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Vaccine shot-limiting: Estimating the prevalence, indicators, and impact on vaccination status — Michigan, 2012

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Abstract

Background—Concerns regarding vaccine safety and pain have prompted certain parents to limit the number of shots their child receives per visit. We estimated the prevalence of shot-limited children in Michigan, described their characteristics, assessed whether shot-limited children were up-to-date on recommended vaccinations, and investigated possible intervention points for vaccination education.

Methods—We analyzed vaccination registry and birth record data of children born in Michigan during 2012 who had ⩾2 vaccination visits, with ⩾1 visits after age 5 months. Shot-limited was defined as receiving ≤2 shots at all visits through age 24 months. Nonlimited children received >2 shots at ⩾1 visits. Up-to-date vaccination was based on receipt of a seven-vaccine series and was determined at ages 24 months and 35 months. Risk ratios (RR) were calculated using risk regression.

Results—Of 101,443 children, a total of 2,967 (3%) children were shot-limited. Mothers of shot-limited children were more likely to be white (RR: 1.2; 95% confidence interval [CI]: 1.2–1.2), college graduate (RR: 1.9; 95% CI: 1.9–2.0), and married (RR: 1.5; 95% CI: 1.5–1.5). Compared with nonlimited children, shot-limited children were more likely to be born in a nonhospital setting (RR: 11.7; 95% CI: 9.4–14.6) and have a midwife attendant (RR: 1.9; 95% CI: 1.7–2.1). Shot-limited children were less likely to be up-to-date on recommended vaccinations (RR: 0.2;

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Conflicts of interest

The authors declare no conflicts of interest.

Note

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

95% CI: 0.2–0.3); this association was stronger for those with a midwife birth attendant (RR: 0.1; 95% CI: 0.1–0.2) rather than a medical doctor (RR: 0.3; 95% CI: 0.2–0.3).

Conclusions—Shot-limited children are less likely to be up-to-date on vaccinations, possibly leading to increased risk for vaccine-preventable diseases. This association was stronger for those with a midwife birth attendant. This analysis should prompt targeted education, such as to midwives, concerning risks associated with shot-limiting behavior.

Keywords

Vaccination; Michigan; Up-to-date vaccination; Shot-limiting; Prevalence

1. Introduction

Vaccinations play an integral role in decreasing the incidence of communicable diseases and preventing childhood morbidity and mortality. The Advisory Committee on Immunization Practices (ACIP) currently recommends children receive vaccinations against 14 diseases by age 19 months [1]. One of the goals of the U.S. Department of Health and Human Services Healthy People 2020 initiative is to achieve 80% vaccination coverage among children aged 19–35 months for a seven-vaccine series [2]. Concerns have been raised that receiving multiple vaccinations at once might overwhelm the immune system or lead to increased adverse events because of perceived vaccine toxicity; however, these concerns are not scientifically supported [3,4]. Parents also worry about the pain associated with receiving multiple shots in a single clinic visit [5]. These apprehensions have led certain parents to deviate from the recommended ACIP schedule by eliminating certain vaccines or decreasing the number of vaccines their child receives per visit [6]. A study utilizing data from the 2003 National Immunization Survey (NIS) indicated that 22% of parents reported intentionally delaying their child's vaccinations, and those children had lower vaccination coverage by age 19 months, compared with children of parents who did not report delaying vaccinations (35% versus 60%, $p < 0.05$) [7]. In a national survey of pediatricians and family physicians, 93% of providers reported being asked to spread out vaccinations and 23% reported an increase in these requests, compared with the previous year [8]. Despite acknowledging that vaccination delays put children at risk for vaccine-preventable diseases, 74% of providers are willing to consider such requests, citing a need to build trust with families and maintain them in their practice [8]. Without additional and more frequent vaccination visits, children whose parents follow deviant vaccination schedules risk not being up-to-date with recommended vaccinations and under-vaccination has been associated with outbreaks of vaccine-preventable diseases including pneumococcal disease, pertussis, and measles [9–11]. These diseases can cause morbidity and mortality, particularly in children, highlighting the benefits of conforming to ACIP-recommended vaccination schedules and not delaying vaccinations [12].

According to the ACIP-recommended schedule, a child might receive up to nine injectable vaccines (shots) at a single well-child visit [1]. Combination vaccines can be used to decrease the number of shots; however, to be up-to-date by 19 months without additional visits, a child would still need to receive >2 shots at at least one visit. Immunization information systems (IIS) data have been used to identify children of parents who limit the

number of shots their child receives per visit, herein referred to as shot-limited. In Oregon, the proportion of shot-limited children increased from 3% in 2006 to 10% in 2009 [13]. These children were less likely to be up-to-date on any vaccination series by age 9 months, compared with nonlimited children.

The extent of vaccine shot-limited children in Michigan and the impact on vaccination status has not been evaluated by using IIS data. This analysis is important because the seven-vaccine series coverage in Michigan, as measured by the 2015 NIS, was 68%, which is below the Healthy People 2020 target of 80% [14]. We hypothesized that the demographics of shot-limited children differed from nonlimited children and shot-limited children were less likely to be up-to-date on vaccinations. Specifically, we hypothesized the type of birth attendant (doctor or midwife) was associated with shot-limited children and may change the relationship between shot-limited children and up-to-date status. The objectives of this analysis were to estimate the prevalence of shot-limited children among those born in Michigan in 2012, describe the epidemiology of shot-limited children, investigate the association between shot-limited children and up-to-date vaccination status, and identify vaccines that parents of shot-limited children might be more likely to delay. Ultimately, understanding the extent of vaccine shot-limiting and associated risks will be useful in targeting public health strategies that emphasize the importance of timely vaccination practices.

2. Methods

Analysis was conducted in September 2015. Michigan vaccination providers are required to report vaccinations provided to children aged <20 years to the Michigan Care Improvement Registry (MCIR), Michigan's web-based IIS. For this retrospective, longitudinal cohort study, vaccination data were obtained from the MCIR for children born in Michigan during January 1, 2012–December 31, 2012. Each unique vaccination date recorded in the MCIR was considered a vaccination visit. To minimize accounting for children who moved out of state, we included children who had at least two MCIR-recorded vaccination visits by age 24 months, with at least one visit after age 5 months. This, by default, excluded children whose parents refused all vaccines. Children who died (452, 0.4%), children without a Michigan county residence (2145, 1.9%), or children whose parent/guardian opted out of the registry (152, 0.1%) were excluded. These criteria are similar to those applied in the Oregon study on shot-limited children [13]. For the remaining children, we recorded the number of MCIR-recorded vaccination visits by age 24 months, which included the Hepatitis B vaccine birth dose. All vaccination shots were included. Combination vaccines were counted as a single shot.

Additional demographic data were obtained from Michigan's electronic birth record system. Variables included the following: maternal race (white, black, Asian, American Indian); maternal ethnicity (Hispanic, non-Hispanic); maternal highest level of education completed (some high school, high school graduate, some college, college graduate or higher); maternal marital status at time of delivery (married, not married); birth setting (hospital, nonhospital which includes nonhospital affiliated birthing centers, home, and other); and the type of healthcare provider who attended the delivery (midwife including certified nurse

midwife, and medical doctor, including doctor of medicine or doctor of osteopathic medicine). Vaccination data were linked to electronic birth record data via a unique ID that is present in both the electronic birth record and the MCIR.

Survey data indicate that pain is one reason parents chose to delay vaccinations [5]; therefore, our analysis focused on injectable vaccines (shots). Vaccines were limited to provider-verified, valid doses. Valid doses are those administered after minimum ages and minimum intervals, consistent with ACIP recommendations [1]. Shot-limited children were defined as those who received ≤2 shots at every vaccination visit from birth through age 24 months [13]. In other words, shot-limited children never received >2 shots at any visit. Conversely, nonlimited children were defined as those who had at least one vaccination visit between birth and age 24 months, in which ⩾3 shots were received. Nonlimited children might have received 1–2 shots at a visit as long as they received 3 or more shots at another visit.

A child was considered up-to-date if he or she received the combined seven-vaccine series, which consists of at least the following: four doses of diphtheria, tetanus toxoids, and acellular pertussis vaccine (DTaP); three doses of poliovirus vaccine (IPV); one dose of measles, mumps, and rubella vaccine (MMR); three or four doses of *Haemophilus influenzae* type b vaccine (Hib) depending on product type; three doses of hepatitis B vaccine (HepB); one dose of varicella vaccine (Var); and four doses of pneumococcal conjugate vaccine (PCV). This definition has been implemented previously to assess vaccination coverage using NIS data [14]. Up-to-date status was assessed at age 24 months, 5 months after a child should be up-to-date if conforming to the ACIP-recommended schedule, and again at age 35 months to allow additional catch-up time. The number of vaccinations required to be up-to-date does not change between ages 24 months and 35 months. Children who had not reached age 35 months at the time the data were obtained were excluded from the up-to-date calculation at 35 months (n = 15,836).

Demographic data were compared by using risk ratios (RR) and 95% confidence intervals (CI). All risk ratios were calculated by using risk regression and adjusted for maternal race and education, a priori-defined sociodemographic confounders. When an outcome is common (>10%) and the sample size is at or near population level, relative risk is considered a better estimator of risk than odds ratios [15]. To test the interaction of the a priori hypothesis for midwife birth attendants, we included it as an interaction term in a separate multivariate risk regression. Statistical analysis was performed using SAS® software version 9.3 (SAS Institute, Cary, North Carolina, USA).

Because this analysis contributes directly to the control and prevention of disease, the investigation was deemed not human subjects research by Michigan Department of Health and Human Services Institutional Review Board and by Centers for Disease Control and Prevention human subjects review.

3. Results

Of the 111,814 children in the 2012 Michigan birth cohort, 10,371 (9%) children were excluded, resulting in 101,443 (91%) children being included in the analysis. Among these, 2,967 (3%) children met the definition for shot-limited. Compared with non-limited children, shot-limited children were more likely to have mothers who were white (91% versus 73%; RR: 1.2; 95% CI: 1.2–1.2), college graduates (65% versus 34%; RR: 1.9; 95% CI: 1.9–2.0), and married (84% versus 56%; RR: 1.5; 95% CI: 1.5–1.5) (Table 1). Shot-limited children were more likely to be born in a nonhospital setting (e.g., home or birthing center) (3% versus 0%; RR: 11.7; 95% CI: 9.4–14.6) and have a midwife birth attendant (11% versus 6%; RR: 1.9; 95% CI: 1.7–2.1), compared with nonlimited children.

Shot-limited children had a higher median number of vaccination visits than nonlimited children (eight visits versus seven) and a greater interquartile range (six visits versus three) (Fig. 1A). When restricted to up-to-date children, the difference in median number of visits was greater (11 visits versus eight) (Fig. 1B). Shot-limited children were less likely to be up-to-date on vaccinations by age 24 months, compared with nonlimited children (RR: 0.3; 95% CI: 0.2–0.3) (Table 2). A total of 582 (20%) shot-limited children were up-to-date, compared with 75,411 (77%) of nonlimited children. The association between shot-limited children and up-to-date vaccination status remained after adjusting for maternal race and education ($RR_{adjusted}$: 0.2; 95% CI: 0.2–0.3).

In our multivariate risk regression, although the main effect of shot-limiting on up-to-date vaccination status was still significant and substantial for children, regardless of birth attendant type, the interaction between shot-limiting and birth attendant was positive and significant. Shot-limited children whose birth was attended by a medical doctor ($RR_{adjusted}$: 0.3; 95% CI: 0.2–0.3) were more likely to be up-to-date than shot-limited children whose birth was attended by a midwife ($RR_{adjusted}$: 0.1; 95% CI: 0.1–0.2) (Table 2).

To allow additional time for shot-limited children to become up-to-date, we also assessed up-to-date status at age 35 months, which is the maximum age included in the NIS coverage survey of children aged 19–35 months [14]. The percentage of shot-limited children who were up-to-date increased from 20% at 24 months to 26% at 35 months. However, shot-limited children remained less likely to be up-to-date, compared with nonlimited children (26% versus 81%; $RR_{adjusted}$: 0.3; 95% CI: 0.3–0.3).

Among shot-limited children, the vaccines with the highest rates of up-to-date coverage were IPV (⩾3 doses, 61%), DTaP (⩾4 doses, 59%), and MMR (⩾1 dose, 51%) (Table 3). The vaccine with lowest coverage rate was PCV (⩾4 doses, 42%). The vaccines with the largest coverage difference between shot-limited and nonlimited children were HepB (44% versus 97%, $p < 0.01$) and Var (46% vs. 93%, $p < 0.01$). In comparison, the vaccine with the smallest coverage difference between shot-limited and nonlimited children was DTaP (59% versus 86%, $p < 0.01$).

4. Discussion

Using IIS data, we estimated the prevalence of shot-limited children in Michigan, identified indicators of shot-limiting, and demonstrated that shot-limited children were less likely to be up-to-date on ACIP-recommended vaccinations, compared with nonlimited children.

Among vaccinated children born in Michigan in 2012, the prevalence of vaccination shot-limited children by age 24 months was 3%, which is within the range of shot-limited children (2–12%) identified in an Oregon study during 2006–2009 [13]. In that study, the overall prevalence was higher (5%); however, shot-limiting was assessed at 9 months, when there are fewer opportunities to receive multiple shots per visit. Differences in the prevalence might also be affected by sociodemographic differences between the populations. We expanded our understanding of delayed vaccination to describe characteristics of shot-limited children. Shot-limited children are more likely to have white, college-educated, married mothers; these findings are similar to another study among parents who intentionally delayed vaccinations [7] and different from children who were undervaccinated because of racial/ethnic disparities [16].

Shot-limited children were less likely to be up-to-date on ACIP-recommended vaccinations, compared with nonlimited children. Coverage might have been low because maintaining an up-to-date shot-limited schedule requires additional visits. Indeed, the median number of visits for shot-limited children was greater than for nonlimited children. Perhaps the additional costs and time associated with maintaining a shot-limited schedule negatively affected catch-up ability. Certain parents of shot-limited children might also have been selectively avoiding a vaccine; therefore, their child would never be up-to-date for the complete series.

Shot-limited children were more likely to have been born in a nonhospital setting and to have a midwife birth attendant. Further, shot-limited children having a midwife birth attendant were less likely to be up-to-date than shot-limited children having a medical doctor birth attendant. A study by Bell et al. similarly determined that parents who delayed vaccinations were more likely to use midwife birth attendants [17]. Our analysis does not address why shot-limited children who had midwife attendants were less likely to be up-to-date. Midwives tend to offer holistic, natural birth support [18]; perhaps parents who prefer less medical intervention at birth, e.g., through midwives or home births, are also more likely to be vaccine hesitant. Vaccination beliefs might also differ among different types of health professionals. A survey of healthcare providers in Australia determined that midwives were more likely to agree with the statement “concurrent immunization might overload the immune system” than general practitioners and nurses [19]. For certain parents, midwives serve as trusted information sources and their perceptions could affect parental vaccination attitudes and choices in pediatricians. Although shot-limited children were more likely to have had a midwife birth attendant, the majority (89%) of shot-limited children had medical doctor birth attendants. Therefore, public health strategies should engage all healthcare providers, including midwives, as follows: (1) to emphasize the benefits and importance of timely vaccination in early childhood and (2) to help parents think through the decision and commitment required to vaccine shot-limit but also maintain an up-to-date vaccine schedule.

The individual vaccine coverage rates differed between shot-limited and nonlimited children. Among shot-limited children, coverage was highest for IPV and DTaP. During 2012, pertussis incidence was the highest it had been in the United States since 1955 [20–22], which might have contributed to the increased DTaP coverage. Since IPV is included in certain combination vaccines with DTaP [23], this might also explain in part why IPV coverage was high. The vaccines with the largest coverage difference between shot-limited and nonlimited children were HepB and Var. The low coverage among shot-limited children might be due to deviant vaccination schedules that encourage parents to delay HepB until at least 2 years of age or avoid live vaccines, including Var, entirely [24,25]. Other schedules promote delaying Var vaccination to allow time for a child to be exposed to the disease and obtain immunity naturally.

This study is subject to limitations. First, we used vaccination data to identify shot-limited children and therefore cannot distinguish parents who intentionally delayed vaccinations from those who delayed vaccinations because of other barriers, e.g., cost or access. However, the observation that demographics of shot-limited children in our analysis are similar to demographics of parents who intentionally delayed vaccinations [7] indicate that this definition might serve as a suitable proxy for identifying shot-limited children from IIS databases. Second, there is the potential for misclassification of shot-limited children. Because of our strict shot-limited definition, we might have underestimated its prevalence. For example, if a parent changed their opinion on shot-limiting, either choosing to delay vaccinations after already receiving >2 shots at a visit or choosing to catch up on vaccinations after delaying, their child would have been classified as nonlimited despite deviating from the recommended schedule. Continuous residence in Michigan was not verified in this analysis; therefore, children who moved out of Michigan after age 5 months might have been misclassified as nonlimited or not up-to-date. Lastly, these findings are on the basis of children born in Michigan during 2012 and might not be generalizable to a larger population.

5. Conclusion

Recent studies have indicated that the number of undervaccinated children is greater than nonvaccinated and this population is growing [13,17]. To reach the Healthy People 2020 goal of achieving 80% coverage for the combined series of seven ACIP-recommended vaccines among children ages 19–35 months, we must understand the factors associated with undervaccination and target increased public health interventions aimed at increasing timely receipt of vaccination. Our analysis demonstrates that shot-limited children in Michigan are less likely to be up-to-date on vaccinations by ages 24 months and 35 months, compared with nonlimited children. Furthermore, parents who chose to limit vaccines are more likely to use a midwife, and children with midwife-attendant births are more likely to be delinquent regarding vaccinations. Therefore, understanding the knowledge, attitudes, and behaviors of midwives toward vaccinations might prove useful in developing a health education approach that emphasizes the importance of being up-to-date and discusses the challenges associated with shot-limiting. Public health professionals should encourage all providers to vaccinate according to the ACIP-recommended schedule and to take additional steps to ensure that children on delayed schedules finish the vaccine series.

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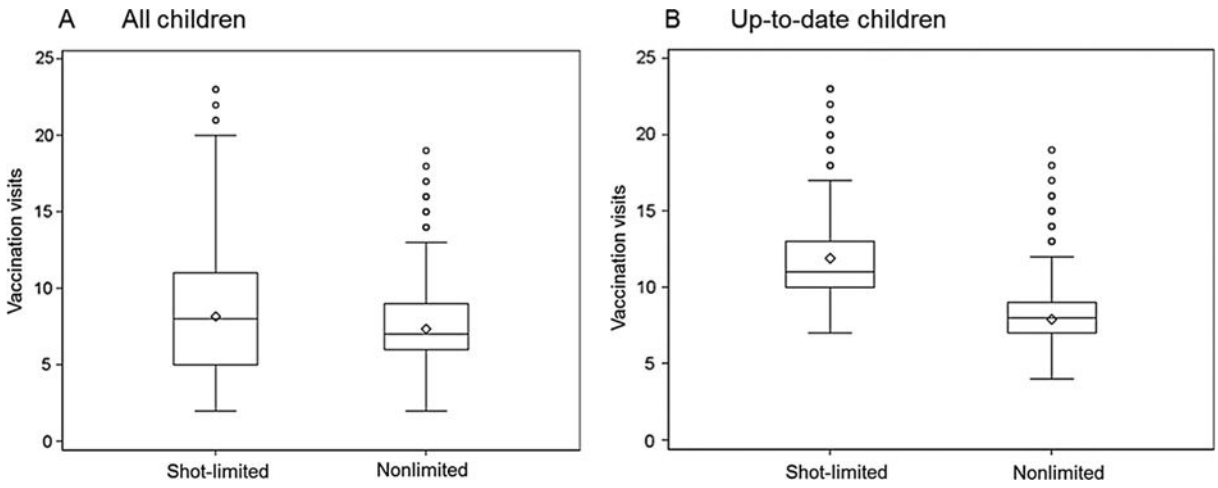

Fig. 1.
Distribution of vaccination visits by shot-limited status – Michigan, 2012.

Table 1

Characteristics of study population by shot-limited status.

Characteristics	Shot-limited *N* = 2,967 *n* (%)	Nonlimited *N* = 98,476 *n* (%)	Total *N* = 101,443 *n* (%)	Risk ratio (95% CI)
Maternal race *(missing = 1,259)*				
White	2,601 (91)	70,726 (73)	73,327 (73)	1.2 (1.2–1.2)
Black	135 (5)	18,753 (19)	18,888 (19)	0.2 (0.2–0.3)
Asian	97 (3)	7,435 (8)	7,532 (8)	0.4 (0.4–0.5)
American Indian	12 (0)	425 (0)	437 (0)	0.9 (0.5–1.7)
Maternal ethnicity (missing = 341)				
Hispanic	91 (3)	6,880 (7)	6,971 (7)	0.4 (0.4–0.5)
Non-hispanic	2,865 (97)	91,266 (93)	94,131 (93)	Ref.
Maternal education (missing = 434)				
College graduate or higher	1,929 (65)	33,426 (34)	35,355 (35)	1.9 (1.9–2.0)
Some college	623 (21)	25,335 (26)	25,958 (26)	0.8 (0.8–0.9)
High school graduate	314 (11)	25,660 (26)	25,974 (26)	0.4 (0.4–0.5)
Some high school	93 (3)	13,629 (14)	13,722 (14)	0.2 (0.2–0.3)
Maternal marital status (missing = 6)				
Married	2,493 (84)	55,536 (56)	58,029(57)	1.5 (1.5–1.5)
Not married	474 (16)	42,934 (44)	43,408 (43)	Ref.
Birth setting (missing = 22)				
Nonhospital (home, birthing center, other)	102 (3)	289 (0)	391 (0)	11.7 (9.4–14.6)
Hospital	2,865 (96)	98,165 (100)	101,030 (100)	Ref.
Birth attendant (missing = 213)				
Midwife	329 (11)	5,814 (6)	6,143 (6)	1.9 (1.7–2.1)
Medical doctor	2,622 (89)	92,465 (94)	95,087 (94)	Ref.

CI: confidence interval.

Table 2

Factors associated with up-to-date vaccination.

Variable	Risk ratio (95% confidence interval)	
	Unadjusted	Adjusted for maternal race and education
Shot-limited	0.3 (0.2–0.3)	0.2 (0.2–0.3)
Midwife birth attendant	0.9 (0.9–1.0)	1.0 (1.0–1.0)
Shot-limited and birth attendant		
Midwife	0.1 (0.1–0.2)	0.1 (0.1–0.2)
Medical doctor	0.3 (0.3–0.3)	0.3 (0.2–0.3)

Table 3

Vaccination status at age 24 months by vaccine series.

Vaccine series	Shot-limited *N* = 2,967 *n* (%)	Nonlimited *N* = 98,476 *n* (%)	Total *N* = 101,443 *n* (%)	Percent difference[a]
⩾4 DTaP	1,735 (59)	84,244 (86)	85,979 (85)	27
⩾3 IPV	1,813 (61)	94,901 (96)	96,714 (95)	35
⩾1 MMR	1,507 (51)	92,306 (94)	93,813 (93)	43
⩾3/4 Hib	1,460 (49)	84,573 (86)	86,033 (85)	37
≥3 HepB	1,302 (44)	95,090 (97)	96,392 (95)	53
⩾1 Var	1,373 (46)	92,000 (93)	93,373 (92)	47
⩾4 PCV	1,252 (42)	83,244 (85)	84,496 (83)	43
Overall up-to-date[b]	582 (20)	75,411 (77)	75,993 (75)	57

[a] All percent differences were significant at $p < 0.01$.

[b] Up-to-date vaccination was assessed at age 24 months according to the combined seven-vaccine series.