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Impact of Simultaneous Administration of Vaccines on the Disparities in Vaccination Coverage

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ABSTRACT

Simultaneous administration of all age-appropriate vaccines was recommended in 2011 for children. Reducing children immunization disparities is an overarching goal of Healthy People 2020. We analyzed the National Immunization Survey (NIS)-ChildPublic-Use Data (2010-2018) to compare the disparities in potentially achievable vs. reported vaccination coverage by children's characteristics over years. Disparities in potentially achievable vaccination coverage by categories of selected factors and for the three vaccine series (4+DTaP, 4+PCV, and Hib-FS) were estimated. We tested the hypothesis that there are no significant differences between the disparities curves in potentially achievable and reported vaccination coverage with the three vaccine series by selected factors and over the calendar years. The 15 out of the total 18 potentially achievable disparities curves were significantly lower than the corresponding reported disparities curves. The average reported disparities ranged from 6.5% to 65.9% with a median of 8.2%, and the average potentially achievable disparities ranged from 1.8% to 35.2% with a median of 4.5%. The significant reduction in potentially achievable disparities occurred with health insurance type, on-time condition of vaccination, mother's education level, and children's family mobility status. Disparities in vaccination coverage between subpopulations of children could be substantially reduced with simultaneous administration of vaccines.

INTRODUCTION

Simultaneous administration of all age-appropriate vaccines at a vaccination visit is recommended by the Advisory Committee on Immunization Practices (ACIP), CDC [1]. This is an important strategy for ensuring that vaccinations are received on schedule, and for bringing children who have fallen behind on their vaccines up to date [2]. Potentially achievable vaccination coverage for 4+DTaP (≥ 4 doses of diphtheria, tetanus, and acellular pertussis vaccine), 4+PCV (≥4 doses of pneumococcal conjugate vaccine), and Hib-FS (full series of *Haemophilus influenzae* type b conjugate vaccine) with simultaneous administration of vaccines among children in the United States has been reported [3].

Disparities in reported vaccination coverage between socio-demographic subpopulations of young children in the United States for some vaccines have been described. Reported vaccination coverage for the 4:3:1:3:3:1 vaccine series was significantly lower during the years 2000-2008 among children whose mothers had 12 years of education or less compared to those children whose mothers had more than 12 years of education [4]. Significant disparities for the 4+DTaP reported vaccination coverage were observed between children with the third dose of DTaP On-time vs. Late, and Family Moved vs. Not Moved [5]. Recent studies have shown that vaccination coverage has been generally lower for children who are uninsured or covered by Any Medicaid than among those children with Private Only Insurance [6-11]. Reducing these disparities is an overarching goal of *Healthy People 2020*[12].

However, disparities in potentially achievable vaccination coverage by characteristics of young children in the United States have not been investigated. The objectives of our current study are: (i). Estimate the disparities in potentially achievable and reported vaccination coverage for 4+DTaP, 4+PCV, and Hib-FS by children's health insurance type, timeliness of vaccination, mother's education level, and family mobility status among children19-35 months in the United States, across the annual years of 2010-2018. (ii). Test whether the curves of disparities in potentially achievable vaccination coverage are the same as the curves of disparities in reported vaccination coverage. (iii). Evaluate the average disparities over the annual years 2010-2018, and identify the significantly different average disparities by vaccine series and socio-demographic subgroups. (iv). Visualize the potentially achievable disparities curves and reported disparities

curves which are significantly different across the annual years 2010-2018 by characteristics of young children and vaccine series.

MATERIALS AND METHODS

Data source

National Immunization Survey-Child (NIS) public-use data were analyzed in this study. The NIS is a random-digit–dialed (RDD) telephone survey of parents/guardians of children aged 19–35 months in the United States. All identified providers are mailed an immunization history questionnaire to report dates and types of vaccines administered. Data from responding providers are combined to create a synthesized vaccination history data for each child. The NIS-Child vaccination coverage estimates are based on children with adequate provider data. The NIS uses a large sample of children to estimate vaccination coverage and disparities; in each year of 2010-2018 NIS, there are about 15,000 children with adequate provider data [13].

Outcome measures and selected factors

The disparities in both potentially achievable vaccination coverage and reported vaccination coverage were evaluated across the year 2010-2018 for children 19-35 months in the United States. This research included the information of children's vaccination with DTaP, PCV, and Hib vaccines; and analyzed the four modifiable factors: children's health insurance types (Private Only, Any Medicaid, Other Insurance, Uninsured), vaccination timeliness condition (On-time vs. Late for the third dose of DTaP, third dose of PCV, and Hib Primary vaccine series), mother's education level (≤12years vs. ≥13 years), and family mobility status (Not Moved vs. Moved). Vaccination coverage disparities were defined as the difference between vaccination coverage rates for children among two different categories for the selected factor [14].

A missed opportunity for vaccination was defined as the failure to administer the fourth dose of DTaP, the fourth dose of PCV, or the booster dose of Hib vaccine for the full series of Hib (Hib-FS) at a vaccination visit, during which a child received one or more other needed and age-appropriate vaccines [3, 15]. Potentially achievable vaccination coverage was defined as the vaccination coverage possible for the recommended 4+DTaP, 4+PCV, and Hib-FS if missed opportunities had been eliminated [3].

Statistical analysis

To test the null hypothesis of the same disparities curves in potentially achievable vaccination coverage vs. reported vaccination coverage, Z-tests are applied in this study, and the disparities curves are defined as the joint point curves of disparities with the standard errors across the years 2010-2018 [16-17]. Potentially achievable and reported vaccination coverages are assessed for children with Descriptive and Crosstab Procedures in SAS/SUDAAN statistical software (v11, SUDAAN, RTI, International, RTP, NC) for data from complex sample surveys.

RESULTS

Test of the equality of disparities curves between potentially achievable vs. reported vaccination coverage across 2010-2018

For each of the three vaccine series, we conducted 6 vaccination coverage comparisons between categories of the four selected factors as shown in the first column of **Table 1.** The disparities in potentially achievable vaccination coverage and the disparities in reported vaccination coverage were estimated across the annual years 2010-2018 by each of the three vaccine series for each of the 6 comparisons, produced 6 pairs of potentially achievable disparities curves and reported disparities curves for each of the three vaccine series. Then we tested the equality of potentially achievable disparities curves vs. reported disparities curves, with Z Test-Statistics (*p-values*), by the 4 selected factors and the 3 vaccine series among children in the United States.

With the disparities of Private Only Insurance vs. Any Medicaid, the potentially achievable disparities curves are significantly lower than the corresponding reported disparities curves for 4+DTaP (Z=5.02, $p<0.01$), for 4+PCV (Z=9.30, $p<0.01$), and for Hib-FS (Z=7.47, $p=0.01$). To the disparities of Private Only Insurance vs. Other Insurance, the potentially achievable disparities curves are significantly lower than the comparable reported disparities curves for 4+PCV (Z=3.97, $p<0.01$), and for Hib-FS (Z=8.02, $p<0.01$). As for the disparities of Private Only Insurance vs. Uninsured, the potentially achievable disparities curves are significantly lower than the corresponding reported disparities curves for 4+PCV (Z=4.04, $p<0.01$), and for Hib-FS (Z=4.08, $p<0.01$). Considering the disparities of On-time vs. Late for the third dose of DTaP, third dose of PCV, and Hib-Primary, the potentially achievable disparities curves are

significantly lower than the respective reported disparities curves with Z=40.87 (*p<0.01*), Z=37.04 (*p<0.01*), and Z=20.37 (*p<0.01*). Regarding the disparities of Mother's Education ≥13 years vs. ≤12 years, the potentially achievable disparities curves are significantly lower than the corresponding reported disparities curves for 4+DTaP, 4+PCVC, and Hib-Primary with all the three *p-values*< 0.01. Finally, for 4+PCV and Hib-FS, the potentially achievable disparities curves are significantly lower than the reported disparities curves for Family Not-Moved vs. Moved with the two *p-values*<0.01. A total of 83% (15 out of 18 comparisons) potentially achievable disparities curves were significantly lower than the corresponding reported disparities curves (**Table 1**).

Average disparities across annual years 2010-2018

Table 2 displays the average disparities in reported and potentially achievable vaccination coverage over the annual years 2010-2018 and their difference by 4+DTaP, 4+PCV, and Hib-FS. The average reported disparities ranged from 6.5 to 65.9 percentage points with mean and median of 15.0 and 8.2 percentage points respectively, while the average potentially achievable disparities ranged from 1.8 to 35.2 percentage points with mean and median of 8.4 and 4.5 percentage points respectively. The disparities in reported coverage decreased 1.5 to 30.7 percentage points due to the simultaneous administration of vaccines; i.e. a 22% to 47% reduction in disparities from reported disparities. The smallest average disparities in potentially achievable vaccination coverage were 1.8 (1.5, 2.2) percentage points for the third dose of PCV Ontime vs. Late.

Table No. 1: Test of the Equality of Disparities Curves Between Potentially Achievable Vs. Reported Vaccination Coverage Across Annual Years 2010-2018 By Selected Factors For 4+Dtap, 4+PCV, And Hib-Fs[a] Among Young Children In The United States

Disparities by factor categories compared	4+DTaP		4+PCV		Hib-FS	
	Z – test	*P*-value	Z – test	*P*-value	Z – test	*P*-value
Private Only Insurance (1) vs. Any Medicaid (2)	**5.02**	**<0.01 ***	**9.30**	**<0.01 ***	**7.47**	**<0.01 ***
Private Only Insurance (1) vs. Other Insurance (3)	1.43	0.15	**3.97**	**<0.01 ***	**8.02**	**<0.01 ***
Private Only Insurance (1) vs. Uninsured (4)	1.50	0.13	**4.04**	**<0.01 ***	**4.08**	**<0.01 ***
On-time (2) vs. Late (1): for the 3rddose of DTaP,3rd dose of PCV, or Primary Series of Hib Vaccination	**40.87**	**<0.01 ***	**37.04**	**<0.01 ***	**20.37**	**< 0.01 ***
Mother's Education level of ≥13 (2) vs. ≤12 (1) years	**3.81**	**<0.01 ***	**7.24**	**<0.01 ***	**6.73**	**<0.01 ***
Family Not-Moved (2) vs. Moved (1).	1.48	0.069	**2.44**	**<0.01 ***	**3.26**	**<0.01 ***

≥4 doses of diphtheria and tetanus toxoids and acellular pertussis vaccine (4+DTaP), ≥4 doses of pneumococcal conjugate vaccine (4+PCV), and the full series of *Haemophilus influenzae* type b vaccine (Hib-FS).

[*] Statistically significant with 2-sided Z-test at the level of 0.01.

Table No. 2: Average reported disparities, average potentially achievable disparities, and the difference of the 2 average disparities across annual years 2010-2018 by selected factors for 4+DTaP, 4+PCV, and Hib-FS[a] among young children in the United States

Disparities by factor categories compared	Average reported disparities % (95%CI[b])	Average potentially achievable disparities % (95%CI)	A difference of average reported vs. potentially achievable disparities % (95%CI)
4+DTaP			
Private Only Insurance (1) vs. Any Medicaid (2)	**6.8(6.0,7.6)**	**4.1(3.5,4.7)**	**2.7(1.7,3.7) ***
Private Only Insurance (1) vs. Other Insurance (3)	6.5(4.4,8.7)	4.4(2.7,6.0)	2.1(-0.6,4.8)
Private Only Insurance (1) vs. Uninsured (4)	24.1(21.6,26.5)	21.4(19.1,23.7)	2.6(-0.8,6.0)
Ontime (2) vs. Late (1): for the 3rd dose of DTaP Vaccination	**16.4(15.5,17.4)**	**4.5(3.9,5.1)**	**12.0(10.8,13.1) ***
Mother education level of ≥13 (2) vs. ≤12 (1) years	**6.6(5.7,7.4)**	**4.5(3.9,5.2)**	**2.1(1.0,3.1) ***
Family Not-moved (2) vs. Moved (1).	6.8(5.4,8.3)	5.3(4.1,6.6)	1.5(-0.4,3.4)
4+PCV			
Private Only Insurance (1) vs. Any Medicaid (2)	**8.3(7.5,9.1)**	**3.4(2.8,4.0)**	**4.9(3.9,5.9) ***
Private Only Insurance (1) vs. Other Insurance (3)	**7.7(5.7,9.7)**	**2.8(1.5,4.1)**	**4.9(2.5,7.3) ***

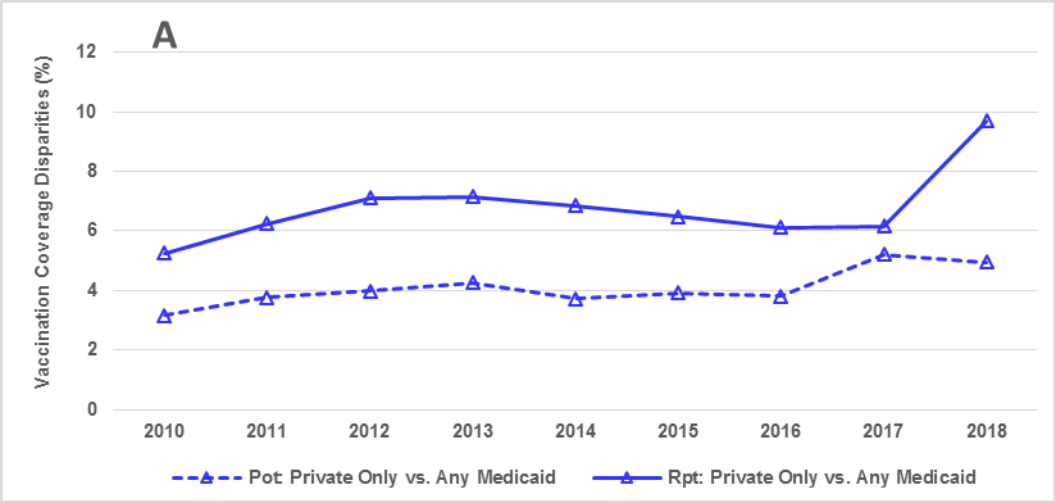
Private Only Insurance (1) vs. Uninsured (4)	**24.4(22.0,26.8)**	**17.4(15.2,19.5)**	**7.0(3.8,10.2) ***
Ontime (2) vs. Late (1): for the 3rd dose of PCV Vaccination	**21.0(20.0,21.9)**	**1.8(1.5,2.2)**	**19.1(18.1,20.1) ***
Mother education level of ≥13 (2) vs. ≤12 (1) years	**8.0(7.1,8.8)**	**3.9(3.3,4.5)**	**4.1(3.0,5.1) ***
Family Not-moved (2) vs. Moved (1).	**10.8(9.2,12.3)**	**8.2(6.8,9.5)**	**2.6(0.6,4.7) ***
Hib-FS			
Private Only Insurance (1) vs. Any Medicaid (2)	**8.0(7.2,8.9)**	**3.8(3.3,4.4)**	**4.2(3.2,5.2) ***
Private Only Insurance (1) vs. Other Insurance (3)	**7.5(5.4,9.5)**	**3.7(2.2,5.1)**	**3.8(1.3,6.3) ***
Private Only Insurance (1) vs. Uninsured (4)	**23.2(20.7,25.7)**	**16.3(14.2,18.4)**	**6.9(3.7,10.1) ***
Ontime (2) vs. Late (1): for the Primary Series of Hib Vaccination	**65.9(64.1,67.7)**	**35.2(33.0,37.5)**	**30.7(27.8,33.5) ***
Mother education level of ≥13 (2) vs. ≤12 (1) years	**7.8(6.9,8.7)**	**4.0(3.4,4.6)**	**3.8(2.7,4.9) ***
Family Not-moved (2) vs. Moved (1).	**9.9(8.3,11.5)**	**6.4(5.2,7.7)**	**3.5(1.4,5.5) ***

[a]≥4 doses of diphtheria and tetanus toxoids and acellular pertussis vaccine (4+DTaP), ≥4 doses of pneumococcal conjugate vaccine (4+PCV), and the full series of *Haemophilus influenzae* type b vaccine (Hib-FS).

*Significant at 5% level

Reported vs. potentially achievable disparities curves, which are significantly different among all of the 6 comparisons across 2010-2018 by the three vaccines series

To visualize the findings in the first section of the results part, if the tests of the equality for the reported disparities curve vs. the potentially achievable disparities curves across the annual years 2010-2018 are significant at a level of *p*-value <0.01, then those curves are shown in **Figures 1 and Figure 2**. For Private Only vs. Any Medicaid for 4+DTaP; Private Only vs. Any Medicaid, Other Insurance, and Uninsured for 4+PCV and Hib-FS, the potentially achievable disparities curves are significantly lower than the corresponding reported disparities curves over the years of 2010-2018 **(Figure 1)**. As for the disparities of vaccination On-time vs. Late, Mother education ≥13 vs. ≤12 years for 4+DTaP; On-time vs. Late, Mother education ≥13 vs. ≤12 years, and Family Not Moved vs. Moved for 4+PCV and Hib-FS, the potentially achievable disparities curves are significantly lower than the respectively reported disparities curves across the years of 2010-2018 (**Figure 2**).



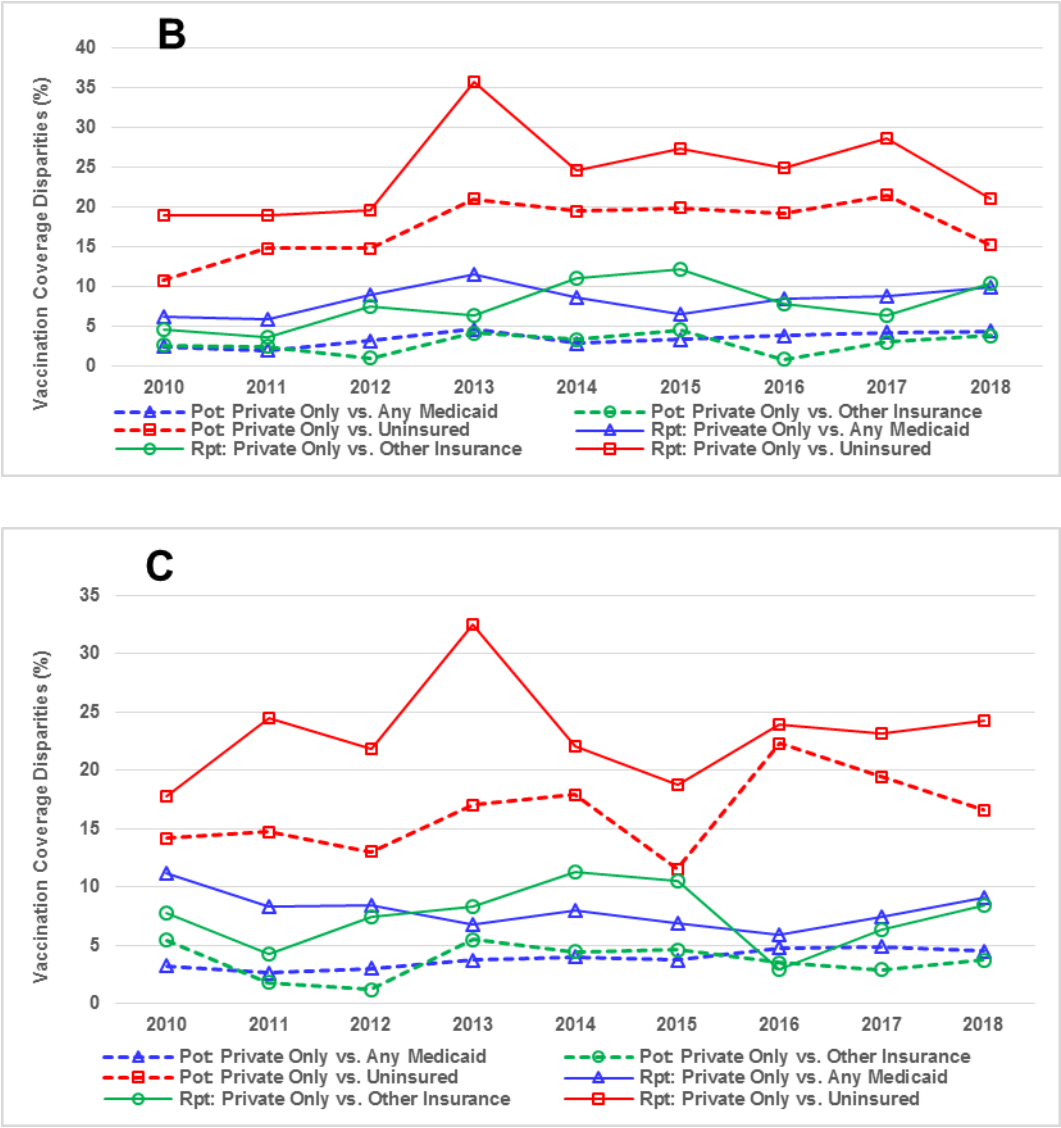


Fig. No. 1: Reported vs. potentially achievable disparities curves which are significantly different for the disparities in health insurance status. A. Private Only vs. Any Medicaid for 4+DTaP. B. Private Only vs. Any Medicaid, Other Insurance, and Uninsured for 4+PCV. C. Same comparisons as B but for Hib-FS.

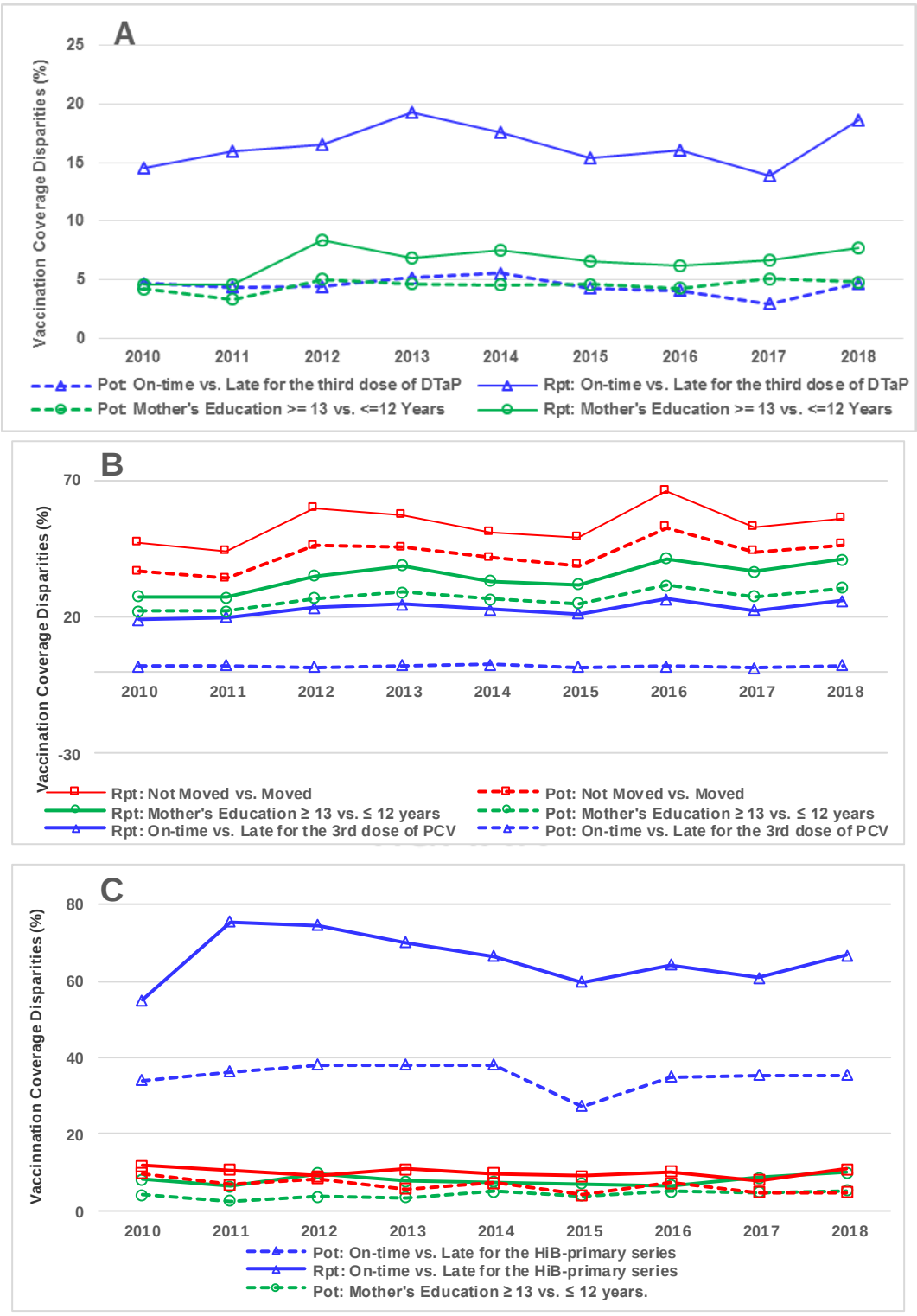


Fig. No. 2: Reported vs. potentially achievable disparities curves which are significantly different for the disparities in 3 factors. A. On-time of the 3rd dose DTaP, Mother's Education. (4+DTaP). B. On-time of the 3rd dose PCV, Mother's Educations, Family Mobility. (4+PCV). C: On-time of the Hib-Primary series, Mother's Education, Family Mobility. (Hib-FS).

DISCUSSION

This is an innovative study that has discovered that among all of the 18 pairs of possible disparities curves investigated, 15 potentially achievable disparities curves are significantly lower than the corresponding reported disparities curves: Private Only Insurance vs. Any Medicaid insurance (4+DTaP, 4+PCV, Hib-FS); Private Only Insurance vs. Other Insurance, and Uninsured (4+PCV, Hib-FS); Vaccination On-time vs. Late, Mother's education ≥13 vs. ≤12 years (4+DTaP, 4+PCV, Hib-FS); and Family Not Moved vs. Moved (4+PCV, Hib-FS). These results highlighted the public health importance of the simultaneous administration of vaccines that could both increase the vaccination coverage overall groups of children and also reduce the disparities in vaccination coverage between subpopulations of socio-economic factors.

Improving the timeliness of vaccinations could be one important measure for reducing vaccination disparities. Vaccination timeliness refers to vaccination administered to children by their health care providers according to the children's ages in months as recommended in the children's immunization schedule by ACIP. The ACIP's recommendations are the standard and practical guides for all of the immunization workers in their efforts to protect children against vaccine-preventable diseases, and the recommended immunization schedule should be implemented in physician's and nurse daily immunization activities.

Client reminder and recall interventions are used to remind members of a target population that vaccinations are due (reminders) or late (recall). Reminders and recalls differ in content and are delivered by various methods (e.g., telephone, letter, postcard, text message). The reminder and recall interventions are based on strong evidence of effectiveness in improving vaccination rates in children [18, 19]. Reminder and recall system prompt parents to take advantage of every possible simultaneous vaccination opportunity which would make their children fully vaccinated as per the ACIP recommended vaccination schedule. Thus, the reminder and recall system could be an effective intervention for reducing the disparities in vaccination coverage for children.

This study was subject to some limitations. The NIS-Child survey uses a list-assisted random-digit-dialing (RDD) design to locate potential participants for a household survey. This could result in bias in the evaluation of vaccination coverage due to non-response and exclusion of households without telephone service. Vaccination coverage could be estimated incorrectly due

to missing provider information and/or inaccurate reporting of children's vaccination history during the provider record check phase for the NIS-Child survey. However, recent publications have shown that the total survey error with the NIS-Child data could be very small [20].

CONCLUSION

Disparities in vaccination coverage between socio-demographic subpopulations of children could be substantially reduced with increased simultaneous administration of vaccines.

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REFERENCES

1. Centers for Diseases Control and Prevention. Recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR*. 2011;60 (January (RR02)):1–60.
2. King GE, Hadler SC. Simultaneous administration of childhood vaccines: an important public health policy that is safe and efficacious. *Pediatr Infect Dis J*. 1994; 13:3 94–407.
3. Zhao Z, Smith PJ, Hill HA. Evaluation of potentially achievable vaccination coverage with simultaneous administration of vaccines among children in the United States. *Vaccine*. 34 (2016) 3030–3036.
4. Zhao Z, Luman ET. Progress Toward Eliminating Disparities in Vaccination Coverage Among U.S. Children, 2000–2008. *Am J Prev Med*. 2010;38(2)127–137.
5. Zhao Z. Risk Factors Associated with Children Missing the Fourth Dose of DTaP Vaccination. British Journal of Medicine & Medical Research. 7(3): 169-179, 2015, Article no. *BJMMR*. 2015.321. ISSN: 2231-0614.
6. National, State, and Local Area Vaccination Coverage Among Children Aged 19-35 Months - United States, 2012. *MMWR*/September 13, 2013/Vol. 62 / No. 36. Reported by Black CL, Yankey D, Kolasa M.
7. Elam-Evans LD, Yankey D, Singleton JA, Kolasa M. National, State, and Selected Local Area Vaccination Coverage Among Children Aged 19–35 Months — United States, 2013. *MMWR*/August 29, 2014/ Vol. 63 / No. 34.
8. Hill HA, Elam-Evans LD, Yankey D, Singleton JA, Kolasa M. National, State, and Selected Local Area Vaccination Coverage Among Children Aged 19–35 Months — United States, 2014. *MMWR*/August 28, 2015// Vol. 64 / No. 33.
9. Hill HA, Elam-Evans LD, Yankey D, Singleton JA, Dietz V. Vaccination Coverage Among Children Aged 19–35 Months — United States, 2015. *MMWR*/October 7, 2016 / Vol. 65 / No. 39.
10. Hill HA, Elam-Evans LD, Yankey D, Singleton JA, Kang Y. Vaccination Coverage Among Children Aged 19–35 Months — United States, 2016. *MMWR*/November 3, 2017 / Vol. 66 / No. 43.
11. Hill HA, Elam-Evans LD, Yankey D, Singleton JA, Kang Y. Vaccination Coverage Among Children Aged 19–35 Months — United States, 2017. *MMWR*/ October 12, 2018 / Vol. 67 / No. 40.
12. US Department of Health and Human Services, Office of Disease Prevention and Health Promotion. Healthy people 2020. Washington, DC. https://www.cdc.gov/nchs/healthy_people/hp2020.htm

13. National Immunization Survey-Child, A User's Guide for the 2018 Public-Use Data File, Centers for Disease Control and Prevention, National Center for Immunization and Respiratory Diseases.https://www.cdc.gov/vaccines/imz-managers/nis/downloads/NIS-PUF18-DUG.pdf
14. Keppel KG, Pamuk E, Lynch J, *et al*. Methodological issues in measuring health disparities. *Vital and health statistics*. Series 2. No. 141. Washington, D.C.: Government Printing Office, 2005. (DHHS publication no. (PHS) 2005-1341).
15. Dietz VJ, Stevenson J, Zell ER, Cochi S, Hadler S, Eddins D. Potential impact on vaccination coverage levels by administering vaccines simultaneously and reducing dropout rates. *Arch PediatrAdolesc Med*. 1994;148:943–94.
16. Zhao Z. Power of tests for comparing trend curves with application to national immunization survey (NIS). *Statist. Med*. 2011; 30:531-540.
17. Barker LE, Chu SY, Li Q, Shaw KM, Santoli JM. Disparities between white and African-American children in immunization coverage. *J Natl Med Assoc.* 2006 Feb;98(2):130-5.
18. Szilagyi PG, Schaffer S, Shone L, Barth R, Humiston SG, Sandler M, and Rodewald LE. Reducing Geographic, Racial, and Ethnic Disparities in Childhood Immunization Rates by Using Reminder/Recall Interventions in Urban Primary Care Practices. *Pediatrics.* Vol, 110 No. 5 November 2002.
19. Centers for Diseases Control and Prevention. Vaccination Programs: Client Reminder and Recall Systems. https://www.thecommunityguide.org/findings/vaccination-programs-client-reminder-and-recall-systems.
20. Wolter KM, Pineau VJ, Skalland B, Zeng W, Singleton JA *et al.* Total Survey Error Assessment for Sociodemographic Subgroups in the 2012 U.S. National Immunization Survey. *Total Survey Error* in Practice. Wiley Online Library, 10 February 2017.