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Varicella vaccination among US adolescents: coverage and missed opportunities, 2007–2014

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Abstract

Context: Since 2007, 2 doses of varicella vaccine have been routinely recommended, with a catch-up second dose recommended for those who received only 1 prior dose.

Objective: To examine 2-dose varicella vaccination coverage and the proportions of adolescents with evidence of immunity to varicella (2 doses of vaccine or varicella history) during 2007–2014. To assess timing of second-dose receipt, factors associated with 2 dose vaccination, and missed second dose opportunities during 2014.

Design, Setting and Participants: We used data from the 2007–2014 National Immunization Survey–Teen (NIS-Teen), which collects information on adolescents ages 13–17 years in the United States.

Results: From 2007 to 2014, 2-dose varicella vaccination coverage increased from 8.3% to 66.9% in 13–15 year-olds, and from 3.6% to 56.7% in 16–17 year-olds. The proportions with evidence of immunity also increased from 68.0% to 84.1% (13–15 year-olds) and 78.6% to 83.4% (16–17 year-olds). In 2014, 13.4% of 13–15 year-olds and 3.2% of 16–17 year-olds had received their second dose at 4–6 years. Factors most significantly associated with lower 2-dose coverage

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Statements of Authorship

Ms. Leung conceptualized and designed the study, analyzed and interpreted the data, drafted the initial manuscript, and reviewed and revised the manuscript.

Dr. Reagan-Steiner conceptualized and designed the study, interpreted the data, and critically reviewed the manuscript.

Ms. Lopez conceptualized and designed the study, interpreted the data, and critically reviewed the manuscript.

Ms. Jeyarajah compiled the survey data, interpreted the data, and critically reviewed the manuscript.

Dr. Marin proposed the study, conceptualized and designed the study, interpreted the data, and critically reviewed the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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were not having a 11–12 year well-child visit, not receiving an adolescent vaccine, and residence in a state with no 2-dose immunization school entry requirement. Seventy-seven percent of 1-dose vaccinated adolescents had 1 missed opportunity to receive their second dose; were they not missed, 2-dose coverage would have increased from 79.5% to 94.8%.

Conclusions: Levels of 2-dose varicella vaccination coverage and the proportion of adolescents with evidence of immunity increased from 2007 to 2014, though 16% lacked evidence of immunity in 2014. Though catch-up campaigns have succeeded, missed vaccination opportunities persist.

Keywords

Varicella; vaccination; United States; NIS-teen; adolescent

INTRODUCTION

Prior to the varicella vaccination program, varicella caused significant morbidity and mortality in the U.S., with an estimated 4 million cases, 11 000 hospitalizations, and 100–150 deaths annually¹. A 1-dose varicella vaccination program was implemented in 1996 with routine administration at age 12–18 months², with 2 doses recommended for susceptible adolescents and adults¹. Although the one-dose varicella vaccination program was highly effective in controlling severe varicella, one-dose of varicella vaccine is approximately 85% effective and cases among vaccinated persons (breakthrough varicella) and outbreaks among highly vaccinated populations were still occurring^{1,3}. In 2007, the policy was changed to a 2-dose vaccination program to improve protection against varicella and prevent outbreaks, with the first dose administered at age 12–15 months and the second at 4–6 years. Second dose catch-up vaccination for children, adolescents, and adults who previously received only 1 dose of varicella vaccine was also recommended; those with a history of disease do not need vaccination¹. The burden of varicella has decreased dramatically since introduction of the vaccine, with a >90% reduction in morbidity and mortality^{4–7}.

Seroprevalence data from the pre-vaccine years showed that 7% of 12–19 year-olds lacked antibodies to varicella-zoster virus (VZV) and were susceptible to varicella⁸; this decreased to 3% in 2009–2010⁹. Due to the decline in varicella incidence⁷, immunity in this age group is currently obtained through vaccination. Though varicella is typically self-limiting, it can be more severe in adolescents and adults, and achieving high vaccination coverage before adolescence is important. The *Healthy People 2020* target for varicella is 90% 2-dose varicella vaccination coverage among 13–15 year-olds¹⁰. In 2006, the National Immunization Survey–Teen (NIS-Teen) was implemented to assess US vaccination coverage among 13–17 year-olds¹¹.

We used NIS-Teen data for 2007–2014 to examine trends in coverage with 2 varicella vaccine doses in adolescents and trends in the proportion of adolescents with evidence of immunity to varicella. Additionally, we used the most recent data (2014) to assess the timing of second-dose receipt, factors associated with 2 dose coverage, and missed opportunities for second-dose vaccination among adolescents.

METHODS

Data Source

We used data from the 2007–2014 NIS-Teen, which collects information on adolescents ages 13–17 years. The survey is conducted in 2 phases: 1) a telephone interview with the parents or guardians of adolescents and 2) a mail survey sent to vaccination providers to collect vaccination and healthcare utilization data for the adolescents whose parents or guardians provided consent to contact providers¹¹. Since 2011, NIS-Teen survey has been a dual-frame survey including both landlines and cellphones. Vaccination coverage estimates are based upon provider-reported vaccination histories. NIS-Teen was implemented in 2006, but data on varicella vaccination were first collected in 2007. We restricted analyses to adolescents from the 50 US states and the District of Columbia with adequate provider data (APD)¹². Through 2013, several criteria were used to define APD that were based on comparing the provider-reported vaccination with parental report of vaccination and were intended to ensure collection of sufficient vaccination data from providers to determine whether a child had received all of the recommended vaccinations for his or her age¹². The definition of APD was revised in 2014¹² to include 1 provider-reported vaccine dose or “completely unvaccinated by parental report” criteria. An evaluation of the impact of the change in APD definition found that this led to lower vaccination coverage estimates with the revised definition and therefore trend analyses cannot be done using 2007–2013 vaccination coverage estimates based on the previous APD definition combined with 2014 vaccination coverage estimates using the revised APD definition¹².

In the 2014 NIS-Teen, household response rates for landline and cell phone samples were 60.3% and 31.2%, respectively; 57% of completed landline and 52% of cell phone interviews met APD criteria¹³. The survey included adolescents born from January 1996 to February 2002¹³.

Study Definitions

Varicella vaccination included receipt of either single-antigen (Varivax®) or combination measles, mumps, rubella, varicella (ProQuad®) vaccine, referred to collectively as varicella vaccine. Varicella vaccination coverage was assessed among adolescents without a history of varicella. One-dose varicella vaccinated adolescents were defined as those who received 1 dose of varicella vaccine at 12 months of age; 2-dose varicella-vaccinated adolescents were defined as those who received a first dose of varicella vaccine at 12 months of age and a second dose a minimum of 28 days after the first dose and included any adolescent who received more than 2 varicella vaccine doses. Varicella disease history was obtained from both providers and parents/guardians (asked about whether adolescent had history of chickenpox or varicella). Teens with a history of varicella, regardless of vaccination status, were excluded from estimates of varicella vaccination coverage. Evidence of immunity to varicella included receipt of 2 doses of varicella vaccine or varicella history. “Receipt of a (non-varicella) adolescent vaccine” was defined as having received 1 dose of tetanus-diphtheria and acellular pertussis (Tdap) vaccine at or after age 10 years, quadrivalent meningococcal conjugate or meningococcal vaccine-(type unknown) at any age, or human papillomavirus (HPV) vaccine at any age, either bivalent or quadrivalent; the Advisory

Committee on Immunization Practices recommends these as routine immunizations for adolescents aged 11–12 years¹⁴. Income-to-poverty ratios were based on reported household income and number of persons living in surveyed households, and calculated using 2013 Census Bureau poverty thresholds¹⁵. Data on well-child visits at 11–12 years were obtained from the provider survey. We used metropolitan statistical area (MSA) as an indicator of residence in an urban, suburban, or rural area. Data on 2-dose varicella immunization school entry requirements for middle school grades (6th or 7th grade) as of school year (SY) 2013–2014 were obtained from each state’s immunization website; 35 states and the District of Columbia had such requirements. A “missed opportunity for a second dose of varicella vaccine among 1-dose vaccinated adolescents” was defined as a provider visit where any vaccine dose was given, other than the second varicella dose. “Achievable 2-dose coverage” was defined as the 2-dose varicella vaccination coverage (among adolescents without disease history) that could have been attained if all 1-dose vaccinated adolescents received their second dose of varicella vaccine at a visit when they received other vaccinations.

Statistical Analysis

Varicella vaccination and disease history, 2007–2014—Using 2007–2014 NIS-Teen data with APD, we calculated (by age group [13–15 and 16–17 years] and calendar year) the weighted proportions of adolescents who received 1 dose of varicella vaccine; who received 2 doses of varicella vaccine; who had a disease history (regardless of varicella vaccine receipt); and who were unvaccinated for varicella and without disease history. We calculated the weighted proportion of adolescents with evidence of immunity by age group. We used logistic regression to test for trends from 2007–2013; because the APD definition changed in 2014^{12, 13}, we were unable to include 2014 in the analysis.

Varicella vaccination in 2014—We conducted additional analyses using only 2014 NIS-Teen data, the most recent year of data available at the time of analysis. Among adolescents who received 2 doses of varicella vaccine, we examined timing of receipt of the second dose by age at the time of survey (13–15 versus 16–17 years).

We conducted multivariate logistic regression to examine factors related to receipt of 2 varicella vaccine doses, including demographic and maternal characteristics, poverty status, health insurance status, healthcare-seeking behavior, receipt of 1 dose of an adolescent vaccine, and residence in a state with a 2-dose varicella immunization school entry requirement. Adjusted prevalence ratios (PR) and *p*-values were used for these comparisons; *p*-values < 0.05 were considered statistically significant.

Lastly, we examined missed opportunities for varicella vaccination and calculated potential 2-dose varicella vaccination coverage if these opportunities had not been missed. Among adolescents who received only 1 dose of varicella vaccine, we examined missed opportunities for a second dose between age 4 and interview date. We restricted our analyses to vaccination visits that occurred after publication of the second-dose recommendation on 6/22/2007¹.

We used SAS-callable SUDAAN (Research Triangle Institute, Research Triangle Park, NC) to analyze all data. All analyses used survey weights to calculate the weighted proportions and confidence intervals. NIS-Teen data collection was approved by the National Center for Health Statistics Research Ethics Review Board. Informed verbal consent is obtained from all respondents to the NIS-teen survey.

RESULTS

Varicella vaccination and disease history, 2007–2014

During 2007–2014, the median annual number of adolescents included in the survey was 19 228. During this period, the proportion of adolescents with 2 doses of varicella vaccine increased from 8.3% to 66.9% among those aged 13–15 years and from 3.6% to 56.7% among those aged 16–17 years [Figure 1]. The proportion of adolescents with evidence of immunity also increased, from 68.0% to 84.1% among those aged 13–15 years and from 78.6% to 83.4% among those aged 16–17 years. The proportion of adolescents with only 1 dose of varicella vaccine decreased for 13–15 year-olds (from 24.0% to 12.1%) and remained stable for 16–17 year-olds (12.4% in 2007 and 12.1% in 2014). The proportion of adolescents unvaccinated for varicella and with no varicella history decreased for both age groups (8.0% to 3.8% among adolescents aged 13–15 years and 9.0% to 4.5% among adolescents aged 16–17 years). All trends were statistically significant during 2007–2013 ($p < 0.0001$), with the exception of the proportion of adolescents aged 16–17 years with 1 dose of varicella vaccine.

Varicella vaccination in 2014

In 2014, there were household interviews conducted for 38 703 teens¹⁶. A total of 20 827 adolescents aged 13–17 years (12 764 aged 13–15 years and 8 063 aged 16–17 years) with APD were included in analysis of 2014 NIS-Teen data. Of these, 13 084 (62.8%) received 2 doses of varicella vaccine, 2 478 (12.1%) received 1 dose, 4 366 (21.0%) had history of varicella, and 899 (4.1%) were unvaccinated and without disease history. Demographic characteristics are shown in Supplementary Table 1.

A higher proportion of adolescents aged 13–15 years (13.4%) received their second varicella vaccine dose at 4–6 years (the recommended age for routine second doses) compared to adolescents aged 16–17 years (3.2%). Among adolescents who received 2 doses of varicella vaccine, 98.3% of those aged 13–15 years and 86.3% aged 16–17 years received the second dose by age 13. An additional 13.7% of adolescents aged 16–17 years received their second dose between age 13 years and the interview date. For the adolescents surveyed in 2014, the highest proportion of second dose vaccination occurred at ages 7–10 for those aged 13–15 years and at ages 11–12 for those aged 16–17 years.

Coverage with 2 varicella vaccine doses among the 16 461 adolescents without disease history was 79.5%, ranging from 72% to 88% by all except one factor examined; the exception was adolescents who did not receive 1 dose of an adolescent vaccine, where coverage was 22% [Supplementary Table 2]. Varicella vaccination coverage with 2 doses was significantly lower among adolescents who were non-Hispanic White, lived in rural

areas, had incomes above 133% of the poverty ratio, did not have a well-child visit at 11–12 years, did not receive 1 dose of an adolescent vaccine, or did not live in a state with a 2-dose varicella immunization school entry requirement [Supplementary Table 2].

Among the 2 478 adolescents who received only one varicella vaccine dose and did not receive their second dose, 77.1% (1 922) had at least 1 missed opportunity to receive a second dose between the age of 4 to the interview date (i.e., they visited a provider and received another vaccine but not a second dose of varicella vaccine). If all of these adolescents had received a second dose of varicella vaccine, then the 2-dose coverage among adolescents would have increased from the observed coverage of 79.5% to 94.8%.

DISCUSSION

Significant progress has been made in 2-dose varicella vaccination coverage in adolescents, reaching 79.5% by 2014 among teens without history of varicella. The proportion of adolescents with evidence of immunity to varicella also increased to 84%. Among adolescents, catch-up second-dose varicella vaccination has proven successful, as many received their second dose after the routinely recommended age. Despite these successes, there is still a substantial proportion of adolescents who only received 1 dose of varicella vaccine (12%), or are unvaccinated without varicella disease history (4%). We found that three-quarters of adolescents who had received their first dose of varicella vaccine and did not receive their second dose had a missed opportunity to receive their second dose.

The varicella vaccination program in the United States caused a significant decrease in incidence of varicella in all age groups, including adolescents^{4–7,17}. Data from 2 active surveillance sites found large declines in varicella incidence between 1995 and 2010: a 92–99% decline in adolescents aged 10–14 years and 85–92% in those ages 15–19, with continued declines after the 2-dose recommendation in 2007^{4,7}. These declines in incidence are in agreement with our finding of decreasing proportions of adolescents with a history of varicella.

Coverage with 2 varicella vaccine doses has increased 8- and 14-fold for 13–15 year-olds and 16–17 year-olds, respectively, since the second dose recommendation. A growing proportion of adolescents acquire their evidence of immunity to varicella through vaccination rather than disease. By 2014, there were still an estimated 2.5 million adolescents who had only received 1 dose of varicella vaccine, and 850 000 without history of varicella vaccination or disease. As varicella incidence continues to decline, high rates of 2-dose varicella vaccination coverage are necessary to ensure protection among adolescents and adults for whom disease is more severe.

We found that most adolescents in 2014 had received their second dose as a catch-up dose, which is expected given that adolescents included in the 2014 NIS-Teen survey were born during 1996–2002, prior to the second dose recommendation in 2007. Over time, an increasing proportion of adolescents will receive their second dose as a routine vaccination at age 4–6 years rather than as a catch-up vaccination at an older age.

Two-dose varicella vaccination coverage among elementary students is high, with a median of 94% (range: 86%–99%) among kindergarteners who lived in states with a 2-dose varicella vaccine requirement during the 2015–2016 academic year, though kindergartners with prior varicella disease history may have been reported as vaccinated or medically exempt, depending on the state vaccination program¹⁸. Other data have shown similar high 2-dose vaccine coverage among kindergarten students¹⁹, and significantly higher coverage in elementary schools than middle and high schools²⁰. School immunization requirements may be one way to help increase vaccination coverage and ensure that adolescents leave high school protected against vaccine-preventable diseases²¹. School immunization requirements are valuable for preventing disease transmission in school settings, but also identifying and vaccinating susceptible populations before they reach adulthood. It is one of the last opportunities to screen and vaccinate a large population.

Differences in vaccination coverage by race/ethnicity, urbanicity, income-to-poverty level, and access to health services (including a well-child visit at 11–12 years) have been associated with other vaccines among adolescents, including Tdap, meningococcal, hepatitis B, and HPV vaccines^{13,20,22–27}. These factors may relate to access to care, or lack of a routine medical provider. Living in a rural/non-MSA was shown to be a strong risk factor for not receiving 1 dose of varicella vaccine, based on data from the 1997–2004 National Immunization Survey of 19–35 month-olds²⁸. We found that 2 dose coverage was most strongly associated with receipt of 1 other adolescent vaccine, a well-child visit at age 11–12 years, and living in a state with a 2-dose school requirement. These results were similar to those reported in an earlier analysis of the 2010 NIS-Teen data²⁴. Well-child visits at 11–12 years have been strongly associated with receipt of other vaccinations^{23,25,26}. The number of provider visits in the last year and number of vaccination providers was not significantly associated with 2-dose varicella vaccination coverage. This suggests that a provider visit alone is not enough to catch-up these adolescents, but other mechanisms may be useful for increasing coverage (e.g., review of vaccination records at each provider visit; systems to remind providers and/or parents/guardians of needed vaccinations, or recall notices for vaccine doses that may be overdue)^{29–31}.

Most adolescents (77%) who received only 1 dose of varicella vaccine and not their second dose had a missed opportunity to receive their second dose. Several other studies have documented missed opportunities for varicella and other vaccines^{20,23,32–34}. Concomitant vaccination (2 vaccinations at the same healthcare visit) improves adolescent vaccination rates by reducing the number of healthcare visits needed³³. Providers should use these opportunities to ensure that adolescents receive both their routine adolescent vaccinations (meningococcal, HPV, and Tdap) as well as their catch-up vaccinations.

This study has several limitations. Our analysis only includes adolescents with adequate provider data, and may not be generalizable to all adolescents¹⁶. Adolescents may have had varicella disease history that was either not indicated in the household survey or documented in medical records, and therefore may have been misclassified. Varicella disease that occurs in previously vaccinated persons is generally milder than in unvaccinated persons and may have been missed because clinical diagnosis can be challenging³⁵. It is also possible that adolescents may have received a varicella vaccine dose by another provider who may not

have been identified by the parent/guardian, or the provider did not report the vaccination history of the child. The nonresponse rate for the landline and cell phone survey samples were 40% and 69%, respectively; it is unknown whether there was any nonresponse bias or if these findings are generalizable to non-responders. Bias in estimates might remain even after adjustment for household nonresponse, provider nonresponse, and phoneless households¹³. Weights have been adjusted for the increasing number of cell phone–only households over time. However, nonresponse bias may change over time, which could affect comparisons of estimates between survey years¹³. Lastly, our analysis of timing of second-dose receipt, factors associated with 2 dose vaccination, and missed second dose opportunities were only performed for 2014 data and the results may not apply for other years. This analysis should be examined in other years to see if these findings are consistent across time.

CONCLUSIONS

In conclusion, we found increases in 2-dose varicella vaccination coverage and the proportion of adolescents with evidence of immunity to varicella. In 2015, coverage of 2 varicella doses was 83% in 13–17 year-olds²², but a significant proportion of adolescents are under- or unvaccinated against varicella, and many 1-dose vaccinated adolescents had missed opportunities to receive a second dose. It is important for providers to ensure that adolescents are up-to-date on all routine vaccinations and are protected from varicella. Our identification of differences in 2-dose varicella vaccination coverage in certain subgroups in the population will help target messages and interventions to increase coverage in these subgroups. These strategies may include creating messages or awareness programs educating parents and guardians about the importance of well-child visits, adding reminder/recall systems about needed vaccinations, and understanding if there may be any barriers to access to well-child visits and/or vaccination that can be overcome²⁹. School immunization requirements for middle and high schools are another important approach of increasing coverage among adolescents^{30,36}. Continued surveillance of varicella vaccination coverage and disease history among adolescents is important to monitor the impact of the varicella vaccination program.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

VZV	varicella-zoster virus
NIS-Teen	National Immunization Survey–Teen
ADP	adequate provider data

Tdap	tetanus-diphtheria and acellular pertussis
HPV	human papillomavirus
MSA	metropolitan statistical area
SY	school year

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Implications for Policy & Practice

- During 2007–2014, we found that significant progress in 2-dose varicella vaccination coverage in adolescents has been made in the U.S., with 2-dose varicella vaccination increasing from 8.3% to 66.9% in 13–15 year-olds, and 3.6% to 56.7% in 16–17 year-olds.
- Nevertheless, there were still 16% of adolescents who were either unvaccinated or under-vaccinated in 2014. There were differences in 2-dose varicella vaccination coverage in certain subgroups. Targeted messages and interventions for these groups may help to increase coverage. As varicella incidence continues to decline, high rates of 2-dose varicella vaccination coverage are necessary to ensure protection among adolescents and adults for whom disease is more severe.
- We found that many 1-dose vaccinated adolescents had a missed vaccination opportunity to receive a second dose of varicella vaccine. School immunization requirements may be one method to increase vaccination coverage. It is also important for providers to ensure that adolescents are up-to-date on both their routine adolescent vaccinations as well as their catch-up vaccinations (for vaccines routinely recommended in childhood such as the varicella vaccine).

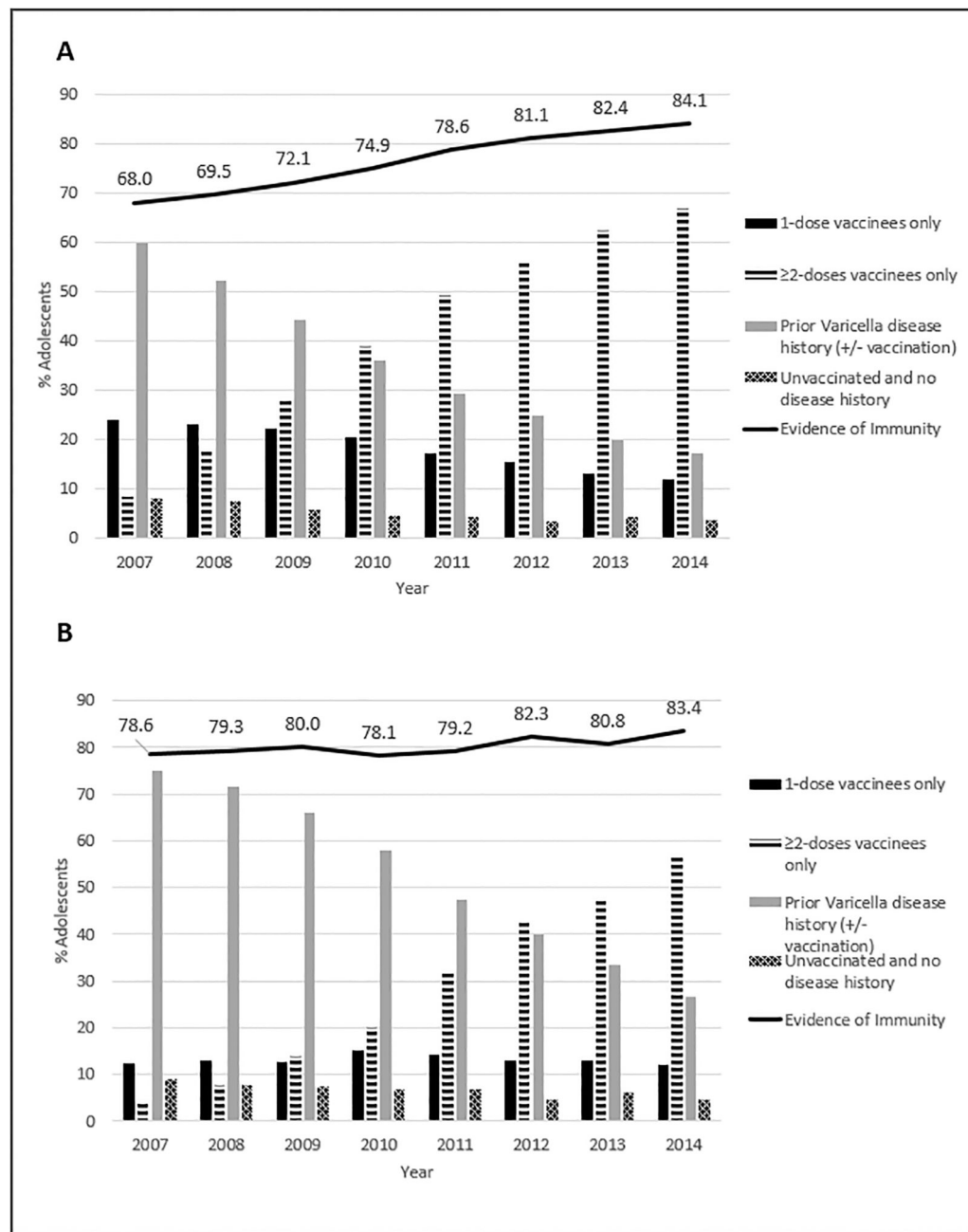


Figure 1. Estimated varicella vaccination coverage and disease history among adolescents aged 13–17 years, by age group and year–National Immunization Survey-Teen, United States, 2007–2014

(A) Varicella Vaccination and Disease History, NIS Teen 2007–2014, 13–15 year-olds. (B) Varicella Vaccination and Disease History, NIS Teen 2007–2014, 16–17 year-olds^a.

^aWe used logistic regression to test for trends from 2007–2013; because the adequate provider definition changed in 2014^{12, 13}, we were unable to include 2014 in the analysis. All trends were statistically significant during 2007–2013 ($p < 0.0001$), with the exception of the proportion of adolescents aged 16–17 years with 1 dose of varicella vaccine.