

B2: Summary table of the univariate analysis of all variables from the demographic summary. Data are drawn only from children with adequate provider data (n=752). Significant results are variables with a p-value of <0.25.

Variable	Estimate	Std error	OR	95% CI	P value
AGEGRP					
24 to 29 mo	0.6929	0.2834	1.999	1.147, 3.485	<0.0001
30 to 35 mo	1.3137	0.3026	3.720	2.056, 6.732	
CHILDNM					
2 or 3	-0.0125	0.1720	0.484	0.238, 0.988	0.0033
4+	0.6998	0.2127	0.244	0.106, 0.559	
CWIC_01	-0.2319	0.1167	0.629	0.398, 0.994	0.0469
CWIC_02					
Yes	0.5616	0.3356	1.753	0.908, 3.385	0.0300
Missing	0.8212	0.3102	2.273	1.238, 4.175	
EDUC1					
12 yrs	-0.5906	0.3701	0.554	0.268, 1.144	0.0051
>12, no college	0.1930	0.3585	1.213	0.601, 2.449	
College grad	0.3801	0.3438	1.462	0.745, 2.869	
FRSTBRN	0.2882	0.2452	1.334	0.825, 2.157	0.2400
I_HISP_K	0.4615	0.2853	1.586	0.907, 2.775	0.1058
INCQ298A					
$20,001-40,000	0.3479	0.3710	1.416	0.684, 2.930	
$40,001-60,000	0.1039	0.3545	1.110	0.554, 2.223	0.2813
$60,001-75,000+	0.6328	0.3251	1.883	0.996, 3.561	
Don’t Know/Rfsd	0.6153	0.6363	1.850	0.532, 6.440	
LANGUAGE					
Spanish	0.9794	0.4112	2.663	1.189, 5.961	0.0249
Other	-0.8659	0.7349	0.421	0.100, 1.776	
M_AGEGRP	0.1603	0.2414	1.174	0.731, 1.884	0.5066
MARTIAL2	0.1740	0.3031	1.190	0.657, 2.156	0.5660
RACE_K					
Black only	0.1066	0.8643	1.112	0.204, 6.053	0.5397
Other/multi race	0.4058	0.3661	1.501	0.732, 3.075	
RACEETHK					
Non-Hisp Black	-0.0845	0.8934	0.919	0.160, 5.294	
Hispanic	0.5122	0.2913	1.669	0.943, 2.954	0.3003
Non-Hisp other/multi race	0.4006	0.3922	1.493	0.692, 3.220	
SEX	-0.00664	0.2375	0.993	0.624, 1.582	0.9777
D6R* *Missing 37 obs.	-0.4252	0.2629	0.654	0.390, 1.094	0.1058
N_PRVR	0.1075	0.3456	1.114	0.566, 2.192	0.7557

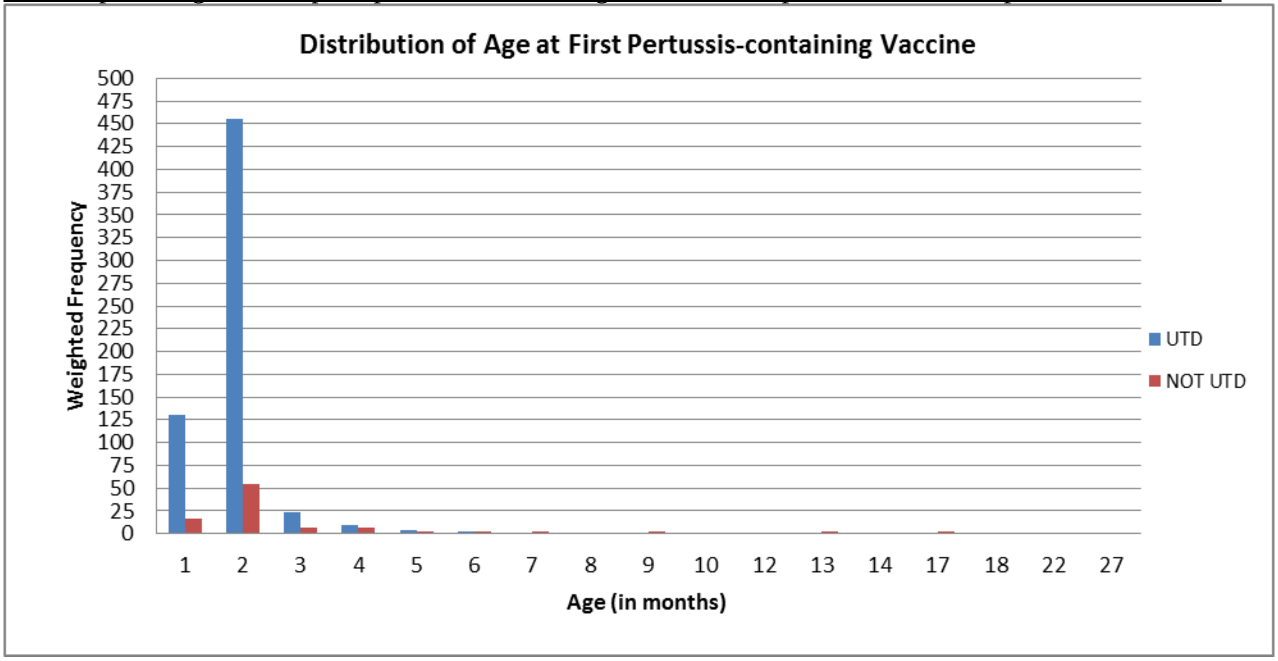
PROV_FAC					
Public	-0.5746	0.3437	0.563	0.287, 1.104	
Hospital	-0.7437	0.3976	0.475	0.218, 1.036	0.1034
Mil/other/mixed	-0.2588	0.3659	0.772	0.377, 1.581	
Unknwn/Mssng	-0.9173	0.4641	0.400	0.161, 0.992	
INS_1					
Yes	0.4389	0.2393	1.551	0.970, 2.479	0.1368
Missing	-0.4477	0.8759	0.639	0.115, 3.558	
INS_2					
Yes	-0.1170	0.2661	0.890	0.528, 1.499	0.7751
Missing	-0.5489	0.9249	0.578	0.094, 3.539	
INS_3					
Yes	-0.3758	0.5154	.0687	0.250, 1.886	0.6825
Missing	-0.2581	0.4902	0.773	0.296, 2.019	
INS_4_5					
Yes	0.4297	0.8096	1.537	0.314, 7.511	0.8686
Missing	0.0164	0.8232	1.016	0.202, 5.103	
INS_6					
Yes	-0.3559	0.3842	0.701	0.330, 1.488	0.4568
Missing	-0.7849	0.8868	0.456	0.080, 2.594	
INS_11					
Yes	-0.7734	0.3674	0.461	0.225, 0.948	0.0003
Missing	-1.2593	0.3332	0.284	0.148, 0.545	

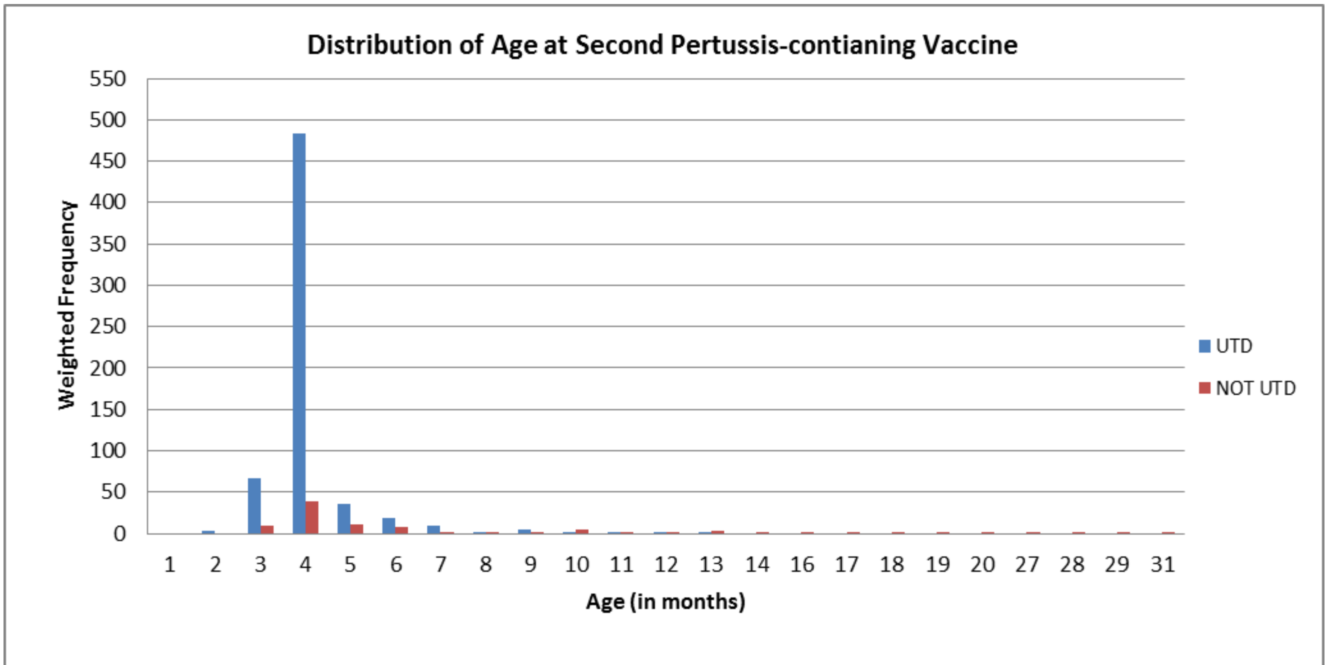
B3: Analysis of confounding. A change of 10% or more in the odds ratio of the main predictor variable (AGEGRP) when another variable is adjusted for in the model is considered indicative of confounding.

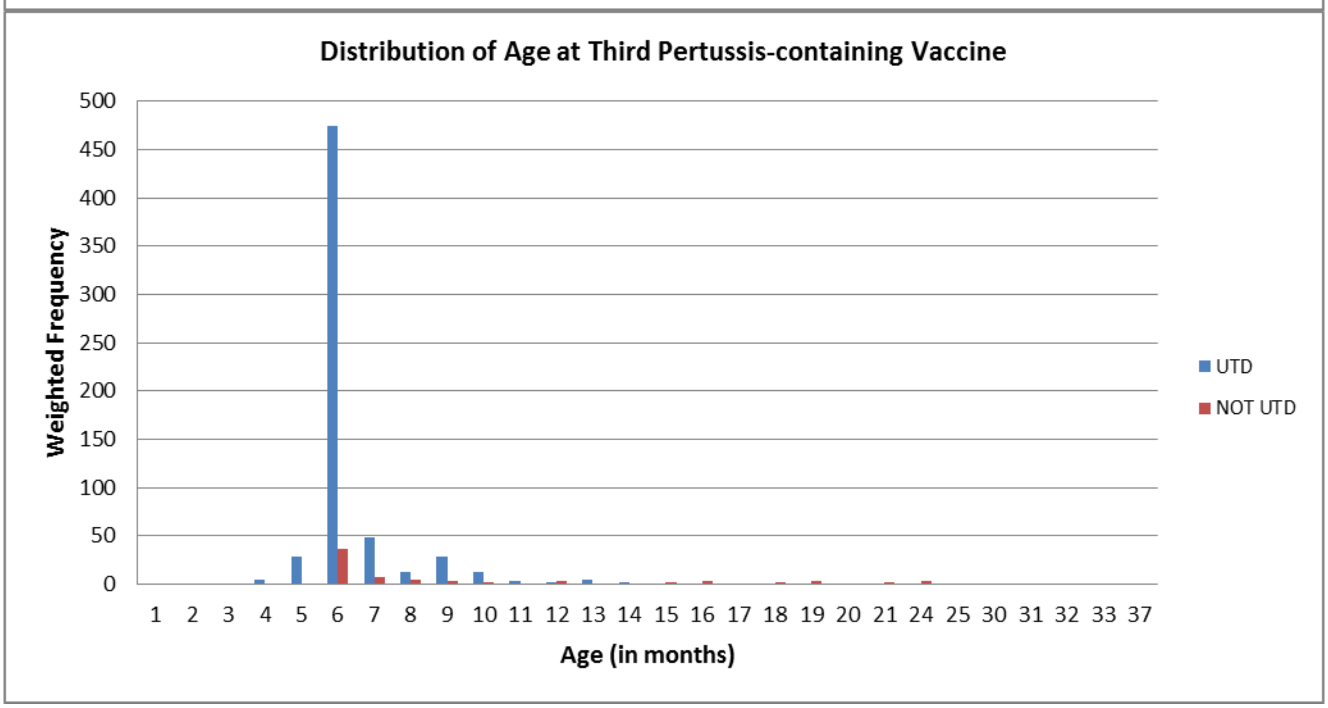
Variable	Crude OR (95% CI)	Adjusted OR (95% CI)	% change in OR
AGEGRP2 (24-29 mo) AGEGRP3 (30-35 mo)	0.500 (0.287, 0.872) 0.269 (0.149, 0.486)		
CHILDNM		0.486 (0.275, 0.859) 0.242 (0.133, 0.437)	2.8 10.04
CWIC_01		0.493 (0.282, 0.861) 0.256 (0.142, 0.462)	1.4 4.8
CWIC_02		0.470 (0.267, 0.828) 0.250 (0.137, 0.454)	6.0 7.1
EDUC1		0.487 (0.282, 0.841) 0.280 (0.153, 0.512)	2.6 4.1
FRSTBRN		0.497 (0.284, 0.869) 0.269 (0.149, 0.487)	0.6 0.0
I_HISP_K		0.514 (0.295, 0.895) 0.271 (0.150, 0.491)	2.8 0.7
INCQ298A		0.484 (0.277, 0.849) 0.251 (0.137, 0.460)	3.2 6.7
LANGUAGE		0.500 (0.286, 0.873) 0.256 (0.140, 0.468)	0.0 4.8
M_AGEGRP		0.503 (0.289, 0.877) 0.270 (0.149, 0.488)	0.6 0.4
MARITAL2		0.494 (0.284, 0.859) 0.269 (0.149, 0.486)	1.2 0.0
RACE_K		0.501 (0.287, 0.877)	0.2

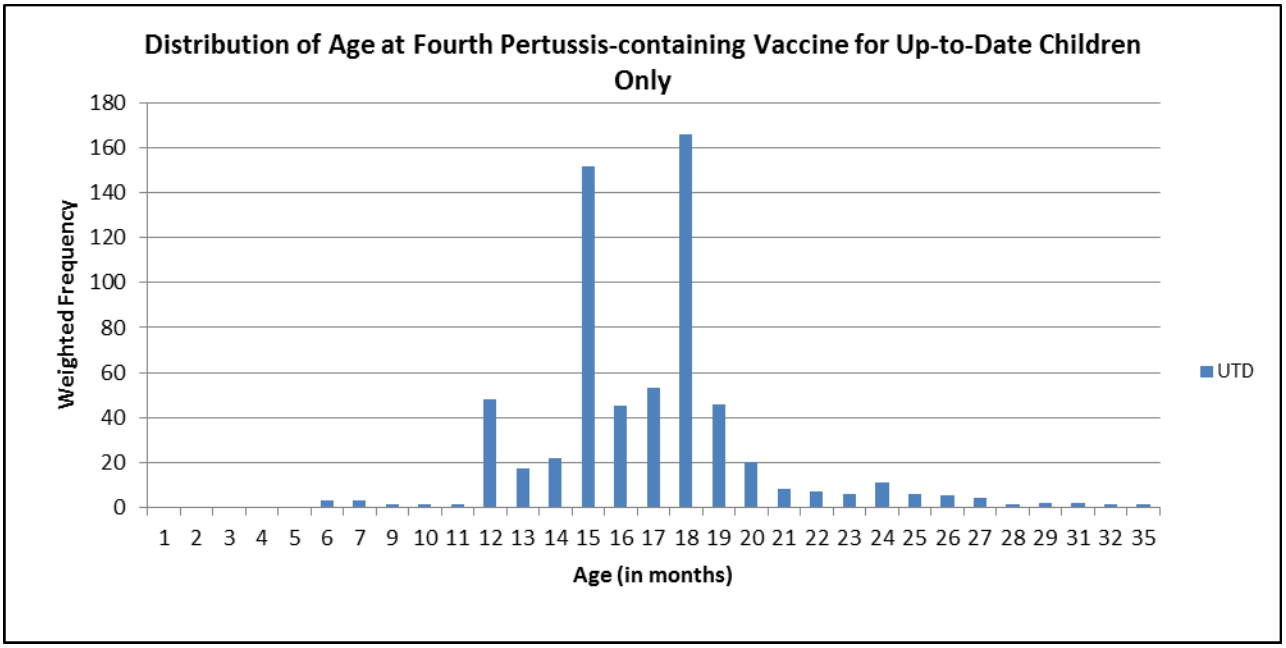
		0.271 (0.150, 0.490)	0.7
RACEETHK		0.510 (0.292, 0.889) 0.272 (0.151, 0.492)	2.0 1.1
SEX		0.499 (0.287, 0.869) 0.268 (0.148, 0.487)	0.2 0.4
D6R		0.496 (0.280, 0.877) 0.256 (0.138, 0.476)	0.8 4.8
N_PRVR		0.512 (0.293, 0.894) 0.274 (0.153, 0.490)	2.4 1.8
PROV_FAC		0.478 (0.273, 0.837) 0.249 (0.136, 0.456)	4.4 7.4
INS_1		0.486 (0.278, 0.849) 0.258 (0.144, 0.462)	2.8 4.1
INS_2		0.500 (0.287, 0.871) 0.262 (0.146, 0.470)	0.0 2.6
INS_3		0.497 (0.285, 0.865) 0.260 (0.145, 0.469)	0.6 3.3
INS_4_5		0.499 (0.286, 0.870) 0.270 (0.149, 0.490)	0.2 0.4
INS_6		0.493 (0.280, 0.866) 0.262 (0.146, 0.470)	1.4 2.6
INS_11		0.454 (0.257, 0.800) 0.260 (0.139, 0.484)	9.2 3.3

B4: Graphs of age at receipt of pertussis-containing vaccines for up-to-date and not up-to-date children.

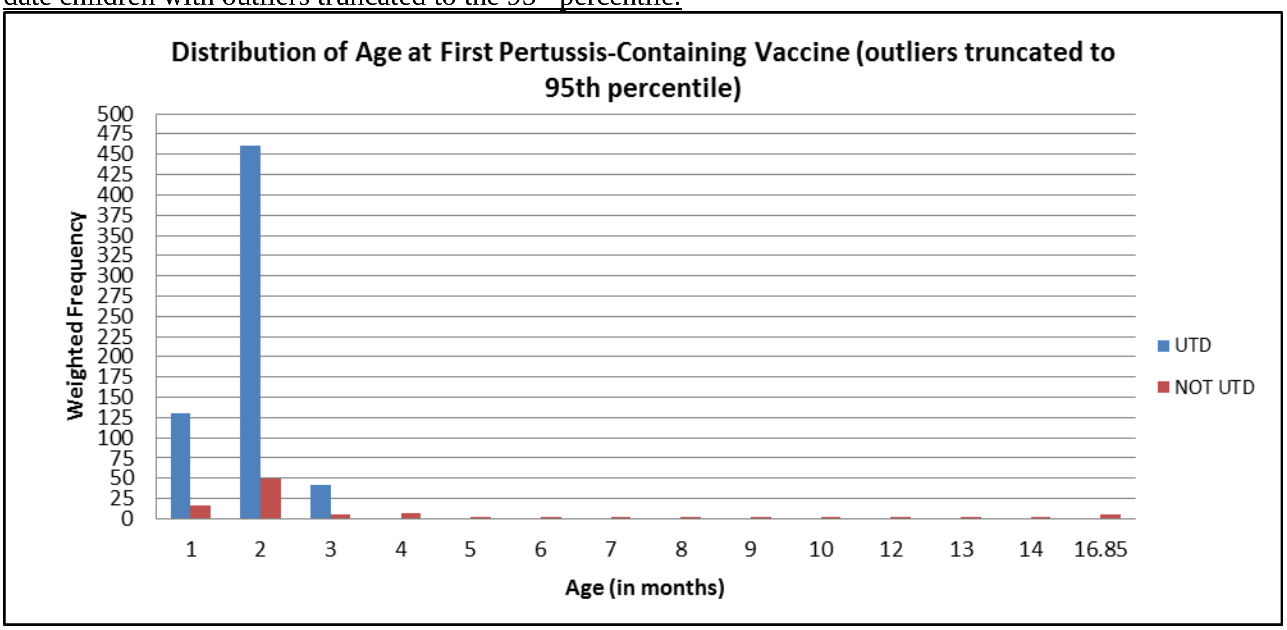


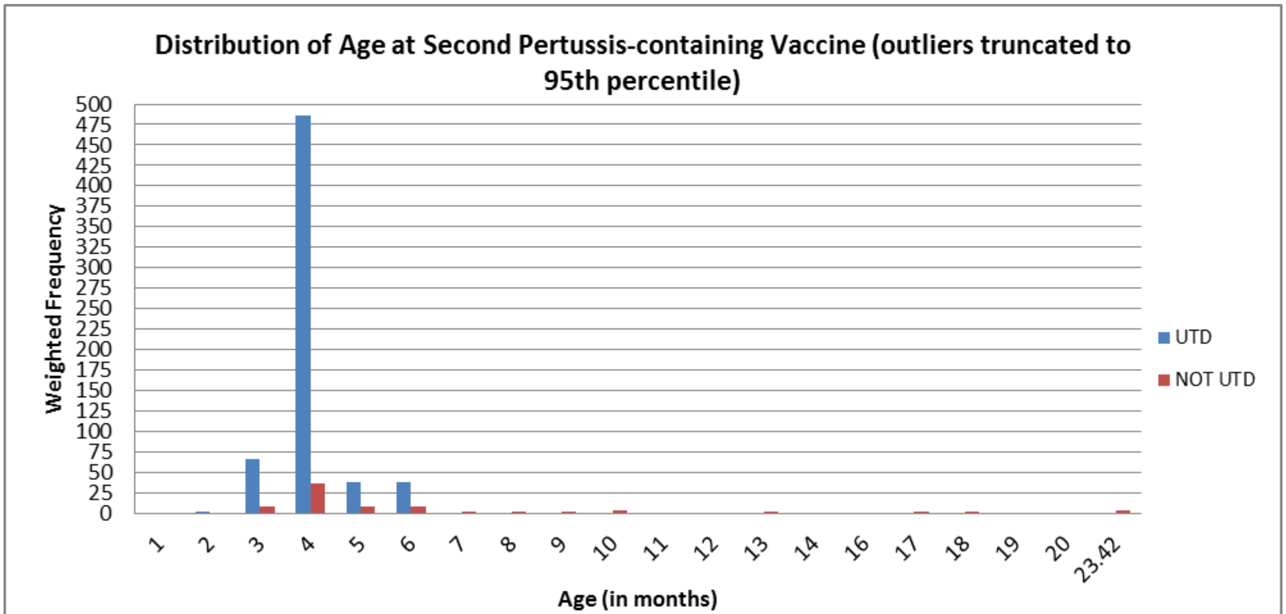

Distribution of Age at Second Pertussis-contianing Vaccine
Weighted Frequency
550
500
450
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20 27 28 29 31
Age (in months)
UTD
NOT UTD

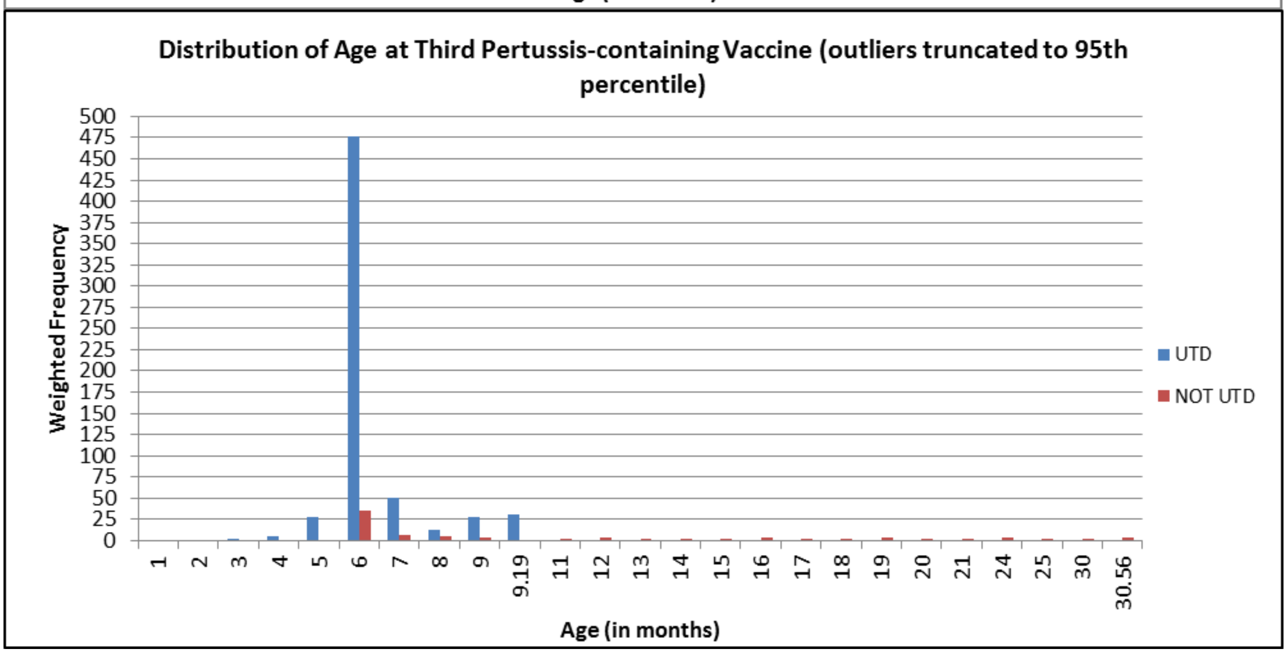

Distribution of Age at Third Pertussis-containing Vaccine
Weighted Frequency
500
450
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 24 25 30 31 32 33 37
Age (in months)
UTD
NOT UTD

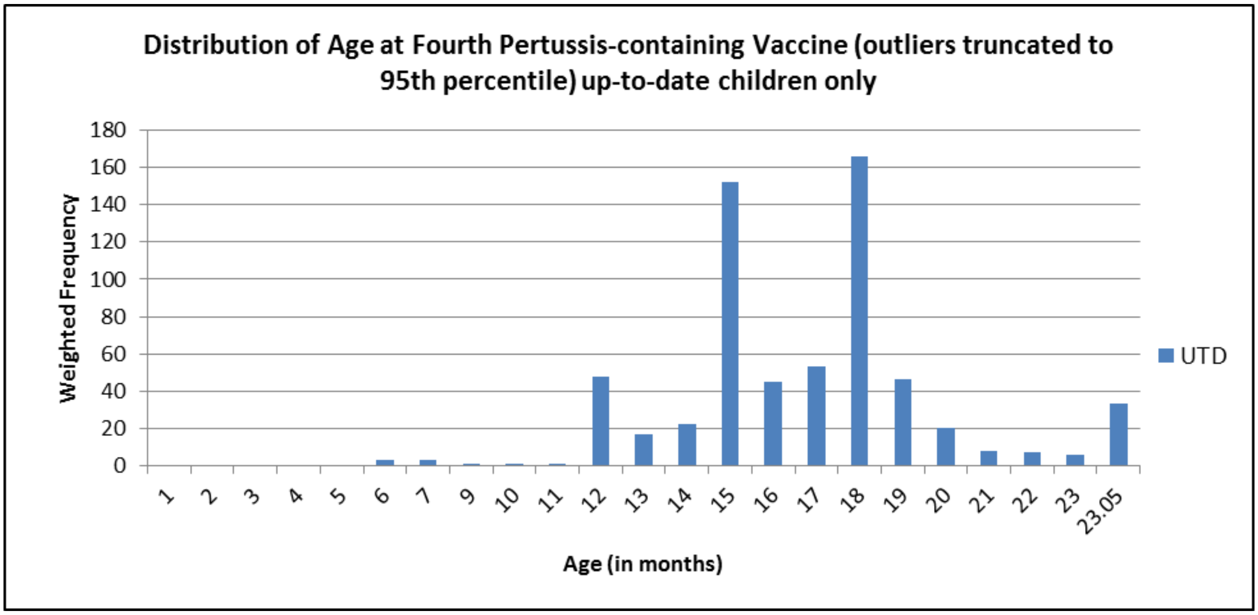


B5: Graphs of age at receipt of each pertussis-containing vaccine for up-to-date children and not up-to-date children with outliers truncated to the 95th percentile.




Distribution of Age at Second Pertussis-containing Vaccine (outliers truncated to 95th percentile)
Weighted Frequency
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20 23.42
Age (in months)
UTD
NOT UTD


Distribution of Age at Third Pertussis-containing Vaccine (outliers truncated to 95th percentile)
Weighted Frequency
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
1 2 3 4 5 6 7 8 9 9.19 11 12 13 14 15 16 17 18 19 20 21 24 25 30 30.56
Age (in months)
UTD
NOT UTD


Distribution of Age at Fourth Pertussis-containing Vaccine (outliers truncated to 95th percentile) up-to-date children only
Weighted Frequency
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
23.05
Age (in months)
UTD