VACCINE STATUS OF CHILDREN IN THE UNITED STATES:

WHO IS NOT VACCINATING THEIR CHILDREN?

AN ANALYSIS OF THE NATIONAL IMMUNIZATION SURVEY, 2002-2006

by

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ABSTRACT

Previous analyses of vaccine status have focused mostly on characteristics of fully-vaccinated versus under-vaccinated children (not distinguishing between children who are un-vaccinated and partly-vaccinated). However, studies indicate recent outbreaks of infectious disease in the United States are due partly to un-vaccinated children whose parents forgo immunizations because of vaccine safety concerns or low perceived risk of disease. Using the National Immunization Survey from 2002-2006, I find a significant increase over five years in the proportion of U.S. children 19-36 months who remain un-vaccinated. Also, vaccine status varies significantly by child, mother and household characteristics (race/ethnicity, WIC, breastfeeding, mother's education, income, family size and region). Whereas prior studies find more children with lower socioeconomic status are under-vaccinated (presumably due to economic constraints), I find children with higher socioeconomic status are more likely to be un-vaccinated altogether (possibly reflecting parental beliefs and choices). Understanding these characteristics is one step towards reducing the incidence of preventable disease.

INTRODUCTION

Vaccine preventable diseases used to be commonplace in the United States with high infant and child morbidity and mortality. Hundreds of thousands of children fell victim and thousands died every year from a host of diseases including smallpox, polio, diptheria, tetanus, pertussis, measles, mumps, rubella, haemophilus influenzae type b (hib), hepatitis and varicella. As recently as the 1940's, panic-stricken parents refused to let their children swim in the local pool or attend a movie theater for fear of contracting a crippling disease.

Then, once childhood immunizations were developed (beginning in the 19th Century but some as recently as the 1990's), incidence rates for most childhood diseases plummeted and, in some cases, were all but eliminated. Only a handful of children contracted these diseases for several decades running.

But, in recent years, there has been a resurgence of many of these childhood illnesses. Pockets of disease have been reported by the media with hundreds, even thousands, of cases being contracted in localized outbreaks reminiscent of the more widespread epidemics of a century before. Often an unsuspecting traveler from another part of the world carries the disease into the United States and exposes children who are left susceptible to illness either because of insufficient vaccine efficacy or because they are entirely un-vaccinated against the disease.

Perhaps most troubling of all are the news reports of parents who believe their children are better off not being vaccinated against these diseases. They are often reported as saying the vaccines themselves can make their children sick and so, since the likelihood of contracting any of these diseases is so low, they don't want to put their children at risk by immunizing them. While these parents most certainly have their children's best interests at heart, their complacency is putting whole communities at risk.

Yet, little research has been done to determine whether there has been an increase in the number of un-vaccinated children in the United States and exactly which communities are not vaccinating their children. Using nationally representative data from the National Immunization Survey over a five year period (2002-2006), I look to see if the proportion of children in the United States who are un-vaccinated has actually increased in recent years, and if so, which communities are most likely not to vaccinate their children. Understanding the vaccine status of various populations in the United States is the first step towards reducing the chance of returning to the widespread epidemics of the past.

BACKGROUND

Since the discovery of smallpox inoculation by Edward Jenner in 1796, childhood vaccinations have been credited with dramatically reducing the incidence of infant and child morbidity and mortality. Immunizations represent an important aspect of the medical innovations that contributed to declines in mortality following the improvements in sanitation, clean water and personal hygiene which are more directly associated with the Demographic Transition of the 19th and early 20th centuries. Today's vaccines protect children against diseases that once caused serious illness, even death, among those children who contracted them and have significantly improved the quality of life for many children and their families. It is for these reasons that childhood immunizations have been proclaimed "one of the greatest public health success stories" (Niederhauser & Markowitz, 2007), if not "the most important medical intervention to prevent disease" (Lewit and Mullahy, 1994).

Benefits of Immunization

Given the historically high proportion of infant and child mortality that has been caused by infectious disease, lowering the incidence of such diseases has greatly improved the quality of life among children both in the United States and abroad (Read, Troendle & Klebanoff, 1997). From a medical as well as a cost-benefit perspective, vaccinations have provided significant improvements in population health by reducing the incidence of vaccine-preventable diseases (VPD's) among children.

Medical Benefits

Vaccines have greatly improved the health of children in the United States by eliminating or significantly reducing the incidence of many childhood diseases and decreasing rates of child mortality (Kimmel et al, 2007). Zhou et al (2005) have estimated that the standard immunization series for U.S. children prevents over 10 million cases of infectious disease and saves 33,000 lives every year. Since implementation of the U.S. Immunization Program with passage of the Vaccination Assistance Act in 1962, several vaccine-preventable diseases (including polio, measles and rubella) have either been eliminated or are near record low levels (Orenstein, 2006).

Polio vaccines, both the "killed" inactivated polio vaccine (IPV) developed by Jonas Salk and first administered in the U.S. in 1955, and the "live" oral polio vaccine (OPV) later developed by Albert Sabin and approved for use in the U.S. in 1961, are credited with reducing the annual number of polio cases from a peak of over 21,000 cases in 1952 to the point of eradication by 1990. The last indigenous "wild virus" cases of polio were reported in the U.S. in 1979 although a handful of polio cases caused by the live OPV have been reported each year as recently as 1999. The CDC now recommends use of the IPV exclusively. (CDC website: polio.pdf; Aylward, 2006).

Before a vaccine for rubella (German measles) was developed in 1969, an epidemic of the disease infected over 12 million people and caused 20,000 cases of infant death and birth defects among infants born to infected mothers. Today, rubella has been virtually eradicated in the United States with fewer than a dozen cases of the disease reported each year (CDC website: rubella.pdf; MMWR 48(26) 1999).

Other vaccines have all but eliminated these vaccine-preventable diseases (VPD's) including the measles vaccine (which, first administered to U.S. children in 1963, dramatically reduced the incidence of the disease from over 750,000 measles cases and over 550 deaths in 1958 alone) and the haemophilus influenzae type b (Hib) vaccine that is responsible for a significant drop in the incidence of meningitis (School Library Journal website; Schoendorf et al, 1994).

Cost Benefits

Not only are vaccines beneficial to the individual from a medical perspective, but they offer significant financial savings to the community as well. The Centers for Disease Control and Prevention (CDC) has estimated that immunizations save $6.30 in direct medical costs for every dollar spent, with a total savings of $10.5 billion (Rapoport, 2003). Indirect societal costs (including losses due to missed work, death and disability) combined with direct medical costs may put the return on investment for immunizations as high as $18.40 for every dollar spent (Rapoport, 2003). Individual vaccines have been estimated to produce between $0.50 and $10.30 in direct medical cost savings and between $2 and $24 in indirect savings (Zhou, et al, 2005).

Herd Immunity

Finally, vaccines are not only beneficial to the individual children who receive them and to the health care system that needs to otherwise pay for the treatment of disease. Vaccines are also instrumental in building "herd immunity" to disease within a population.

Herd immunity is the resistance of a group of people to attack by an infectious disease when a large enough proportion of the population is immune to that disease so that even people who are not immune are protected against illness because their chances of being exposed to the disease are sufficiently reduced (Lewit & Mullahy, 1994; TFAH, 2004; Gordis, 2008). When enough of the population is immune to a disease, and the people who are infected (infectious) or un-immunized (susceptible) are randomly distributed across the population (random mixing), transmission is interrupted because potential contraction of the disease is lessened.

Medical research has provided evidence that vaccines can create herd immunity even in scenarios where vaccine coverage is less than universal (Haber, et al, 2007). For example, rubella may have reached a level of immunity in the U.S. population over 90 percent, a "threshold of viral elimination" above which transmission of that disease is prevented because rubella has a herd immunity level of about 87% (Bloom, et al, 2006; Hyde, et al, 2006; Hethcote, 1983). Likewise, Hutchins, et al (2004) calculated that population immunity to measles stands at 93%. However, while the low incidence of measles transmission in the U.S. today offers some evidence that herd effects have assisted in decreasing the incidence of disease, over 93% of the population would have to be remain immune to prevent a measles epidemic. The possibility exists that outbreaks may occur if vaccine coverage in the population falls below this threshold.

Childhood Immunization Initiative

In the early 1990's, United States health officials at the CDC asserted that, even though vaccinations have had a substantial impact on the reported occurrence of childhood diseases, these declines in the incidence of disease and mortality could only be sustained by further improvements in the already high vaccination levels among U.S. infants and children (MMWR 43(04), 1994). The implementation of efforts to sustain and even increase vaccine coverage among children was considered a necessary step towards improving the health of all children in the U.S. through the reduction, and even eradication, of once-common childhood diseases.

It was within this framework that, in 1993, President Clinton signed into law the Childhood Immunization Initiative (CII), a coordinated national effort to increase immunization rates among children in the United States. CII was designed primarily to increase immunization coverage rates for individual vaccines among 2-year-olds to at least 90 percent by 1996 (by 1998 for the Hepatitis B vaccine), and to eliminate six vaccine-preventable diseases (diphtheria, tetanus, polio, measles, rubella, and haemophilus influenzae type b (Hib)) from the U.S. population by the same year (MMWR 43(04), 1994).

In order to meet these goals, CII developed efforts to:

(1) Improve vaccines: by developing safer, more effective vaccines (to reduce vaccine risks) and simplified vaccine schedules (to reduce provider barriers to immunization);

(2) Reduce the cost of vaccines: to reduce financial barriers to vaccination through programs such as Vaccines for Children;
(3) Increase community participation and education: to improve parent awareness of the need for vaccinations;
(4) Improve vaccination-delivery systems: to increase public access to immunizations;
(5) Strengthen partnerships between federal agencies and private organizations: to improve vaccine administration; and
(6) Improve surveillance of immunization coverage and monitoring of disease: by using the newly-created National Immunization Survey (NIS) to provide an on-going database of vaccination coverage estimates, and by developing an immunization registry to identify under-vaccinated populations and to monitor progress in achieving coverage goals for U.S. children on both a state and national level.

Healthy People

More recently, the *Healthy People 2000* and *Healthy People 2010* campaigns have updated the original CII vaccine target goals to reflect the recent progress made in child immunization coverage. First, a varicella vaccine was added to the list of recommended childhood immunizations in 1996 in hopes of having 90 percent of two year olds in the U.S. immunized against chicken pox [www.healthypeople.gov/document/html/objective/14-22.htm]. Second, a new goal was set to have 80 percent of U.S. children receive a standard series of recommended immunizations to combat ten different childhood diseases [NIS DUG, 2006]. Finally, CDC aimed to eliminate by 2010 indigenous cases of several vaccine-preventable diseases (including diptheria, tetanus, polio, measles, mumps, rubella and Hib), to reduce by 41% the number of cases of pertussis (whooping cough) and to all but eliminate cases of hepatitis B (reducing the number of cases by 99%) and varicella "chicken pox" (also by 99%).

Recommended Childhood Immunizations

Six vaccines currently make up the "431331" series of immunizations recommended by the CDC for all children in the United States by the age of 18 months. Table 1 below specifies the types of vaccines and number of recommended doses that make up the "431331" vaccine series (so called for the recommended number of doses of each vaccine).

Table 1: Type of Vaccine and Number of Doses in the "431331" Vaccine Series

Type of Vaccine	Number of Doses Recommended
Diphtheria-Tetanus-acellular Pertussis (DTaP)	4
Inactivated Poliomyelitis "Polio" Virus (IPV)	3
Measles-Mumps-Rubella (MMR)	1
Haemophilus influenzae type b (Hib)	3
Hepatitis B (HepB)	3
Varicella "chicken pox" (VRC)	1

Although a pneumococcal conjugate vaccine (PCV) is also now recommended for U.S. children, I have not included PCV in my current analysis for two reasons. To begin, 2002 was the first entire year for which NIS data were available for the PCV vaccine (2002 DUG; MMWR, 52(31), 2003). Therefore, while the proportion of children who received the PCV vaccine steadily increased throughout 2002 (rising from 25% to 56% during the year), only a fraction of children who were eligible actually received the vaccine during the year due a period of adjustment associated with the introduction of a new vaccine (during which coverage rates are typically less than universal). Perhaps more significantly, there was a shortage of PCV so that the vaccine was not fully available for a period of time that year. The duration and severity of the shortage caused the CDC's Advisory Committee on Immunization Practices (ACIP) to reduce the number of recommended doses and during the resulting "catch-up schedule" some children were registered as having fully complied with the recommended number of doses (2002 DUG). In an analysis that classifies children by vaccine status based on the number of recommended vaccines they received, this coding could create inconsistencies across the five years of data (MMWR 50(50), 2001; CDC, 2002 and 2003). DTaP, MMR and varicella vaccines also experienced shortages in 2002 but the severity of these shortages was less than for the PCV vaccine and they had been on the market for a longer period of time so the impact of the shortage on immunizations for these vaccines was lower than on PCV immunization rates.

On the other hand, I have included the varicella (chicken pox) vaccine in my analysis. The VRC vaccine was recommended to U.S. children beginning in the later half of 1996 and administration of the vaccine increased quickly so that by 2002, the first year of NIS data in my analysis, the percent of children who received VRC had reached a proportion comparable to the other recommended vaccines.

Table 2 below identifies the recommended timing for the administration of the six vaccines in the "431331" series for children aged 0-18 months in the United States in 2006. The other four years in my analysis (2002-2005) have the same time recommendations.

Table 2: Recommended Childhood Immunization Schedule by Vaccine and Age, CDC 2006, Approved by the Advisory Committee on Immunization Practices (ACIP).

<table>
<tr><th rowspan="2"><u>Vaccine</u></th><th rowspan="2"><u>Doses</u></th><th colspan="8">Age (in months)</th></tr>
<tr><th>Birth</th><th>1mo</th><th>2mos</th><th>4mos</th><th>6mos</th><th>12mos</th><th>15mos</th><th>18mos</th></tr>
<tr><td>DTaP</td><td>4</td><td></td><td></td><td>DTaP</td><td>DTaP</td><td>DTaP</td><td></td><td colspan="2">DTaP</td></tr>
<tr><td>Polio</td><td>3</td><td></td><td></td><td>IPV</td><td>IPV</td><td colspan="4">IPV</td></tr>
<tr><td>MMR</td><td>1</td><td></td><td></td><td></td><td></td><td></td><td colspan="2">MMR</td><td></td></tr>
<tr><td>Hib</td><td>3</td><td></td><td></td><td>Hib</td><td>Hib</td><td></td><td colspan="2">Hib</td><td></td></tr>
<tr><td>Hep B</td><td>3</td><td>HepB</td><td colspan="2">HepB</td><td></td><td colspan="4">HepB</td></tr>
<tr><td>Varicella</td><td>1</td><td></td><td></td><td></td><td></td><td></td><td colspan="3">VRC</td></tr>
</table>

Schedule obtained from "MMWR" 54(52), January 6, 2006, page 3.

The vast majority of children in the United States are being fully vaccinated against these childhood diseases. Not only have over three-quarters of U.S. children received the six vaccines in the recommended "431331" series, but the numbers have continued to increase over the past several years, from 65.5% in 2002 to 76.9% in 2006 (MMWR 55(36), 2006; CDC, 2006).

This is promising news. However, by the CDC's own admission, maintaining these gains in vaccination coverage continues to be a challenge (MMWR 52(31), 2003). This challenge is all the more acute when public expenditures for the elderly (both for health care services and medical research) far outweigh the money spent on children's concerns (Preston, 1984). Yet, there is reason for hope. Research has begun to focus on the impact that conditions during childhood (both in utero and in the first few years of life) have on one's long-term health and socio-economic outcomes over the life course (Palloni, 2006). Barker, too, has highlighted the importance of early life conditions on health in later life (Barker, 1998; Barker, 1992).

Recent Outbreaks of Disease: Evidence of Immunization Failure

In spite of these positive trends, there are some negative signs. Recent outbreaks of several vaccine-preventable diseases (VPD's) indicate that these diseases may not in fact have been completely eradicated in the United States. Although we cannot always pinpoint the precise cause of each of these outbreaks, there is some indication that either decreased vaccine effectiveness or reduced rates of immunization coverage may be playing a part.

Examples

Mumps. The CDC has reported many instances of "breakthrough" mumps (or vaccine failure) in which people previously vaccinated against the disease contract the illness. Over 200 cases of mumps were reported annually in the United States between 2001-05 (CDC, 2003-07) including an outbreak of mumps in 2006 in which many patients (mostly in Iowa) had already received one or more doses of mumps vaccine (CDC, 2006). Another mumps outbreak occurred among 31 people at a children's overnight camp in upstate New York in the summer of 2005; while the index case was an un-vaccinated counselor from the United Kingdom, several people who previously had been vaccinated contracted the disease. These incidences provide evidence that mumps outbreaks do occur despite near-universal vaccination coverage (Schaffzin, et al, 2007). Several other studies have provided additional evidence of mumps cases among previously vaccinated children (Hersh, et al, 1991; Briss, et al, 1994; Cheek, et al 1995; Whitman, 1998).

Varicella (Chicken Pox). Similarly, a 2001 outbreak of chickenpox among Oregon school children resulted in 422 students getting sick. Of these children, 211 (50%) who had not previously had a case of chickenpox but who had received the chickenpox vaccine (presumably preventing them from getting sick) went on to contract the disease (Tugwell, et al, 2004). These findings have led some medical professionals to question the efficacy of one VRC dose and to suggest the possible need for a second (or booster) dose of the vaccine.

Pertussis (Whooping Cough). Pertussis cases have also increased in recent years, with several outbreaks being reported in the Midwest. During the first half of 2004, over 800 cases of whooping cough were reported in Wisconsin (Wisconsin DHFS, 2004) and another 100 cases were reported in Chicago alone (ABC News, 2004). More broadly, the number of pertussis cases across the United States in 2004 (a total of 25,827 reported cases) was higher than any year since 1959. Additionally, the incidence rate (number of new pertussis cases reported among 100,000 population at risk) increased over 30 years from about 1.1 cases per 100,000 in 1974 to 8.9 in 2004. Strikingly, this incidence rate in 2004 was twice the rate reported just a year before and three times higher than the rate in 2001 (CDC, 2006).

Rubella. Westchester County, NY experienced a rubella outbreak in 1997-98 with 95 confirmed cases of the disease. The index case was a 23-year-old man from Mexico who himself was exposed to the disease by a co-worker in Port Chester, NY where an outbreak was ongoing and had spread along train lines and work sites. Ninety-three percent of the people infected were foreign born, none of whom had received the rubella vaccine. All native US-born patients who contracted rubella in the outbreak were either too old to have received the vaccine as children (near-universal exposure to the disease before the vaccine was developed in the 1960's was considered to have provided immunity from illness for people over a certain age) or were infants too young to be immunized (since they were less than 12 months old, the age at which the MMR vaccine is recommended) (MMWR 48(26), 1999; School Library Journal website, 2008).

Measles. Perhaps most notably (in terms of sheer numbers), several measles outbreaks have occurred recently across the United States. One measles outbreak in 1989-1991 caused a reported 55,000 cases, 11,000 hospitalizations and 123 deaths (Development of Community and State-Based Immunization Registries, 1999). The outbreak was at least partly due to low vaccine coverage and poor administration of recommended vaccines (National Vaccine Advisory Committee, 1991). In some affected communities, only half of the children had received the recommended measles vaccine (Atkinson, et al, 2000). Partly in response to this reported measles outbreak, a national campaign was waged to increase childhood coverage rates; as a result, fewer than 200 cases of measles were reported in the first half of 1993 (Lewit & Mullahy, 1994).

More recently, another measles outbreak occurred in Indiana in 2005, this time as the result of an importation of the measles virus from Romania (via an un-vaccinated traveler) into a church community characterized as "white, middle class, and well educated." Of the 34 confirmed measles cases, 32 patients (94%) were un-vaccinated and two patients (6%) represented vaccine failure. A vast majority of these patients were children left un-vaccinated due to parental concern for vaccine safety. Interestingly, 24 out of the 34 confirmed cases (70.6%) were from only four households (one with as many as ten people) and 20 out of the 28 infected children (71.4%) were home-schooled (Parker, et al, 2006).

Even more recently, another outbreak of measles occurred just this year in San Diego. Twelve children who had not been vaccinated against the disease became ill: three of the children (25%) were younger than the recommended age for vaccines, and nine children (75%) had not received the immunization because their parents chose not to inoculate them (New York Times, 2008). With more measles cases in the first seven months of the year than were reported in all of the past twelve years combined (131 cases between January and July), 2008 is on track to have a record number of measles cases (Medical News Today, 2008).

As these reported outbreaks seem to suggest, there is at least anecdotal evidence of an increase in the number of parents opting out of vaccinating their children. While it is not conclusive, and other factors (such as uncertain vaccine efficacy and lack of access to immunization services) likely play a part in the proportion of children who are immune to disease, it is reasonable to conclude that the number of voluntarily un-vaccinated children in the United States may be an important component in the recent outbreaks of these otherwise preventable diseases.

Possible Causes

These recent outbreaks should give pause to anyone who thinks that vaccine-preventable diseases have been eradicated. While childhood immunizations rates are the highest they have been in history, there is at least anecdotal evidence that many communities in the United States are susceptible to several diseases once thought to be eliminated.

Epidemiological evidence suggests that these outbreaks are likely caused by a combination of factors: vaccine failure (vaccines are rarely 100 percent effective, and some vaccines appear to lose their effectiveness over time, leaving people increasingly at risk to disease and leading some researchers to call for booster vaccines); a susceptibility to illness among populations either too old or too young for routine vaccinations; and rates of un-vaccinated children that are too high to fully protect a population from exposure to disease.

Since an evaluation of vaccine effectiveness and age-specific recommendations for vaccine administration are beyond the scope of this paper, I will focus instead on the barriers to immunization that may help explain the number of un-vaccinated children in the United States.

Barriers to Immunization

Several obstacles to achieving CII target immunization rates have been described in the literature, including larger systems barriers, health care provider barriers, and parent or patient barriers (Kimmel et al, 2007).

System Barriers

Both economic and administrative factors impact the structure and efficiency of the health care system in the United States. Federal, state and local government agencies must coordinate with public and private health care providers to pay for and administer vaccines to children across the country.

Economic Costs. The total cost of vaccinations for all U.S. children in 2004 was approximately $298 million. However, the federal government appropriated only $220 million for vaccine purchases, a shortfall of $78 million that caused many states to limit vaccine outreach, education and delivery systems (TFAH, 2004).

At the same time, the cost of immunizing each child has increased in recent years (from $186 per child in 1999 to $472 in 2003) as the number of recommended vaccines increases, the cost of developing vaccines goes up, and taxes are levied to cover vaccine compensation awards (TFAH, 2004, Lewit & Mullahy, 1994). These rising costs in turn often increase the use of public health clinics, many of which are already overburdened and short on funds (Lewit & Mullahy, 1994). Finally, the health insurance system itself contributes to lower immunization rates by allowing health insurance plans that cover to varying degrees the cost of well-child visits and child immunizations (or not providing health insurance at all to some children) and by not compensating for disparities in socio-economic status that undermine the ability of some parents to pay for childhood immunizations.

System Administration. Vaccine supply, distribution and delivery also affect the availability of vaccines. As of 2003, only five companies produced all the vaccines administered to children in the United States (Institute of Medicine, 2003). This centralized system limits the development, manufacture and approval process for new vaccines and potentially limits vaccine supply (TFAH, 2004). Partially as a result of this system, shortages have occasionally interrupted the distribution of vaccines (such as a 2001-2002 shortage of DTaP, MMR and varicella vaccines). Likewise, changes in the composition of vaccines (such as when thimerosal was eliminated from vaccines production) have lead to a disruption of vaccine availability (TFAH, 2004).

Despite recent efforts to improve vaccine coverage rates (including programs such as Vaccine for Children and All Kids Count that are designed to reduce the financial and administrative burdens associated with vaccine programs), system barriers continue to be a challenge to full child immunization coverage (Wooten et al, 2007).

Provider Barriers

Provider barriers to immunization refer to a lack of provider knowledge about vaccines, the inefficiency of vaccine administration, and unknown or incomplete medical records of past childhood immunizations.

Vaccine Knowledge. Providers often do not take sufficient time to communicate to parents the important information about vaccine risks and benefits, and may be uncertain themselves about vaccine administration including whether combination vaccines (that protect against multiple diseases with one injection) may be harmful (Burns and Zimmerman, 2005). Also, providers sometimes have an incomplete understanding themselves of vaccine contraindications (specific conditions in which a vaccine should not be administered) or fail to administered vaccines to children with colds or other mild illnesses.

Provider Administration. Other provider barriers include missed opportunities for immunization (such as when unrelated medical visits are not seen as a chance to bring a child's immunization status up to date). Also, since a physical exam is often required prior to the child's receiving a vaccine, delays in scheduling can reduce the timeliness of vaccine administration (Niederhauser & Markowitz, 2007).

Immunization Records. A final barrier to improving immunization rates is the lack of access to a patient's prior immunization records (Lewit & Mullahy, 1994). Increasingly, electronic medical record systems combined with the use of immunization registries (databases that join vaccination records from multiple health care providers) are raising immunization rates by ensuring that a child's immunizations are complete and up-to-date (Kimmel et al, 2007). Also, reminder/recall systems improve the timeliness and cost efficiency of vaccines by sending reminders to parents when immunizations are due (Kimmel et al, 2007; TFAH, 2004).

<u>Parent & Patient Barriers</u>

Individual barriers to immunization generally fall into four categories: first, logistical problems that limit access to immunizations; second, perceptions about the necessity of child immunizations (given the high level of immunity to childhood diseases that are reported throughout the country today); third, concerns about the perceived safety of vaccines; and fourth, personal beliefs about immunizations that may be in conflict with government-mandated policy. Of the four barriers, logistical problems are generally the most tangible: lack of transportation to the vaccine provider, confusing immunization schedules, inconvenient clinic hours, scheduling delays, and vaccine costs all present more easily identifiable (if not treatable) barriers. Parental concern for vaccine safety and a low perceived risk of contracting childhood diseases are also important factors in the decision of whether or not to vaccinate a child, although it may be hard to document the process by which parents gained the information upon which their decisions were based. Finally, a reluctance to succumb to federally-mandated medical procedures may be the most difficult to quantify because beliefs and attitudes about the health of one's children can be based on many, often deeply held, religious or philosophical foundations.

Perceived Herd Immunity. Potentially more difficult to address than logistic barriers are the perceptions about the need for childhood vaccines. A significant barrier to higher immunization rates is the complacency among some parents regarding the risk of vaccine-preventable diseases (Lewit & Mullahy, 1994). Ironically, it is through the phenomenal success of these very vaccines that some parents and providers alike perceive there to be little or no risk of contracting these once-common childhood illnesses. Since many of these diseases have been all but eliminated from the population, few people have personally experienced these diseases. Failing to appreciate the seriousness of these diseases, parents make a decision to forgo some or all of the recommended immunizations since contracting one of these illnesses seems highly unlikely.

Vaccine Safety Concerns. At the same time, the perceived risk of health complications associated with the vaccines themselves has increased in recent years. Some recent media reports, alternative Internet websites, non-traditional medical practitioners (such as some chiropractors), and anti-vaccine advocates have circulated stories speculating about (and even disputing) the safety of various vaccines (TFAH, 2004).

Much of the concern about vaccine safety has focused on the measles-mumps-rubella (MMR) vaccine. Uncertainty about the combination vaccine was first generated with a study published in the Lancet (Wakefield et al, 1998) that suggested a causal link between the MMR vaccine and autism. Although the study has since been disavowed by several authors of the original publication, and a recent analysis has failed to replicate Wakefield's original study results (Hornig et al, 2008), concern continues to circulate today among "anti-vaccinationists" (Schlenker, 2004) that the MMR vaccine, or other combination vaccines, are not safe.

More broadly, three acute and chronic illnesses are rumored to be (at least partly) caused by specific recommended vaccines. Besides the claim that autism is associated with the MMR vaccine, it is suggested that the hepatitis B vaccine may be responsible for causing cases of multiple sclerosis (MS), and the diptheria-tetanus-pertussis (DTaP) vaccine is said to have ties to sudden infant death syndrome (SIDS). Unfortunately, these rumors continue to circulate despite insufficient medical proof of a causal relationship (Gust et al, 2004).

Speculation also continues to circulate that thermarasol, a mercury-based preservative used for a period of time in the manufacture of the MMR vaccine, or even more recently, aluminum (Sears, 2008) which is contained in several of the recommended childhood vaccines, may be harmful to children who receive vaccines containing these ingredients.

This speculation continues even despite a recent study of children in California that concluded that removing mercury from the process of vaccine development did not hamper the rise of autism cases (reported in Los Angeles Time, January 2008) and despite any medical studies looking specifically at the effects of aluminum on the health of children.

Perhaps as a result of this speculation, a significant proportion of the current literature on childhood immunizations addresses the issue of parental concerns about vaccine safety (Allred et al (2005); Bardenheier et al (2004); Enriquez et al (2005); Gellin, Maibach & Marcuse (2000); Gust et al (2004); Gust et al (2006); Lewit & Mullahy (1994); Luman et al (2004); Smith et al (2006); van Damme et al (2000); and Zagminas et al (2007)).

Gust et al (2004) found that beliefs about vaccine safety concerns contribute substantially to under-immunization in the United States. In turn, Parker et al (2006) conclude unequivocally that the 2005 measles outbreak in Indiana was caused by the introduction of measles into a community of children left un-vaccinated by parents concerned with vaccine safety. So while current rates of childhood immunization in the United States may be sufficient to provide immunity from some epidemics, speculation and rumors about vaccine safety have the potential to undermine this past success and leave the U.S. population at risk of an increased incidence of these diseases and susceptible to future epidemics if a large enough proportion of the population fail to immunize their children out of fear or misinformation (TFAH, 2004).

Personal Beliefs. Finally, anecdotal evidence from media coverage of recent disease outbreaks seems to reflect a resistance on the part of some parents to follow the federally-mandated immunization schedule for children. Whether perceived as religious intolerance, socialized medicine, or an affront to a more health-conscious, back-to-nature, organic movement that many people in communities around the country are experiencing, the vaccines that make up the “431331” immunization series are seen as objectionable by many parents. These objections may coincide with devout religious beliefs, a more libertarian/anti-government political stance, resistance to pharmaceutical prescriptions offered by the medical community, or health and nutrition concerns about physical well-being. In any case, there appears to be a reluctance among many parents to vaccinate their children for one or more reasons. Scientific analysis is now needed to understand the underlying characteristics of these communities that are choosing not to vaccinate their children.

Previous Research

Medical investigations have identified with a high degree of certainty the immediate causes of these recent disease outbreaks. Research has found that, given an index case of a disease from an outside location by an unsuspecting carrier, either a sufficient number of un-vaccinated people or insufficient immunity despite previous vaccination have allowed diseases to take hold in local populations (Parker et al, 2006; Schaffzin et al, 2007; Tugwell et al, 2004; Lopez et al, 2006; Davis et al, 2007; NY Times, 2008).

Unfortunately, most of the existing sociological research into childhood immunization patterns in the United States focuses only on whether children are fully-immunized (up-to-date, UTD, on their recommended immunizations) or under-immunized (not-up-to-date, NUTD). These studies consider a wide range of factors when analyzing the differences between these two groups, including: race/ethnicity (Barker et al, 2006; Darling et al, 2005; Groom et al, 2007; Herrera et al, 2001; Strine et al, 2003); socio-economic factors, such as mother’s education or income and poverty status (Barker et al, 2006; Dombkowski, Lantz &

Freed, 2004; Groom et al, 2007; Gust et al, 2004; Kim et al, 2007); mother's age and marital status (Dombkowski, Lantz & Freed, 2004); number and birth order of children in household (Gust et al, 2004); state or geographic region of the country (Barker et al, 2006; Groom et al, 2007; Stokley et al, 2001); and the type and cost of health care providers, either public or private (Dombkowski, Lantz & Freed, 2004; Groom et al, 2007; Gust et al, 2004; Kahane et al, 2000; Lewit & Mullahy, 1994; Posfay-Barbe et al, 2005).

However, most research does not consider the *degree* to which children are under-immunized (to differentiate between children who are partly-immunized and those who are un-immunized altogether). Nor has there been much research to determine which populations in the United States are not vaccinating their children. Despite conducting a wide-ranging literature review, I found only two articles that either analyze the number of un-vaccinated children (as distinct from partly- and fully-vaccinated children) or describe the populations from which they come.

The first article, by Schlenker (2004), looks to see if there has been a trend in the number of "anti-vaccinationist" parents requesting "personal conviction waivers" for their children in the state of Wisconsin and, given this trend, which vaccines these parents were avoiding, and whether the number of waivers has had any impact on immunization coverage rates in Wisconsin. He found that in the 14 years between 1989 and 2003, there was a 371% increase (from 0.7% to 2.6%) in the proportion of Wisconsin parents who requested such a waiver (as distinct from medical or religious waivers). Based on a survey of pediatricians, he also found, among parents who expressed concerns about immunizations (most frequently regarding the MMR vaccine and autism, or autism and thimerosal), that parents most frequently cited family and friends (28%), the Internet (21%), and alternative medicine providers, most often chiropractors (14%) as sources of information about vaccines. He also found that the most commonly refused vaccines were varicella (46%) and MMR (34%) followed by Hepatitis B (10%) and DTaP (10%). However, resorting once again to the typical analysis of UTD versus NUTD children, he also found that the overall coverage rates for childhood immunizations in the state (including MMR coverage among two-year-olds) were not significantly affected by these trends (declining from 95% to 92% over the period).

In the other article, Smith, Chu & Barker (2004) used National Immunization Survey (NIS) data from 1995-2001 to look at un-vaccinated children as distinct from fully-vaccinated and partly-vaccinated children. Smith et al found not only that un-vaccinated children had “characteristics that are distinctly different” from those of partly-vaccinated children, but also that un-vaccinated children were “clustered geographically, increasing the risk of transmitting vaccine-preventable diseases” to both un-vaccinated and partly-vaccinated children. Specifically, Smith et al found that un-vaccinated children were more likely to be White and male, have a mother who was married with a college degree, live in a household with annual income exceeding $75,000, and live in states that allowed philosophical exemptions from immunization. The parents of un-vaccinated children also were more likely to express concern about vaccine safety. By comparison, under-vaccinated children more often were Black, had a younger, un-married mother who had not graduated from college and lived in a household near the poverty level.

It should be noted that the previous wording is that of the authors. While Smith et al stated that un-vaccinated and partly-vaccinated children had “distinctly different” characteristics, they might have more accurately stated that un-vaccinated and partly-vaccinated children came from “distinctly different” U.S populations. This revised wording would have better reflected an interest in the immunization status of different social groups (where vaccine status is dependent on population characteristics, rather than the other way around).

RESEARCH QUESTIONS

Given the relative importance of un-vaccinated children in the recent outbreaks of childhood diseases, and the dearth of research examining which populations in the United States are not vaccinating their children, the purpose of this paper is to answer three overarching questions.

First, has there been a detectable increase between 2002 and 2006 in the number of children in the United States who are un-vaccinated for the “431331” immunization series? (In other words, is the anecdotal evidence from reported disease outbreaks supported by nationally representative data?) Also, among partly-vaccinated children, has there been a significant increase in the proportion of children who are un-vaccinated for any of the individual vaccines that make up the “431331” immunization series? (This particular analysis may shed light on parental concerns regarding the rumored association between some vaccines and acute or chronic illness.)

Second, if there has been an increase in the number of un-vaccinated children, can this increase be explained by changes in the characteristics of the United States population? (Specifically, what are the characteristics of children, mothers or households that are significantly associated with a child being un-vaccinated, and has there been an increase in the size of U.S. populations with these characteristics (a shift in the U.S. population) sufficient to explain the increase in un-vaccinated children?)

And third, if there has been a change in the vaccine status of children (beyond an underlying shift in the U.S. population), then who is more likely not to vaccinate their child? That is, after controlling for other independent measures, what child, mother and household characteristics are significantly associated with a child being un-vaccinated? Understanding the profile of communities that are more likely not to vaccinate their children may shed light on the reasons behind the recent increase in un-vaccinated children and may suggest strategies necessary to counter this trend in vaccine status.

Hypotheses

Based on these research questions, I will test the following specific hypotheses:

Trend Analysis

Vaccine Status Over Time. While the proportion of children who are fully-vaccinated has increased over time, and the proportion of children who are partly-vaccinated has decreased, evidence from news reports of recent disease outbreaks leads me to expect that the proportion of children who are un-vaccinated, although very small, has increased significantly between 2002 and 2006.

Individual Vaccines Over Time. Due to the recent debate and media coverage surrounding vaccine safety, I expect there has been a significant increase in the proportion of children who are at least partly-vaccinated (but who have not received all the recommended vaccine doses in the "431331" immunization series) who have received zero doses of those vaccines rumored to be associated with specific illnesses: MMR (autism); Hepatitis B (multiple sclerosis); and DTaP (SIDS).

Bivariate Analysis

I expect that several individual characteristics are significantly associated with vaccine status. In particular, I expect a higher proportion of White, male, younger children to be un-vaccinated, along with children whose mothers graduated from college. I also expect children who live in households with income above $50,000 per year, with four or more children, in the western United States, and in states that allow philosophical exemptions from immunization to have a higher proportion of un-vaccinated children. The reasoning for these expectations is spelled out in the Multivariate Analysis section below.

Decomposition Analysis

I expect that this increase in un-vaccinated children over time extends beyond any increase in prevalence of the characteristics associated with being un-vaccinated. That is, I expect that the increased proportion of un-vaccinated children is due not solely to recent changes in the composition of the United States population but to a true rise in the proportion of children who are un-vaccinated.

Multivariate Analysis

Building on the previous research by Smith, Chu and Barker (2004) and recent media reports regarding outbreaks of childhood disease, my hypotheses focus specifically on several measures that I expect are most closely associated with vaccine status:

Child's Race/Ethnicity. I expect vaccine status differs significantly by child's race/ethnicity. In particular, based on previous research and media coverage of parents who choose not to vaccinate their children, I expect White children are more likely to be un-vaccinated than children of other races or ethnicities, especially Blacks.

Child's Gender. Based on epidemiological evidence that shows a 3:1 ratio of male:female cases of autism and the rumored association between autism and the MMR vaccine (Muhle et al, 2004), I expect more males than females are un-vaccinated.

Child's Age Group. I expect child's age is positively associated with vaccine status. Specifically, because of the ongoing controversy about vaccine safety, I expect a greater proportion of younger children to be un-vaccinated (19-23 month olds who would have been due for their vaccines more recently) than older children (30-35 month olds who would have been scheduled to receive their vaccines before the most recent media coverage). [Every child in the NIS sample is old enough to have received all the recommended vaccines by the time of the survey (19 months of age).]

WIC Benefits History. Based on Smith, Chu & Barker findings regarding socio-economic status (SES), I expect a child's history of receiving WIC benefits to be negatively associated with vaccine status. In particular, I expect a smaller proportion of children who ever received WIC benefits to be un-vaccinated than children who never received WIC benefits.

Breastfeeding History. Based on media reports of mothers who choose not to vaccinate their children, I expect children who were ever breastfed are more likely to be un-vaccinated than children who were never breastfed.

Mother's Level of Education. I expect mother's level of education is negatively associated with vaccine status. Because parents with more education are generally better able to understand the complex information contained in medical articles and web sites (from which many obtain arguments against immunizations), I expect that children whose mothers graduated from college are more likely to be un-vaccinated than children whose mothers did not graduate high school.

Household Income & Poverty Status. I expect income/poverty status is negatively associated with vaccine status. Specifically, I expect that children who live in households with higher income (above $50,000 per year) are more likely to be un-vaccinated than children who live in households with lower income (below poverty).

Number of Children in Household. Based partly on the previous research by Smith, Chu and Barker, and partly on anecdotal evidence from reports of disease outbreaks, I expect the NIS data will also show that family size is positively associated with vaccine status. That is, I expect a greater proportion of children who live in larger households (with four or more children) to be un-vaccinated than children who live in smaller households (with one or two-three children).

Child's Residence. This analysis contains two measures of geographical location: region of the country (based on state of child's residence during the NIS interview); and state exemption policy (a dichotomous measure of whether or not the state allowed in 2006 for a philosophical exemption to the required immunization series).

Census Region. I expect region of the country is significantly associated with vaccine status. Specifically, because of the concentration of religious communities in some western states (such as Utah and Idaho) and the libertarian reputation among westerners, I expect children who live in the West are more likely to be un-vaccinated than children who live in other regions.

Philosophical Exemption. I expect state exemption policy is negatively associated with vaccine status. In particular, I expect children who live in states that allow a vaccine exemption for philosophical reasons are more likely to be un-vaccinated than children who live in states without the exemption. I expect either their family moved to the state to take advantage of the more lenient immunization policy, or they already lived in the state but were influenced by others in their community who also chose to obtain a philosophical exemption.

DATA

National Immunization Survey

The National Immunization Survey (NIS) has collected data on U.S. children 19-35 months of age every year since 1995 in order to satisfy the CII mandate to identify under-vaccinated children and monitor progress in reaching immunization coverage goals. The data has been collected and processed through the CDC, the National Center for Immunization and Respiratory Diseases, the National Center for Health Statistics, the National Immunization Program, Abt Associates, Inc., and the National Opinion Research Center.

The NIS uses two phases of data collection to obtain vaccination information on young children in the United States: (1) a Random Digit Dialing (RDD) telephone survey identifies households with age-eligible children, and (confidentially and voluntarily via informed consent) obtains from a parent or guardian vaccine information from the child’s shot card as well as demographic and socioeconomic characteristics of the mother and child. At the end of the interview, the respondent is asked for permission (informed consent) to contact the child's vaccination provider(s) by mail with (2) the Provider Record Check (PRC) Study. The PRC obtains provider-reported vaccination histories from the child’s medical records to verify the child's vaccination information as reported by the respondent in the household survey (NIS Data User’s Guide (DUG), 2006; Smith et al, 2001). Together, RDD and PRC data are available to the public in annual Public-Use Data Files (PUF’s) available for download from the CDC website (NIS Data 2002-2006, US Department of Health and Human Services, 2007).

Random Digit Dialing (RDD) Survey of Households

Every three months, independent samples of (non-cellular) telephone numbers are drawn from selected geographic areas, or strata. The number of strata have changed very slightly over the course of the NIS (from 78 areas when the NIS was first established to 80 areas in 2006), but every year the strata include 25-30 urban areas (designated "Immunization Action Plan" (IAP) areas that were developed to increase vaccination coverage following the 1989-1991 measles outbreak) and another 50 strata that are either entire states or a "rest of state" area (when the state contains one or more IAP urban areas). Because the same data collection methodology and survey instruments are used in all estimation areas, the NIS produces comparable coverage estimates across all strata and time (NIS DUG, 2006).

The RDD household survey uses a list-assisted method to randomly select residential telephone numbers from banks of 100 consecutive telephone numbers that are updated quarterly (but which exclude cellular telephone numbers). Despite the recent increase in cell phone use in the United States, and an estimated 6 million U.S. children (8.6%) living in homes without landline telephones (Blumburg and Luke, 2006), the NIS still excludes cell phones from its sampling frame both because most households with children still have landline telephones (Blumberg et al. 2006) and because most cell phone services charge for incoming calls making it costly for respondents to participate in phone surveys (NIS DUG, 2006). [See the *Selection Bias* section below for a discussion of the possible bias in NIS data due to the exclusion of cell phone households from the study.]

Provider Record Check (PRC) Study

Given parental consent to contact the child's vaccine provider(s), an Immunization History Questionnaire (IHQ) is mailed to each provider. The IHQ, which constitutes the PRC portion of the study, simply asks the provider for information from the child's medical records including the types of vaccines the child received, number of doses of each vaccine, and the dates of administration for each dose. Once the IHQ is received by the NIS, these PRC data are entered, cleaned and merged with RDD data to produce a child level record (NIS DUG, 2006).

For my analysis, I use immunization data collected from the PRC portion of the NIS. Not only is provider immunization data more complete and accurate than respondent data, but RDD data on the number of doses received by the child for each of the individual vaccines in the "431331" series (that I use to construct dependent measures of vaccine status) are not available in the Public Use Files (PUF's) before 2006.

Response Rates

Table A1 in the Appendix provides response rates for key stages in the RDD (household) and PRC (provider) phases of the NIS in 2006. Other years in the analysis, 2002-2005, have comparable response rates.

The resolution rate (83%, row 2) is the percentage of the total telephone numbers selected that are classifiable as residential, non-residential, or non-working while there were 1,137,706 households (row 3) with working telephone numbers. The screening completion rate (90%, row 4) is the percentage of households with working phones that were successfully screened for the presence of age-eligible children; only 33,960 households (row 5) in fact had children age-eligible to participate in the study. The interview completion rate (85%, row 6) is the percentage of households with one or more age-eligible children who completed a household interview; this is the best measure of overall RDD response rate.

The number of IHQ's mailed to providers (30,073, row 9) exceeds the number of completed interviews for children with consent (24,193, row 8) because some children have more than one vaccination provider. The IHQ return rate (94.5%, row 10) is the percentage of providers who returned an IHQ questionnaire; this is the best measure of overall PRC response rate.

The unconditional adequacy rate (70%, row 11) is the percentage of children with completed household interviews (29,880, row 7) who either had adequate vaccination histories based on provider reporting (20,924) or had no vaccinations based on household reporting (120 children). This last number is the number of un-vaccinated children in the 2006 NIS sample. As of 2002, these 120 children are considered to have adequate provider data because, in fact, no provider data would be expected from children who did not receive any immunizations.

Selection Bias

Bias in the NIS sample due to selection of un-vaccinated children should not be a problem assuming under-reporting and over-reporting of un-vaccinated children balance out. Parents who chose not to vaccinate their children might be *less* likely to answer the NIS than parents who fully-vaccinate their children since they may distrust the government agency that administers the NIS for the same reasons that they distrust the vaccines themselves. On the other hand, these same parents may have strong opinions about child immunizations so they may be *more* inclined to voice their beliefs than parents who are just following their pediatrician's advice. Also, people with higher socioeconomic status (including some of these parents of un-vaccinated children) are generally more likely to respond to surveys. Therefore, it is not clear whether rates of un-immunized children would be under-reported or over-reported in the NIS, if either, due to any selection bias (positive or negative) of the parents of un-vaccinated children.

I am also assuming that selection bias, if any, is not likely to change over time, that parents of un-vaccinated children were no more or less likely to respond to the NIS in 2002 than they were in 2006.

Bartlett et al (2001) did find using 1995-96 data from the National Health Interview Survey (NHIS) that children in households without telephones had lower vaccination rates than children who live in telephone households (NIS DUG, 2006). This may suggest over-reported vaccination rates in the NIS sample that excludes non-telephone households. However, the number of non-telephone households has increased in the ten years between the NHIS and NIS samples due to rapidly growing numbers of wireless cell phones. Since these non-landline households are now a greater proportion of the U.S. population and may be more similar to other households in the sample, they may be less likely to represent un-immunized children more than the public in general. Therefore, Bartlett's analysis would need to be updated before making any conclusions about the possible selection bias that may result in the NIS sample by excluding these non-telephone households.

Imputation and Composite Variables

The NIS uses a “sequential hot-deck method” (Ford 1983) to impute and replace data that are missing for those socioeconomic and demographic variables needed to create sampling weights. Imputed variables include child’s race/ethnicity, child’s gender, child’s firstborn status, mother’s level of education, mother’s age group and marital status (NIS DUG, 2006).

Most of the independent measures used in this analysis are composite variables created and included in the PUF’s in lieu of the originally collected data. Unfortunately, these composite variables often limit a researcher’s flexibility to recode basic variables according to one’s own analytical needs. Household composite variables used in this analysis include: child’s race/ethnicity; child’s age group; number of children in household; mother’s level of education; mother’s age group; and household income/poverty status.

Since the vaccine status information used to create my dependent variable is based only on the individual number of doses received for each vaccine, no provider composite variables were used in this analysis. [More information on the exact coding of household composite variables is provided in the *Measures* section below.]

Sampling Weights

A sampling (or probability) weight can be interpreted as “the approximate number of children in the target population that a child in the sample represents” (Wooten et al, 2007; NIS DUG, 2006). Because I am interested in extrapolating this analysis of vaccine status from the NIS sample to the larger U.S. population, I use weighted data in all my analyses. Tables and figures report weighted results (unless noted otherwise).

RDD and PRC Weights. Each child in the NIS has both an RDD and PRC sampling weight that is applied to data collected in that phase of the survey. RDD weights are used to analyze children with "completed household interviews" and cover demographic, geographic and socioeconomic characteristics of the child, mother and household. PRC weights pertain to data collected from vaccination providers and are used "to form estimates of vaccination coverage" for children with "adequate provider data," including un-vaccinated children, as defined in the following section (NIS DUG, 2006).

Weights are revised periodically to account for the probability of selection into the sample by taking into account a variety of characteristics, including: each child's probability of having one of the selected telephone numbers; the working residential number rate; interview completion rates; number of telephones in the household; non-coverage of households without land-line telephones; and non-response by providers (NIS DUG, 2006). Both RDD and PRC sampling weights were adjusted in 2002, 2003 and 2005.

<u>Un-Vaccinated Children</u>

Beginning in 2002, the NIS changed the way un-vaccinated children were defined and coded in the Public-Use Data Files (PUF's). Starting that year, the definition of children with adequate provider data was expanded to include un-vaccinated children (where "adequate provider data" means that the NIS has sufficient information to determine how many doses of each vaccine the child has received). Un-vaccinated children are now defined as children who either have RDD data that indicates they have not received any vaccines (and therefore have no PRC vaccine information) or have data from an immunization provider indicating the child has not received any vaccines.

Unfortunately, un-vaccinated children were defined differently before and after 2002. Prior to 2002, NIS treated as "missing" provider data (not un-vaccinated) those children whose providers reported receiving no vaccines. This coding made the assumption that the vaccination status for these children was missing at random and, as a result, undercounted un-vaccinated children. Starting in 2002, NIS changed the way un-vaccinated children were coded. Children are now coded as un-vaccinated if they either had RDD household data showing they had received no vaccines (and therefore had no provider vaccine information) or had PRC provider data indicating the child had not received any vaccinations (Smith et al, 2005). Therefore, children that were without provider data because they had received no vaccines (who used to be coded as missing vaccine data) are now coded as being un-vaccinated. Unfortunately, since not all children with "missing" provider data prior to 2002 were actually un-vaccinated (and not just missing provider data), pre-2002 and post-2002 vaccine status data cannot be reconciled.

The CDC did conduct an analysis to determine the degree to which this change in definition altered vaccination coverage estimates. At the national level, the revised accounting was determined to have had "very little effect" on the estimates, most often "around two percentage points" (NIS DUG, 2006). However, because my study focuses precisely on these few un-vaccinated children (rather than the more general question of vaccine coverage for the total population of children), this relatively small change could have large implications for the results of my analyses. Therefore, I have decided to narrow my analysis to include only 2002-2006, those years in which the NIS definition of un-vaccinated children remained consistent.

Given this background, my analysis develops estimates of vaccine coverage between 2002 and 2006 for children with adequate provider data based on PRC immunization histories that are considered more accurate than household RDD immunization reports (NIS DUG, 2006).

Combining NIS Sample Years: Pooled Data 2002-2006

Over the five-year period from 2002 to 2006, the NIS collected vaccine data on over 103,000 children in the United States (un-weighted sample size), including data on between 17,563 children in 2005 and 21,998 children in 2004 (See Table 2 below). This sample represents an average of 5.9 million U.S. children each year and a total of over 29 million U.S. children (weighted count) across the five-year period.

Table 2. Un-Weighted Sample Size, Weighted Count and Percent of Total by Year, NIS 2002-2006.

	Un-Weighted		Weighted	
Year	Sample Size	Percent of Total	Count	Percent of Total
2002	21,410	20.72%	5,845,539.05	19.77%
2003	21,310	20.62%	5,899,319.14	19.95%
2004	21,998	21.29%	5,874,423.78	19.87%
2005	17,563	17.00%	5,935,946.53	20.08%
2006	21,044	20.37%	6,010,242.66	20.33%
Total Pooled	103,325	100.00%	29,565,471.16	100.00%

Un-Weighted Sample Size = total number of children in NIS with "adequate provider data." Weighted Count = number of estimated children the NIS data represent based on un-weighted sample size and yearly provider weights.

The large number of children included in the NIS allows for a study of vaccination rates across many different subgroups in the U.S. population (as defined by the covariates discussed in the literature review above) despite the fact that un-vaccinated children make up only a small proportion of the total sample.

Several characteristics of the total NIS sample do change significantly across the five years (see Table 4 in the Measures section below). However, since I am running my analyses looking at the 2002-2006 average of pooled data across five years, I am making no assumptions about whether characteristics of the sample are consistent across this period.

Measures

I use the following measures in my analysis of children in the NIS sample.

Dependent Variable: Vaccine Status

Each year, PRC data include information on the number of doses a child is reported to have received from the provider for each of the six recommended vaccines in the "431331" series (DTaP, Polio, MMR, Hib, HepB and Varicella). Adding up the total number of doses reported for each of the six vaccines, I calculated the total number of all doses that child received. The result is a summary measure that ranges from 0 to 15, where 0 = child received no doses for any of the six vaccines and 15 = child received all recommended doses for all six vaccines (where 4+3+1+3+3+1=15 doses).

For my analysis, un-vaccinated children are defined (based on CDC documentation) as those children who either had received none of the 15 doses of recommended vaccines (summary measure = 0), or who were classified as having "adequate provider data" (as discussed above) but had no provider record of receiving any recommended vaccine doses (summary measure = missing data).

Vaccine Status. Based on this definition of a child being un-vaccinated, I identified three groups of children in each sample between 2002 and 2006 (un-vaccinated, partly-vaccinated and fully-vaccinated children) to create a three-category dependent variable (see Table 3).

From these three groups, I also created a two-category dependent variable by combining children who were either partly-vaccinated or fully-vaccinated into one group of children with "any vaccinations" (resulting in a binary measure that distinguishes between children who were un-vaccinated and those who had any vaccinations).

Table 3: Definition of Vaccine Status Categories

Category	**Definition**
Un-Vaccinated	Provider reported child received none of the recommended doses of vaccine, or child had adequate provider data but data on doses received was missing.
Partly-Vaccinated	Provider reported child received 1-14 doses, but is not up-to-date (NUTD) on one or more of the recommended vaccines.
Fully-Vaccinated	Provider reported child received 15 or more doses, so is up-to-date (UTD) on all six recommended vaccines.

Individual Vaccines. I also sum the total number of doses received for each vaccine separately (DTaP, IPV, MMR, Hib, HepB and VCR) and define children as either vaccinated or un-vaccinated for each vaccine (to see if a more children are receiving zero doses of particular vaccines).

Independent Variables

Previous studies have considered a wide range of factors when analyzing the differences between fully-immunized and under-immunized children in the United States. This analysis will include many of the same measures, collected in the RDD household survey:

1) Year of NIS Data (2002-2006);
2) Child characteristics: race/ethnicity, gender, age group, first-born status, history of ever receiving Women, Infant and Children (WIC) benefits, and whether child had ever been breastfed;
3) Mother characteristics: level of education, age group, and marital status; and

4) Household characteristics: income & poverty status, number of children less than 18 years old in the household, U.S. census region of residence (see Figure A1 in the Appendix for a map of states by U.S. Census Region), and philosophical exemption status of the state of residence (whether or not the child lived in one of 17 states that allowed, in 2005-2006, an exemption from school immunization requirements for philosophical reasons, as distinguished from medical or religious reasons; see Table A2 in the Appendix for a list of states that did allow and did not allow a philosophical exemption in 2005-2006).

It should be noted that income and poverty data collected in the NIS changed over time. All years provide either a basic poverty variable (with only two categories: below poverty, and above poverty) or a more detailed income/poverty variable (with three categories defined as: below poverty, above poverty but less than a given income quantity, or above poverty but more than a given income quantity). For 2002-04, this three category component measure is split at $50,000 per year; for 2005-06, the split is made at $75,000. All years also provide a measure of total family income (with several income categories followed by a final category top-coded at either $50,001 or $75,001 per year). In order to keep income/poverty data usable and consistent for all five years 2002-2006, I created a new income/poverty variable with three categories: below poverty; above poverty with income less than $50,000 per year; and above poverty with income more than $50,000 per year.

State philosophical exemption laws also changed over time. The exempt measure I use in this analysis codes each state as either allowing or not allowing a philosophical exemption based on state laws in 2005-2006 (CDC Immunization Laws, 2006). However, exemption status of each state may or may not reflect laws in place when the parent made a decision about immunization. There is no certainty that the child was vaccinated before or after the law took effect.

Table 4 (below) shows the weighted percent distribution of children across each independent measure I include in this analysis, both in the five individual years of analysis and in the pooled 2002-2006 data.

Table 4: Weighted Percent Distribution of Independent Measures, NIS Yearly and Pooled 2002-2006

Child Characteristics	2002	2003	2004	2005	2006	Pooled
Race/Ethnicity ***						
Hispanic	24.36	26.25	27.10	26.81	28.98	26.71
White, non-Hispanic (ref)	53.75	52.00	51.20	51.65	50.07	51.72
Black, non-Hispanic	13.59	13.07	13.05	12.85	12.08	12.92
Other/multiple	8.30	8.69	8.65	8.69	8.87	8.64
Gender						
Male (ref)	51.50	51.10	51.15	51.18	51.17	51.22
Female	48.50	48.90	48.85	48.82	48.83	48.78
Child's Age						
19-23 months	29.89	29.69	29.91	29.78	29.97	29.85
24-29 months	35.50	34.51	35.14	34.16	34.30	34.72
30-35 months (ref)	34.61	35.81	34.95	36.07	35.73	35.44
First Born ***						
No (ref)	62.86	61.88	63.09	54.13	53.90	59.14
Yes	37.14	38.12	36.91	45.87	46.10	40.86
Ever Received WIC ***(4 years)						
No (ref)	na	42.96	42.57	45.64	45.89	44.28
Yes	na	57.04	57.43	54.36	54.11	55.72
Ever Breast Fed ***(4 years)						
No (ref)	na	28.29	28.64	25.67	26.10	27.17
Yes	na	71.71	71.36	74.33	73.90	72.83
Mother Characteristics	**2002**	**2003**	**2004**	**2005**	**2006**	**Pooled**
Education Level ***						
LT 12 years	17.39	22.30	21.99	17.02	19.09	19.56
12 years	35.31	31.52	31.35	35.57	33.27	33.41
13-15 years	15.55	21.24	21.42	12.84	17.39	17.68
GE 16 years (ref)	31.74	24.94	25.24	34.57	30.25	29.36
Mother's Age ***						
Under 20 years	3.34	3.11	2.94	2.69	3.05	3.03
20-29 years	44.81	46.43	46.03	42.88	41.52	44.32
30 years or older (ref)	51.85	50.46	51.03	54.42	55.42	52.65
Marital Status *						
Widow/div/sep/dead	7.67	8.76	8.82	7.88	7.95	8.22
Never married	21.71	22.62	23.07	22.09	22.38	22.38
Currently married (ref)	70.62	68.61	68.11	70.03	69.67	69.41
Household Characteristics	**2002**	**2003**	**2004**	**2005**	**2006**	**Pooled**
Income & Poverty Status ***						
Below poverty level (ref)	24.15	27.99	28.72	27.33	27.38	27.12
Income <= $50k, abv poverty	39.30	38.47	35.73	32.24	30.99	35.27
Income > $50k	36.55	33.54	35.54	40.42	41.63	37.61
Number of Children in HH **						
One (ref)	27.17	25.42	25.41	24.90	24.18	25.41
Two-three	59.70	60.51	60.51	60.63	60.50	60.37
Four or more	13.13	14.08	14.09	14.47	15.32	14.22
Census Region						
Northeast	17.02	16.91	16.81	16.85	16.67	16.85
Midwest	22.04	21.79	21.59	21.58	21.47	21.70
South	36.77	36.94	37.05	36.81	37.06	36.93
West (ref)	24.17	24.35	24.55	24.75	24.79	24.52
Philosophical Exemption						
No (ref)	57.17	56.87	56.71	56.74	56.90	56.88
Yes	42.83	43.13	43.29	43.26	43.10	43.12

*Significant Change in Distribution Over Five Years: + p<0.1, * p<0.05, ** p < 0.01, *** p<0.001.*

Finally, data on whether a child ever received WIC benefits and whether a child was ever breastfed were only collected by the NIS starting in 2003. These factors are important when considering a child's health status in general, and may be associated with their vaccine status. Therefore, while including these two measures will limit my analysis to four rather than five years, I have included WIC and breastfeeding in my final model.

Methods

I will use Stata statistical software (StataCorp, 2008) to conduct a complete analysis of the NIS data between 2002 and 2006.

First, in a univariate analysis, I will insure that each variable in my analysis has sufficient variation and sample size to include in my multivariate model. Also, I will determine which years of the NIS sample have complete data for all the variables of interest so I can run my analyses on only those years for which there is complete data. (For example, NIS data on WIC benefits and breastfeeding history were not collected before 2003, but these measures are important enough to be included in my analysis despite the abbreviated time frame.)

Second, I will conduct a trend analysis using t-tests to determine whether vaccine status has changed significantly across time (whether there has been a significant increase or decrease in the proportion of un-vaccinated children between 2002-2006). I will also see whether there have been significant increases in the proportion of children not being vaccinated for specific individual vaccines.

Next, I will run a series of bivariate analyses. The main purpose of these analyses will be, using a Pearson chi-square test, to identify those variables that have an significant bivariate relationship with vaccine status (so that they are included in the later models) and to shed light on significant relationships found in the following multivariate analysis. I will not use this step to exclude independent variables from my models, as it is possible that, while a variable may not appear to be significantly related to vaccine status, it may in fact be significantly related once my regression model controls for other factors.

Finally, I will run a series of logistic regression models that include vaccine status as a dependent variable coded with either three categories (children are un-vaccinated, partly-vaccinated or fully-vaccinated) or two categories (children are un-vaccinated or have any vaccinations) with one or more child, mother or household independent characteristics. From these models, I will report odds ratios, standard errors, and p-value levels of significance, along with likelihood ratio (LR) tests and Wald chi-square tests.

Using these logistic regression models, I will run both: a Decomposition Analysis, to determine whether the change in vaccine status over time is simply a function of a change in the composition of the U.S. population; and a Multivariate Analysis, to determine whether vaccine status is significantly different for children with various characteristics (after controlling for other independent factors).

RESULTS

The following analyses determine whether there has been a significant increase in the proportion of children who are un-vaccinated, whether this increase can be explained by a change in the composition of the U.S. population, and what the characteristics are of the U.S. communities that are not vaccinating their children.

Trend Analysis

To assess the need for an analysis of un-vaccinated children, I begin by determining whether there was a significant change (or trend) in the number and type of vaccines children received over the five-year period from 2002 to 2006.

Number of Doses

Overall, the proportion of children who have received all 15 of the recommended vaccines (are fully-vaccinated) has increased between 2002 and 2006. At the same time, the proportion of children who have received only some (1-14 doses) of the recommended vaccine (are partly-vaccinated) has declined over the same period of time (especially the proportion who have received 3 or more doses). However, the proportion of children who have received only a few vaccine doses or none at all (0-2 doses) has actually increased over the five-year period. [See Table A3 and Figure A2 in the Appendix for more information on the count and percent of children with each single number of doses by year 2002-2006.]

It is interesting to note the marked increase in the percent of children who received one vaccine dose in 2006 (compared to previous years) and the coinciding drop in the proportion of un-vaccinated children in the same year. Perhaps children who might have otherwise fallen into the un-vaccinated (0 doses) category in 2005 moved into the one-dose category in 2006. However, a brief analysis of these subgroups (zero and one-dose children) showed that un-vaccinated children have characteristics that are distinct from one-dose children. Therefore, even though these two groups together might seem to represent U.S. children who are increasing likely to get few if any immunizations, because they appear to be made up of children with different characteristics, I have not combined these two groups of children in my analysis.

Vaccine Status

Overall, the weighted proportion of children who have received all of the recommended vaccines (are fully-vaccinated) has increased (from 65% to 77%) between 2002 and 2006. Consequently, the proportion of children who are under-vaccinated (all children who are not fully vaccinated) has decreased over the same time. [Tables A4 and A5 in the Appendix are a full listing of both un-weighted and weighted percent and frequency of children by vaccine status for each year 2002-2006.]

However, these under-vaccinated children are made up of two groups: partly-vaccinated children (who have received some but not all of the recommended immunizations) and un-vaccinated children (who have received none of the recommended vaccines). While the proportion of partly-vaccinated children has declined each year (from 34% in 2002 to 22.5% in 2006) mirroring the proportions in the larger under-vaccinated group, the percent of children who are un-immunized altogether, although very small, has actually increased over the five-year period (as shown in Table 5 below). The weighted number and proportion of all children 19 to 35 months old who were un-vaccinated grew from an estimated 0.27% of all U.S. children in 2002 (n=15,958) to an estimated 0.48% children (n=28,964) in 2006 with as many as 0.56% (n=32,780) un-vaccinated children in 2004.

Table 5: Children in Each Level of Vaccine Status (NIS 2002-2006 and Pooled), Weighted Count and Percent

Count						
Vaccine Status	**2002**	**2003**	**2004**	**2005**	**2006**	**Pooled 2002-06**
Un-Vaccinated	15,958	24,533	32,780	30,041	28,964	132,276
Partly-Vaccinated	2,002,920	1,597,010	1,377,889	1,387,955	1,351,243	7,717,017
Fully-Vaccinated	3,826,661	4,277,775	4,463,755	4,517,951	4,630,035	21,716,178
Total	5,845,539	5,899,319	5,874,424	5,935,947	6,010,243	29,565,471
Percent						
Vaccine Status	**2002**	**2003**	**2004**	**2005**	**2006**	**Pooled 2002-06**
Un-Vaccinated	0.27%	0.42%	0.56%	0.51%	0.48%	0.45%
Partly-Vaccinated	34.26%	27.07%	23.46%	23.38%	22.48%	26.10%
Fully-Vaccinated	65.46%	72.51%	75.99%	76.11%	77.04%	73.45%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

As confirmation of the number and percent of un-vaccinated children in the United States, the un-weighted count and percent of un-vaccinated children for each NIS sample between 2002 and 2006 taken from the Public Use Files (PUF's) roughly coincide with the un-weighted numbers provided by the CDC (no weighted data are available) in its NIS data documentation. [See Table A6 and Figures A3 and A4 in the Appendix for a comparison of CDC and PUF un-weighted and weighted counts and percents.]

The incidence of un-vaccinated children appears to have increased even over this brief five-year period. However, the proportion of children who are un-vaccinated is so small relative to the proportion of partly-vaccinated and fully-vaccinated children that any change to the size of the un-vaccinated group alone would be overwhelmed (statistically–speaking) by changes to the other two (relatively large) groups. In other words, the statistical significance of any change in the proportion of children in each of these three categories of vaccine status would be determined not by a change in the proportion of un-vaccinated children but rather by the relative increase or decrease in the proportions of fully-vaccinated and partly-vaccinated children.

Therefore, to test the statistical significance of this increase, I collapse the partly-vaccinated and fully-vaccinated children into one group (children with any vaccinations) and compare the proportion of un-vaccinated children to the proportion of children with any vaccinations in 2002 and each subsequent year, as shown in Table 6 below. (Note: since the proportion of children coded "1" in any binary variable is also the mean of that variable, the proportion of children who are un-vaccinated is also the mean number of un-vaccinated children in the sample.) Also, in order not to overstate the significance of this association (that could occur if I used weighted standard errors around a weighted mean in my large sample of U.S. children), I use un-weighted standard errors with weighted means to calculate the following t-test statistics.

Table 6: Children Either Un-Vaccinated or with Any Vaccinations (NIS 2002-2006 and Pooled), Weighted Count and Percent

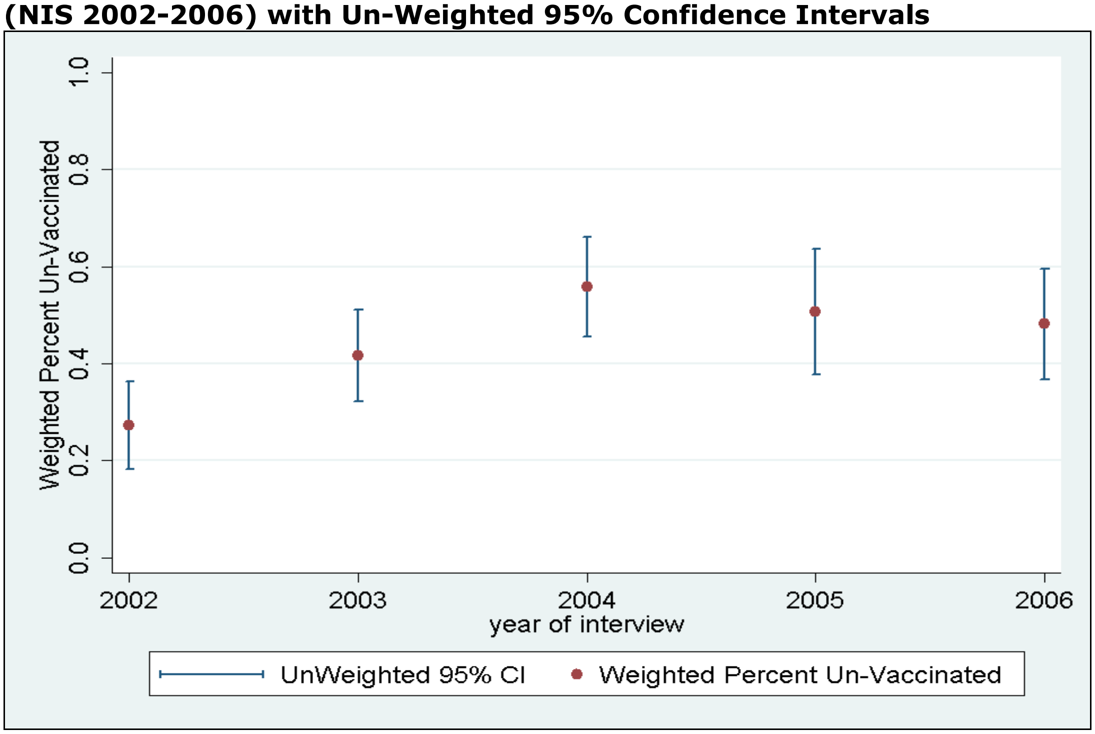
Count	**2002**	**2003**	**2004**	**2005**	**2006**	**Pooled 2002-06**
Un-Vaccinated	15,958	24,533	32,780	30,041	28,964	132,276
Any Vaccinations	5,829,581	5,874,786	5,841,644	5,905,906	5,981,278	29,433,196
Total	5,845,539	5,899,319	5,874,424	5,935,947	6,010,243	29,565,471
Percent	**2002**	**2003**	**2004**	**2005**	**2006**	**Pooled 2002-06**
Un-Vaccinated	0.27%	0.42%	0.56%	0.51%	0.48%	0.45%
Any Vaccinations	99.73%	99.58%	99.44%	99.49%	99.52%	99.55%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 7 and Figure 2 (below) show the results of t-tests that compare the proportion of un-vaccinated children in 2002 to the proportion un-vaccinated in each subsequent year.

Table 7: T-test Comparison of Weighted Proportion of Un-Vaccinated Children In 2002 and 2003-06 (NIS 2002-2006)

Year	Un-Wt'ed Sample Size	Wt'ed Mean	Un-Wt'ed St Dev	95% CI	2-sided T-test	p-value	Signif
2002	21,410	0.0027	0.0675	0.0018 - 0.0036	-	-	
2003	21,310	0.0042	0.0707	0.0032 - 0.0051	-2.1363	0.0327	*
2004	21,998	0.0056	0.0775	0.0046 - 0.0066	-4.0884	0.0000	***
2005	17,563	0.0051	0.0873	0.0038 - 0.0064	-2.8975	0.0038	**
2006	21,044	0.0048	0.0844	0.0037 - 0.0060	-2.8137	0.0049	**

Figure 2: Weighted Proportion of Un-Vaccinated Children Each Year (NIS 2002-2006) with Un-Weighted 95% Confidence Intervals



There was a significant increase in the proportion of un-vaccinated children between 2002 and each subsequent year in the five year period. Significance levels range from p<0.05

(when comparing 2002 and 2003), to p<0.01 (in 2005 and 2006) and p<0.001 (comparing 2002 and 2004).

These results confirm the hypothesized increase in the proportion of un-vaccinated children during the five years from 2002-2006. They also justify separating the children who are entirely un-vaccinated from those who are at least partly-vaccinated. In subsequent analyses, I will use both the original three category dependent variable (un-vaccinated, partly-vaccinated and fully-vaccinated children) and the new two category variable (where children are either un-vaccinated or have any vaccinations).

Individual Vaccines

As shown in Table 8 (below), there were very significant increases between 2002 and 2006 in the proportions of partly-vaccinated children who were un-vaccinated for specific vaccines in the "431331" series.

Specifically, about three times as many partly-vaccinated children were un-vaccinated for the *Haemophilus influenzae* type b (Hib) vaccine in 2006 than in 2002 (5.45% up from 1.63%) and about twice as many were un-vaccinated for the Polio (IPV) vaccine (6.18% up from 3.10% five years earlier). There were also statistically significant (although smaller) increases in the proportion of partly-vaccinated children who had not received any doses of the Measles-Mumps-Rubella (MMR) vaccine (for which about a quarter of the children had not received the one recommended dose) and the Diphtheria-Tetanus-Pertussis (DTaP) vaccine (making up for a brief drop in 2003 due to a temporary vaccine shortage). Perhaps surprisingly, significantly fewer partly-vaccinated children were skipping the Varicella "chicken pox" (VRC) vaccine in 2006 than in 2002 (down to 45.27% from 55.96%) although this vaccine was still the most commonly omitted from the "431331" series. There was no significant change over the five years in the proportion of partly-vaccinated children who were un-vaccinated for the Hepatitis B (HepB) vaccine (although between 3.5% and 4.5% were un-vaccinated for the disease).

Table 8: Weighted Percent (and 95% Confidence Interval) of Partly-Vaccinated Children Who Have None of the Recommended Doses For Individual Vaccines, NIS 2002-2006.

Vaccine	2002	2003	2004	2005	2006	Pooled 2002-2006
DTaP **	3.81%	2.28%	2.46%	3.10%	3.95%	3.15%
	(3.19-4.55)	(1.67-3.12)	(1.80-3.36)	(2.34-4.10)	(3.10-5.03)	(2.82-3.52)
Polio ***	3.10	6.11	5.71	5.71	6.18	5.20
	(2.61-3.66)	(5.02-7.42)	(4.59-7.08)	(4.64-7.02)	(5.04-7.55)	(4.74-5.69)
MMR **	22.88	23.68	26.22	27.83	26.51	25.17
	(21.16-24.71)	(21.84-25.63)	(24.21-28.34)	(25.52-30.27)	(24.34-28.81)	(24.27-26.10)
Hib ***	1.63	3.49	3.43	3.97	5.45	3.43
	(1.30-2.05)	(2.62-4.64)	(2.66-4.42)	(3.13-5.01)	(4.34-6.83)	(3.06-3.84)
Hep B	3.58	4.25	4.49	3.76	3.60	3.92
	(2.99-4.28)	(3.40-5.30)	(3.55-5.66)	(2.89-4.88)	(2.74-4.71)	(3.54-4.34)
VRC ***	55.96	54.48	51.11	49.69	45.27	51.79
	(54.02-57.89)	(52.32-56.62)	(48.71-53.51)	(46.98-52.40)	(42.77-47.79)	(50.75-52.82)
Total N	2,002,920.18	1,597,010.47	1,377,888.76	1,387,954.94	1,351,242.84	7,717,017.20

*Significant Change Over Five Years: + p<0.1, * p<0.05, ** p < 0.01, *** p<0.001.*

These proportions generally coincide with Schlenker's (2004) findings. Schlenker found that VRC and MMR were the most commonly refused vaccines. However, he found a higher proportion (10%) of Wisconsin parents refusing both the Hepatitis B and DTaP vaccines; in the NIS sample representing the whole United States, closer to 3-4% of children were un-vaccinated for these specific diseases.

Contrary to my original hypotheses, the most significant increases in the proportion of un-vaccinated children were found for Hib and IPV, vaccines *not* rumored to be associated with specific illness. However, MMR and DTaP (rumored to be associated with autism and SIDS) did display significant increases as expected (p=0.0024 and 0.0081, respectively) over the five-year period. Therefore, there does appear to have been at least some impact of vaccine safety concerns (and the fear of a causal link between these vaccines and child illness) on immunization rates.

Bivariate Analysis

The weighted percent distributions of children across three vaccine status groups (un-vaccinated, partly-vaccinated and fully-vaccinated) for each category of all independent variables in the pooled sample from 2002-2006 are shown in Table 9 below. These analyses indicate how vaccine status differs across children with various characteristics. In particular, which children are more (or less) likely to be un-vaccinated? As hypothesized, I expect there to be higher proportions of un-vaccinated children among younger, White males who never received WIC benefits but who were ever breastfed, have mothers who graduated college, live in households with income above $50,000 per year, live in households with four or more children, live in the western United States, and live in states that allow philosophical exemptions from immunization.

While Table 9 displays the proportions of children in three vaccine status groups for each characteristic, the level of significance indicates the magnitude of the p-value for a Pearson

Table 9: Weighted Percent Distribution and Level of Significance of Vaccine Status by Independent Measures, NIS Pooled 2002-2006

Child Characteristics	Sig	Un-Vacc	Partly-Vacc	Fully-Vacc	Total N
Race/Ethnicity	+				
Hispanic		0.33	26.19	73.48	7,897,546.27
White, non-Hispanic (ref)		0.53	25.30	74.17	15,292,616.03
Black, non-Hispanic		0.38	29.48	70.14	3,821,009.53
Other/multiple		0.42	25.59	73.99	2,554,299.33
Gender					
Male (ref)		0.47	26.03	73.50	15,143,383.85
Female		0.42	26.17	73.40	14,422,087.31
Child's Age					
19-23 months		0.49	31.74	67.77	8,824,377.09
24-29 months		0.45	25.05	74.50	10,264,004.65
30-35 months (ref)		0.40	22.38	77.22	10,477,089.42
First Born	**				
No (ref)		0.51	28.70	70.79	17,483,673.91
Yes		0.35	22.34	77.31	12,081,797.26
Ever Received WIC (4 years)	**				
No (ref)		0.63	21.39	77.99	10,421,988.14
Yes		0.38	26.24	73.38	13,114,359.06
Ever Breast Fed (4 years)	***				
No (ref)		0.26	26.45	73.28	6,421,150.49
Yes		0.57	23.16	76.27	17,215,914.30
Mother Characteristics					
Education Level					
LT 12 years		0.57	29.14	70.28	5,781,825.53
12 years		0.41	28.35	71.24	9,876,538.63
13-15 years		0.38	26.23	73.40	5,227,454.18
GE 16 years (ref)		0.45	21.44	78.11	8,679,652.82
Mother's Age					
Under 20 years		0.34	29.63	70.03	894,969.78
20-29 years		0.50	28.26	71.25	13,103,645.46
30 years or older (ref)		0.41	24.08	75.50	15,566,855.93
Marital Status					
Widow/div/sep/dead		0.64	29.76	69.60	2,429,303.77
Never married		0.36	28.88	70.76	6,615,314.90
Currently married (ref)		0.45	24.77	74.77	20,520,852.49
Household Characteristics					
Income & Poverty Status					
Below poverty level (ref)		0.38	29.02	70.60	7,117,623.11
Income <= $50k, abv poverty		0.49	28.07	71.44	9,254,949.83
Income > $50k		0.44	22.15	77.41	9,869,656.24
Number of Children in HH	***				
One (ref)		0.29	21.49	78.22	7,511,367.81
Two-three		0.36	26.19	73.45	17,849,114.11
Four or more		1.11	33.95	64.94	4,204,989.25
Census Region	**				
Northeast		0.34	23.81	75.85	4,981,985.11
Midwest		0.48	27.57	71.95	6,414,304.10
South		0.37	25.06	74.57	10,918,354.89
West (ref)		0.61	27.95	71.44	7,250,827.08
Philosophical Exemption	**				
No (ref)		0.38	25.29	74.33	16,816,460.45
Yes		0.54	27.17	72.30	12,749,010.71

*Significant Change in Distribution Over Five Years: + p<0.1, * p<0.05, ** p < 0.01, *** p<0.001.*

chi-square statistic on the dichotomous vaccine status variable (children who are un-vaccinated versus those who have any vaccinations) for each independent measure. Reference categories, (ref), are indicated for each independent variable included later in the multivariate analyses.

Demographic Characteristics

Vaccine status is significantly associated with several demographic characteristics, including child's race/ethnicity, number of children in the household (a proxy for family size), child's first born status and breastfeeding history.

Child's Race/Ethnicity. Race and ethnicity are significantly associated with vaccine status. As hypothesized, White children are significantly more likely than children of any other race or ethnicity to be un-vaccinated (and less likely either to be partly-immunized or to have any vaccinations (be partly- or fully-vaccinated)). Interestingly, this significance holds despite the fact that a higher proportion of White children are fully-immunized than any other race/ethnicity.

Meanwhile, Blacks are less likely to be either un-vaccinated or fully-immunized than Whites, and more likely to be partly-immunized than all other race/ethnicities. Based on previous research (that distinguished between under-immunized and fully-immunized children), this result was not unexpected.

Somewhat unexpected, however, was the finding that Hispanics were least likely to be un-vaccinated of all race/ethnicities. Perhaps this finding helps explain to some extent what has been referred to as the "Hispanic Health Paradox" (the observation that Hispanics are often healthier than Whites despite lower socio-economic status).

Number of Children in the Household. The number of children in a household is also significantly associated with vaccine status. As expected, children who live in households with larger families (four or more children) are much more likely to be un-immunized than are their counterparts in smaller families (with an only child or two-to-three children). Again, as with race/ethnicity, this relationship is still significant despite the finding that a higher proportion of larger families (compared to smaller families) also partly-vaccinate their children and a lower proportion have fully-vaccinated children.

I expect this result may reflect two possibilities: the greater likelihood that any one child in a larger family is un-vaccinated (compared to a smaller family) simply because there are more children at risk of begin un-vaccinated; and, perhaps of greater interest to this paper, that the same parents who chose to have a large family (possibly for religious reasons) may also have philosophical objections to vaccines (as seen in some of the recent medical analyses of disease outbreaks).

First Born Status. Whether a child is the first born in their family (or the later born, younger sibling) is also significantly associated with whether they have any vaccinations (although not whether they would be un-vaccinated versus partly-vaccinated). First born (older) children are much less likely to be un-vaccinated (than they are to be partly- or fully-vaccinated) compared to their higher birth order (younger) siblings.

I did not anticipate that first born status would have a significant association with vaccine status (and so did not include this measure among my hypotheses). However, first born status does roughly coincide with the age of a child (first born children tending to be older than their younger siblings), and the hypothesized relationship between child's age and vaccine status (in which I expected younger children to be more un-vaccinated) does coincide with these findings of first born status.

In terms of simple percentages, younger siblings are more likely than first born children to be either un-vaccinated or partly-vaccinated, while first born children are more likely than younger siblings to have received all their vaccinations. This measure is a good example of how the difference in proportions of fully-vaccinated and partly-vaccinated children would overwhelm the proportion of un-vaccinated children in a chi-square test of significance.

Breastfeeding History. While breastfeeding is not a typical demographic measure, it is a common topic of demographic research and so is included in this section.

Having been breastfed is significantly associated with vaccine status. Children who were ever breastfed are significantly more likely to be un-vaccinated than they are to have received any vaccinations. This higher proportion of breastfed children who are un-vaccinated may reflect an association between these two characteristics though a common link, possibly the back-to-nature movement that has a particular interest in organic foods and physical well-being that may influence their attitudes towards vaccinations.

Interestingly, breastfed children are also more likely to be fully-vaccinated than children who were not breastfed. However, breastfed children are so much more likely to be un-vaccinated that the larger number that are fully-vaccinated is balanced out by the smaller number who are partly-vaccinated (so that together, breastfed children are significantly less likely to have had any vaccinations).

Several other demographic measures had interesting (although insignificant) associations with vaccine status.

Child's Gender. Despite my hypothesis that gender and vaccine status were related, male and female children were not significantly different in their vaccine status. However, the slightly higher percentage of boys who are un-vaccinated may still reflect some fear of autism among their parents. Recent reports have perpetuated a rumored association between vaccines and the mysterious disease (that is believed to afflict boys more often than girls). That a slightly (although not significantly) higher percentage of boys in the NIS sample are un-vaccinated may yet reflect some parents' decision to forgo vaccinating their son in fear of exposing them to a risk of autism.

Child's Age. All children in the NIS sample are older than 18 months, the age at which all "431331" vaccine doses are recommended, so every child in the sample is old enough to be fully-vaccinated. Nevertheless, while the overall association between vaccine status and child's age (in Table 9 above) is not significant, the relationship between these two variables was in the expected direction. For the pooled sample across all five years, the proportion of children who were un-vaccinated altogether was higher among the youngest children (0.49%) than the oldest (0.40%), and the proportion of children who were fully-vaccinated was lower among the youngest children (68%) compared to the oldest children (77%).

The reasons for this pattern are not clear from this preliminary analysis. The tendency for younger age groups to receive fewer immunizations could indicate a recent preference away from vaccines through either a cohort effect (if there is an increase in the proportion of younger children who are un-vaccinated compared to older children) or a period effect (if there is an increase across time in the proportion of children of all ages who are un-vaccinated). Table 10 (below) shows the results of a more in-depth analysis that looks at the changes in the proportion of children who are un-vaccinated by age across time.

Table 10: Weighted Percent Distribution of Un-Vaccinated Children By Child's Age and Year, NIS 2002-2006 and Pooled

	2002	2003	2004	2005	2006	Pooled 2002-06	P-value	sig
Child's Age								
19-23 months	0.42	0.59	0.52	0.38	0.56	0.49	0.618	
24-29 months	0.20	0.33	0.63	0.60	0.50	0.45	0.047	*
30-35 months	0.22	0.36	0.51	0.52	0.39	0.40	0.197	
Total	0.27	0.42	0.56	0.51	0.48	0.45		
P-value	0.059	0.161	0.787	0.408	0.563	0.451	0.023	*
sig	+							

*Significant Difference in Vaccine Status: + p<0.1, * p<0.05, ** p < 0.01, *** p<0.001.*

Overall, there appears to be a weak cohort effect taking place in the proportion of un-vaccinated children in this sample. The youngest children (19-23 months) had higher proportions of un-vaccinated children than all older children, not only in several individual years (2002, 2003 and 2006) but also in the pooled sample (2002-2006).

However, despite these higher proportions of un-vaccinated children in the younger age groups, there appears to be a stronger period effect taking place in immunization rates among children of all ages. As mentioned above, the proportions of un-vaccinated children increased in all three age groups, significantly rising in the pooled data from 0.27% to 0.48% with a peak of 0.56% in 2004. In particular, the proportion of children aged 24-29 months who were un-vaccinated increased significantly across the five years (from 0.20% to 0.50%), while the proportion of un-vaccinated children in the youngest age group increased across the five years (although not significantly). This seems to be consistent with the overall trend in rates of un-vaccinated children between 2002-2006 (Table 7 and Figure 2, above) where the rates of un-vaccinated children overall have increased significantly between 2002 and 2006 but have slowed somewhat in the last year or two (2005 and 2006).

Perhaps the youngest children are not being left un-vaccinated at the same rate as their somewhat older siblings. Has there been a recent slowing in the increased proportion of un-vaccinated children? If so, could it be that the recent media attention given to the controversy regarding a possible link between vaccinations and autism, and the medical community's effort to "reassure" parents about vaccine safety, had an impact on immunization rates? Further research would need to be conducted to answer these questions.

Mother's Age. There appears to be an insignificant linear relationship between mother's age and the proportion of children who are either fully-immunized or partly-immunized: children with older mothers tend to be fully-immunized and children with younger mothers tend to be partly-immunized.

More central to the focus of this study, mother's age appears to have a U-shaped relationship with the proportion of children who are un-vaccinated: mothers in the middle age group (20-29 year olds) tend to have more un-vaccinated children than either older mothers (aged 30 years and older) or younger mothers. Generally, though, there is a fairly even distribution of un-vaccinated children across all three age groups of mothers.

Marital Status. While a higher proportion of married mothers have fully-immunized their children, and a higher proportion of widowed/divorced/separated/deceased mothers have only partly-immunized theirs, both of these groups of mothers have higher proportions of un-immunized children compared to mothers who have never married.

Again, this relationship is not statistically significant but does indicate something of a positive relationship between marriage and being fully-immunized and a negative relationship with being partly-immunized. Similar to the association we saw with mother's age, there is a fairly even distribution of un-vaccinated children across all three marital status groups of mothers, albeit with a somewhat higher proportion of un-vaccinated children among mothers who are widowed, divorced, separated or deceased.

Geographic Characteristics

Smith, Chu & Barker (2004) found that un-vaccinated children were distributed in geographic clusters across the United States, raising the risk of transmitting disease when outbreaks did occur. My analysis also finds that geographic factors are significantly associated with vaccine status on a bivariate level.

Census Region. As hypothesized, children who live in the West (but also to a great extent, children who live in the Midwest) are significantly more likely to be un-vaccinated than they are to have received any vaccinations (compared with children who live in other regions of the United States, especially the Northeast and South).

As with the association between number of children in the household and vaccine status, the difference between un-vaccinated children and those with "any" vaccinations is still significant despite a higher proportion of children in the West (and Midwest) who are only partly-vaccinated and a lower proportion who are fully-vaccinated (two groups that together make up the group of children with "any" vaccinations and whose differences might have been expected to balance each other out). Overall, greater proportions of children in the West and Midwest are either un-vaccinated altogether or only partly-vaccinated while children on the Northeast and South are more likely to be fully-vaccinated.

Philosophical Exemption. Not surprisingly, children who live in states that allow a philosophical exemption from recommended vaccinations are also significantly more likely to be un-vaccinated compared with children who live in states that do not allow such exemptions (that only allow religious or medical exemptions, as most states do). As with census region, this association was in the expected direction.

Unfortunately, we do not have data on whether families moved to a state because of its exemption policy (or whether they lived there already when the exemption law was enacted), so we cannot assume a causal relationship either way between a state's philosophical exemption policy and a family's choice to live in that state. However, it seems reasonable to assume that some of the children who are un-vaccinated would have received at least some, if not all, of their recommended vaccines if philosophical exemption laws were not in place.

Socio-Economic Status Characteristics

All three of the socio-economic status (SES) measures in this analysis (mother's level of education, income and poverty status, and having ever received WIC benefits) are significantly associated with vaccine status.

Mother's Level of Education. The least educated and most educated mothers (those who did not complete high school and those who graduated from college) have the highest proportions of un-vaccinated children in the sample. However, children with more highly educated mothers also tend to be fully-vaccinated and children with less educated mothers also tend to be partly-vaccinated. So, children of college graduates tend to be either un-vaccinated or fully-vaccinated, while children of mothers who did not finish high school tend to be either un-vaccinated or partly-vaccinated.

This finding counters the hypothesized association between mother's level of education and vaccine status (in which I expected to find, based on previous research, that mothers with a college degree, more than any other education level, would have the highest rate of un-vaccinated children). As such, these results appear to offer a partial contradiction to the SES-health gradient theory: whereas higher SES is commonly associated with better child health and lower SES with worse child health, these data show a tendency for mothers with both the highest and lowest levels of SES (as measured by levels of maternal education) to be associated with worse health (as measured by higher proportions of un-vaccinated children).

Income/Poverty Status. As with mother's education, income/poverty status demonstrates that socio-economic factors may influence vaccine status. As hypothesized, these data show that a relationship does exist between income/poverty and vaccine status (where households with higher incomes tend to have higher rates of un-vaccinated children). However, the proportion of un-vaccinated children does not vary significantly by income category, and the association that does exist is not simply linear as I had expected. Rather, the relationship is slightly U-shaped (not unlike the relationship between education and vaccine status, but in the opposite direction).

The highest proportion of un-vaccinated children are in households with incomes above poverty but less than $50k per year (moderate income), followed by households with incomes above $50k per year (the highest income category). Households with income below poverty have the lowest proportion of un-vaccinated children (and yet these same households have the highest proportion of partly-vaccinated children).

Children in higher income households are least likely to be partly-vaccinated relative to moderate income households and those below poverty. At the same time, higher income households are more likely to have children who are fully-immunized than either households in the other two income/poverty categories. Clearly, a different dynamic is at work among these social groups to generate such distinct patterns of vaccine status.

WIC Benefits. WIC data were only collected in the NIS sample between 2003 and 2006 (not 2002). However, even in this slightly abbreviated sample (four years instead of five), having ever received WIC benefits has one of the strongest associations with vaccine status.

Children who ever received WIC benefits are less likely to be un-immunized (and more likely to have received any vaccinations, be partly-immunized or fully-immunized) than children who never received WIC benefits. Ironically (again, in contradiction to previous socio-economic analysis), children with higher SES (in this case, as measured by never receiving WIC benefits) are more, not less, likely to be un-vaccinated.

While the relationship between WIC and vaccine status is in the direction opposite from the relationship (previously discussed) between breastfeeding and vaccine status, these two independent measures (WIC and breastfeeding) seem to reflect a similar socio-economic division in the population: higher SES children (who never received WIC benefits) and children who were ever breastfed both appear more likely to be either un-vaccinated or fully-vaccinated; lower SES children (who ever received WIC benefits) and children who were never breastfed appear more likely to be partly-vaccinated.

This finding may reflect an underlying socio-economic division between children who are either un-vaccinated or fully-vaccinated (higher SES) and children who are partly-vaccinated (lower SES). The same immunization pattern seems to appear with household income/poverty status (and, to a lesser extent, with mother's education level, as discussed above), two common measures of socio-economic status.

Unfortunately, data on WIC and breastfeeding history was only collected in the NIS sample between 2003 and 2006 (not 2002). However, because both of these measures were found to be very significant in this bivariate analysis, they will both be included in the multivariate analysis below (even though including them will truncate the time frame of the analysis to only four years).

Overall, there appears to be a U-shaped relationship between vaccine status and several independent characteristics (including mother's level of education, income/poverty status, WIC benefits, breastfeeding history, and child's race/ethnicity). On the one hand, there exists a linear relationship between these independent measures and vaccine status: the proportion of children who are partly-immunized either increases or decreases across categories of a given characteristic (while the proportion of children who are fully-immunized moves in the opposite direction increasing or decreasing, respectively, across these same categories). At the same time, the children who are more likely to be fully-vaccinated also tend to be the same children who are un-vaccinated. This overall pattern seems to confirm the expectation that vaccine status (specifically, the probability of being un-vaccinated) varies significantly by child, mother and household characteristics.

Decomposition Analysis

This decomposition analysis will show whether or not there has been a significant increase over the five-year period in the proportion of children who are un-vaccinated beyond that which would be expected given recent changes in characteristics of the population (as described by independent variables in the *Bivariate Analysis* above). In this analysis, vaccine status is defined as a dichotomous (two category) variable that codes children as either having no immunizations (being un-vaccinated) or having any vaccinations (being partly-vaccinated or fully-vaccinated).

Results of the decomposition analysis are shown below in Table 11. Displayed in the table are results from three sets of binomial logistic regression models, each intended to show whether or not vaccine status changed significantly over time when controlling for none, one, or all of the available independent variables:

(1) Base Model, a logistic regression of vaccine status on time (as measured by the year of NIS data):

Vaccine Status = Year.

This model tells us simply whether there has been a significant change in vaccine status over the five year period (as would be indicated by a significant coefficient for the Year variable);

(2) Single Characteristic Models, each a separate logistic regression of vaccine status on time and one of the available independent variables (X):

Vaccine Status = X + Year.

These models tells us whether there was still a significant change in vaccine status over the five year period (as indicated by a significant coefficient for the Year variable) after controlling for the selected independent variable (characteristic) that also could affect vaccine status;

(3) Full Model, the final logistic regression of vaccine status on time and all available independent variables together (all X's):

Vaccine Status = X1 + X2 + X3 +…+ Xi + Year.

This model tells us whether, after controlling for all the population characteristics across the five years, there is still a significant effect of time on vaccine status. If the Year coefficient is no longer significant, then the change in vaccine status is explained by changes in population composition. On the other hand, if the Year coefficient is still significant after controlling for other variables, then there has been a change in vaccine status over the five years beyond that which would be expected given changes in the population composition.

Table 11: Decomposition of Independent Measures across Time: Binomial Logistic Models of Vaccine Status on Year Controlling for None, Some or All Independent Variables (Weighted NIS Pooled 2002-2006)

	Un-Vaccinated (versus Any Vaccinations)					
	Obs (n)	OR	SE	95% CI	P-value	Sig
Base Model: VacStat = Year	103,325	1.121	0.045	1.036-1.213	0.005	**
Controlling for Single Independent Variable: VacStat = X+Year						
Child Characteristics						
Race/Ethnicity	103,325	1.125	0.045	1.039-1.217	0.004	**
Male Child	103,325	1.121	0.045	1.036-1.213	0.005	**
Child's Age	103,325	1.121	0.045	1.036-1.213	0.005	**
First Born	103,325	1.132	0.046	1.045-1.227	0.002	**
Ever Received WIC (1)	81,195	1.035	0.062	0.920-1.165	0.566	
Ever Breast Fed (1)	81,637	1.030	0.062	0.916-1.159	0.622	
Mother Characteristics						
Education Level	103,325	1.121	0.045	1.035-1.213	0.005	**
Mother's Age	103,325	1.123	0.046	1.037-1.216	0.004	**
Marital Status	103,325	1.121	0.045	1.036-1.213	0.005	**
Household Characteristics						
Income & Poverty Status	94,776	1.101	0.046	1.014-1.195	0.021	*
Number of Children in HH	103,325	1.111	0.045	1.026-1.202	0.009	**
Census Region	103,325	1.120	0.045	1.035-1.212	0.005	**
Philosophical Exemption	103,325	1.121	0.045	1.035-1.213	0.005	**
Full Model (Controlling for All Indep. Vars): VacStat = X1+X2+X3+... +Xi+Year						
w/o WIC, BreastFed (5yrs)	94,776	1.097	0.047	1.008-1.193	0.032	*
w/ WIC, BreastFed (4yrs)	74,464	1.000	0.067	0.877-1.141	0.994	

*Levels of Significance: + p<0.1, * p<0.05, ** p < 0.01, *** p<0.001.*
(1) WIC and Breast Fed data were collected in 2003-06 only (not 2002).

Table 12 (below) shows the results of the Likelihood Ratio and Wald tests that were obtained by running each binomial logistic regression model (Base, Single Characteristic, and Full Model) with and without the Year variable. A significant Likelihood Ratio or Wald test again indicates that Year is a significant factor in explaining vaccine status.

Table 12: Decomposition of Independent Measures across Time: Likelihood Ratio and Wald tests for Differences between Binomial Logistic Models (Weighted NIS Pooled 2002-2006)

		Log Likelihood				Wald Test		
	Obs (n)	With Year	Without Year	LR	Sig	Yr=0	P-value	Sig
Base Model: VacStat = Year	103,325	-2,956.0	-2,961.9	11.86	***	8.00	0.005	**
Controlling for Single Independent Variable: VacStat = X+Year								
Child Characteristics								
Race/Ethnicity	103,325	-2,946.3	-2,952.6	12.65	***	8.51	0.004	**
Male Child	103,325	-2,955.3	-2,961.3	11.88	***	8.00	0.005	**
Child's Age	103,325	-2,954.3	-2,960.3	11.92	***	8.00	0.005	**
First Born	103,325	-2,947.3	-2,954.3	14.02	***	9.26	0.002	**
Ever Received WIC (1)	81,195	-2,493.9	-2,494.2	0.59		0.33	0.566	
Ever Breast Fed (1)	81,637	-2,504.8	-2,505.0	0.44		0.24	0.622	
Mother Characteristics								
Education Level	103,325	-2,951.0	-2,956.9	11.84	***	7.96	0.005	**
Mother's Age	103,325	-2,953.4	-2,959.6	12.26	***	8.10	0.004	**
Marital Status	103,325	-2,950.9	-2,956.9	11.94	***	8.04	0.005	**
Household Characteristics								
Income & Poverty Status	94,776	-2,688.5	-2,692.4	7.66	**	5.30	0.021	*
Number of Children in HH	103,325	-2,891.2	-2,896.3	10.09	**	6.80	0.009	**
Census Region	103,325	-2,944.1	-2,949.9	11.75	***	7.93	0.005	**
Philosophical Exemption	103,325	-2,948.8	-2,954.7	11.82	***	7.96	0.005	**
Full Model (Controlling for All Indep. Vars): VacStat=X1+X2+X3+...+Xi+Year								
w/o WIC, BreastFed (5yrs)	94,776	-2,564.0	-2,567.4	6.87	**	4.59	0.032	*
w/ WIC, BreastFed (4yrs)	74,464	-2,120.3	-2,120.3	0.00		0.00	0.994	

Likelihood Ratio statistic (LR) = 2[(ln(L) Model with Year) - (ln(L) Model without Year)]*
P-values for ChiSquare(df=1): if chi2 >2.71/p<0.1; 3.84/0.05; 6.63/0.01; 10.83/0.001
(Agresti, Statistical Methods for Social Sciences)
*Levels of Significance: + p<0.1, * p<0.05, ** p < 0.01, *** p<0.001.*
(1) WIC and Breast Fed data were collected in 2003-06 only (not 2002).

First, results of the base model show that the odds of a child being un-vaccinated (relative to the odds of having any vaccinations) have increased significantly over the five-year period. The odds of a child being un-vaccinated increased by an average of 12% annually between 2002 and 2006 (odds ratio = 1.121, p<0.001). When controlling for any of the single independent characteristics (except WIC and breastfeeding), the odds of being un-vaccinated increased significantly by an average of between 10-13% per year (p=0.002-0.021), indicating "year" is still a significant factor in predicting vaccine status. Even after controlling for all the independent variables together in the full model (except WIC benefits and breastfeeding history), the odds of a child being un-vaccinated versus having any vaccinations increases significantly over the five years by nearly 10% annually (odds ratio = 1.097, p<0.05). Unfortunately, after controlling for WIC and breastfeeding, the odds of being un-vaccinated does not change significantly over the four years for which we have these data.

Over the total five-year period, controlling for all the changes in population characteristics, the odds of a child being un-vaccinated (versus having any vaccinations) increase by nearly 59 percent (1-EXP[ln(1.097)*5 years] = 58.867%).

Finally, likelihood ratio and Wald chi-square tests confirm the finding that vaccine status changes significantly between 2002 and 2006, even after controlling for independent characteristics of the population. Likelihood ratio tests find "year" is a significant factor in determining vaccine status whether looking at the base model (LR=11.86, p<0.001), models with just one independent variable in addition to "year", or the full model with all independent variables together (LR=6.87, p<0.01). Wald tests also find "year" is consistently significant, if at a lower level of significance.

Therefore, there has been a significant increase in the proportion of children who are un-vaccinated even after controlling for changes in the composition of the U.S. population. As hypothesized, the proportion of children who remain un-vaccinated has increased significantly during the five-year period *beyond* that which would be expected given recent changes to the composition of the U.S. population (as reflected in the child, mother and household characteristics included in my model).

Multivariate Analysis

The previous decomposition analysis showed a significant increase in the proportion of children who were un-vaccinated over the five years from 2002 and 2006. This increase justifies taking the next step and asking, in this multivariate analysis, "what child, mother and household characteristics are significantly associated with a child being un-vaccinated?"

Although I used five years of data (2002-2006) to show that there was an increase over time in the proportion of children who were un-vaccinated, I use only four years of data (2003-06) in this multivariate analysis in order to include data on WIC and breastfeeding. This should not be a problem because time is not a factor at this stage of the analysis; I only want to learn about the characteristics of the children who are un-vaccinated across the total four year period.

Tables 13 and 14 below present results from two models that regress vaccine status on the full set of independent variables. The first model (in Table 13) is a multinomial logistic regression where vaccine status is defined as a three-category dependent variable (including un-vaccinated, partly-vaccinated and fully-vaccinated children). The second model (in Table 14) is a binomial logistic regression where vaccine status is defined as a two-category dependent variable (un-vaccinated children, and children with any vaccinations).

Table 13: Multinomial Logistic Regression of Vaccine Status (Three Category) Controlling for Child, Mother and Household Characteristics (NIS 2003-06)

Child Characteristics	Un- vs Partly-Vacc			Un- vs Fully-Vacc			Partly- vs Fully-Vacc		
Race/Ethnicity	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig
Hispanic	0.481	0.134	**	0.414	0.115	**	0.862	0.038	**
White, non-Hispanic (ref)	1.000	-		1.000	-		1.000	-	
Black, non-Hispanic	0.795	0.253		0.831	0.264		1.046	0.053	
Other/multiple	0.925	0.282		0.902	0.272		0.975	0.058	
Gender									
Male (ref)	1.000	-		1.000	-		1.000	-	
Female	0.952	0.154		0.969	0.155		1.017	0.031	
Child's Age									
19-23 months	0.804	0.151		1.351	0.252		1.679	0.064	***
24-29 months	1.009	0.200		1.244	0.244		1.232	0.046	***
30-35 months (ref)	1.000	-		1.000	-		1.000	-	
First Born									
No (ref)	1.000	-		1.000	-		1.000	-	
Yes	1.348	0.322		1.233	0.292		0.915	0.042	+
Ever Received WIC									
No (ref)	1.000	-		1.000	-		1.000	-	
Yes	0.399	0.098	***	0.397	0.097	***	0.996	0.044	
Ever Breast Fed									
No (ref)	1.000	-		1.000	-		1.000	-	
Yes	2.601	0.661	***	2.365	0.598	**	0.909	0.033	**
Mother Characteristics									
Education Level	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig
LT 12 years	1.434	0.487		1.919	0.647	+	1.338	0.078	***
12 years	0.810	0.194		0.998	0.237		1.233	0.054	***
13-15 years	0.642	0.128	*	0.757	0.150		1.179	0.049	***
GE 16 years (ref)	1.000	-		1.000	-		1.000	-	
Mother's Age									
Under 20 years	0.887	0.815		0.949	0.871		1.070	0.116	
20-29 years	1.440	0.319	+	1.667	0.367	*	1.158	0.042	***
30 years or older (ref)	1.000	-		1.000	-		1.000	-	
Marital Status									
Widow/div/sep/dead	1.778	0.573	+	2.113	0.676	*	1.188	0.068	**
Never married	1.424	0.406		1.492	0.423		1.048	0.051	
Currently married (ref)	1.000	-		1.000	-		1.000	-	
Household Characteristics									
Income & Poverty Status	OR	SE	Sig	OR	SE	Sig	OR	SE	Sig
Below poverty level (ref)	1.000	-		1.000	-		1.000	-	
Income <= $50k, abv poverty	1.261	0.336		1.377	0.365		1.092	0.049	+
Income > $50k	1.100	0.396		1.011	0.362		0.919	0.052	
Number of Children in HH									
One (ref)	1.000	-		1.000	-		1.000	-	
Two-three	1.210	0.325		1.549	0.411	+	1.280	0.065	***
Four or more	4.030	1.198	***	7.509	2.202	***	1.863	0.127	***
Census Region									
Northeast	0.649	0.173		0.530	0.140	*	0.816	0.044	***
Midwest	0.777	0.167		0.717	0.152		0.922	0.041	+
South	0.681	0.149	+	0.560	0.122	**	0.823	0.036	***
West (ref)	1.000	-		1.000	-		1.000	-	
Philosophical Exemption									
No (ref)	1.000	-		1.000	-		1.000	-	
Yes	1.174	0.200		1.211	0.205		1.032	0.033	

Model Statistics: N=74,464; Wald chi-sq(df48)=849.96 (P>chi2= 0.000); LR= -42,097.1
*Levels of Significance: + p<0.1, * p<0.05, ** p < 0.01, *** p<0.001.*

Table 14: Binomial Logistic Regression of Vaccine Status (Two Category) Controlling for Child, Mother and Household Characteristics (NIS 2003-06)

Child Characteristics	Un-Vaccinated vs Any Vaccinations		
Race/Ethnicity	**OR**	**SE**	**Sig**
Hispanic	0.431	0.120	**
White, non-Hispanic (ref)	1.000	-	
Black, non-Hispanic	0.821	0.260	
Other/multiple	0.907	0.274	
Gender			
Male (ref)	1.000	-	
Female	0.965	0.154	
Child's Age			
19-23 months	1.171	0.218	
24-29 months	1.181	0.231	
30-35 months (ref)	1.000	-	
First Born			
No (ref)	1.000	-	
Yes	1.260	0.298	
Ever Received WIC			
No (ref)	1.000	-	
Yes	0.398	0.097	***
Ever Breast Fed			
No (ref)	1.000	-	
Yes	2.430	0.615	***
Mother Characteristics			
Education Level			
LT 12 years	1.780	0.601	+
12 years	0.950	0.226	
13-15 years	0.730	0.144	
GE 16 years (ref)	1.000	-	
Mother's Age			
Under 20 years	0.932	0.855	
20-29 years	1.603	0.352	*
30 years or older (ref)	1.000	-	
Marital Status			
Widow/div/sep/dead	2.009	0.642	*
Never married	1.473	0.418	
Currently married (ref)	1.000	-	
Household Characteristics			
Income & Poverty Status			
Below poverty level (ref)	1.000	-	
Income <= $50k, abv poverty	1.346	0.357	
Income > $50k	1.033	0.370	
Number of Children in HH			
One (ref)	1.000	-	
Two-three	1.464	0.388	
Four or more	6.363	1.859	***
Census Region			
Northeast	0.559	0.148	*
Midwest	0.733	0.155	
South	0.590	0.128	*
West (ref)	1.000	-	
Philosophical Exemption			
No (ref)	1.000	-	
Yes	1.201	0.203	

Model Statistics: N=74,464; Wald chi-sq(df24)=188.60 (P>chi2= 0.000); LR=-2,120.3
*Levels of Significance: + p<0.1, * p<0.05, ** p < 0.01, *** p<0.001.*

In both models, categorical independent variables have been added as a series of dummy, dichotomous variables. Each independent variable has a reference category, identified in the tables as (ref), that is chosen either because it is the category with the greatest frequency of cases, it was the reference group used in the Smith, Chu and Barker analysis, or it is the “no” category of a dichotomous variable (simplifying interpretation). In any case, the choice of reference category (for dependent or independent variables) does not change whether the relationship between vaccine status and that independent measure is significant, only the odds ratios that are reported.

Reported results include an odds ratio (OR), robust standard error (SE) and p-value level of significance (Sig). An odds ratio is the ratio of the odds of being in one dependent variable category (e.g., un-vaccinated) relative to the odds of being in the base category of the dependent variable (e.g., having any vaccinations) for that specified level of each independent variable relative to the reference level for that independent variable (which by definition has an odds of 1.00). That is, the odds ratio is the change in the odds (of having one vaccine status versus the other) when moving from the reference category of a characteristic to the specified category (Long & Freese, 2006).

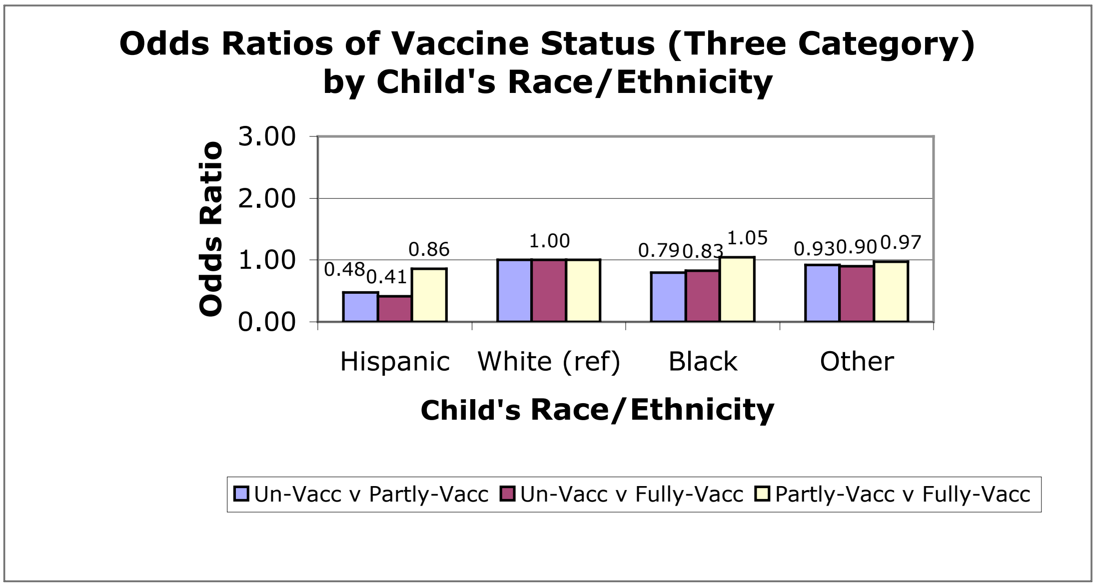
Factors associated with a child’s vaccine status can be described in three general categories: demographic, geographic, and socio-economic status characteristics.

Demographic Characteristics

Demographic characteristics refer to the child’s race and ethnicity, age, gender, birth order and household family size as well as the age and marital status of the mother. These demographic characteristics include some of the most significant odds ratios in the analysis.

Child's Race/Ethnicity. This analysis finds that vaccine status varies significantly by race/ethnicity. Of course, previous studies have found differences in the proportions of children of various race/ethnicities who are up-to-date (UTD) and not-up-to-date (NUTD) on their immunizations, but this multinomial logistic regression also finds significant differences in the odds of children being un-vaccinated by race/ethnicity (see Figure 3).

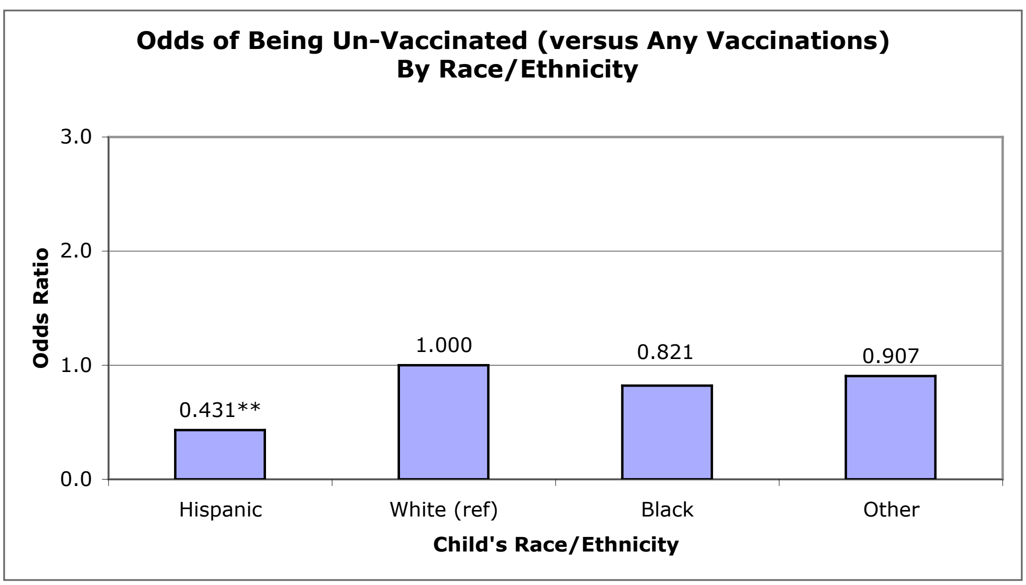
Figure 3



White children are more likely to be un-vaccinated than children of any other race/ethnic group. In particular, the odds that a White child is un-vaccinated (rather than either partly-vaccinated or fully-vaccinated) is significantly higher than the odds for an Hispanic child. Specifically, Whites are over two times more likely to be un-vaccinated than partly-vaccinated compared to Hispanic children (1/0.48=2.08), and nearly 2.5 times more likely to be un-vaccinated than fully-vaccinated (1/0.41=2.42) compared with Hispanic children. White children are also significantly (16%) more likely than Hispanic children to be fully-vaccinated than they are to be partly-vaccinated (1/0.86=1.16). On the other hand, White children are up to 27% more likely (1/0.79=1.27) to be un-vaccinated than they are to be partly-vaccinated or fully-vaccinated compared to Black children or children of “other or multiple” races, but this difference is not significant.

Looking at the results of the binomial logistic regression (the odds of children of different race/ethnic groups being un-vaccinated versus having any vaccinations), White children are more likely to be un-vaccinated than children of any other race/ethnic group, but especially compared with Hispanic children (see Figure 4 below). The odds of a White child being un-vaccinated (rather than having any vaccinations) is 2.3 times (1/0.431=2.32) higher than the odds for an Hispanic child.

Figure 4



While I did find as expected that Whites are more likely than any other race/ethnicity to be un-vaccinated (findings that concurred with results from Smith, Chu and Barker, 2004), the largest difference in vaccine status is not between Whites and Blacks (as I had hypothesized) but between Whites and Hispanics. Not only are White children most likely among all racial/ethnic groups to be un-vaccinated, but Black children are more likely to be partly-vaccinated than children of other groups, and Hispanic children are unexpectedly most likely to be fully-vaccinated and least likely to be partly-vaccinated or un-vaccinated.

Child's Age and First Born Status. Multinomial logistic regression shows that younger children in the NIS sample are significantly more likely to be partly-vaccinated than they are to be fully-vaccinated. Compared to older children, younger children also tend to be more un-vaccinated than fully-vaccinated (but not significantly so), but are somewhat more likely to be partly-vaccinated (than un-vaccinated) compared to the older children.

The youngest children (19-23 month olds) are significantly more likely to be partly-immunized than they are to be fully-immunized relative to the oldest children in the sample (30-35 month olds); the odds that these younger children are partly-vaccinated (rather than fully-vaccinated) are 68% higher than older children. Even 24-29 month olds (the middle age group) were significantly more likely to be partly-immunized (than fully-immunized) compared with older children; the odds of receiving some vaccines were over 23% higher among the middle age group. These findings appear to reflect the trend towards less than fully-vaccinated children over the period between 2002 and 2006.

However, there was no significant difference in the odds of being un-vaccinated (versus partly-vaccinated or fully-vaccinated) by age of child. While the two youngest age groups were 35% and 24% (respectively) more likely to be un-vaccinated than fully-vaccinated (compared to the oldest children), the youngest were 24% more likely to be partly-vaccinated (1/0.804=1.244) than they were to be un-vaccinated. Although these differences are not significant, they may reflect the slight decline (seen previously in Figure 2) in the overall proportion of un-vaccinated children in 2005 and 2006.

Looking at the binomial analysis, the odds of a child being un-vaccinated (versus having any vaccinations) does decline slightly with the age of the children (although, again, the difference is not significant). The odds that 19-23 month old and 24-29 month old children were un-vaccinated were 17% and 18% higher, respectively, than the odds for a 30-35 month old. Again, these differences are not significant, but they do tend to indicate a general shift away from vaccinations during the five year period.

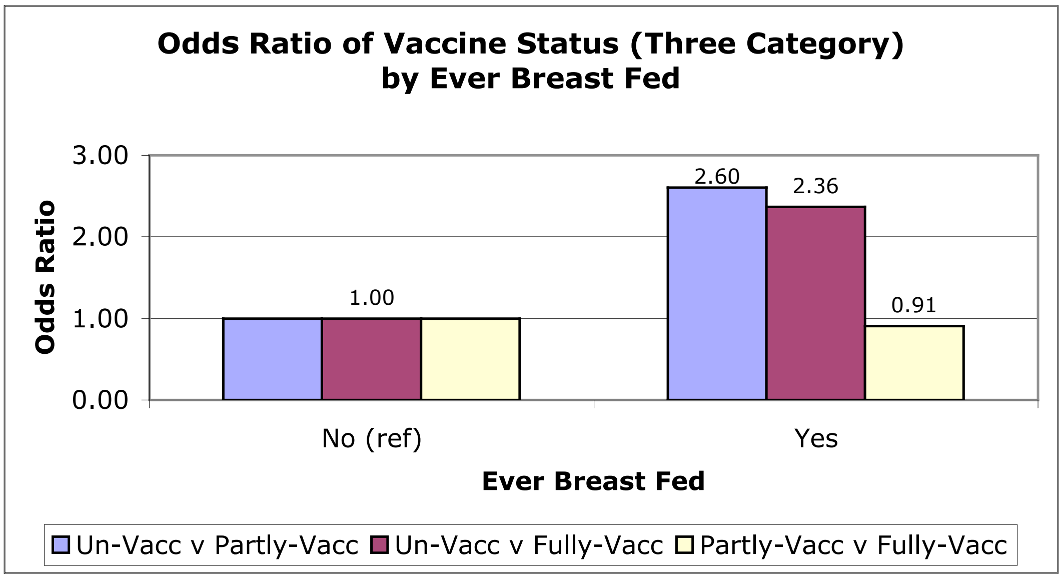
While firstborn status was not a significant predictor of a child being un-vaccinated after controlling for the other independent variables, this measure did generally support the findings on child's age. Firstborn (older) children had 9% higher odds of being fully-vaccinated (rather than partly-vaccinated) compared to their younger siblings. Also, younger siblings tended to be un-vaccinated rather than either partly-vaccinated or fully-vaccinated. This last finding was supported by the binomial regression analysis that found younger siblings were 26% more likely to be un-vaccinated than they were to have any vaccinations compared with their older (first born) siblings.

Since all children in the NIS sample are old enough (19 to 35 months, or 1-1/2 to 3 years) to have received all the recommended "431331" vaccinations, these results must be due reasons other than their eligibility for immunizations.

Breastfeeding History. As in the bivariate analysis above, whether or not a child was ever breastfed is significantly associated with vaccine status in this multivariate analysis.

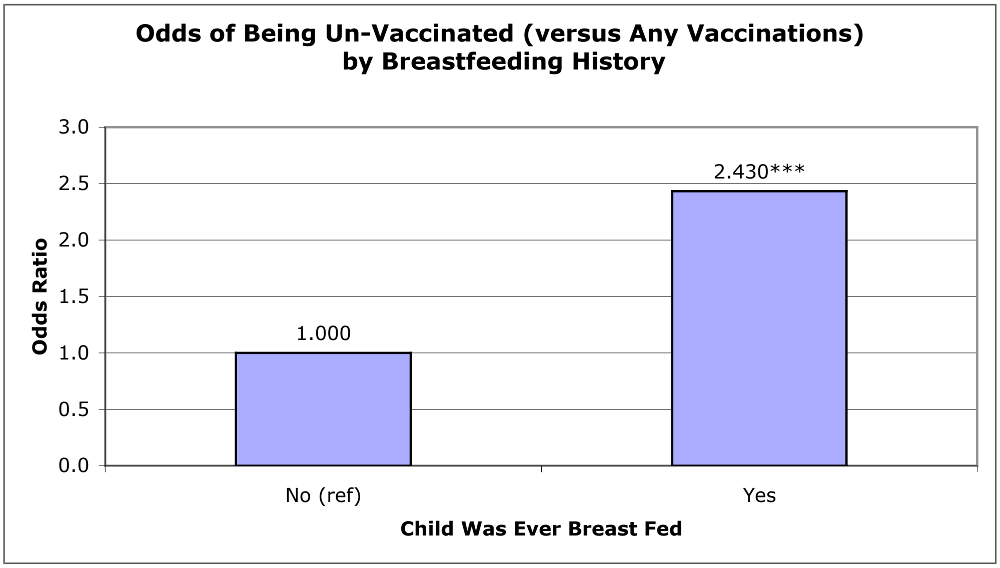
While children who were breastfed were actually significantly (10%) more likely to be fully-vaccinated (than partly-vaccinated) compared to children who were never breastfed, a history of being breastfed was even more significantly associated with being un-vaccinated. Figure 5 (below) shows that children who were ever breastfed had odds of being un-vaccinated that were almost 2.4 times higher than their odds of being fully-vaccinated and 2.6 times higher than their odds of being partly-vaccinated.

Figure 5



In the binomial model (seen in Figure 6 below), children who were ever breastfed are significantly (nearly 2.5 times) more likely to be un-vaccinated than they are to have received any vaccinations compared to children who were never breastfed.

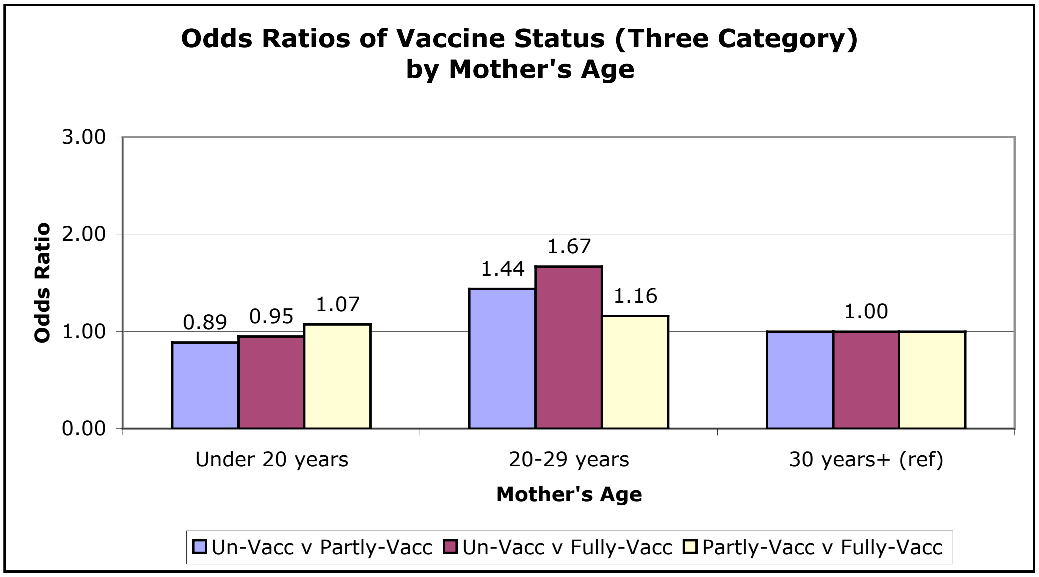
Figure 6



This higher proportion of un-vaccinated children among those who had ever been breastfed may reflect an association between these two characteristics through an interest in a back-to-nature philosophy or organic lifestyle. It could also be that both measures simply reflect a greater emphasis on physical well-being (since breastfeeding today is understood to be a healthy choice for mother and child alike, and is fairly common across a wide variety of communities in the United States).

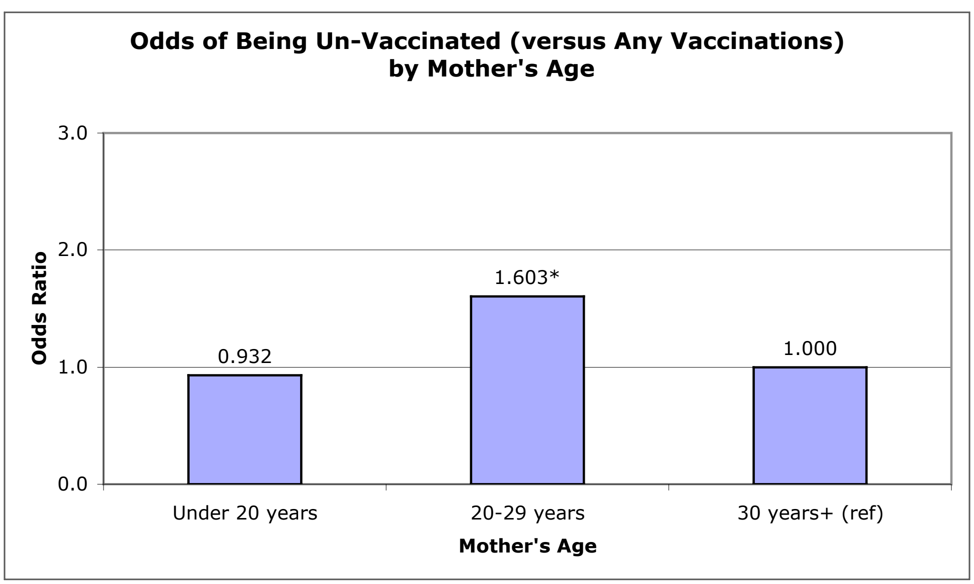
Mother's Age. Mothers in their 20's are significantly less likely to vaccinate their children than mothers 30 years and over. Not only do these younger mothers have marginally (44%) higher odds of having children who are un-vaccinated than children who are partly-vaccinated, but Figure 7 (below) shows that they have significantly (67%) higher odds of having an un-vaccinated child than one who is fully-vaccinated, and significantly (16%) more partly-vaccinated children than fully-vaccinated children.

Figure 7



Overall, younger mothers in their twenties had significantly (60.3%) higher odds of having an un-vaccinated child than having a child with any immunizations compared with older mothers age 30 and over (Figure 8).

Figure 8

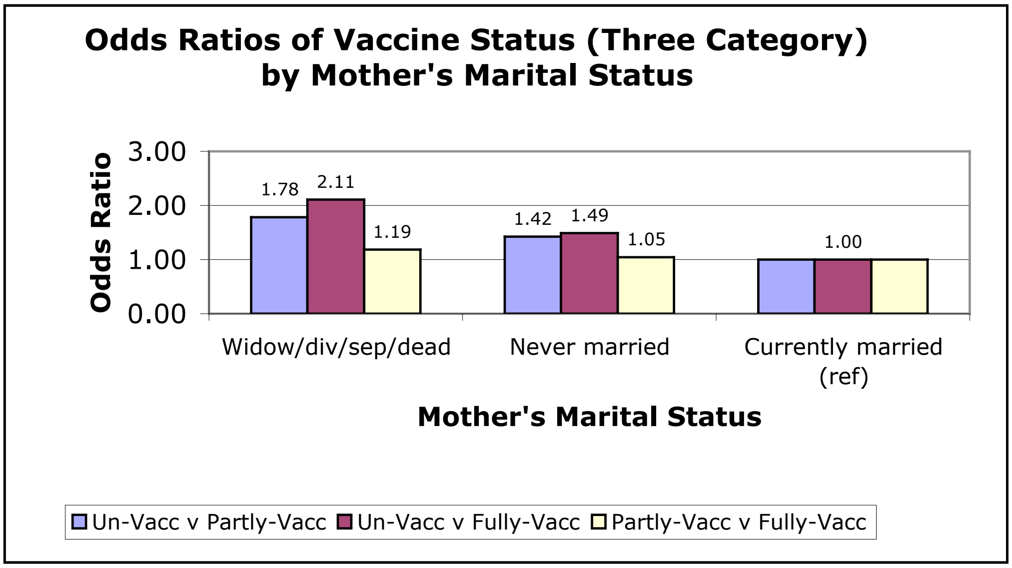


Perhaps mother's age reflects an underlying cohort pattern similar to child's age. Younger mothers in their twenties are having children and getting them (or not getting them) vaccinated at a time of greater uncertainty about the risks associated with immunizations; they have not been alive as long as older mothers to remember when there was less concern about autism. Also, while all these mothers had their children less than three years ago, older mothers may bring to parenting a broader perspective on child health issues. Mothers over the age of 30 may remember, or have relatives who can tell them about, epidemics of these once-common childhood diseases (for example, polio outbreaks in the 1940's) that younger mothers might not have experienced.

Marital Status. Contrary to previous research by Smith, Chu & Barker (2004), who found un-vaccinated children tended to have mothers who were married, these multivariate results indicate that "never married" mothers had somewhat more un-vaccinated children than married mothers, and mothers who were widowed, divorced, separated or deceased were significantly more likely than mothers who was married to have an un-vaccinated child.

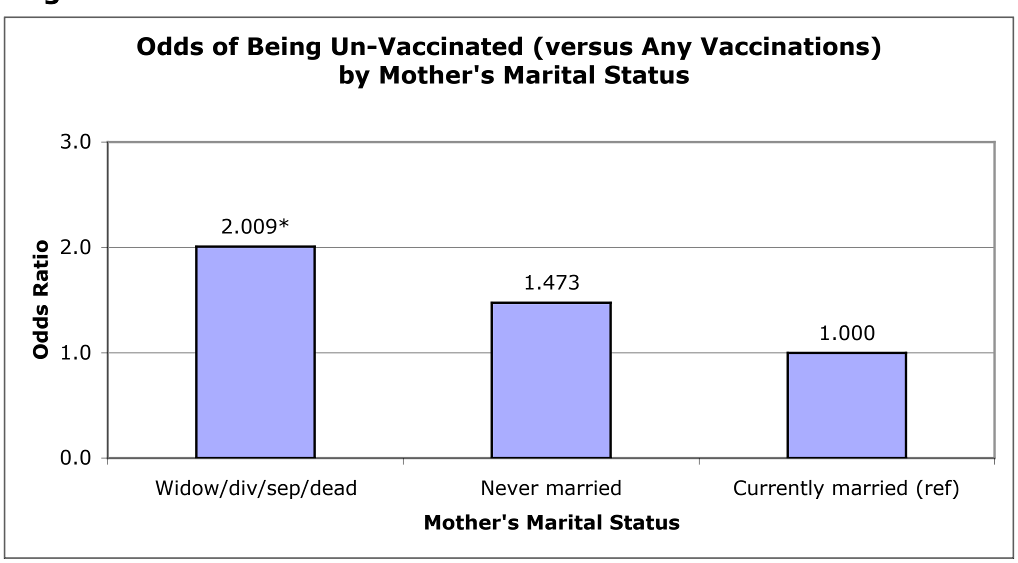
Widowed, divorced, separated and deceased mothers are a diverse group of women with a wide range of characteristics. Nevertheless, as a group, their children are likely to have lower rates of immunization (to be either partly-vaccinated or un-vaccinated) than the children of never married and currently married mothers (see Figure 9 below). Not unlike the pattern in mother's age, these widowed/divorced/separated/deceased mothers had marginally (78%) higher odds of having children who are un-vaccinated than children who are partly-vaccinated compared with married mothers. However, they also had significantly (2.1 times) higher odds of having an un-vaccinated child than one who is fully-vaccinated and significantly (19%) more partly-vaccinated children than fully-vaccinated children.

Figure 9



As seen in the bivariate analysis (Figure 10 below), never married mothers tended (were 47% more likely) to have an un-vaccinated child than currently married mothers, and previously married mothers were (significantly) twice as likely to have an un-vaccinated child than a child with any immunizations (compared with currently married mothers).

Figure 10

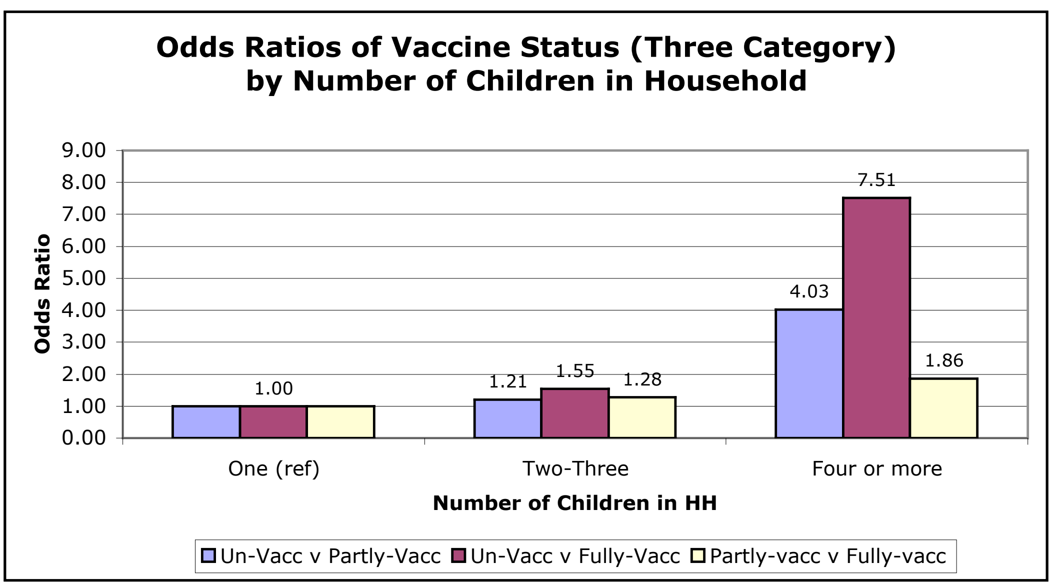


Controlling for other independent characteristics, marital status no longer shows signs of the U-shaped relationship found in the bivariate analysis above (where both married mothers and previously married mothers were more likely to have un-vaccinated children).

Number of Children in the Household. The number of children in the household is one of the most significant indicators of vaccine status in this analysis. Children in households with larger families (four or more children) were significantly more likely than only children to be un-vaccinated than they were to have received any immunizations. This finding is in the expected direction but the strength of the relationship is surprising; the odds ratios for this characteristic are the highest in both the multinomial and binomial models.

The odds of having fewer immunizations clearly increase with the number of children in the household (Figure 11).

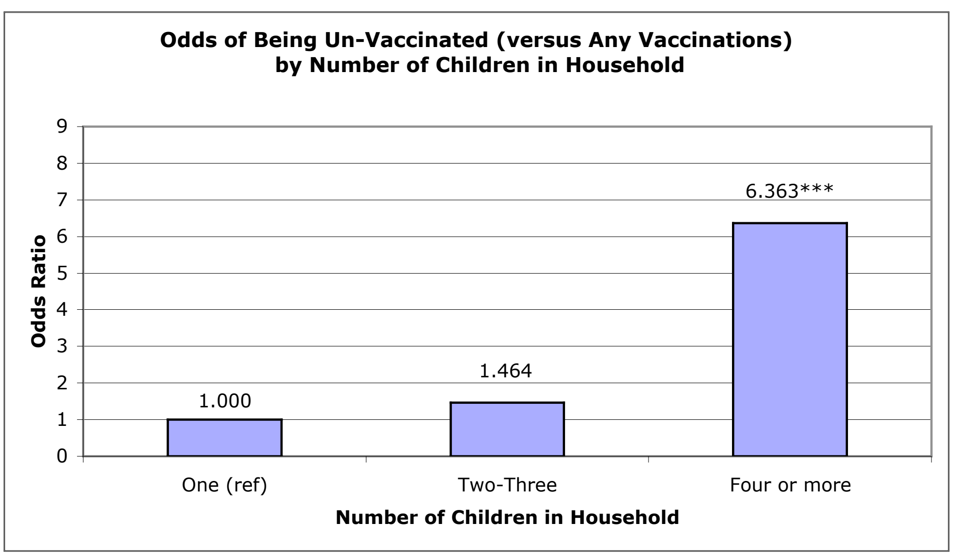
Figure 11



In the multinomial model, children in households with 2-3 children were significantly (28%) more likely to be partly-vaccinated than fully-vaccinated, were marginally (55%) more likely to be un-vaccinated than fully-vaccinated, and tended to be (21%) more un-vaccinated than partly-vaccinated (compared to households with only one child). More strikingly, children in households with four or more children were significantly (86%) more likely to be partly-vaccinated than fully-vaccinated, significantly (750%, or 7.5 times) more likely to be un-vaccinated than fully-vaccinated, and significantly (400%, or 4 times) more likely to be un-vaccinated than partly-vaccinated (compared to households with one child).

In the binomial model (Figure 12 below), children who lived in households with larger families (four or more children) were significantly (over six times) more likely than households with one child to be un-vaccinated than they were to have received any immunizations. They were also over four times more likely than households with 2-3 children to be un-vaccinated. This finding is in the expected direction but the strength of the relationship is surprising; the odds ratios are the highest in the model.

Figure 12



It is not readily apparent what factors distinguish these larger, un-vaccinated families from smaller families with more vaccinated children. However, in the previously cited study of a 2005 measles outbreak at a large church function in Indiana, seventy-one percent of the 34 patients (24 people) were from only four households and 20 of the 28 infected children (71%) were home-schooled (Parker, et al, 2006). These findings may suggest lower vaccination rates among religious communities that are often inclined towards home-schooling and higher fertility rates. The higher rates of un-vaccinated children among families with more children may also reflect other personal convictions (such as a libertarian political outlook or engagement with the back-to-nature, organic movement) although it is not clear whether these philosophies are associated with higher fertility rates.

Taken together, these demographic characteristics suggest that certain children (younger, White children who had ever been breastfed and who lived in large families with mothers in their 20's who were either previously or never married) had significantly higher odds of getting fewer vaccinations. Black children were somewhat more likely than Whites to be partly-vaccinated; and Hispanic children, along with older, first born and only children who had ever been breastfed with older, married mothers, had significantly higher odds of being fully-vaccinated.

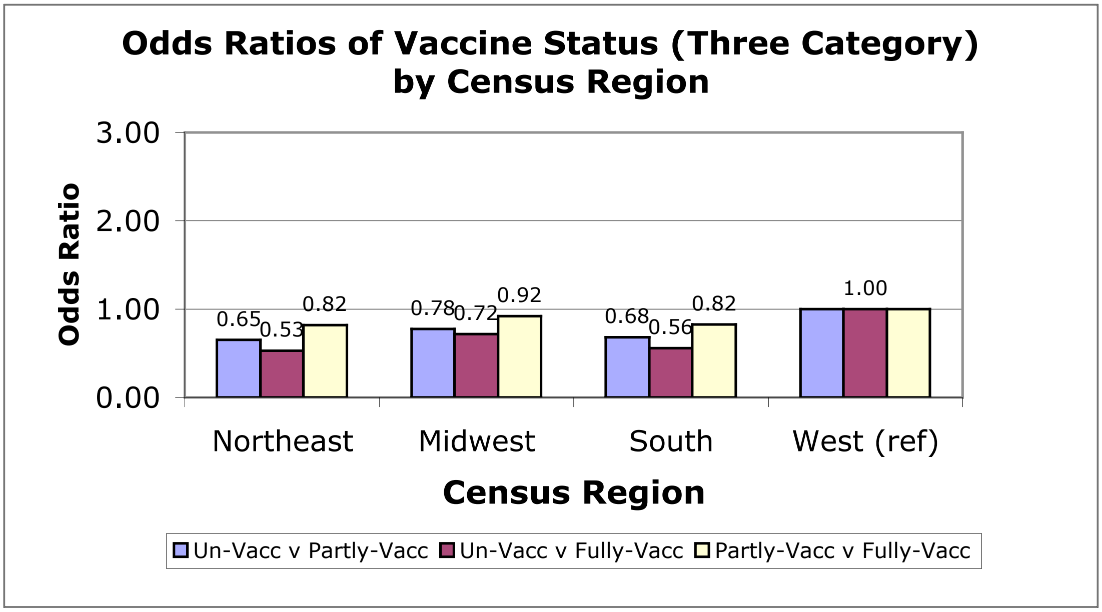
Geographic Characteristics

Children who live in states that allow parents to opt out of immunizing their children for philosophical reasons do have slightly higher odds of being un-vaccinated or partly-vaccinated than children who live in states without this exemption policy. However, after controlling for census region and other independent factors, living in a state with the option of philosophical exemption from immunization requirements is no longer a significant determinant of a child's vaccine status. On the other hand, census region is still significantly associated with whether a child has been vaccinated.

Census Region. As hypothesized, and consistent with results from Smith, Chu & Barker (2004), children living in the West had higher odds of being un-vaccinated or partly-vaccinated than children living in any other region of the United States.

Children who live in the West were significantly more likely to be partly-vaccinated than fully-vaccinated compared with children of all other regions. However, they were also significantly more likely to be un-vaccinated than fully-vaccinated compared to children in the Northeast and South, and even marginally more likely to be un-vaccinated than partly-vaccinated compared to children in the South. In the multinomial model (in Figure 13), the odds that a child living in the West was un-vaccinated (rather than fully-vaccinated) were 89% higher (1/0.53=1.89) than the odds for a child living in the Northeast and 79% higher (1/0.56=1.79) than the odds for a child living in the South. Also, children in the West were 47% more likely (1/0.68=1.47) to be un-vaccinated than partly-vaccinated compared to children in the South. Overall, the vaccine status of children in the South is most distinct from children in the West; children in the South have higher odds of being either partly-immunized or fully-immunized compared to children in the West.

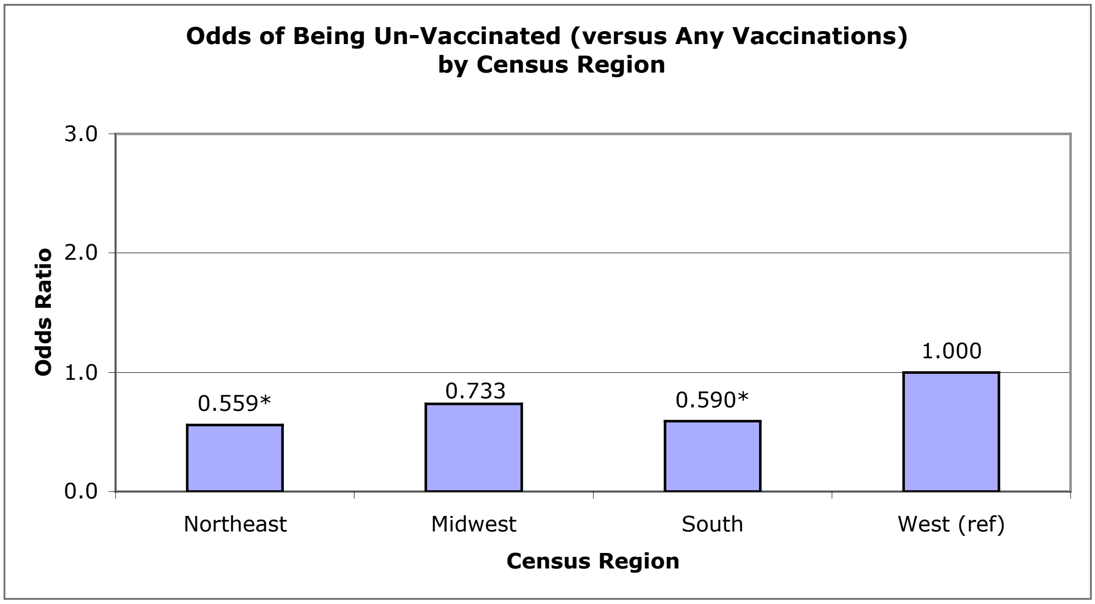
Figure 13



In the binomial model (Figure 14 below), the results are much the same. Children in the West have somewhat higher odds of being un-vaccinated (than having any vaccinations) compared to children in the Midwest, but are significantly more likely to be un-vaccinated than children in either the Northeast (79% higher odds, 1/0.559=1.79) or the South (69% higher odds, 1/0.590=1.69).

These higher rates of un-vaccinated children among children in the West may reflect personal convictions, including a libertarian political outlook, that are sometimes associated with residents of the West.

Figure 14



These higher rates of un-vaccinated children among children in the West may reflect personal convictions, including a libertarian political outlook, that are sometimes associated with residents of the West.

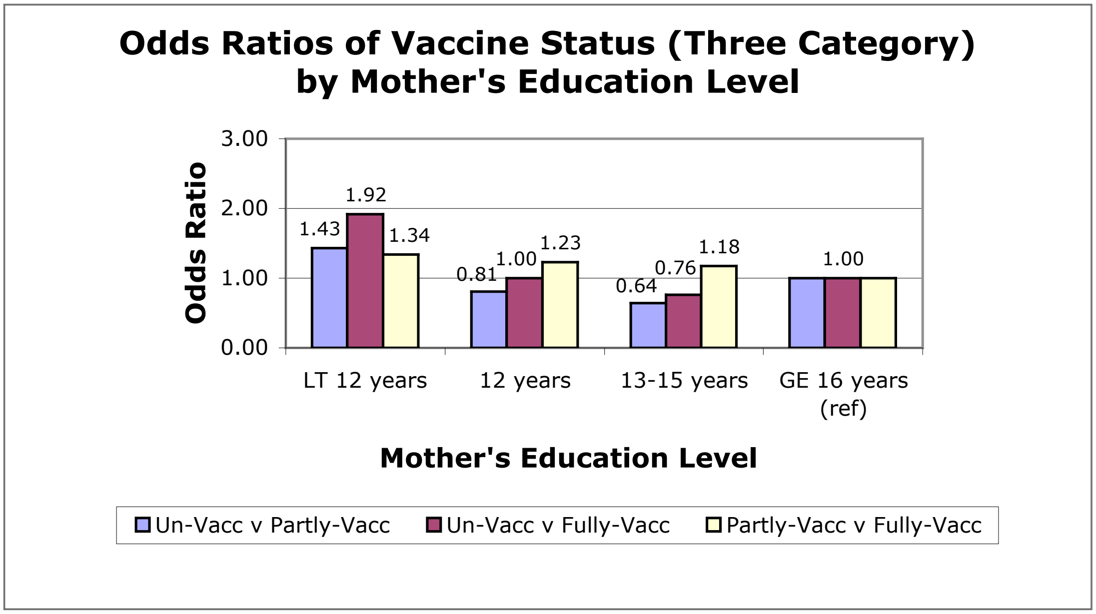
<u>Socio-Economic Status Characteristics</u>

Unfortunately, NIS data on whether a child ever received WIC benefits (along with data on whether a child had ever been breastfed) were not collected in 2002. Therefore, including these measures necessarily limits the time frame of a multivariate analysis to four years (2003-2006) instead of five. However, both WIC benefits and breastfeeding histories were significantly associated with vaccine status on the bivariate level. Therefore, both measures are included in the multivariate analyses presented here. Results of the association between WIC and vaccine status are presented along with the other two measures of socio-economic status (mother's level of education, and household income/poverty status).

Mother's Education Level. Both mothers who did not finish high school and those who graduated from college (mothers with the least and most amount of education in the NIS) were more likely to have un-vaccinated children (than either partly-vaccinated or fully-vaccinated children) compared to mothers with more moderate levels of education. At the same time, mothers with the most years of education (who graduated college) were more likely to fully-vaccinate their children than any mothers with less education.

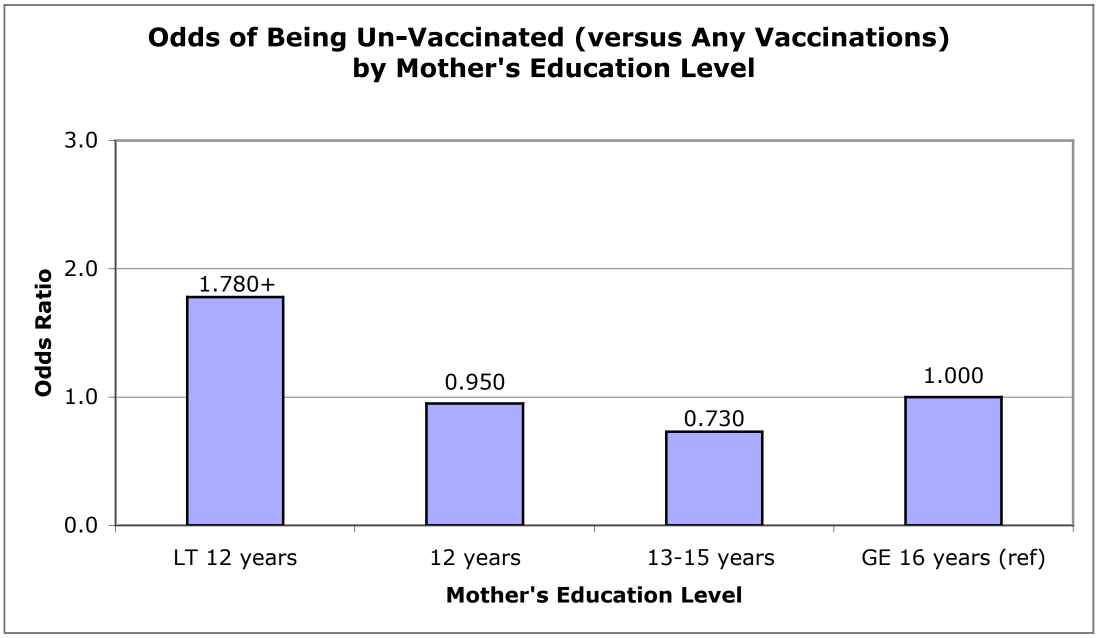
Multinomial results (in Figure 15 below) show that mothers who graduated from college were significantly more likely to have fully-vaccinated (than partly-vaccinated) children compared to mothers with less education; mothers who did not graduate from college were 18% to 34% more likely to have a child who was only partly-vaccinated than one who was fully-vaccinated. Also, mothers who did not finish high school were 43% more likely (OR=1.43) to have an un-vaccinated child than a partly-vaccinated child, and nearly twice as likely (OR=1.92) to have an un-vaccinated child than a child who was fully-vaccinated, compared to mothers who graduated from college. Meanwhile, college graduates had significantly (56%, where 1/0.64=1.56) higher odds of having an un-vaccinated child than a partly-vaccinated child compared to mothers who attended college, but did not graduate.

Figure 15



Binomial results (in Figure 16 below) reflect a similar relationship between mother's education and vaccine status. Mothers with either less than 12 or at least 16 years of education were significantly more likely to have an un-vaccinated child (than to have a child with any vaccinations) compared to mothers with more moderate amounts of education (both high school graduates and mothers who attended some college). In particular, mothers who did not finish high school were 78% more likely to have an un-vaccinated child than to have a child with any vaccinations (compared with college graduates). Meanwhile, mothers who at least finished high school, but did not graduate college, tended to have children with any vaccinations (either partly-vaccinated or fully-vaccinated) compared to college graduates.

Figure 16



Contrary to Smith, Chu & Barker (2004) who found mothers who had graduated college were more likely to have un-vaccinated children, these results indicate that mothers who did not graduate from high school were equally, if not more, likely than college graduates to have an un-vaccinated child.

Overall, mothers with the lowest level of education consistently had the lowest rates of vaccination. Meanwhile, college graduates were significantly more likely than any of the other three education groups to have a fully-immunized child (rather than a partly-immunized child). But in some cases, college graduates were also significantly more likely to have an un-immunized child (especially when compared to mothers who just finished high school or only attended some college).

The finding that mothers with less education had greater odds of having un-vaccinated or only partly-vaccinated children (compared to mothers with more education) might not be surprising given prior research showing an SES-health gradient: poorer health outcomes among children whose mothers have less education. What is unexpected perhaps is the finding that, while mothers with a college degree were more likely than mothers with less education to have a fully-vaccinated child, they were also more likely than mothers with all but the least amount of education (those without a high school diploma) to have an un-vaccinated child. These results suggest a U-shaped relationship between mother's education and vaccine status: both lower and higher levels of maternal education were associated with having an un-vaccinated child.

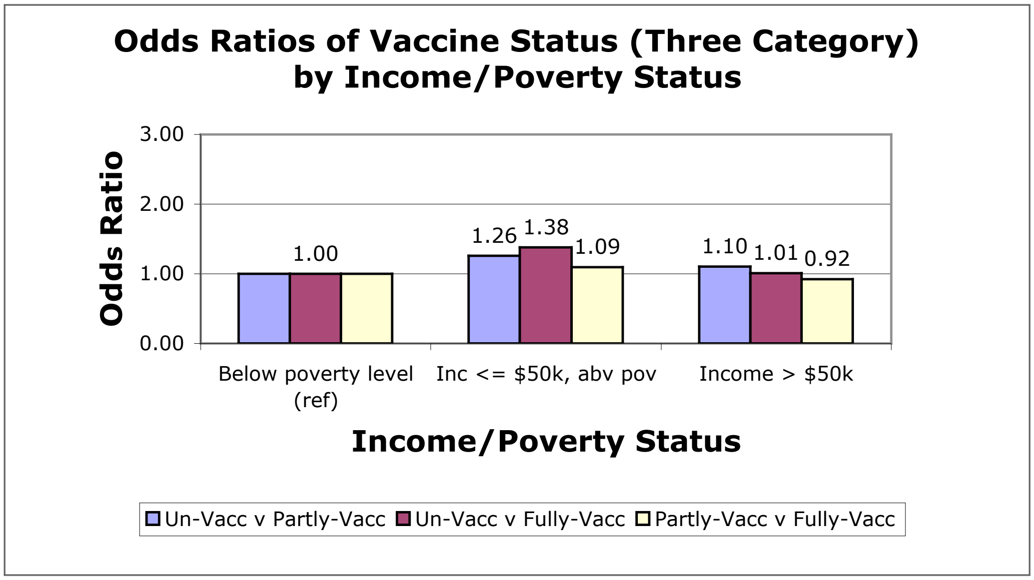
On the one hand, there appears to be a simple (well-documented) linear effect of mother's education on vaccination rates: less education is associated with lower odds of a child being fully-vaccinated, and more education is associated with higher odds of being fully-vaccinated. And yet, there is some indication of a two-tailed effect of education on vaccine status: both the lowest and highest levels of maternal education increase the odds of having an un-vaccinated child. These results would seems to suggest that, while education in general improves a child's odds of being vaccinated, there is a sizable segment of well-educated mothers who are choosing not to vaccinate their children, who appear to have very different vaccination practices from women with comparable levels of education.

Income and Poverty Status. Smith, Chu & Barker (2004) found un-vaccinated children tended to live in households with annual incomes over $75,000. It is perhaps surprisingly then that this analysis finds income/poverty status is not a very significant factor with regard to vaccine status. Also, while my analysis finds un-vaccinated children are more likely to live in households with annual incomes above poverty, they are more likely to live in middle incomes households (where incomes are above poverty but less than or equal to $50,000 per year), not households with the highest incomes (incomes greater than $50,000 per year). Still, as shown in Figures 17 and 18 below, middle income children and, to a much lesser extent, upper income children do tend to be un-vaccinated, rather than either partly-vaccinated or fully-vaccinated (have any vaccinations), compared with children who live below poverty.

The multinomial analysis finds that children in middle income households are marginally (about 9%) more likely than children who live below poverty to be partly-immunized (rather than fully-immunized). Meanwhile, children in upper income households actually tend slightly towards being fully-vaccinated (rather than partly-vaccinated) compared to children who live below poverty.

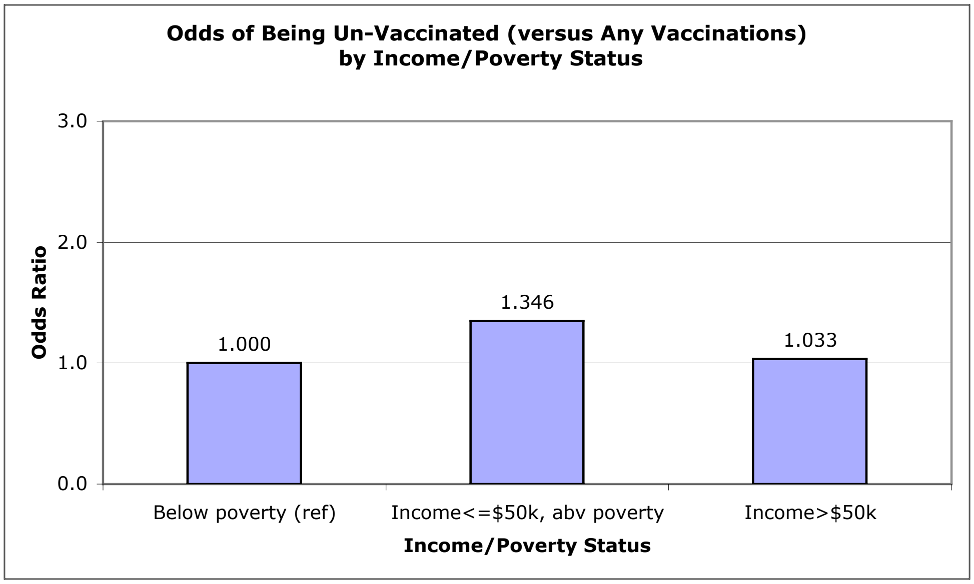
At the same time, children in upper income households also tend towards being un-vaccinated (rather than either partly-vaccinated or fully-vaccinated) compared to children who live below poverty. However, it is the children in middle income households who are most likely to be un-vaccinated (rather than either partly-vaccinated or fully-vaccinated) compared to children who live below poverty; while these proportions are not significant, children in middle income households are 26% more likely to be un-vaccinated than partly-vaccinated and 38% more likely to be un-vaccinated than fully-vaccinated (compared to children who live below poverty). So whereas upper income children have somewhat higher odds of being un-vaccinated than children who live below poverty, the greatest likelihood of being un-vaccinated lies with middle income children.

Figure 17



Similarly, binomial analysis finds an insignificant difference in the odds of being un-vaccinated for children by income/poverty status. Middle income children tend to have a somewhat (35%) higher odds of being un-vaccinated than of having any vaccinations (relative to the odds of being un-vaccinated for children living below poverty) but the difference is not significant. Likewise, the odds that children in an upper income household are un-vaccinated (rather than having any vaccinations) is almost identical to (only 3% different from) the odds of being un-vaccinated among children who live below poverty.

Figure 18



Overall, this analysis finds that the greatest likelihood of being un-vaccinated lies with middle income children, not upper income as Smith, Chu and Barker (2004) found. Children on either end of the income spectrum (below poverty and upper income) are more likely to be fully-vaccinated, while middle income children are more likely to be either partly-vaccinated or un-vaccinated altogether.

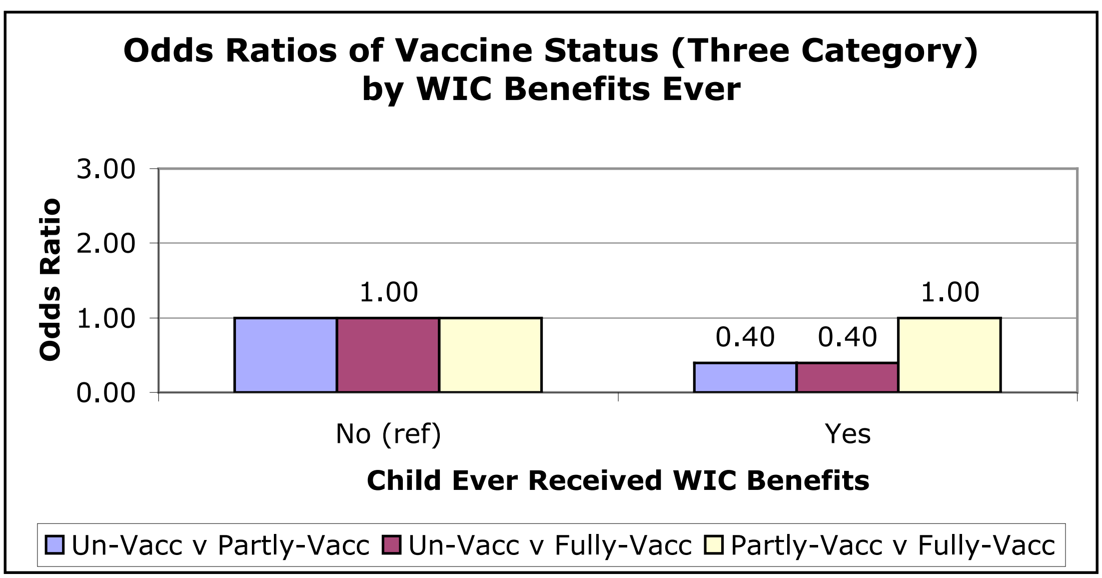
When we distinguish between middle and upper income households, we find a relationship between income and immunizations not unlike the U-shaped association between mother's education and vaccine status: children in the highest SES group are more likely to be both fully-vaccinated and un-vaccinated than children in the lowest SES group. In the first case, children in upper income households tend to be fully-vaccinated more often than children who live below poverty, while children in middle and upper income households (above poverty) tend to be un-vaccinated more than children who live below poverty.

Therefore, when looking at just two income/poverty status groups (above and below poverty), income has a somewhat negative relationship with vaccine status: income above poverty is more associated with being un-vaccinated, while below poverty income is more associated with having any vaccinations (being either partly-vaccinated or fully-vaccinated). However, in order to better measure the association between income and vaccine status, I would need to develop a more sensitive measure than the two or three category variable used in this analysis.

WIC Benefits. Having never received WIC benefits is one of the strongest predictors of a child's odds of being un-vaccinated (along with race/ethnicity, breastfeeding history, and number of children in the household).

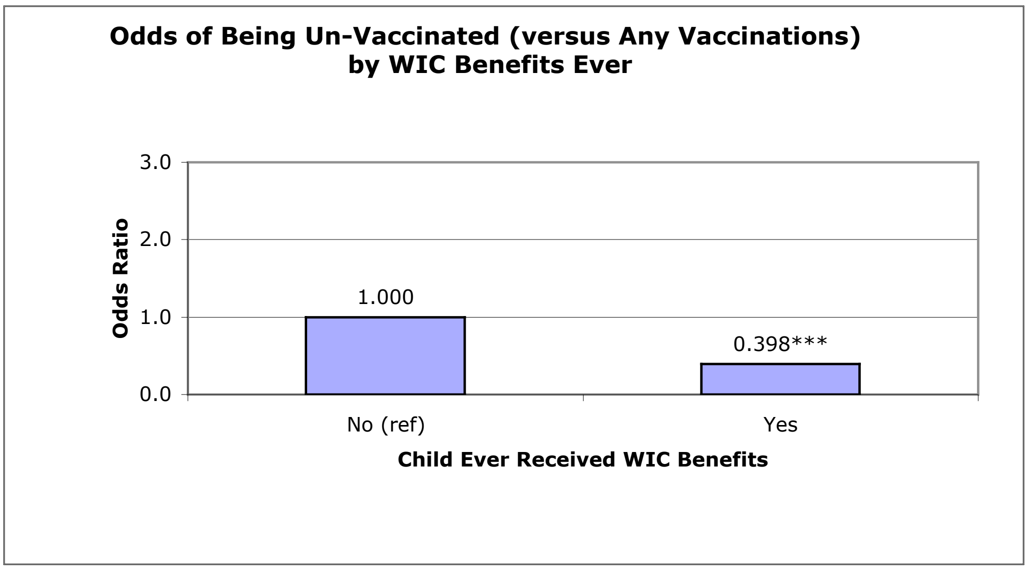
Figure 19 shows that children who never received WIC benefits were 2.5 times more likely (1/0.40=2.5) to be un-vaccinated than they were to be either partly-vaccinated or fully-vaccinated (compared to children who ever received WIC benefits).

Figure 19



Consequently, as seen in Figure 20, children who had never received WIC benefits were also 2.5 times more likely (1/0.398=2.5) to be un-vaccinated than they were to have received any vaccinations (compared to children who ever received WIC benefits).

Figure 20



These findings support the previous analyses of mother's level of education and household income/poverty status which showed that children with higher socioeconomic status tend to have greater odds of being un-vaccinated (than of having any vaccinations) compared to children with lower socioeconomic status.

DISCUSSION

While the proportion of children in the United States who are fully-vaccinated has increased in recent years, a smaller but not less significant proportion of children who are un-vaccinated has also increased. This paper has attempted to determine the characteristics of U.S communities who were most likely not to vaccinate their children.

This analysis found that children had higher odds of being un-vaccinated if they were White (non-Hispanic), had been breastfed as a baby, had never received WIC benefits or were living in households above poverty status, with four or more children in the western United States (rather than the South or Northeast), with a previously married mother in her twenties who either did not have a high school diploma or graduated from college.

Interestingly, children with higher socioeconomic status (SES), including children whose mothers had graduated college, who lived in households above poverty and who never received WIC benefits, were among the children most likely to be un-vaccinated. Children with lower SES (whose mothers had graduated from high school but had not graduated college, who lived in poverty or had ever received WIC benefits) had higher odds of receiving any vaccinations (being either partly-vaccinated or fully-vaccinated). If one assumes being vaccinated is one component of being healthy, then this association between higher SES and being un-vaccinated appears to contradict a well-documented positive correlation, or gradient, between SES and health. However, this association between higher SES and un-vaccinated children appears to corroborate the 2004 analysis by Smith, Chu and Barker as well as recent media reports of infectious disease outbreaks among children whose well-educated mothers had not vaccinated their children.

Meanwhile, children whose mothers had the lowest levels of education (had not finished high school) were also more likely to be un-vaccinated (along with children whose mothers had graduated college). This seemingly contradictory association (in which both the most and least educated mothers were likely to have un-vaccinated children) seems to suggest a U-shaped relationship between child's SES and vaccine status (particularly regarding mother's education): higher rates of un-vaccinated children appear at either end of the maternal education spectrum.

However, since higher levels of SES are also (more typically) associated with children being fully-immunized, these data seem to suggest that some higher SES mothers (in deciding not to vaccinate their children) have splintered off in their vaccination practices from other higher SES mothers who more often fully-vaccinate their children.

So, on the one hand, there appear to be two distinct SES groups (mothers with the lowest and those with the highest levels of education, as well as households with above poverty income and those who never received WIC benefits) who are deciding not to vaccinate their children. On the other hand, parents with similarly high SES characteristics (mothers who graduated from college) seem to have decided either to fully-vaccinate their children or to not vaccinate their children at all.

It is important to understand why these associations exist by clarifying a parent's reasons behind vaccination decisions including the process by which parents gain information about immunizations. I'm inclined to believe there are other factors at play in determining a parent's decision about whether or not (or to what extent) to vaccinate their child besides just socioeconomic status.

Perhaps lower SES children get fewer vaccinations due to economic constraints to health care, including limited access to health care services. Children who live below poverty likely receive some (but maybe not all) of the recommended vaccinations as a function of being engaged with welfare services such as the WIC system. Misinformation about the importance and safety of immunizations may also play an important role in the higher rates of un-vaccinated children among lower SES populations.

Meanwhile, mothers of higher SES children, who presumably do not lack the access to health care services (including immunizations) that hinder lower SES mothers, might be making more of a deliberate choice not to vaccine their children. The decisions by these higher SES mothers not to vaccinate their children may be based more on misinformation about vaccine safety concerns or a lack of perceived need for immunizations. Increased rates of un-vaccinated children in higher SES populations may simply be due to fears and misconceptions about vaccines. While choice may be one reason for higher rates of un-vaccinated or partly-vaccinated children in both lower and higher SES populations, economic constraints would naturally play less of a role among higher SES parents.

Previous research offers some support for both of these explanations. On the one hand, the relationship between lower SES and lower immunization rates is well documented with regard to economic & structural barriers that limit access to health care, including immunizations (National Vaccine Advisory Committee, 1991 and 1999; Orenstein et al, 1990; Klevens and Luman, 2001; Wooten et al, 2007). There is also research to support the relationship between higher SES and better health in general (Kitagawa and Hauser, 1973; Link and Phelan, 1995; Ross and Mirowsky, 1999; House, 2002), as well as the relationship between higher SES and better children's health specifically (Currie and Moretti, 2003; Case, Lubotsky and Paxson, 2002; Newacheck, 1994) and the relationship between higher SES and higher rates of fully-immunized children in particular (Racine and Joyce, 2007; Wooten et al, 2007).

There has also been research that shows an association between parental concerns about vaccine safety (as well as a belief in the protective nature of herd immunity) and lower child immunization rates (Parker, et al, 2006). Some limited research has been conducted that also shows an association between higher SES and concerns about vaccine safety (Gust et al, 2004). Likewise, Smith, Chu and Barker (2004) showed an association between higher SES and higher rates of un-immunized children. Unfortunately, both the Gust et al and Smith, Chu & Barker studies used NIS data from the 2001 Parental Knowledge and Attitudes/Experiences Module (PKM) that are currently not available to the general public.

When combined with this previous research, my analysis appears to support the premise that an association between higher socio-economic status (indicated by mother's education, income and WIC measures) and higher rates of un-vaccinated children may be explained by increased parental concerns about vaccine safety and misconceptions about the protective properties of herd immunity.

Exactly how, then, are these concerns and misconceptions translated into higher rates of vaccinated children? I believe at least part of answer to this question may lie in a study published by Van de Walle and Knodel (1980) that helped explain the fertility decline in 19th Century Europe. Their explanation focuses on the "cultural setting" of communities that "shared a means of communication and common standards of conduct" (typically a common language or religion). This "ease of communication" in turn allowed for the "onset and spread" of family planning through "a flow of information and the process of diffusion" that encouraged the subsequent fertility decline to "cluster regionally."

While their conclusion specifically refutes the notion that fertility decline was a result of shared socio-economic circumstances, my findings suggest that at least some, although certainly not all, of a parent's decision about whether or not to vaccinate their child is associated with their socio-economic status. Nevertheless, Van de Walle and Knodel's explanation of fertility decline through a cultural "diffusion of ideas" lends itself well to the recent phenomenon of un-vaccinated children. In both scenarios, interactions between like-minded people increase communication on topics of concern to a family's wellbeing.

With regard to immunizations, information may be shared both through more traditional lines of communication (schools, churches, neighbors and medical providers), or somewhat less traditional lines of communication (such as home-schooling or chiropractors), as well as through more modern means of communication (such as internet websites, e-mail, blogs and chat rooms). Even if these forums do not independently suggest theories about vaccine safety or beliefs about herd immunity that deter parents from vaccinating their children, they provide an arena for people to share their concerns and may reinforce a parent's prior decision not to vaccinate their child.

This concept of diffusion seems to make sense whether talking about religious sects, political philosophies or the recent back-to-nature/organic movement. All these communities have strongly held beliefs. They also have some of the characteristics found in populations associated with higher proportions of un-vaccinated children. For example, highly religious communities often home-school their children (providing a close-knit community of parents in which beliefs and concerns may be shared) and are often cited as having high fertility rates (creating households with large numbers of children, a characteristic significantly associated with un-vaccinated children). Similarly, people with certain Libertarian political philosophies espouse a more laissez-faire approach to life that includes a preference for less government regulation and intrusion into personal matters (including perhaps immunizations) and is often associated with populations living in the western United States (a region significantly associated with un-vaccinated children). Even the back-to-nature movement emphasizes the consumption of organic foods (grown on their own or purchased at a local organic grocery cooperative) along with physical well-being that likely includes breastfeeding children (although the practice is certainly more pervasive today that just organic communities) and sometimes enlists the care of chiropractors (some of whom have circulated concerns with vaccine safety). All of these communities may be more open to the concept of parents not vaccinating their children (for one reason of another) and have, in some cases, been known to express doubts about vaccine safety.

Simply put, people tend to make contact and have relationships with others who share their attitudes and beliefs. When parents meet other people who share their concerns about immunizations, this contact likely increases the chances that their own child will not be vaccinated. Differentiating themselves from alternative perspectives, some of these parents "refuse to sacrifice [their] children for the greater good" as did Sybil Carlson, a mother of two sons (ages 6 and 3) in San Diego (DeLamater & Myers, 2007; Steinhauer, 2008).

It may appear that parents who do not vaccinate their children are making a decision *despite the risk* to their children's health. To the contrary, I think parents who do not vaccinate their children are making a decision *because of the perceived risks* that vaccines pose to their children's health. Parents continue to make decisions based on what they think is in the best interest, health and safety of their children. These findings do not contradict this fact. Rather, in the eyes of these parents, better child health means forgoing vaccinations.

I believe these are well-intentioned, if miss-guided, parents.

Different Strategies

Based on this analysis, parental reasons for not vaccinating a child likely vary across population sub-groups. Policymakers need to focus their efforts on using different strategies to decrease the numbers of un-vaccinated children in specific communities and for particular vaccines. Since identifiable segments of the U.S. population have higher percentages of un-vaccinated children than others, public health strategies need to be designed and adjusted specifically to reach the rising numbers of parents in these communities who have not vaccinated their children.

Various strategies for countering low immunization rates and the relative success of such campaigns have been discussed in the literature, including an immunization registry, state requirements for childhood immunizations, and improved timeliness of vaccine administration (Aguilar, 2007; Bloom, 1994; Bloom et al, 2006; Burns & Zimmerman, 2005; Daniels et al, 2001; Davis et al, 2004; De Gourville et al, 2006; Findley et al, 2006; Gellin, Maibach & Marcuse, 2000; George et al, 2007; Hinman et al , 2005; Jiles et al, 2001; Khare et al, 2006; Kimmel et al, 2007; Lee et al, 2004; Lee et al, 2007; Leman et al, 2001; Niederhauser & Markowitz, 2007; Ramirez et al, 2006; Salmon et al, 2006; Shaw & Barker, 2005; Shimabukuro et al, 2007; Szilagyi et al, 2002; and Zimmerman et al, 2005.

Many strategies have already been implemented, but new and different efforts need to be made to decrease the rate of un-vaccinated children. A multi-pronged approach is needed (on both the individual and population level) to decreased the rates of un-vaccinated children by addressing both socio-economic status (as an indicator of which specific barriers to immunization are likely at work) and the process of diffusion (to challenge the questionable information some parents are getting about vaccines).

Specifically, among lower SES populations, strategies should continue to further reduce the economic and structural barriers to immunizations. If mothers with lower levels of education do not vaccinate or only partly-vaccinated their children, this may reflect a need for more public health campaigns that not only lower health care costs (to improve access to and utilization of health care facilities) but also increase the quality of information parents receive about vaccines and vaccine safety.

Meanwhile, parents with higher SES may have more access to health facilities than lower SES parents, but may still decide not to fully-vaccinate their children. Strategies are needed for these higher SES parents that focus more on correcting misconceptions about the low need for childhood vaccinations (because of herd immunity) and the perceived risk that is rumored (but not proven) to be associated with certain vaccines. That some mothers of un-vaccinated children have higher levels of education suggest a different form of public health campaign may be needed to counter misinformation (more than a lack of information) about vaccine safety and the importance of immunizations.

All parents of un-vaccinated children may need not only reassurance about the safety of immunizations, as well as a greater understanding of the historical success of vaccines (and conversely, a heightened appreciation of the risk (both disability and death) associated with these diseases), but also a plea for a greater sense of community to boost the likelihood of their acting in the public good to maintain the herd immunity to disease. As Parker (2006) said, “different approaches may be necessary for populations…where belief systems, rather than access to health care, are the primary barrier to vaccination.”

CONCLUSION

The goals of this paper were three fold: using data from the National Immunization Survey (NIS) between 2002 and 2006, my aims were to determine (1) whether there had been a significant increase over the five year period in the proportion of children who were un-vaccinated for the recommended "431331" immunization series; (2) whether this increase could be explained by changes during this same period in the underlying composition of the U.S. population; and (3) if there had been a true increase in the proportion of children who were un-vaccinated, then who was not vaccinating their children? What child, mother and household characteristics were significantly associated with a child not being vaccinated?

First, using t-tests, I found a significant increase in the weighted proportion of children in the NIS sample between 2002 and 2006 who had received none of the recommended childhood immunizations (from a low of 0.27% in 2002 to a peak of 0.56% in 2004 and ending at 0.48% in 2006). I also ran a brief analysis of individual vaccines and found significant increases over five years in the proportions of children who were un-vaccinated for Hib, polio, MMR and DTaP.

Second, using a series of binomial logistic regression models, I ran a decomposition analysis and found that this increase was indeed significant beyond any changes to the composition of the United States population during that five year period.

Finally, I ran a multivariate analysis using both multinomial and binomial logistic regression models to estimate characteristics that were significantly associated with the odds of a child being un-vaccinated. Confirming some, but not all, of the results from Smith, Chu and Barker (2004), I found demographic characteristics, census region and socio-economic status were all significantly associated with a child's odds of being un-vaccinated. White (non-Hispanic) children living in the West had consistently higher odds of being un-vaccinated, as were children who had ever been breastfed, lived in a household with four or more children and with income above poverty, who had never received WIC benefits, had a mother in her twenties who was previously married, and whose mother either had not completed high school or had graduated from college.

Socio-economic status certainly plays a role in influencing whether a parent has access to the health care necessary to receive vaccinations for their child. However, demographic and cultural factors appear to be equally, if not more, significant in determining the odds of whether a child is un-vaccinated. For parents who are concerned about vaccine safety and uncertain about the current need for childhood immunizations, personal history and social context may provide both a mechanism for diffusion of information about immunizations and support for their beliefs about vaccines.

A multi-pronged approach is needed (on both the individual and population level) to counter the recent increase in un-vaccinated children. Certainly current strategies should continue to reduce the cost of vaccines while increasing access to and utilization of health care services. In addition, public service campaigns and community-based intervention efforts could be mounted to improve the quality of information parents receive about vaccines by correcting misconceptions about the (lack of) need for and (perceived) risks associated with childhood vaccinations. Of course, the scientific community can also play a part by conducting studies that either confirm the safety of vaccines or identify any risks associated with vaccines.

Future Research

To better understand not only which communities are currently at risk of not vaccinating their children but also why parents choose not to vaccinate their children, additional research could be conducted.

First, if the 2001 Parental Knowledge and Attitudes/Experiences Module (PKM) data could be obtained from the CDC, further analysis could be conducted into parental reasons for not vaccinating their children.

Second, the data available in the NIS Public Use File were predominantly categorical measures. The analysis conducted here between socio-economic status and un-vaccinated children would benefit greatly if continuous measures could be obtained instead for variables such as income/poverty status and mother's years of education.

Third, if small area geographic data could be obtained, a spatial analysis could be conducted by state, metropolitan area, or even census tract. This analysis could assist in better understanding the characteristics of specific communities across the country that have high concentrations of un-vaccinated children.

Fourth, it is important to understand the characteristics of parents who forgo specific individual vaccines (whose children are only partly-vaccinated), the reasons behind their vaccination decisions, and to what extent children in the U.S. are getting sick with diseases for which they have not been vaccinated. The following vaccines are of particularly interest (due to reasons highlighted in parentheses):

MMR (high proportion not getting vaccinated (25%), diseases can cause severe illness, has raised intense media interest concerning possible association with autism, measles is present worldwide creating a serious risk of disease transmission);

Polio (significant increase in proportion of partly-vaccinated children not getting the vaccine (3% to 6%), causes severe disability, still endemic in several countries);

Hib (also showed a significant increase in proportion of partly-vaccinated children not getting the vaccine (1.5% to 5.5%)); and

Varicella (proportion of partly-vaccinated children not getting the vaccine is high (50%), even though the illness is less severe).

Finally, another statistical method, recursive partitioning, could be used to further analyze the characteristics of parents and communities that do not vaccinate their children. This method has the capacity to tease apart those factors jointly associated with a child not being vaccinated in order to better understand the clusters of characteristics that make up these communities.

In conclusion, if vaccines are truly safe, the public needs to be reassured of that fact. On the other hand, if parents are justified in being concerned about vaccine safety, further scientific study must be conducted to understand and resolve these safety issues. Either way, the government must take steps to convince a skeptical public about the importance and safety of immunizations so that both children and whole communities in the United States can be better protected against outbreaks of these dangerous, yet preventable, diseases.

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APPENDIX

Tables

Figures

Table A1: Response Rates for RDD Household & PRC Provider Phases, NIS 2006

Row	Key Indicator	Number	Percent
	RDD Household Phase		
1	Total selected telephone numbers	5,037,830	-
2	Resolved telephone numbers (Resolution rate)	4,197,242	83.3% (Row 2/Row 1)
3	Households identified (Working residential number rate)	1,137,706	27.1% (Row 3/Row 2)
4	Households successfully screened for presence of age-eligible children (Screening completion rate)	1,029,073	90.5% (Row 4/Row 3)
5	Households with age-eligible children (Eligibility rate)	33,960	3.3% (Row 5/Row 4)
6	Households with age-eligible children with completed household interviews (Interview completion rate)	29,065	85.6% (Row 6/Row 5)
7	Age-eligible children with completed household interviews	29,880	-
	PRC Provider Phase		
8	Children with consent to contact vaccination providers (Consent rate)	24,193	81.0% (Row 8/Row 7)
9	Immunization history questionnaires mailed to providers	30,073	-
10	Immunization history questionnaires returned from providers (IHQ return rate)	28,427	94.5% (Row 10/Row 9)
11	Children with adequate provider data (Unconditional adequacy rate)	21,044	70.4% (Row 11/Row 7)

Figure A1: Map of United States Census Regions

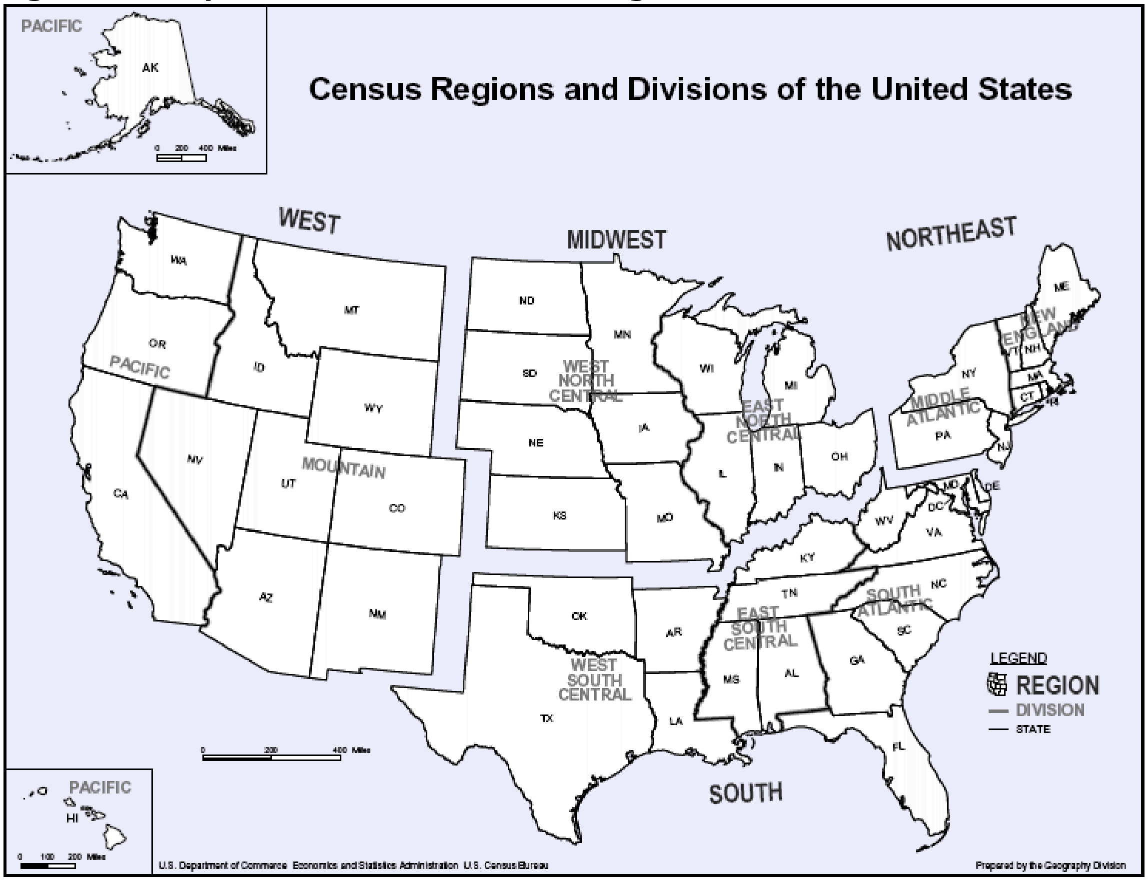

Table A2: Vaccination Exemptions Allowed by State (2005-2006)

	EXEMPTIONS ALLOWED (2005-2006)			
	Medical			
	Temporary	Permanent	Religious	Philosophical
Alabama		X	X	
Alaska	X	X	X	
Arizona	X	X	**	*
Arkansas	X		X	X
California	X	X	X	X
Colorado	X	X	X	X
Connecticut		X	X	
Delaware	X	X	X	
District of Columbia	X	X	X	
Florida	X	X	X	
Georgia	X		X	
Hawaii	X	X	X	
Idaho	X	X	X	X
Illinois		X	X	
Indiana^	X	X	X	
Iowa	X	X	X	
Kansas	X		X	
Kentucky	X	X	X	
Louisiana	X	X	X	X
Maine	X		X	X
Maryland	X	X	X	
Massachusetts	X	X	X	
Michigan	X	X	X	X
Minnesota	X	X	X	X
Mississippi	X	X		
Missouri	X		*	**
Montana	X	X	X	
Nebraska	X	X	X	
Nevada	X	X	X	
New Hampshire	X		X	
New Jersey	X	X	X	
New Mexico	X	X	X	X
New York	X	X	X	
North Carolina	X	X	X	
North Dakota		X	X	X
Ohio	X	X	X	X
Oklahoma	X	X	X	X
Oregon	X	X	X	
Pennsylvania	X	X	X	
Rhode Island	X	X	X	
South Carolina	X	X	X	
South Dakota		X	X	
Tennessee	X	X	X	
Texas	X	X	X	X
Utah	X	X	X	X
Vermont	X	X	X	X
Virginia	X	X	X	
Washington	X	X	X	X
West Virginia	X	X		
Wisconsin	X	X	X	X
Wyoming	X	X	X	

X Exemption allowed
* Allowed in schools only
** Allowed in childcare and head start facilities only
^ Medical exemptions are referred to as "Acute" and "Chronic"

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Table A3. Un-Weighted Sample Size, Weighted Count and Percent of Children with Each Number of Doses of the Six Vaccines that make up the "431331" Vaccine Series, NIS 2002-2006.

	2002			2003		
Number of Doses	Un-Weighted Sample Size	Weighted Count	Weighted Percent	Un-Weighted Sample Size	Weighted Count	Weighted Percent
0	98	15,957.61	0.27	107	24,533.17	0.42
1	73	15,780.60	0.27	101	32,323.33	0.55
2	16	2,873.16	0.05	29	12,912.46	0.22
3	39	12,028.30	0.21	33	10,743.27	0.18
4	82	23,811.34	0.41	63	25,287.12	0.43
5	75	24,627.39	0.42	65	20,084.72	0.34
6	54	18,391.70	0.31	58	11,447.85	0.19
7	59	12,598.40	0.22	57	14,571.72	0.25
8	157	60,897.84	1.04	136	33,322.33	0.56
9	175	56,289.90	0.96	116	38,635.88	0.65
10	296	99,161.12	1.70	183	55,247.27	0.94
11	523	158,045.62	2.70	321	80,752.09	1.37
12	735	205,814.08	3.52	598	180,583.69	3.06
13	1,105	303,807.48	5.20	822	263,516.24	4.47
14	3,767	1,008,793.26	17.26	3,023	817,582.51	13.86
15	14,156	3,826,661.26	65.46	15,598	4,277,775.49	72.51
Total	21,410	5,845,539.06	100.00	21,310	5,899,319.14	100.00

	2004			2005		
Number of Doses	Un-Weighted Sample Size	Weighted Count	Weighted Percent	Un-Weighted Sample Size	Weighted Count	Weighted Percent
0	133	32,779.64	0.56	135	30,040.78	0.51
1	101	24,512.59	0.42	89	31,408.49	0.53
2	27	6,718.82	0.11	31	17,562.16	0.30
3	31	10,763.61	0.18	25	7,397.51	0.12
4	69	24,536.94	0.42	61	15,794.93	0.27
5	83	25,073.66	0.43	61	16,190.89	0.27
6	34	12,432.76	0.21	49	18,618.96	0.31
7	53	11,748.56	0.20	42	13,598.11	0.23
8	151	53,826.35	0.92	115	51,460.78	0.87
9	150	40,919.61	0.70	90	29,684.60	0.50
10	186	49,394.43	0.84	112	38,669.37	0.65
11	316	94,812.21	1.61	238	97,406.00	1.64
12	478	136,895.48	2.33	432	136,473.76	2.30
13	772	231,324.91	3.94	637	219,571.16	3.70
14	2,584	654,928.82	11.15	2,019	694,118.24	11.69
15	16,830	4,463,755.38	75.99	13,427	4,517,950.80	76.11
Total	21,998	5,874,423.77	100.00	17,563	5,935,946.54	100.00

Table A3, cont. Un-Weighted Sample Size, Weighted Count and Percent of Children with Each Number of Doses of the Six Vaccines that make up the "431331" Vaccine Series, NIS 2002-2006.

	2006		
Number of Doses	Un-Weighted Sample Size	Weighted Count	Weighted Percent
0	151	28,964.37	0.48
1	157	47,498.09	0.79
2	21	10,112.38	0.17
3	32	7,866.53	0.13
4	95	25,263.14	0.42
5	67	15,140.99	0.25
6	42	11,982.17	0.20
7	63	14,376.05	0.24
8	114	34,066.89	0.57
9	125	37,686.61	0.63
10	110	37,045.04	0.62
11	263	77,312.51	1.29
12	516	135,442.75	2.25
13	703	222,981.89	3.71
14	2,368	674,467.81	11.22
15	16,217	4,630,035.45	77.04
Total	21,044	6,010,242.67	100.00

Figure A2: Weighted Percent of Children with Each Number of Doses of Six Vaccines in the 431331 Vaccine Series, NIS 2002-2006

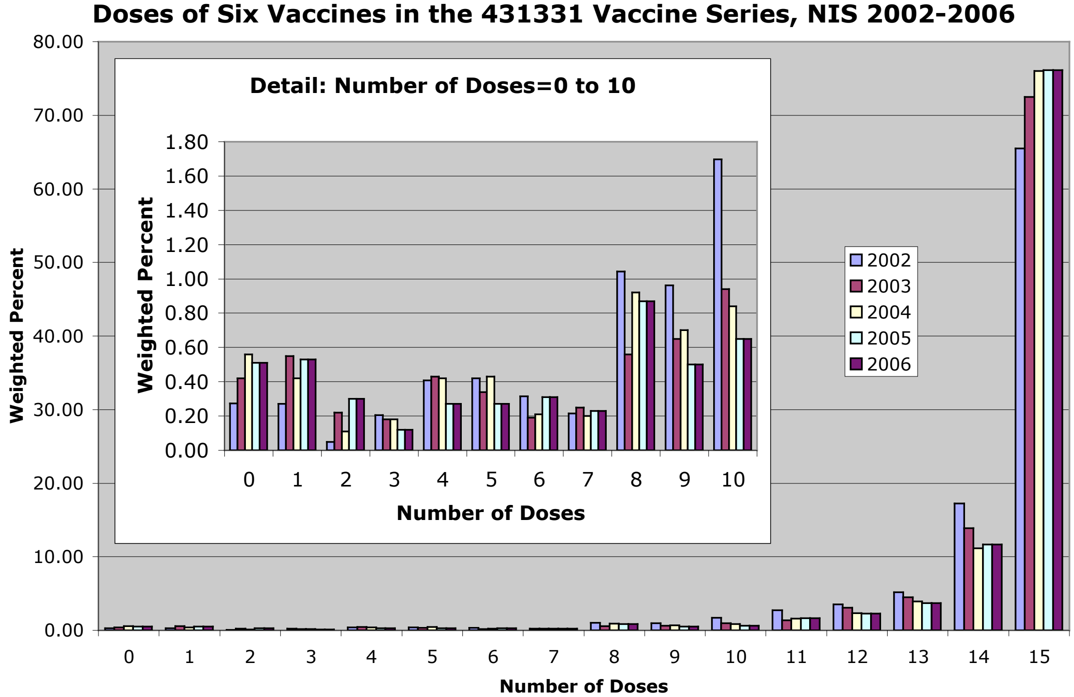

Table A4. Un-Weighted Percent and Sample Size of Children in Each Level of Vaccine Status, Three Different Groupings, NIS 2002-2006.

Un-Weighted Percent

Vaccine Status	2002	2003	2004	2005	2006	Pooled 2002-06
Under-Vaccinated	33.88%	26.80%	23.49%	23.55%	22.94%	26.23%
Fully-Vaccinated	66.12%	73.20%	76.51%	76.45%	77.06%	73.77%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Un-Vaccinated	0.46%	0.50%	0.60%	0.77%	0.72%	0.60%
Partly-Vaccinated	33.42%	26.30%	22.89%	22.78%	22.22%	25.62%
Fully-Vaccinated	66.12%	73.20%	76.51%	76.45%	77.06%	73.77%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Un-Vaccinated	0.46%	0.50%	0.60%	0.77%	0.72%	0.60%
Any Vaccinations	99.54%	99.50%	99.40%	99.23%	99.28%	99.40%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Un-Weighted Sample Size

Vaccine Status	2002	2003	2004	2005	2006	Pooled 2002-06
Under-Vaccinated	7,254	5,712	5,168	4,136	4,827	27,097
Fully-Vaccinated	14,156	15,598	16,830	13,427	16,217	76,228
Total	21,410	21,310	21,998	17,563	21,044	103,325
Un-Vaccinated	98	107	133	135	151	624
Partly-Vaccinated	7,156	5,605	5,035	4,001	4,676	26,473
Fully-Vaccinated	14,156	15,598	16,830	13,427	16,217	76,228
Total	21,410	21,310	21,998	17,563	21,044	103,325
Un-Vaccinated	98	107	133	135	151	624
Any Vaccinations	21,312	21,203	21,865	17,428	20,893	102,701
Total	21,410	21,310	21,998	17,563	21,044	103,325

Table A5. Weighted Percent and Count of Children in Each Level of Vaccine Status, Three Different Groupings, NIS 2002-2006.

Weighted Percent

Vaccine Status	2002	2003	2004	2005	2006	Pooled 2002-06
Under-Vaccinated	34.54%	27.49%	24.01%	23.89%	22.96%	26.55%
Fully-Vaccinated	65.46%	72.51%	75.99%	76.11%	77.04%	73.45%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Un-Vaccinated	0.27%	0.42%	0.56%	0.51%	0.48%	0.45%
Partly-Vaccinated	34.26%	27.07%	23.46%	23.38%	22.48%	26.10%
Fully-Vaccinated	65.46%	72.51%	75.99%	76.11%	77.04%	73.45%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Un-Vaccinated	0.27%	0.42%	0.56%	0.51%	0.48%	0.45%
Any Vaccinations	99.73%	99.58%	99.44%	99.49%	99.52%	99.55%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Weighted Count

Vaccine Status	2002	2003	2004	2005	2006	Pooled 2002-06
Under-Vaccinated	2,018,878	1,621,544	1,410,668	1,417,996	1,380,207	7,849,293
Fully-Vaccinated	3,826,661	4,277,775	4,463,755	4,517,951	4,630,035	21,716,178
Total	5,845,539	5,899,319	5,874,424	5,935,947	6,010,243	29,565,471
Un-Vaccinated	15,958	24,533	32,780	30,041	28,964	132,276
Partly-Vaccinated	2,002,920	1,597,010	1,377,889	1,387,955	1,351,243	7,717,017
Fully-Vaccinated	3,826,661	4,277,775	4,463,755	4,517,951	4,630,035	21,716,178
Total	5,845,539	5,899,319	5,874,424	5,935,947	6,010,243	29,565,471
Un-Vaccinated	15,958	24,533	32,780	30,041	28,964	132,276
Any Vaccinations	5,829,581	5,874,786	5,841,644	5,905,906	5,981,278	29,433,196
Total	5,845,539	5,899,319	5,874,424	5,935,947	6,010,243	29,565,471

Table A6. Weighted Count and Un-Weighted Sample Size and Percent of Children who are Un-Vaccinated: CDC and Public-Use File (PUF) Estimates assuming "adequate provider data", NIS 2002-2006.

CDC Estimates

Year	Weighted			Un-Weighted		
	Count	Population	Percent	Count*	Sample**	Percent
2002				120	21,410	0.56%
2003				101	21,310	0.47%
2004		(not available)		108	21,998	0.49%
2005				115	17,563	0.65%
2006				120	21,044	0.57%

PUF Estimates

Year	Weighted			Un-Weighted		
	Count***	Population	Percent	Count****	Sample	Percent
2002	15,957.61	5,845,539.05	0.27%	98	21,410	0.46%
2003	24,533.17	5,899,319.14	0.42%	107	21,310	0.50%
2004	32,779.64	5,874,423.78	0.56%	133	21,998	0.60%
2005	30,040.78	5,935,946.53	0.51%	135	17,563	0.77%
2006	28,964.37	6,010,242.66	0.48%	151	21,044	0.72%

** CDC Un-Weighted Count = number of un-vaccinated children (from NIS DUG).*
*** Un-Weighted Sample = total number of children in NIS with "adequate provider data"*
**** PUF Weighted Count is based on un-weighted counts and yearly provider weights.*
***** PUF Un-Weighted Count = number of children with either (zero vaccine doses) or (number of vaccine doses is missing and child has "adequate provider data").*

Figure A3: Un-Weighted Count of Children who are Un-Vaccinated from CDC and Public-Use Files, NIS 2002-06

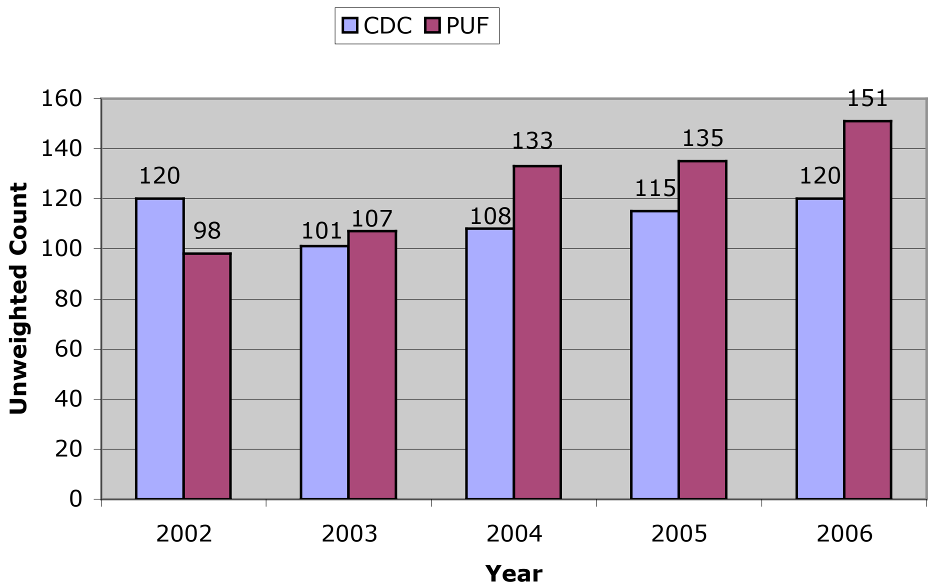

Figure A4: Un-Weighted Percent of Children who are Un-Vaccinated from CDC and Public-Use Files, NIS 2002-06