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Impact of the COVID-19 pandemic on pediatric and adolescent vaccinations and well child visits in the United States: A database analysis

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ABSTRACT

Background: The COVID-19 pandemic has disrupted healthcare, including immunization practice and well child visit attendance. Maintaining vaccination coverage is important to prevent disease outbreaks and morbidity. We assessed the impact of the COVID-19 pandemic on pediatric and adolescent vaccination administration and well child visit attendance in the United States.

Methods: This cross-sectional study used IBM MarketScan Commercial Database (IMC) with Early View (healthcare claims database) and TriNetX Dataworks Global Network (electronic medical records database) from January 2018–March 2021. Individuals $\leq$ 18 years of age who were enrolled during the analysis month of interest (IMC with Early View) or had $\geq$ 1 health encounter at a participating institution (TriNetX Dataworks) were included. We calculated the monthly percent difference between well child visit attendance and vaccine administration rates for 10 recommended pediatric/adolescent vaccines in 2020 and 2021 compared with 2018–2019. Data were stratified by the age groups 0–2 years, 4–6 years, and 9–16 years.

Results: In IMC with Early View, the average monthly enrollment for children 0–18 years of age was 5.2 million. In TriNetX Dataworks, 12.2 million eligible individuals were included. Well child visits and vaccinations reached the lowest point in April 2020 compared with 2018–2019. Well child visit attendance and vaccine administration rates were inversely related to age, with initial reductions highest for adolescents and lowest for ages 0–2 years. Rates rebounded in June and September 2020 and stabilized to pre-pandemic levels in Fall 2020. Rates dropped below baseline in early 2021 for groups 0–2 years and 4–6 years.

Conclusions: We found substantial disruptions in well child visit attendance and vaccination administration for children and adolescents during the COVID-19 pandemic in 2020 and early 2021. Continued efforts are needed to monitor recovery and catch up to avoid outbreaks and morbidity associated with vaccine-preventable diseases.

1. Introduction

The COVID-19 pandemic has disrupted healthcare, including immunization practice. Maintaining high vaccination coverage is crucial to prevent outbreaks and longer-term consequences of vaccine-preventable diseases. The United States (U.S.) Centers for Disease Control and Prevention (CDC) reported decreases in vaccination administration rates for children and adolescents during March–May 2020, corresponding with the beginning of the pandemic and stay-at-home orders [1–3]. Similar declines were described in reports from New York City, Ohio, Colorado, and California [4–7]. The American Academy of Pediatrics (AAP) and the U.S. Centers for Disease Control and Prevention (CDC) have urged routine visits and vaccinations to continue [8].

While recent reports have documented the decline in routine childhood and adolescent vaccinations and routine preventative care visits due to the COVID-19 pandemic in the U.S., the majority of these reports were from a single city or state or from the beginning of the pandemic [1,2,4–7]. More recent reports provide information for one health system only [7]. Furthermore, most U.S. studies assessed uptake of specific vaccines (e.g. measles) or total

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vaccine uptake instead of providing an assessment of all pediatric and adolescent vaccines individually [5,7,9]. Additionally, the impact of COVID-19 on compliance with the well child visit schedule, an important component of preventative care for a variety of health conditions, is not yet fully understood [10,11].

In this analysis, we assessed the impact of the COVID-19 pandemic on pediatric and adolescent vaccination rates and well child visits in the U.S. up to March 2021. Results can inform public health efforts to encourage timely vaccination and catch-up campaigns and highlight age groups and diseases most at risk.

2. Methods

We compared rates of well child visit attendance and vaccine administration from January 2020-March 2021 to rates during 2018–2019 to quantify the impact of COVID-19 on pediatric and adolescent preventative care services. We used two data sources: IBM MarketScan Commercial Database (IMC) with Early View and TriNetX Dataworks Global Network. The IMC database used in this analysis includes medical and pharmacy claims data covering 203 million individuals with commercial insurance coverage in the U.S. up to September 2020. The Early View data consist of a preview of adjudicated claims data from October 2020–March 2021 [12]. TriNetX Dataworks Global Network is a large, federated research network that includes electronic health record (EHR) data from 54 health care organizations and 75 million patients worldwide, with approximately 85% from the U.S. Data for this analysis were restricted to the U.S. and to individuals $\leq$ 18 years of age who were enrolled during the analysis month of interest (IMC with Early View) or had at least one health encounter at a participating institution (TriNetX Dataworks).

We calculated the percent difference between well child visit attendance or vaccination rates in 2020 or 2021 compared with 2018–2019 for children $\leq$ 18 years of age. In IMC with Early View, we estimated the monthly well child visit rate or vaccination rate by dividing the well child visit attendance or the number of vaccines administered by the number of individuals enrolled in that month. We then calculated a monthly ratio dividing the 2020 or 2021 rate by the average rate from 2018 to 2019. In TriNetX, the number of enrollees per month remains stable. Therefore, the ratio was calculated as the number of vaccines administered in 2020 or 2021 / the average number of vaccines in 2018–2019. To determine the percent difference in both datasets, we calculated (ratio $-$ 1) $\times$ 100%.

Well child visits were stratified by the following age groups: 0–2 years, 4–6 years, and 9–16 years. In line with the Advisory Committee on Immunization Practices (ACIP) immunization schedule recommendations, we analyzed the following vaccines separately by age group: 0–1 year: rotavirus; 0–2 years: hepatitis B, diphtheria, tetanus and acellular pertussis (DTaP) containing vaccines, *Haemophilus influenzae* type b (Hib), pneumococcal conjugate, measles-containing vaccines, hepatitis A; 4–6 years: DTaP-containing vaccines, measles-containing vaccines; 9–16 years: tetanus, diphtheria, and acellular pertussis (Tdap), human papilloma virus (HPV), meningococcal conjugate.[13] We used IMC with Early View for all vaccines and well child visits of interest. For TriNetX Dataworks, select vaccines were chosen for analysis (rotavirus, measles-containing vaccines, DTaP-containing vaccines, HPV, and meningococcal conjugate) and data were downloaded for analysis on 7/28/2021 and 8/12/2021. For both IMC and TriNetX Dataworks, vaccine administration and well child visits were determined using Current Procedural Terminology (CPT) codes and Healthcare Common Procedure Coding System (HCPCS) codes (Supplemental Table 1). For IMC, age at the time of vaccination or well child visit was determined by year of birth. For TriNetX Dataworks, age was calculated based on age at the time of vaccination. Data sources were analyzed separately using SAS Studio release 3.8 (Cary, NC, USA) and Microsoft Excel.

Both IMC and TriNetX Dataworks Global Network contain only de-identified data as per the de-identification standard defined in Section §164.514(a) of the HIPAA Privacy Rule. For both data sources, the process by which the data is de-identified is attested to through a formal determination by a qualified expert as defined in Section §164.514(b)(1) of the HIPAA Privacy Rule. Because this study used only de-identified patient records and did not involve the collection, use, or transmittal of individually identifiable data, this study was exempt from Institutional Review Board approval.

3. Results

In IMC with Early View, the average monthly enrollment for children 0–18 years of age was 5.4 million in 2018–2019 and 5.0 million in 2020. In TriNetX Dataworks, 12.2 million eligible individuals 0–18 years of age were included in this analysis.

3.1. Well child visits (IMC with Early View only)

Across all ages (0–18 years) and within each age group (0–2 years, 4–6 years, 9–16 years), the rate of well child visits in the pre-pandemic period (January–February 2020) was similar to the average rate from the same period in 2018–2019 (Table 1, Fig. 1). Well child visits started to decrease in March 2020 (-24.0% decrease), reaching the lowest point in the year in April 2020, reflecting a 47.3% decrease compared with 2018–2019. Visit rates rebounded to 2018–2019 levels in June 2020 (5.6% increase), reaching a peak in September 2020 (16.9% increase) and maintained near equal levels to 2018–2019 during October–December 2020. In January–March 2021, visits dipped below baseline with the largest decrease in January 2021 ($-$9.2%).

Well child visit attendance varied by age. In April 2020, well child visit rates decreased with increases in age, with children 9–16 years of age most affected (% difference: $-$71.3%), followed by 4–6 years (% difference: $-$66.2%), and 0–2 years (% difference: $-$20.8%). Overall, 0–2 year olds experienced the smallest reductions in well child visits. In this age group, the attendance rate increased to 2018–2019 levels in June (7.7% increase), and then remained slightly at or below the 2018–2019 level for the remainder of 2020. Rates decreased again in 2021, with a 14.2% decrease in March 2021. For 4–6 year olds and 9–16 year olds, well visits reached peak recovery in September, with 23.5% and 34.3% increases compared with 2018–2019, respectively. The attendance rate remained above 2018–2019 levels through the remainder of 2020 for 9–16 year olds and returned to 2018–2019 rates during January–March 2021.

4. Vaccine uptake

4.1. IMC with Early View

For all vaccines, regardless of age group, and across all vaccines, vaccine administration started to decrease in March 2020. When compared to 2018–19, the greatest reduction in vaccine administration occurred in April 2020 (Table 2, Fig. 2), except for rotavirus, which had the largest relative decrease in October 2020 (-6.0%). Similar to well child visits, vaccine administration varied by age. The reduction in April 2020 vaccine uptake rate was smallest among children 0–2 years of age (range: rotavirus: $-$4.6% to measles-containing vaccines: $-$28.7%), and largest for adolescents (9–16 years), with decreases upwards of 72%. Well child visit

Table 1
Comparison of well child visits by age, 2020 and 2021 vs. 2018–2019, IBM MarketScan Commercial Database with Early View.

	0–18 years		0–2 years		4–6 years		9–16 years	
	2020 or 2021 vs. 2018–2019		2020 or 2021 vs. 2018–2019		2020 or 2021 vs. 2018–2019		2020 or 2021 vs. 2018–2019	
	Ratio	% difference	Ratio	% difference	Ratio	% difference	Ratio	% difference
2020								
January	1.06	5.9	1.03	2.7	1.06	6.1	1.10	10.4
February	1.04	4.3	1.00	0.3	1.05	4.8	1.08	8.4
March	0.76	−24.0	0.86	−14.2	0.65	−34.8	0.67	−32.6
April	0.53	−47.3	0.79	−20.8	0.34	−66.2	0.29	−71.3
May	0.78	−22.5	0.94	−6.3	0.73	−27.1	0.60	−39.9
June	1.06	5.6	1.08	7.7	1.20	20.1	0.98	−2.2
July	0.99	−1.0	0.98	−1.7	1.07	7.4	0.95	−4.7
August	0.91	−9.2	0.94	−6.5	0.93	−6.7	0.88	−12.3
September	1.17	16.9	0.99	−1.2	1.24	23.5	1.34	34.3
October	1.06	5.5	0.94	−6.4	1.10	9.5	1.17	17.0
November	0.98	−1.6	0.94	−5.5	0.98	−2.5	1.04	3.9
December	1.04	3.8	1.03	3.4	1.00	−0.1	1.08	7.5
2021								
January	0.91	−9.2	0.88	−11.7	0.89	−11.4	0.96	−4.0
February	0.95	−4.6	0.91	−8.9	0.94	−5.6	1.02	2.3
March	0.93	−7.2	0.86	−14.2	0.90	−9.5	1.03	3.5

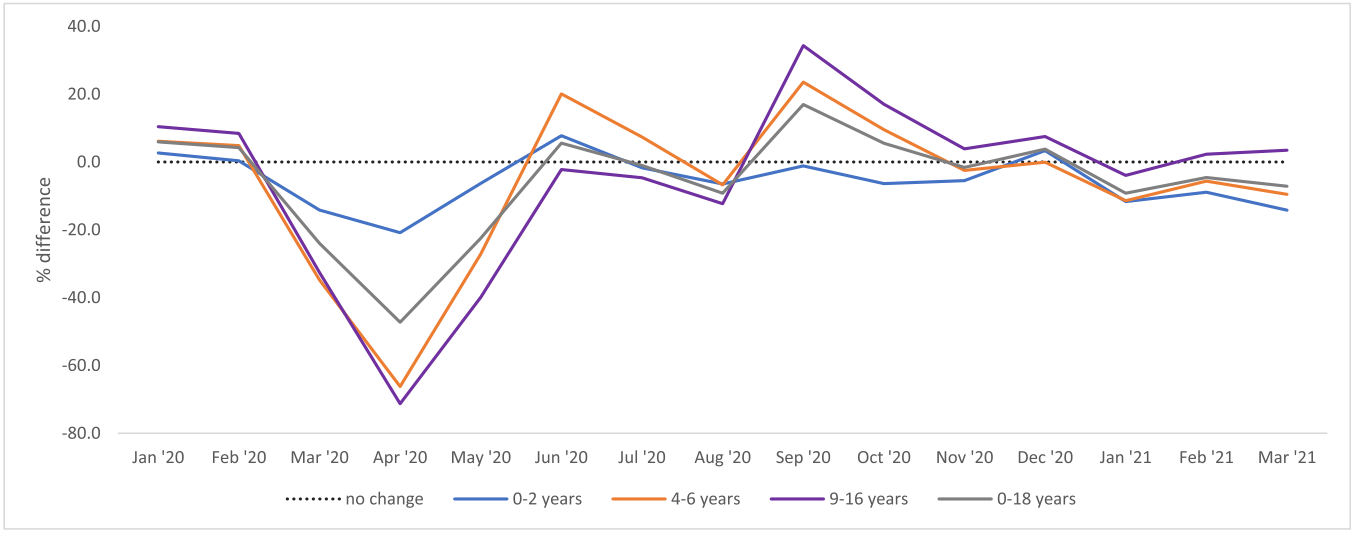


Fig. 1. Percent difference of well child visits, 2020 and 2021 vs. 2018–2019, IBM MarketScan Commercial Database with Early View.

attendance and vaccination administration per age group trended closely together (Fig. 2).

For the 0–2 age group, with the exception of measles-containing vaccines (-14.3%), vaccine uptake rebounded to near pre-pandemic levels in May 2020 (range: pneumococcal conjugate: −0.9% to hepatitis B: −4.3%). For 4–6 year olds, there was a substantial decrease in vaccination during March–May 2020, up to a 67% decline compared to pre-pandemic vaccination (Table 2, Fig. 2). For children 0–2 years of age, uptake peaked in June, September, and December 2020 and for children 4–6 years of age, uptake peaked in June and September 2020. In both age groups, vaccine administration remained below pre-pandemic levels from January–March 2021, with decreases in Hepatitis B, Hib, and pneumococcal vaccines near April 2020 levels, which was the lowest point during the pandemic.

Measles-containing vaccines for 0–2 years were more affected than Hepatitis A vaccine, which is recommended at the same time in this age group (12 months of age). While initial declines in April 2020 were the same (-28.7%), measles-containing vaccines had smaller gains from May 2020–March 2021, with increases lower than other vaccines.

Adolescent vaccine uptake remained below 2018–2019 levels from March–August 2020. In September 2020, adolescents had the highest vaccine administration percent increase in a single month, exceeding 2018–2019 levels by 28.5% (HPV), 37.4% (meningococcal), and 37.8% (Tdap). Tdap and meningococcal vaccine rates continued above pre-pandemic levels for October–December 2020 (>10% increase) and around baseline during January–March 2021, while HPV did not recover as strongly during this period (range: October 2020: +6.0% to January 2021: −10.9%).

4.2. TriNetX Dataworks

For select vaccines analyzed from TriNetX Dataworks (rotavirus, measles-containing vaccines, DTaP containing vaccines, HPV, meningococcal), the data illustrated similar trends as IMC with Early View (Table 2, Fig. 3). In TriNetX, during September–December 2020, vaccination uptake rates were at or above pre-pandemic

Table 2
Monthly percent differences by vaccine, IBM MarketScan Commercial Database (IMC) with Early View and TriNetX Dataworks, 2020 and 2021 vs. 2018–2019.

	0–1 years		0–2 years									4–6 years				9–16 years				
	Rotavirus		Hep B	Hib	DTaP		PCV	Measles		Hep A	DTaP		Measles		Tdap	Meningococcal		HPV	
	IMC	TriNetX	IMC	IMC	IMC	TriNetX	IMC	IMC	TriNetX	IMC	IMC	TriNetX	IMC	TriNetX	IMC	IMC	TriNetX	IMC	TriNetX
2020																			
Jan	3.1	4.6	1.6	2.3	3.1	9.0	3.2	6.0	12.3	9.5	5.6	14.8	4.2	13.7	4.7	8.0	17.7	7.3	15.8
Feb	2.6	6.1	−0.7	0.4	1.0	9.0	1.3	−3.3	3.3	2.9	−0.2	7.7	−3.6	5.9	2.2	4.6	10.0	3.9	8.2
Mar	−5.1	−2.1	−10.9	−11.5	−9.7	−7.5	−8.6	−16.9	−16.1	−18.8	−35.9	−34.7	−37.2	−34.6	−37.6	−34.6	−40.6	−33.6	−38.6
Apr	−4.6	−3.5	−12.9	−15.4	−12.8	−10.1	−11.1	−28.7	−27.6	−28.7	−65.0	−72.8	−66.7	−72.1	−72.8	−72.7	−84.3	−72.1	−83.6
May	−1.4	−2.4	−4.3	−2.7	−1.8	−3.7	−0.9	−14.3	−9.7	−1.2	−24.3	−27.6	−29.5	−28.7	−39.6	−38.8	−45.1	−37.3	−46.3
June	6.2	0.6	6.0	8.7	8.0	5.5	9.0	2.7	8.3	18.3	21.9	21.0	15.2	14.7	−5.3	−2.1	−8.7	−3.0	−6.3
July	1.4	−1.4	−3.3	−1.4	1.0	0.5	1.4	−5.8	−0.2	3.3	3.5	−1.2	−0.7	−4.7	−12.2	−7.7	−13.0	−8.0	−13.5
Aug	−4.6	−13.3	−8.0	−5.6	−4.6	−9.7	−4.0	−6.7	−10.1	−1.9	−10.1	−19.3	−13.8	−21.1	−15.5	−13.5	−19.5	−14.7	−17.7
Sept	4.5	−6.4	−0.7	3.9	5.4	−0.3	4.9	2.2	0.2	7.8	22.5	14.2	17.8	10.5	37.8	37.4	11.6	28.5	6.8
Oct	−6.0	−8.2	−6.9	−6.1	−5.2	−3.2	−5.2	−7.3	−3.9	−6.3	8.8	8.4	6.2	5.4	26.0	22.0	8.7	6.0	−1.5
Nov	−4.4	−3.8	−5.5	−6.2	−4.7	0.8	−4.5	−7.6	1.6	−4.7	0.7	11.3	−1.9	9.9	10.0	9.6	12.1	−3.4	2.3
Dec	4.8	4.6	3.4	4.8	5.9	6.7	5.4	0.7	10.5	8.4	3.4	7.3	0.9	4.8	12.7	13.6	9.8	0.9	0.2
2021																			
Jan	−8.9	−11.7	−11.4	−13.4	−9.8	−7.3	−9.4	−10.0	1.1	−6.2	−8.9	−3.6	−11.5	−5.6	−1.9	−2.1	1.1	−10.9	−9.5
Feb	−5.6	−9.3	−8.2	−10.0	−6.5	−5.3	−6.3	−9.6	−5.6	−3.9	−5.5	−3.8	−8.3	−7.2	3.4	3.9	−1.3	−7.4	−9.1
Mar	−9.6	0.1	−12.3	−13.8	−9.6	3.8	−9.8	−9.2	11.2	−3.4	−11.2	6.2	−13.6	1.8	1.3	4.0	15.7	−1.2	11.0

Abbreviations: IMC = IBM MarketScan Commercial Database with Early View, Hep B = Hepatitis B, DTaP = diphtheria, tetanus and acellular pertussis (DTaP) containing vaccines, Hib = *Haemophilus influenzae* type b, PCV = pneumococcal conjugate, Measles = measles-containing vaccines, Hep A = Hepatitis A, Tdap = tetanus, diphtheria, and acellular pertussis, HPV = human papilloma virus, Meningococcal = meningococcal conjugate.

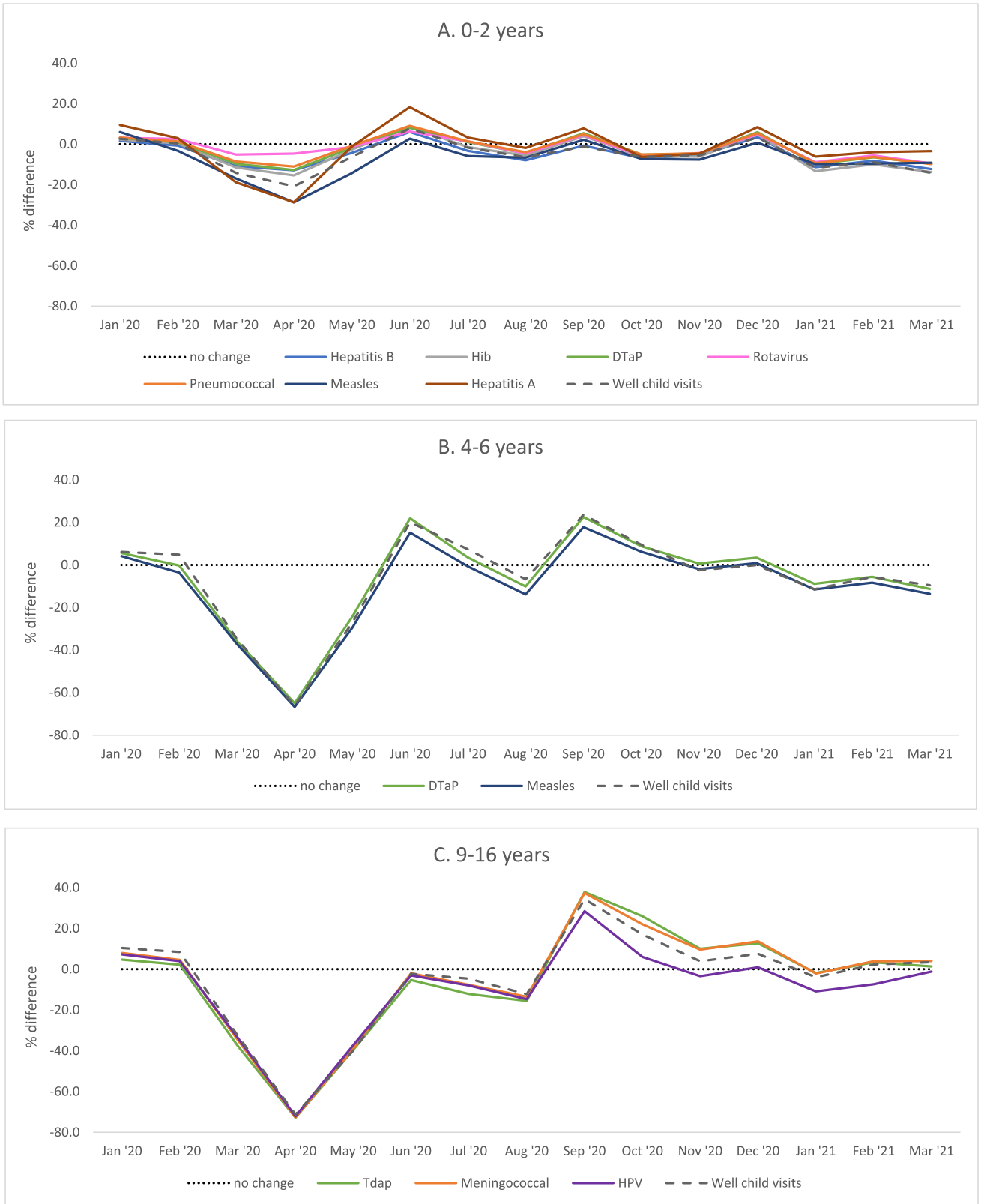
levels, with the exception of rotavirus vaccine. For 0–2 year olds (rotavirus, measles-containing vaccines, DTaP-containing vaccines) and 4–6 year olds (measles-containing vaccines, DTaP-containing vaccines), vaccination uptake rates dipped in January and February 2021 and began to stabilize in March 2021, with March rates at or above 2018–2019 levels (range: +0.1% to + 11.2%). For adolescent vaccines (HPV, meningococcal), rates, reached a peak in March 2021, with a 15.7% increase for meningococcal and 11.0% increase for HPV over 2018–2019 – the highest since the start of the COVID-19 pandemic.

5. Discussion

In this analysis of two healthcare databases, we illustrate substantial reductions in vaccine administration and well child visits during the COVID-19 pandemic in 2020 and 2021 compared with the same time period in 2018–2019, for all vaccines and age groups investigated. To our knowledge, this is the first study to assess the impact of the COVID-19 pandemic on vaccination and well child visit rates through the entirety of 2020 and beginning of 2021, and to assess the uptake of the majority of recommended vaccines individually. Trends in the two databases were similar. The initial drop in March–April 2020 in both well child visits and vaccinations coincided with the beginning of the pandemic, with rates rebounding in June and September, as states reopened, and children returned to school. Rates then stabilized to pre-pandemic levels in Fall 2020, with signs of catch up, particularly for adolescents. In early 2021, vaccination uptake dropped below baseline for the younger age groups (0–2 years and 4–6 years). During the analysis period, increases in vaccination and well child visits, however, were likely not enough to reach pre-pandemic levels, leaving many children and adolescents vulnerable to vaccine-preventable diseases.

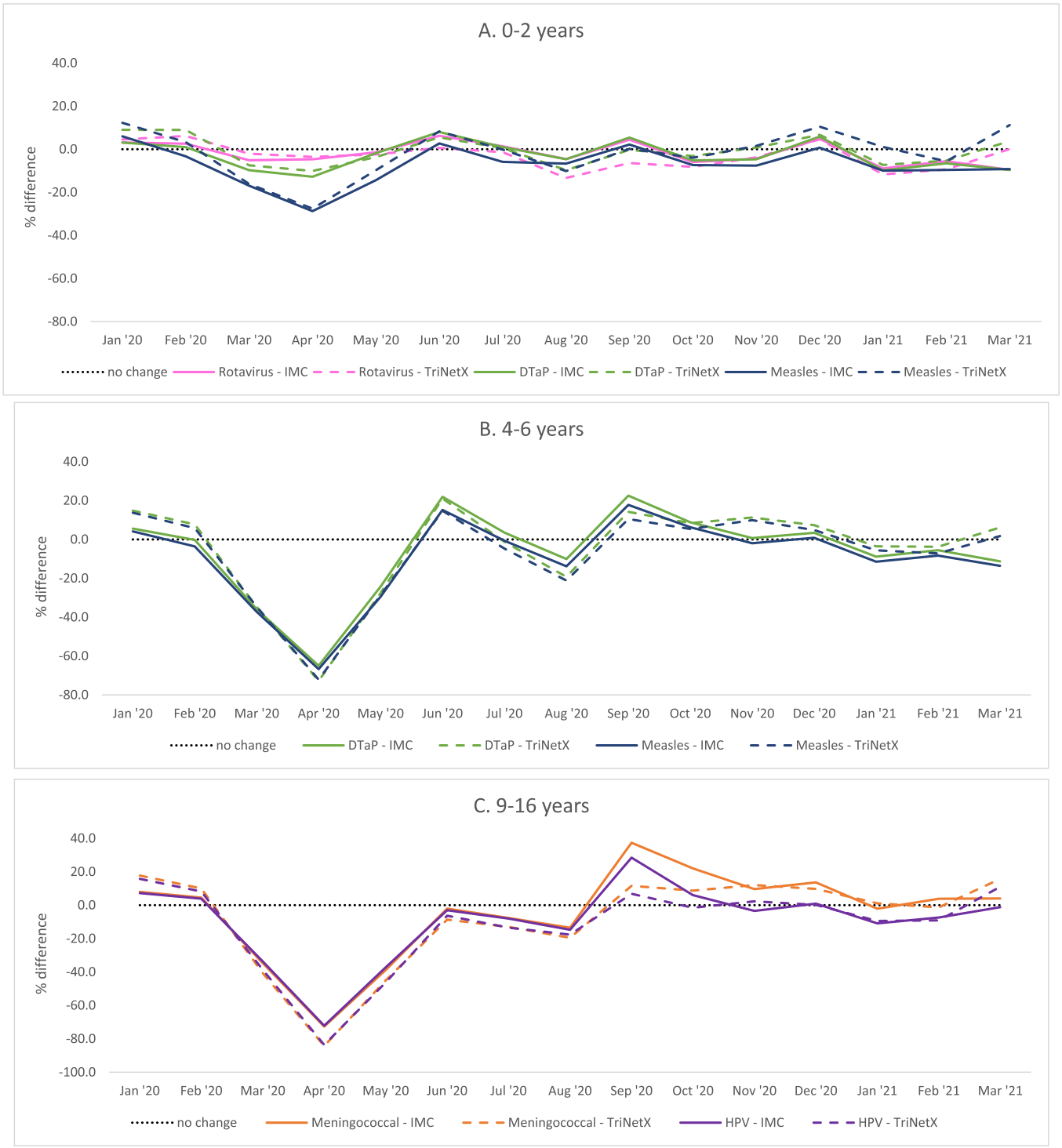
Well child visit attendance and vaccine administration rates were inversely related to age, with initial reductions highest for adolescents (9–16 years) and lowest for infants and toddlers (0–2 years). This is similar to other reports [4,7,9,14]. Among all vaccinations analyzed, rotavirus vaccine had the smallest decrease in vaccination administration at the beginning of the pandemic in April 2020. This may be because we assessed rotavirus vaccination among infants 0–1 years of age, while the other vaccinations assessed included a wider age range from 0 to 2 years. However, this is an encouraging finding as the maximum age for rotavirus vaccine is 32 weeks [15]. Trends in well child visits and vaccination administration by age group were similar, indicating that healthcare providers may have used well visits as opportunities to administer recommended vaccines. The decline in well visits is not only a missed opportunity for vaccination, but also for the diagnosis and management of other childhood conditions and illnesses. Well child visits are an important hallmark of preventative services and missed visits are associated with increases in health care resource utilization [11,16].

Measles-containing vaccines experienced reductions among both 0–2 year olds and 4–6 year olds. Reductions were more severe for children 4–6 years of age, potentially indicating a bigger gap in coverage for the second measles dose. Part of the difference in measles vaccinations in 2020 and 2021 compared with 2018–2019 may be explained by increased uptake in those years, which corresponded to the largest measles outbreak in the U.S. since elimination in 2000 (Supplemental Fig. 1) [17]. As social distancing continues to relax and travel resumes, lower levels of measles vaccination coverage without catch-up vaccinations may increase the risk of outbreaks [18]. In 2020, immunization services were disrupted in at least 68 countries, and the World Health Organization estimated that about 117 million children were at risk of missing



Abbreviations: Hep B = Hepatitis B, DTaP = diphtheria, tetanus and acellular pertussis (DTaP) containing vaccines, Hib = *Haemophilus influenzae* type b, PCV = pneumococcal conjugate, Measles = measles-containing vaccines, Hep A = Hepatitis A, Tdap = tetanus, diphtheria, and acellular pertussis, HPV = human papilloma virus, Meningococcal = meningococcal conjugate

Fig. 2. Percent difference of vaccination administration, 2020 and 2021 vs. 2018–2019, by age group, IBM MarketScan Commercial Database with Early View: (A) 0–2 years, (B) 4–6 years, (C) 9–16 years.



Abbreviations: IMC = IBM MarketScan Commercial Database with Early View, DTaP = diphtheria, tetanus and acellular pertussis (DTaP) containing vaccines, Measles = measles-containing vaccines, HPV = human papilloma virus, Meningococcal = meningococcal conjugate

Fig. 3. Percent difference of vaccination administration, 2020 and 2021 vs. 2018–2019 and 2021 vs. 2018–2019, for select vaccines, IBM MarketScan Commercial Database (IMC) with Early View and TriNetX Dataworks: (A) 0–2 years, (B) 4–6 years, (C) 9–16 years.

measles vaccines due to the COVID-19 pandemic [19]. These disruptions and missed vaccinations could potentially contribute to measles outbreaks in other countries, increasing the risk of imported cases to the U.S., leading to outbreaks in under-vaccinated U.S. communities.

In the adolescent age group, vaccination was significantly disrupted in 2020, with declines up to 84% compared to 2018–2019. In particular, HPV vaccine administration lagged meningococcal and Tdap vaccines in 2020 and 2021 vs. 2018–2019 in both databases. HPV vaccination coverage has improved over time, with CDC reporting that 72% of adolescents aged 13–17 received $\geq$ 1 dose in 2019, up from 68% in 2018 [20]. However, this progress may be threatened by the COVID-19 pandemic. Lower HPV vaccination coverage may have long term health implications. One

modeling study demonstrated that reductions in HPV vaccine coverage would result in excess cases of genital warts and cervical cancer [21].

Public health strategies are needed to ensure that vaccination rates do not fall farther behind. Outreach efforts, such as alerting parents to missed well child visits or vaccinations, and vaccination pods or mobile events may increase coverage rates [22]. For example, in New York City, the health department took active measures to improve uptake, such as sending health alerts to providers, encouraging the use of reminder and recall tools, and holding webinars for pediatric providers [4]. Strategies may need to be tailored to specific age groups. COVID-19 vaccines are available to adolescents 12 years of age and older as of May 2021 [23]. ACIP has recently recommended co-administration of COVID-19 vaccines with other vaccines for adults and adolescents [24]. This new guidance may provide an opportunity for adolescents to catch up any missed vaccines when COVID-19 vaccines are administered.

Our analysis is subject to a few limitations. IMC with Early View represents the commercially insured population in the U.S. Persons insured through public insurance and the individual marketplace are underrepresented. The results are therefore likely to underestimate the gaps in vaccination, as publicly insured or uninsured populations are more likely to have lower vaccination coverage levels [25]. Further, we calculated rates in IMC with Early View based on a moving denominator each month. In both databases, we were unable to determine vaccination coverage rates or total impact on vaccination uptake during the time period of interest, only rates of administration. Due to these limitations, the findings may not be generalizable to the U.S. population. Lastly, in IMC, age was calculated based on year of birth and was not a precise estimate of age at the time of well child visit or vaccine administration. Age could therefore be overestimated or underestimated depending on month of birth and month of the claim.

6. Conclusions

In an analysis of commercial claims data and EMR data, we found substantial disruptions in well child visits and vaccination administration for children and adolescents during the COVID-19 pandemic from April 2020 into early 2021. Continued efforts are needed to monitor and highlight the urgency of recovery and to catch up vaccinations to avoid outbreaks and morbidity associated with vaccine-preventable diseases.

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All authors attest they meet the ICMJE criteria for authorship.

Declaration of Competing Interest

All authors are employees of Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Kenilworth, NJ, USA and may own stock and/or hold stock options in the Company.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2021.12.064.

References

[1] Bramer CA, Kimmins LM, Swanson R, Kuo J, Vranesich P, Jacques-Carroll LA, et al. Decline in Child Vaccination Coverage During the COVID-19 Pandemic — Michigan Care Improvement Registry, May 2016–May 2020. MMWR Morb Mortal Wkly Rep 2020;69(20):630–1.

[2] Santoli JM, Lindley MC, DeSilva MB, Kharbanda EO, Daley MF, Galloway L, et al. Effects of the COVID-19 Pandemic on Routine Pediatric Vaccine Ordering and Administration — United States, 2020. MMWR Morb Mortal Wkly Rep 2020;69(19):591–3.

[3] Murthy BP, Zell E, Kirtland K, Jones-Jack N, Harris L, Sprague C, et al. Impact of the COVID-19 pandemic on adminsitration of selected routine childhood and adolescent vaccinations - 10 U.S. Jurisdictions, March-September 2020. MMWR Morb Mortal Wkly Rep. 2021;70(23).

[4] Langdon-Embry M, Papadouka V, Cheng I, Almashhadani M, Ternier A, Zucker JR. Notes from the Field: Rebound in Routine Childhood Vaccine Administration Following Decline During the COVID-19 Pandemic — New York City, March 1–June 27, 2020. MMWR Morb Mortal Wkly Rep 2020;69(30):999–1001.

[5] Bode SM, Gowda C, Mangini M, Kemper AR. COVID-19 and Primary Measles Vaccination Rates in a Large Primary Care Network. Pediatrics. 2021;147(1). Epub 2020/11/21. doi: 10.1542/peds.2020-035576. PubMed PMID: 33214332.

[6] O'Leary ST, Trefren L, Roth H, Moss A, Severson R, Kempe A. Number of Childhood and Adolescent Vaccinations Administered Before and After the COVID-19 Outbreak in Colorado. JAMA Pediatr 2021;175(3):305. https://doi.org/10.1001/jamapediatrics.2020.4733.

[7] Ackerson BK, Sy LS, Glenn S, Qian L, Park CH, Riewerts RJ, et al. Pediatric Vaccination During the COVID-19 Pandemic. Pediatrics. 2021. Epub 2021/04/17. doi: 10.1542/peds.2020-047092. PubMed PMID: 33858983.

[8] American Academy of Pediatrics. Guidance on providing pediatric well-care during COVID-19 2020 [cited 2021 March 15]. Available from: https://services.aap.org/en/pages/2019-novel-coronavirus-covid-19-infections/clinical-guidance/guidance-on-providing-pediatric-well-care-during-covid-19/.

[9] Schweiberger K, Patel SY, Mehrotra A, Ray KN. Trends in Pediatric Primary Care Visits during the COVID-19 Pandemic. Acad Pediatr. 2021. Epub 2021/05/14. doi: 10.1016/j.acap.2021.04.031. PubMed PMID: 33984496.

[10] Daniels AM, Mandell DS. Children's Compliance with American Academy of Pediatrics' Well-Child Care Visit Guidelines and the Early Detection of Autism. J Autism Dev Disord 2013;43(12):2844–54.

[11] Hakim RB, Bye BV. Effectiveness of compliance with pediatric preventive care guidelines among Medicaid beneficiaries. Pediatrics. 2001;108(1):90-7. Epub 2001/07/04. doi: 10.1542/peds.108.1.90. PubMed PMID: 11433059

[12] IBM Watson Health. IBM MarketScan Research Databases for Health Services Researchers. 2019.

[13] Centers for Disease Control and Prevention (CDC). Recommended Child and Adolescent Immunization Schedule for Ages 18 Years or Younger, United States, 2021 2021 [cited 2021 May 15]. Available from: https://www.cdc.gov/vaccines/schedules/hcp/imz/child-adolescent.html.

[14] DeSilva MB, Haapala J, Vazquez-Benitez G, Daley MF, Nordin JD, Klein NP, et al. Association of the COVID-19 Pandemic With Routine Childhood Vaccination Rates and Proportion Up to Date With Vaccinations Across 8 US Health Systems in the Vaccine Safety Datalink. JAMA Pediatr. 2021. Epub 2021/10/08. doi: 10.1001/jamapediatrics.2021.4251. PubMed PMID: 34617975; PubMed Central PMCID: PMCPMC8498937

[15] Centers for Disease Control and Prevention (CDC). Vaccine Information Statement: Rotavirus Vaccine. 2019

[16] Tom JO, Tseng C-W, Davis J, Solomon C, Zhou C, Mangione-Smith R. Missed Well-Child Care Visits, Low Continuity of Care, and Risk of Ambulatory Care–Sensitive Hospitalizations in Young Children. Arch Pediatr Adolesc Med 2010;164(11). https://doi.org/10.1001/archpediatrics.2010.201.

[17] Centers for Disease Control and Prevention (CDC). Measles Cases and Outbreaks. 2021

[18] Carias C, Pawaskar M, Nyaku M, Conway JH, Roberts CS, Finelli L, et al. Potential impact of COVID-19 pandemic on vaccination coverage in children: A case study of measles-containing vaccine administration in the United States (US). Vaccine 2021;39(8):1201–4.

[19] Measles and Rubella Initiative. More than 117 million children at risk of missing out on measles vaccines, as COVID-19 surges 2020 [cited 2021 March 15]. Available from: https://measlesrubellainitiative.org/measles-news/more-than-117-million-children-at-risk-of-missing-out-on-measles-vaccines-as-covid-19-surges/.

[20] Elam-Evans LD, Yankey D, Singleton JA, Sterrett N, Markowitz LE, Williams CL, et al. National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years — United States, 2019. MMWR Morb Mortal Wkly Rep 2020;69(33):1109–16.

[21] Daniels V, Saxena K, Roberts C, Kothari S, Corman S, Yao L, et al. Impact of reduced human papillomavirus vaccination coverage rates due to COVID-19 in the United States: A model based analysis. Vaccine 2021;39(20):2731–5.

[22] American Academy of Pediatrics. Immunizations: Reminder & Recall Systems 2021 [cited 2021 June 2]. Available from: https://www.aap.org/en-us/advocacy-and-policy/aap-health-initiatives/immunizations/Practice-Management/Pages/reminder-recall-systems.aspx.

[23] Wallace M, Woodworth KR, Gargano JW, Scobie HM, Blain AE, Moulia D, et al. The Advisory Committee on Immunization Practices' Interim Recommendation for Use of Pfizer-BioNTech COVID-19 Vaccine in

Adolescents Aged 12–15 Years — United States, May 2021. MMWR Morb Mortal Wkly Rep 2021;70(20):749–52.
[24] Centers for Disease Control and Prevention (CDC). Interim Clinical Considerations for the Use of COVID-19 Vaccines Currently Authorized in the United States 2021 [cited 2021 June 2]. Available from: https://www.cdc.gov/vaccines/covid-19/clinical-considerations/covid-19-vaccines-us.html.
[25] Hill HA, Yankey D, Elam-Evans LD, Singleton JA, Pingali SC, Santibanez TA. Vaccination Coverage by Age 24 Months Among Children Born in 2016 and 2017 — National Immunization Survey-Child, United States, 2017–2019. MMWR Morb Mortal Wkly Rep 2020;69(42):1505–11.