



# Tri-State Evaluation of the Effects of the COVID-19 Pandemic on Routine Vaccine Uptake in Iowa, Minnesota, and North Dakota, 2017–2021

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## Abstract

The objective of this analysis was to evaluate and compare the effects of the COVID-19 pandemic on routine and annual influenza vaccination in Iowa, Minnesota, and North Dakota. Routine and annual influenza vaccination uptake and coverage between 2017 and 2021 was collected from each state's immunization information system (IIS) by age group and stratified by provider and vaccine type. Data from 2017 to 2019 were averaged to obtain a pre-pandemic baseline and compared to 2020 and 2021 data. Percent changes were calculated to evaluate differences in uptake and coverage. Changes in coverage and administration varied by state, but each state had some level of decreased administration across the different age groups and vaccine types. The most consistent decreases in vaccine administration occurred in the 15-year-old cohort with each state finding decreased administrations in 2020 and 2021. The 12-year-old age group had decreased administration of hepatitis B, measles, mumps, and rubella, and varicella vaccine while the 2-year-old age group had the most consistent decrease in coverage across all vaccines analyzed. Trends by provider type were also noted in all three states, with local public health (LPH) experiencing the largest and most consistent declines in vaccine administrations by age group. Adult influenza coverage improved to varying degrees in 2020 (+14.1% IA, +2.1% MN, +1.5% ND), but either decreased or approached the 2017–19 average in 2021. All three states saw some level of decreased vaccine administration across the age groups, vaccines, and provider types assessed. The COVID-19 pandemic affected how many children and adults received recommended immunizations, leaving communities vulnerable to vaccine-preventable diseases.

**Keywords** Demographic factors · Immunization registries · Preventive medicine · Immunizations · COVID-19 · Immunization information system

## Introduction

On March 11, 2020, the World Health Organization (WHO) declared the novel coronavirus (COVID-19) outbreak a global pandemic. The COVID-19 pandemic presented an

unprecedented challenge to public health. During the pandemic, a variety of public health strategies were implemented to reduce the spread of the virus, including masking and social distancing measures such as closing schools and certain businesses, limiting social gatherings, and recommending residents stay home as much as possible. Partially due to these prevention measures, there was a notable decrease in health care visits for non-COVID-19 related conditions like well-child appointments during the peak of the pandemic [1, 2].

With the COVID-19 emergency response phase ending in May 2023, it is important to continue to identify and evaluate the impacts of the COVID-19 pandemic on preventative care services like routine immunizations. Current data indicates routine immunizations were affected both nationwide and globally, with substantial declines in

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uptake following implementation of social distancing recommendations [3–5]. A notable decrease in pediatric vaccine ordering and administrations by Vaccines for Children (VFC) providers following the COVID-19 emergency declaration has also been reported [6]. Missed routine vaccinations leave children, adolescents, and adults susceptible to vaccine-preventable diseases (VPDs).

Receiving on-time vaccinations provides immunity to children before they are exposed to the disease. A recent study modeling the impact of vaccination for the Immunization Agenda 2030 [7] estimated that 51 million deaths could be averted due to vaccinations administered between 2021 and 2030 worldwide, if the immunization targets are met. Pertussis and measles are two examples of VPDs that continue to pose a risk to children in the U.S. Un- and under-vaccinated individuals are at greater risk for not only contracting but also spreading the disease to others [8]. Maintaining high vaccination rates through timely vaccinations not only protects children at the individual-level but also helps to ensure there is not a resurgence in incidence of VPDs by providing community-level protection. Following the Advisory Committee on Immunization Practices (ACIP) recommended schedule [9] provides early, long-term, and the best protection against VPDs and prevents severe complications.

The objective of this analysis is to evaluate and compare the impact of the COVID-19 pandemic on routine and annual influenza vaccination by age group, vaccine type, and provider type in three states: Iowa, Minnesota, and North Dakota. While several states have used immunization information system (IIS) data to examine the effects on routine immunizations during the pandemic, few have analyzed the impact and changes to provider types administering immunizations compared to previous years. This analysis seeks to add information to the growing literature on the impacts of the COVID-19 pandemic on vaccine administration from three states with robust IIS data and high participation among immunizing providers. This information will be useful for understanding the impact to vaccinators and guide strategies to improve vaccine uptake.

## Methods

### Data Sources

Iowa's Immunization Registry Information System (IRIS), the Minnesota Immunization Information Connection (MIIC), and the North Dakota Immunization Information System (NDIIS) are three statewide IIS that consolidate immunization records across their residents' lifespan. Records are submitted by thousands of participating

organizations as well as electronic birth records. More than 90% of immunization data is submitted within 1 day of administration for all three states. Mandatory reporting does differ across the three states: VFC providers and pharmacy use (IRIS), pharmacy data (MIIC), immunizations administered to children (NDIIS).

### Population and Vaccines

Data for this analysis was extracted from the NDIIS, MIIC, and IRIS. Five different age groups were included in this analysis over the 5-year study period (2017–2021). Immunization data for children and adolescents that turned 2, 6, 12, and 15 years of age during each analysis year were collected (Supplemental Table 1). Adults aged 18 years or older as of the first day of the flu season, beginning August 1 and ending on May 31 of the following year, were included in the adult influenza analysis. Only clients who had addresses listed in the state of interest were included. Deceased clients were excluded within the coverage analysis if their death date was prior to the year of analysis.

The inclusion criteria differed for the doses administered and coverage rate assessments. The dose administered analysis only included doses administered between January 1, 2017 through December 31, 2021 that were non-historical, valid, and administered by providers considered for our analysis (Supplemental Table 2). Non-historical doses are doses that were entered as administered doses by the administering provider and validity is primarily based on the standard vaccine schedule. The up-to-date (UTD) coverage rate analysis included all valid doses administered to individuals in the age groups of interest prior to or during the year of analysis. Despite the similarity between annual influenza uptake and coverage, coverage rates were calculated to account for historical doses and multiple administrations within the same season.

The following vaccine types included in the analysis were chosen based on ACIP recommendations [9] for childhood and adolescent vaccines: diphtheria, tetanus, and acellular pertussis (DTaP); poliovirus (polio); measles, mumps, rubella (MMR); *Haemophilus influenzae* type B (Hib); hepatitis B (HepB); varicella; pneumococcal conjugate (PCV); meningococcal (MenACWY); tetanus, diphtheria, and acellular pertussis (Tdap), and human papillomavirus (HPV). Influenza was not assessed for children. For consistency, uniform vaccine types were determined using a CVX (vaccine administered) code set and provider types were defined a priori.

## Procedure

Each state analyzed their data separately and only rates and counts were compared. Each state used uniform processes to ensure comparability. The number of doses administered was tabulated for each year and age group by vaccine type and provider type. The 2017–2019 average was then calculated as a baseline to compare using percent change to 2020 and 2021. For combination vaccines, each vaccine component was counted in every component's category. The UTD coverage rate for each vaccine and cohort was calculated and the percent change was determined by comparing the 2017–19 average coverage rate to the 2020 and 2021 coverage rate.

## Results

### Iowa

During 2020, there were 117,013 routine immunizations administered to the defined childhood and adolescent cohorts in Iowa and 123,674 immunizations in 2021. This was a 16.1% and 11.3% decrease in immunization administrations compared with the 2017–19 average of 139,434 immunization administrations, respectively. Immunization uptake decreased for all age groups in 2020 and 2021, however, 2020 saw a larger decline in uptake than 2021 (Table 1).

The 2-year-old and 15-year-old age groups saw a decrease in vaccine uptake across all vaccine types in 2020 and 2021 (Table 2). For 2-year-olds, polio vaccine had the largest percent decrease in uptake in both 2020 and 2021 (-39.3%, -19.9%) followed by HepB (-35.5%, -18.8%) and MMR (-20.7%, -18.1%). For the 6-year-old age group, HepB had the largest decrease in uptake in 2020 (-29.2%) followed by MMR (-26.1%), while PCV had the largest decrease in 2021 (-30.4%). Only Hib vaccine saw an increase in uptake in 2020 (+8.6%), however, uptake decreased 22.4% in 2021. Adolescent vaccine uptake had large decreases both years for MMR, varicella, and HepB ranging from 46.0 to 60.8% in 2020 and 8.1–50.4% in 2021. The 15-year-old age group also had a large decrease in MenACWY (-73.6%, -83.8%) uptake both years. Although HPV vaccine uptake slightly increased (+0.2% ,+0.03%) both years in the 12-year-old age group, the 15-year-old age group saw a large decrease both years (-36.2%, -35.3%, ).

Larger percent decreases in UTD coverage were greater in 2021 than 2020 for the 2-, 6-, and 12-year-old age groups, while the 15-year-olds saw percent increases in almost all vaccine types and series completion both years (Table 3). In the 2-year-old age group, only PCV coverage rates increased both years (+1.8%, +0.5%) while the 7-vaccine series completion rate increased 0.8% in 2020 but decreased 1.5% in 2021. A similar pattern was seen in the 6-year-old age group, with PCV and the 7-vaccine series completion coverage rate improving the greatest both years. For adolescent coverage rates, the 12-year-old age group had the largest percent decrease in HPV vaccine series completion

**Table 1** Number of routine and influenza immunizations administered by age and year, 2017–2021

	2017-19 Avg	2020	% Change <sup>a</sup>	2021	% Change <sup>a</sup>
<b>Iowa</b>					
2-year-old	52,084.0	42,703	-18.0%	44,656	-14.3%
6-year-old	17,188.7	13,109	-23.7%	15,772	-8.2%
12-year-old	59,935.7	55,685	-7.1%	56,882	-5.1%
15-year-old	10,226.3	5,516	-46.1%	6,364	-37.8%
Influenza 18+ <sup>b</sup>	871,626	990,400	13.6%	943,353	8.2%
<b>Minnesota</b>					
2-year-old	80,885.3	66,079	-18.3%	72,795	-10.0%
6-year-old	20,507.3	14,317	-30.2%	19,547	-4.7%
12-year-old	97,085.0	80,102	-17.5%	92,636	-4.6%
15-year-old	15,866.3	9,837	-38.0%	12,550	-20.9%
Influenza 18+ <sup>b</sup>	1,332,486.3	1,505,590	13.0%	1,686,227	26.5%
<b>North Dakota</b>					
2-year-old	8,722.7	8,760	0.4%	8,231	-5.6%
6-year-old	3,269.3	3,063	-6.3%	2,825	-13.6%
12-year-old	12,275	12,537	2.1%	12,042	-1.9%
15-year-old	1,288.7	1,086	-15.7%	1,254	-2.7%
Influenza 18+ <sup>b</sup>	169,715.3	186,740	10.0%	188,674	11.2%

<sup>a</sup> Percent (%) change was calculated for both years using the 2017–19 average (avg) as the comparison value

<sup>b</sup> Influenza season includes vaccine doses administered between August 1st of that year and ending on May 31st of the following year (i.e., 2020 = 8/1/2020–5/31/2021)

**Table 2** Number of routine immunizations administered by age, year, and vaccine type, among children and adolescents, 2017–2021

<b>Iowa</b>					
	<i>2017-19 Avg</i>	<i>2020</i>	<i>% Change<sup>a</sup></i>	<i>2021</i>	<i>% Change<sup>a</sup></i>
2-year-old					
DTaP	15,967	13,848	-13.3%	14,232	-10.9%
HepB	1,719	1,108	-35.5%	1,395	-18.8%
Hib	10,593.7	8,880	-16.2%	9,225	-12.9%
MMR	6,573.7	5,211	-20.7%	5,383	-18.1%
PCV	8,282.7	6,585	-20.5%	6,792	-18.0%
Polio	1,727.7	1,049	-39.3%	1,383	-19.9%
Varicella	7,219.7	6,022	-16.6%	6,246	-13.5%
6-year-old					
DTaP	4,074.7	3,225	-20.9%	3,822	-6.2%
HepB	571.7	405	-29.2%	420	-26.5%
Hib	19.3	21	8.6%	15	-22.4%
MMR	4,195.3	3,101	-26.1%	3,771	-10.1%
PCV	18.7	17	-8.9%	13	-30.4%
Polio	3,989.7	3,108	-22.1%	3,774	-5.4%
Varicella	4,319.3	3,232	-25.2%	3,957	-8.4%
12-year-old					
HPV	20,582	20,632	0.2%	20,589	0.03%
HepB	419.7	213	-49.2%	208	-50.4%
MMR	379	158	-58.3%	276	-27.2%
MenACWY	19,328.3	17,486	-9.5%	17,963	-7.1%
Tdap	18,723.3	16,944	-9.5%	17,507	-6.5%
Varicella	503.3	252	-49.9%	339	-32.6%
15-year-old					
HPV	6,809.3	4,346	-36.2%	4,404	-35.3%
HepB	374.3	202	-46.0%	279	-25.5%
MMR	357	145	-59.4%	328	-8.1%
MenACWY	1,441.3	233	-83.8%	381	-73.6%
Tdap	731.3	389	-46.8%	547	-25.2%
Varicella	513	201	-60.8%	425	-17.2%
<b>Minnesota</b>					
	<i>2017-19 Avg</i>	<i>2020</i>	<i>% Change<sup>a</sup></i>	<i>2021</i>	<i>% Change<sup>a</sup></i>
2-year-old					
DTaP	26,367	22,624	-14.2%	24,419	-7.4%
HepB	3,129.7	2,383	-23.9%	2,963	-5.3%
Hib	20,997.7	19,288	-8.1%	2,1307	1.5%
MMR	13,491	6,895	-48.9%	7,879	-41.6%
PCV	16,129	14,735	-8.6%	16,510	2.4%
Polio	8,278.7	7,172	-13.4%	8,724	5.4%
Varicella	9,394	7,432	-20.9%	8,713	-7.2%
6-year-old					
DTaP	8,448	6,355	-24.8%	8,634	2.2%
HepB	1,165	597	-48.8%	873	-25.1%
Hib	44	36	-18.2%	49	11.4%
MMR	7,593.3	5,224	-31.2%	7,048	-7.2%
PCV	72	49	-31.9%	65	-9.7%
Polio	8,288.7	6,311	-23.9%	8,577	3.5%
Varicella	7,965	5,952	-25.3%	8,253	3.6%
12-year-old					
HPV	34,447.7	32,604	-5.4%	35,287	2.4%
HepB	885	472	-46.7%	460	-48.0%
MMR	627	313	-50.1%	369	-41.1%
MenACWY	31,052.7	23,808	-23.3%	28,691	-7.6%
Tdap	29,515.3	22,609	-23.4%	27,492	-6.9%
Varicella	845.3	445	-47.4%	537	-36.5%
15-year-old					

**Table 2** (continued)

HPV	11,877	7,598	-36.0%	9,014	-24.1%
HepB	717	346	-51.7%	483	-32.6%
MMR	463	216	-53.3%	316	-31.7%
MenACWY	1,135.3	572	-49.6%	1,006	-11.4%
Tdap	1,118	856	-23.4%	1,342	20.0%
Varicella	618.7	284	-54.1%	439	-29.0%
<b>North Dakota</b>					
2-year-old	<i>2017-19 Avg</i>	<i>2020</i>	<i>% Change<sup>a</sup></i>	<i>2021</i>	<i>% Change<sup>a</sup></i>
DTaP	3,692	4,424	19.8%	3,941	6.7%
HepB	416.7	1,349	223.8%	548	31.5%
Hib	3,097.3	3,206	3.5%	2,979	-3.8%
MMR	1,226.3	926	-24.5%	1,061	-13.5%
PCV	1,580.3	1,243	-21.3%	1,314	-16.9%
Polio	2,075	3,011	45.1%	2,318	11.7%
Varicella	1,225.7	991	-19.1%	1,131	-7.7%
6-year-old					
DTaP	1,452	1,664	14.6%	1,349	-7.1%
HepB	146.7	119	-18.9%	115	-21.6%
Hib	2.7	3	12.5%	3	12.5%
MMR	1,458.3	1,131	-22.4%	1,285	-11.9%
PCV	4.7	10	114.3%	4	-14.3%
Polio	1,413.3	1,639	16.0%	1,307	-7.5%
Varicella	1,491.3	1,148	-23.0%	1,295	-13.2%
12-year-old					
HPV	5,367.7	5,503	2.5%	5,398	0.6%
HepB	76.3	51	-33.2%	43	-43.7%
MMR	59.3	52	-12.4%	31	-47.8%
MenACWY	3,539.7	3,530	-0.3%	3,381	-4.5%
Tdap	3,453.7	3,520	1.9%	3,394	-1.7%
Varicella	75	59	-21.3%	41	-45.3%
15-year-old					
HPV	985.7	773	-21.6%	812	-17.6%
HepB	48	35	-27.1%	42	-12.5%
MMR	37	18	-51.4%	21	-43.2%
MenACWY	117.3	117	-0.3%	126	7.4%
Tdap	123.7	166	34.2%	253	104.6%
Varicella	52.7	28	-46.8%	28	-46.8%

<sup>a</sup> Percent (%) change was calculated for both years using the 2017-19 average (avg) as the comparison value

(-14.1%, -32.2%) and the adolescent series containing HPV (-14.0%, -32.1%) in 2020 and 2021. The 15-year-old age group had a 3.4% increase in HPV series completion in 2020 but had a slight decrease of 0.1% in 2021.

The majority of provider types saw percent decreases in vaccine administrations both years, however, percent changes fluctuated between age groups both in 2020 and 2021 (Table 4). Local public health (LPH) was the only provider type that consistently had large decreases ranging from 23.5 to 56.8% across all age groups and years. There was also a large decrease in hospital vaccine administrations for the 2-, 6-, and 15-year-old age groups in 2020, however, uptake improved in 2021 with large increases for the 2- and 6-year-olds. School-based health clinics (SBHC) increased in 2020 for childhood immunization administrations but

decreased for adolescent immunizations with the 12-year-old age group, seeing an 81.4% decrease in 2020 and 45.0% decrease in 2021.

Influenza immunization uptake in adults 18 years and older increased 13.6% during the 2020-21 flu season and 8.2% during the 2021-22 season in Iowa, compared to the 2017-19 average (Table 1). A similar trend was seen in influenza coverage rates with a 14.1% increase in coverage during the 2020-21 season and a 5.6% increase during the 2021-22 season (Table 5). Pharmacies and private practices continue to administer the largest number of influenza vaccines each flu season, followed by LPH and hospitals. Pharmacy, home health, college/university, nursing home/long term care (LTC), SBHC, veterans health administration (VHA), correctional facility, and other provider type all had

**Table 3** Up-to-date routine immunization coverage by age, year, and vaccine type, among children and adolescent, 2017–2021

<b>Iowa</b>					
	<i>2017-19 Avg</i>	<i>2020</i>	<i>% Change<sup>a</sup></i>	<i>2021</i>	<i>% Change<sup>a</sup></i>
2-year-old					
4 DTaP	89.0%	85.9%	-3.5%	83.4%	-6.2%
3 Polio	91.8%	90.0%	-1.9%	88.9%	-3.1%
1 MMR	93.0%	90.1%	-3.1%	87.9%	-5.5%
Hib Complete <sup>b</sup>	87.7%	87.3%	-0.4%	86.3%	-1.6%
3 HepB	91.8%	90.1%	-1.9%	89.4%	-2.7%
1 Varicella	92.6%	89.6%	-3.2%	87.6%	-5.4%
4 PCV	78.8%	80.2%	1.8%	79.1%	0.5%
4-3-1-3-3-1-4 Series <sup>c</sup>	77.1%	77.7%	0.8%	75.9%	-1.5%
6-year-old					
5 DTaP	76.0%	76.9%	1.2%	77.2%	1.5%
4 Polio	80.1%	80.4%	0.4%	80.1%	0.0%
2 MMR	83.2%	83.1%	-0.1%	82.6%	-0.7%
Hib Complete <sup>a</sup>	85.2%	86.5%	1.5%	87.2%	2.3%
3 HepB	90.1%	91.1%	1.2%	91.7%	1.8%
2 Varicella	82.8%	82.7%	-0.1%	82.2%	-0.7%
4 PCV	74.0%	76.4%	3.2%	77.8%	5.2%
4-3-1-3-3-1-4 Series <sup>b</sup>	72.4%	74.8%	3.2%	76.3%	5.3%
12-year-old					
3 HepB	89.3%	89.7%	0.5%	89.1%	-0.2%
1 MenACWY	81.1%	78.6%	-3.0%	76.5%	-5.7%
2 Varicella	83.0%	83.3%	0.3%	82.4%	-0.7%
1 Tdap	81.3%	79.7%	-2.1%	77.5%	-4.7%
2 MMR	84.7%	84.5%	-0.2%	83.6%	-1.3%
HPV (≥ 1 dose)	65.9%	62.5%	-5.1%	57.9%	-12.1%
HPV Complete <sup>d</sup>	56.7%	48.7%	-14.1%	38.4%	-32.2%
3-1-2-1-2 Series <sup>e</sup>	73.4%	72.0%	-1.8%	69.9%	-4.7%
MenACWY, Tdap, HPV Series <sup>f</sup>	56.3%	48.4%	-14.0%	38.2%	-32.1%
15-year-old					
3 HepB	84.5%	89.1%	5.4%	89.4%	5.7%
1 MenACWY	78.0%	82.3%	5.5%	81.3%	4.1%
2 Varicella	75.7%	82.9%	9.5%	83.2%	10.0%
1 Tdap	78.1%	81.6%	4.5%	81.7%	4.5%
2 MMR	80.4%	84.9%	5.6%	84.7%	5.4%
HPV (≥ 1 dose)	63.7%	66.7%	4.7%	66.4%	4.3%
HPV Complete <sup>d</sup>	57.2%	59.2%	3.4%	57.2%	-0.1%
3-1-2-1-2 Series <sup>e</sup>	67.2%	73.6%	9.5%	73.7%	9.6%
MenACWY, Tdap, HPV Series <sup>f</sup>	56.2%	58.7%	4.5%	56.9%	1.2%
<b>Minnesota</b>					
2-year-old	<i>2017-19 Avg</i>	<i>2020</i>	<i>% Change<sup>a</sup></i>	<i>2021</i>	<i>% Change<sup>a</sup></i>
4 DTaP	77.9%	76.4%	-1.5%	75.0%	-2.9%
3 Polio	85.6%	85.4%	-0.2%	84.7%	-0.9%
1 MMR	84.7%	82.3%	-2.5%	81.2%	-3.5%
Hib Complete <sup>b</sup>	83.0%	81.3%	-1.7%	81.5%	-1.5%
3 HepB	85.3%	85.5%	0.2%	85.2%	-0.1%
1 Varicella	84.0%	83.0%	-0.9%	82.3%	-1.7%
4 PCV	74.2%	74.5%	0.3%	72.7%	-1.5%
4-3-1-3-3-1-4 Series <sup>c</sup>	68.5%	68.3%	-0.2%	66.0%	-2.5%
6-year-old					
5 DTaP	72.9%	73.3%	0.4%	72.6%	-0.4%
4 Polio	76.4%	76.3%	0.0%	75.0%	-1.4%
2 MMR	79.3%	79.2%	-0.1%	79.5%	0.2%
Hib Complete <sup>a</sup>	84.8%	85.9%	1.1%	86.8%	2.0%
3 HepB	85.5%	86.5%	1.1%	87.2%	1.7%
2 Varicella	78.3%	78.0%	-0.2%	78.2%	-0.1%

**Table 3** (continued)

4 PCV	72.0%	73.6%	1.6%	74.5%	2.5%
4-3-1-3-3-1-4 Series <sup>b</sup>	60.5%	62.2%	1.6%	62.9%	2.4%
12-year-old					
3 HepB	81.4%	84.7%	3.3%	85.6%	4.2%
1 MenACWY	60.3%	58.2%	-2.2%	60.7%	0.4%
2 Varicella	77.6%	80.7%	3.1%	81.0%	3.4%
1 Tdap	62.3%	60.6%	-1.7%	63.1%	0.7%
2 MMR	79.5%	82.2%	2.7%	82.2%	2.8%
HPV (≥ 1 dose)	45.0%	48.6%	3.6%	49.4%	4.4%
HPV Complete <sup>d</sup>	17.1%	20.6%	3.5%	21.2%	4.1%
3-1-2-1-2 Series <sup>e</sup>	50.2%	50.3%	0.1%	52.9%	2.7%
MenACWY, Tdap, HPV Series <sup>f</sup>	16.5%	19.8%	3.3%	19.8%	3.3%
15-year-old					
3 HepB	78.8%	81.8%	3.0%	82.2%	3.4%
1 MenACWY	76.5%	75.4%	-1.1%	76.1%	-0.4%
2 Varicella	74.7%	77.4%	2.7%	78.4%	3.7%
1 Tdap	77.2%	76.1%	-1.1%	76.7%	-0.5%
2 MMR	77.9%	79.3%	1.3%	80.2%	2.2%
HPV (≥ 1 dose)	57.8%	61.3%	3.6%	63.2%	5.5%
HPV Complete <sup>d</sup>	42.4%	46.8%	4.4%	49.4%	7.0%
3-1-2-1-2 Series <sup>e</sup>	62.0%	63.5%	1.5%	63.8%	1.8%
MenACWY, Tdap, HPV Series <sup>f</sup>	40.9%	45.7%	4.8%	48.4%	7.5%
<b>North Dakota</b>					
2-year-old	<i>2017-19 Avg</i>	<i>2020</i>	<i>% Change<sup>a</sup></i>	<i>2021</i>	<i>% Change<sup>a</sup></i>
4 DTaP	75.1%	71.0%	-4.1%	74.1%	-1.0%
3 Polio	84.5%	81.6%	-2.9%	83.2%	-1.3%
1 MMR	85.4%	83.1%	-2.3%	82.2%	-3.2%
Hib Complete <sup>b</sup>	73.4%	70.9%	-2.5%	72.5%	-0.9%
3 HepB	85.6%	83.5%	-2.1%	84.5%	-1.1%
1 Varicella	84.5%	82.5%	-2.0%	81.8%	-2.6%
4 PCV	76.5%	75.5%	-0.9%	73.5%	-2.9%
4-3-1-3-3-1-4 Series <sup>c</sup>	67.2%	65.2%	-2.1%	66.7%	-0.6%
6-year-old					
5 DTaP	75.8%	76.1%	0.4%	77.2%	1.5%
4 Polio	81.2%	80.9%	-0.3%	82.0%	0.8%
2 MMR	82.9%	81.3%	-1.6%	81.9%	-1.0%
Hib Complete <sup>a</sup>	76.2%	77.1%	0.9%	78.9%	2.7%
3 HepB	88.9%	88.6%	-0.4%	89.3%	0.3%
2 Varicella	81.9%	80.5%	-1.4%	81.2%	-0.7%
4 PCV	75.9%	76.2%	0.3%	78.3%	2.4%
4-3-1-3-3-1-4 Series <sup>b</sup>	64.3%	66.0%	1.7%	68.3%	4.0%
12-year-old					
3 HepB	88.8%	89.9%	1.1%	90.8%	2.0%
1 MenACWY	62.5%	64.8%	2.3%	64.0%	1.4%
2 Varicella	82.3%	84.6%	2.3%	85.2%	2.9%
1 Tdap	64.1%	66.1%	2.0%	65.7%	1.6%
2 MMR	84.2%	85.8%	1.6%	86.5%	2.3%
HPV (≥ 1 dose)	49.8%	53.0%	3.2%	52.1%	2.2%
HPV Complete <sup>d</sup>	24.7%	26.5%	1.8%	27.1%	2.3%
3-1-2-1-2 Series <sup>e</sup>	59.4%	62.1%	2.7%	61.6%	2.2%
MenACWY, Tdap, HPV Series <sup>f</sup>	24.3%	26.3%	1.9%	26.7%	2.4%
15-year-old					
3 HepB	82.2%	88.1%	5.9%	89.9%	7.7%
1 MenACWY	71.0%	75.5%	4.5%	78.1%	7.0%
2 Varicella	74.5%	81.3%	6.8%	84.0%	9.5%

**Table 3** (continued)

1 Tdap	72.0%	76.2%	4.2%	78.8%	6.8%
2 MMR	78.0%	83.3%	5.3%	85.7%	7.6%
HPV ( $\geq 1$ dose)	56.1%	62.3%	6.2%	65.3%	9.2%
HPV Complete <sup>d</sup>	47.1%	52.9%	5.8%	56.3%	9.2%
3-1-2-1-2 Series <sup>e</sup>	66.5%	72.0%	5.4%	74.8%	8.2%
MenACWY, Tdap, HPV Series <sup>f</sup>	46.6%	52.4%	5.8%	55.9%	9.3%

<sup>a</sup> Percent (%) change was calculated for both years using the 2017-19 average (avg) as the comparison value

<sup>b</sup> Hib completion may be 3 or 4 doses, depending on the product used to initiate the series

<sup>c</sup> 4-3-1-3-3-1-4 Series = 4 DTap, 3 Polio, 1 MMR, 3 Hib, 3 HepB, 1 Varicella, 4 PCV

<sup>d</sup> HPV completion may be 2 or 3 doses, depending on the age of the child at series initiation

<sup>e</sup> 3-1-2-1-2 Series = 3 HepB, 1 MenACWY, 2 Varicella, 1 Tdap, 2 MMR

<sup>f</sup> MenACWY, Tdap, HPV Series = 1 MenACWY, 1 Tdap, and HPV completion

an increase in influenza vaccine administrations for 2020-21 and 2021-22, while private practice, hospital, and LPH provider types decreased both seasons (Table 6).

## Minnesota

According to MIIC, there were 170,335 routine immunizations administered to the identified childhood and adolescent cohorts in Minnesota in 2020 and 197,528 immunizations in 2021, a 20.5% and 7.8% decrease from the 2017-19 uptake average respectively. All age groups experienced a decrease both years and the 2020 decrease was consistently larger than 2021. The greatest decline for both years was in the 15-year-olds, while the smallest decrease was in the 12-year-olds (Table 1).

Breaking down vaccine uptake by age, all vaccines in all four age groups decreased in 2020 compared to the 2017-19 average, while a few increased in 2021 (Table 2). For 2-year-olds, MMR experienced the largest decrease (-48.9%, -41.6%) both years, with HepB (-23.9%) and varicella (-20.9%) following in 2020 and DTaP (-7.4%) and varicella (-7.2%) in 2021. The 6-year-olds had some overlap, with HepB (-48.8%, -25.1%) having the largest decrease followed by PCV (-31.9%, -9.7%) and MMR (-31.2%, -7.2%) both years. For the adolescents, both age groups experienced larger decreases for MMR, HepB, and varicella both years with the 2020 decreases ranging from 46.7 to 54.1% and 2021 ranging from 29.0 to 48.0%. 12-year-old HPV uptake fared the best, with only a small decrease of 5.4% in 2020 and an increase of 2.4% in 2021.

Change in UTD coverage rates across these age groups saw different patterns (Table 3). While nearly all 2-year-old coverage rates experienced a decrease in both 2020 and 2021, most vaccines in the other ages experienced slight coverage increases compared to the 2017-19 average. The youngest age group had larger decreases in coverage for nearly all vaccines, with MMR experiencing the largest decline both years (-2.5, -3.5%). DTaP (-1.5, -2.7%) and Hib

completion (-1.7, -1.5%) also experienced larger decreases in 2020, joined by varicella (-1.7%), PCV (-1.5%), and the overall childhood series (-2.5%) in 2021. For 6-year-olds, only polio coverage in 2021 (-1.4%) had a percent decrease over 1%, while MMR, DTaP, and varicella coverage experienced a slight decrease in one or both years. Both adolescent age groups saw decreases in MenACWY and Tdap coverage and there was an improvement in coverage in 2021 for all vaccines. HPV completion (+7.0%) and the adolescent series containing HPV (+7.5%) in 2021 notably saw the highest increase for the adolescent age groups.

Looking at vaccine administration by provider type, private practices continued to be the largest providers of routine immunizations, generally followed by hospitals and LPH although all experienced decreases both years (Table 4). LPH had one of the largest decreases each year for all age groups with small rebounds in 2021. Indian health services (IHS), another large provider of routine immunizations, also had large decreases in 2020 but rebounded in 2021 to have smaller decreases and an increase in 12-year-olds. Similarly, SBHCs for the three school-aged groups experienced large decreases in 2020 but then increased in 2021, compared to the 2017-19 average. Convenience/retail clinics and pharmacies, on the other hand, experienced increases for both years across all age groups.

The uptake of influenza immunizations in adults increased in both the 2020-21 (+13.0%) and 2021-22 (+26.5%) flu seasons, compared to the 2017-20 average (Table 1). Inversely, seasonal influenza coverage had a slightly higher increase compared to the 2017-20 flu season average in 2020-21 (+2.1%) compared to 2021-22 (+1.3%) (Table 5). Private practices again remained the largest providers, with pharmacies remaining the second largest provider (Table 6). Private practices, home health, college/university, and LPH all experienced decreases in both seasons. Conversely, a few organization types had increases both seasons with pharmacies, convenience/retail clinics, nursing home/LTCs, and correction facilities having the largest increases.



**Table 4** Number of routine immunizations administered by age, year, and provider type, among children and adolescents, 2017–2021

<b>Iowa</b>					
	<b>2017-19 Avg</b>	<b>2020</b>	<b>% Change<sup>a</sup></b>	<b>2021</b>	<b>% Change<sup>a</sup></b>
2-year-old					
Hospital	120.7	44	-63.5%	211	74.9%
Indian Health Services	47.7	40	-16.1%	37	-22.4%
Local Public Health	7,379.7	4,825	-34.6%	4,783	-35.2%
Pharmacy	0	2	--	0	--
Private Practice	44,320.7	37,669	-15.0%	39,512	-10.8%
School-Based Health Clinic	14.7	27	84.1%	11	-25.0%
6-year-old					
Hospital	39	26	-33.3%	129	230.8%
Indian Health Services	6.7	4	-40.0%	25	275.0%
Local Public Health	3,464.3	2,389	-31.0%	2,845	-17.9%
Pharmacy	0.7	2	200.0%	0	-100.0%
Private Practice	13,564.3	10,592	-21.9%	12,570	-7.3%
School-Based Health Clinic	51.7	59	14.2%	91	76.1%
12-year-old					
Hospital	198.7	197	-0.8%	147	-26.0%
Indian Health Services	53.3	42	-21.3%	48	-10.0%
Local Public Health	9,158.3	6,587	-28.1%	6,815	-25.6%
Pharmacy	124.3	95	-23.6%	123	-1.1%
Private Practice	50,150	48,682	-2.9%	49,555	-1.2%
School-Based Health Clinic	129	24	-81.4%	71	-45.0%
15-year-old					
Hospital	66	26	-60.6%	49	-25.8%
Indian Health Services	9.3	3	-67.9%	5	-46.4%
Local Public Health	1,767	763	-56.8%	1,352	-23.5%
Pharmacy	23.7	7	-70.4%	9	-62.0%
Private Practice	8,200.3	4,640	-43.4%	4,816	-41.3%
School-Based Health Clinic	74.3	63	-15.2%	67	-9.9%
<b>Minnesota<sup>b</sup></b>					
2-year-old	<i>2017-19 Avg</i>	<i>2020</i>	<i>% Change<sup>a</sup></i>	<i>2021</i>	<i>% Change<sup>a</sup></i>
Convenience/Retail Clinic	1.0	0	-100.0%	9	800.0%
Hospital	1,975.7	889	-55.0%	946	-52.1%
Indian Health Services	713.0	515	-27.8%	615	-13.7%
Local Public Health	750.3	418	-44.3%	254	-66.1%
Pharmacy	0	22	--	33	--
Private Practice	77,404.3	64,190	-17.1%	70,916	-8.4%
School-Based Health Clinic	24.7	31	25.7%	5	-79.7%
6-year-old					
Convenience/Retail Clinic	3.3	4	20.0%	24	620.0%
Hospital	413.3	183	-55.7%	332	-19.7%
Indian Health Services	162.3	76	-53.2%	139	-14.4%
Local Public Health	716.0	324	-54.7%	361	-49.6%
Pharmacy	0	6	--	2	--
Private Practice	19,057.7	13,631	-28.5%	18,403	-3.4%
School-Based Health Clinic	152.7	87	-43.0%	256	67.7%
12-year-old					
Convenience/Retail Clinic	254.7	264	3.7%	449	76.3%
Hospital	1,997.3	1,060	-46.9%	1,846	-7.6%
Indian Health Services	894	588	-34.2%	999	11.7%
Local Public Health	1,394.3	551	-60.5%	691	-50.4%
Pharmacy	3.3	25	650.0%	59	1670.0%
Private Practice	92,148.7	77,434	-16.0%	88,045	-4.5%
School-Based Health Clinic	387.7	178	-54.1%	419	8.1%
15-year-old					
Convenience/Retail Clinic	27.7	33	19.3%	54	95.2%

**Table 4** (continued)

Hospital	371	201	-45.8%	267	-28.0%
Indian Health Services	135	76	-43.7%	128	-5.2%
Local Public Health	538.7	202	-62.5%	310	-42.5%
Pharmacy	16.7	17	2.0%	29	74.0%
Private Practice	14,337.3	9,156	-36.1%	11,286	-21.3%
School-Based Health Clinic	432.7	152	-64.9%	452	4.5%
<b>North Dakota<sup>c</sup></b>					
2-year-old	2017-19 Avg	2020	% Change <sup>a</sup>	2021	% Change <sup>a</sup>
Hospital	8.0	12	50.0%	11	37.5%
Indian Health Services	524.3	341	-35.0%	367	-30.0%
Local Public Health	1,104.0	725	-34.3%	861	-22.0%
Pharmacy	0.7	1	50.0%	0	--
Private Practice	7028.0	7,629	8.6%	6,947	-1.2%
6-year-old					
Hospital	2.7	2	-25.0%	4	50.0%
Indian Health Services	74.0	42	-43.2%	76	2.7%
Local Public Health	687.3	516	-24.9%	497	-27.7%
Pharmacy	--	--	--	--	--
Private Practice	2,498.3	2,495	-0.1%	2,231	-10.7%
12-year-old					
Hospital	18.3	23	25.5%	16	-12.7%
Indian Health Services	634.3	429	-32.4%	491	-22.6%
Local Public Health	2,891.7	2,396	-17.1%	2,492	-13.8%
Pharmacy	5.7	7	23.5%	16	182.4%
Private Practice	8,668.7	9,613	11.0%	8,935	3.1%
15-year-old					
Hospital	13.3	9	-32.5%	14	5.0%
Indian Health Services	71.7	35	-51.2%	79	10.2%
Local Public Health	299.7	204	-81.2%	228	-79.0%
Pharmacy	0.7	1	50.0%	0	--
Private Practice	890.7	835	-0.6%	918	3.1%

<sup>a</sup> Percent (%) change was calculated for both years using the 2017-19 average (avg) as the comparison value

<sup>b</sup> Convenience/Retail Clinics were only analyzed in Minnesota

<sup>c</sup> School-Based Health Clinics were not included in North Dakota

**Table 5** Influenza vaccine coverage by season <sup>a</sup>, among adults 18 years and older, 2017–2021

	2017-19 Avg	2020	% Change <sup>b</sup>	2021	% Change <sup>b</sup>
Iowa	28.6%	32.6%	14.1%	30.2%	5.6%
Minnesota	30.0%	32.1%	2.1%	31.3%	1.3%
North Dakota	26.6%	28.1%	1.5%	25.4%	-1.2%

<sup>a</sup> Influenza season includes vaccine doses administered between August 1st of that year and ending on May 31st of the following year (i.e., 2020=8/1/2020–5/31/2021)

<sup>b</sup> Percent (%) change was calculated for both years using the 2017-19 average (avg) as the comparison value

## North Dakota

The number of routine immunizations administered in North Dakota dropped some in 2020 but dropped across all cohorts in 2021 compared to the 2017-19 average. In 2020, 25,446 routine immunizations were administered to the cohorts

studied which represents a 0.4% decrease in the number of childhood and adolescent immunizations administered. In 2021, the number dropped further to 24,836 (-4.7%). Broken down by the age cohorts, the 15-year-old and 6-year-old cohorts saw the largest decline in immunization administration across the period assessed (Table 1).

Changes in routine immunization uptake varied by vaccine type. Across all age groups, MMR and varicella coverage decreased in 2020 and 2021 compared to the 2017–2019 average (Table 2). HepB uptake decreased for the 6-, 12-, and 15-year-old cohorts, but not for the 2-year-old cohort in 2020 and 2021. For the 2-year-old cohorts, three vaccines saw consistent decreases in immunization uptake across 2020 and 2021; MMR (-24.2%, -12.7%), PCV (-21.4%, -16.8%), and varicella (-19.0%, -7.0%). Immunization uptake for the other vaccines in the 2-year-old cohorts was not consistent across the two years and many immunizations had increases in the number of doses administered.

**Table 6** Number of influenza immunizations administered by season <sup>a</sup> and provider type, among adults 18 years and older, 2017–2021

	2017-19 Avg	2020	% Change <sup>b</sup>	2021	% Change <sup>b</sup>
<b>Iowa</b>					
College/University	5,413.3	6,467	19.5%	6,785	25.3%
Corrections Facility	187.3	3,068	1537.7%	3,381	1704.8%
Home Health	427.3	693	62.2%	394	-7.8%
Hospital	41,563.3	39,948	-3.9%	40,180	-3.3%
Indian Health Services	340.3	283	-16.8%	601	76.6%
Local Public Health	49,085.3	45,112	-8.1%	45,945	-6.4%
Nursing Home/Long Term Care	4,381	6,767	54.5%	7,519	71.6%
Pharmacy	337,152.3	459,673	36.3%	433,682	28.6%
Private Practice	429,151.3	419,465	-2.3%	394,399	-8.1%
School-Based Health Clinic	9.3	17	82.1%	15	60.7%
Veterans Health/Military	2,699.7	7,051	161.2%	6,479	140.0%
Other	1,215.3	1,856	52.7%	3,973	226.9%
<b>Minnesota <sup>c</sup></b>					
College/University	5,096.7	3,535	-30.6%	4,492	-11.9%
Convenience/Retail Clinic	20,100.7	40,737	102.7%	31,088	54.7%
Corrections Facility	445.3	526	18.1%	2,904	552.1%
Home Health	710.3	257	-63.8%	221	-68.9%
Hospital	89,578.0	92,096	2.8%	143,116	59.8%
Indian Health Services	6,823.7	6,021	-11.8%	7,696	12.8%
Local Public Health	18,554.3	15,961	-14.0%	17,421	-6.1%
Nursing Home/Long Term Care	2,414.3	3,710	53.7%	6,671	176.3%
Pharmacy	350,755.3	540,087	54.0%	665,229	89.7%
Private Practice	787,197.7	762,806	-3.1%	759,620	-3.5%
School-Based Health Clinic	326.3	369	13.1%	285	-12.7%
Other	50,483.7	39,485	-21.8%	47,484	-5.9%
<b>North Dakota <sup>d</sup></b>					
College/University	2,695.7	3,465	28.5%	1,936	-28.2%
Corrections Facility	737.7	451	-38.9%	499	-32.4%
Hospital	7,708.7	6,414	-16.8%	8,686	12.7%
Indian Health Services	4,909.7	4,629	-5.7%	3,812	-22.4%
Local Public Health	27,838.3	27,129	-2.5%	27,404	-1.6%
Nursing Home/Long Term Care	2,944.0	3,997	35.8%	4,075	38.4%
Pharmacy	35,873.7	39,498	10.1%	46,128	28.6%
Private Practice	85,244.7	98,484	15.5%	92,136	8.1%
Veterans Health/Military	0.7	6	800.0%	0	--
Other	1,762.3	2,667	51.3%	3,998	126.9%

<sup>a</sup> Influenza season includes vaccine doses administered between August 1st of that year and ending on May 31st of the following year (i.e., 2020 = 8/1/2020–5/31/2021)

<sup>b</sup> Percent (%) change was calculated for both years using the 2017-19 average (avg) as the comparison value

<sup>c</sup> Convenience/Retail Clinics were only analyzed in Minnesota and Veterans Health/Military were not included in Minnesota

<sup>d</sup> School-Based Health Clinics were not included in North Dakota

Specifically, DTaP (+19.8%, +6.7%), HepB (+223.8%, +31.5%), and Polio (+45.1%, +11.7%) saw increases in both 2020 and 2021. For the 6-year-old cohorts, MMR (-21.5%, -12.8%), varicella (-22.2%, -14.2%), and HepB (-13.7%, -22.4%) uptake decreased in 2020 and 2021. In 2020, the 6-year-old cohort received more doses of DTaP (+14.6%) and Polio (+16.0%) in 2020, but the 2021 cohort received fewer doses of both vaccines compared to the 2017-19 average. Most immunizations saw decreased uptake for the 12-year-old cohorts in 2020 and 2021. The largest percent decrease was HepB (-28.6%) in 2020 and MMR (-46.4%) in 2021. The 2021 and 2022 12-year-old cohorts received more HPV doses compared to the 2017-19 average. In the 15-year-old cohorts, uptake for MMR

(-48.5%, -36.4%) and varicella (-45.5%, -43.4%) decreased the largest percent in 2020 and 2021.

In the 2-year-old cohorts, the change in percent of children UTD for each vaccine was small, but all vaccines saw a decrease in 2020, 2021, or both (Table 3). The vaccine with the largest difference shifted from DTaP in 2020 (-4.1%) to MMR in 2021 (-3.2%). The percent of 2-year-olds who were fully UTD for the series dropped in 2020 (-2.1%), but bounced back in 2021 to close to the 2017-19 average. The 6-year-old cohort trends match the uptake trends, but the percent of the cohort that was UTD for the complete series increased in 2020 and 2021. The 12- and 15-year-old cohorts saw increases in the percent of individuals UTD for all immunizations including the series.

Assessing routine immunization by provider type, LPH, and IHS facilities saw the largest decrease in routine immunizations provided in 2020 and 2021 by percent change from the pre-pandemic average (Table 4). LPH saw the most consistent drop in vaccine administration across all age groups. Private practices had different trends across the age groups, but mostly increased in 2020.

Influenza immunization administration in the 18 years and older cohort increased slightly in the 2020–21 and 2021–22 flu seasons (Table 1). LPH administered fewer immunizations in both flu seasons compared to the 2017–20 average, while pharmacy and private practice administered a larger number of doses (Table 6). When rates are assessed, the percent of individuals aged 18 years and older who received influenza vaccine was higher in the 2020–21 influenza season but dropped slightly in the 2021–22 influenza season. The overall percent change was small in both years (Table 5).

## Discussion

### Childhood & Adolescent Routine Vaccination

Childhood and adolescent routine vaccination uptake declined in the analyzed three Midwestern states during the COVID-19 pandemic, consistent with previously published studies [2–5]. While decline due to initial pandemic response and stay-at-home mitigation efforts (i.e., restrictions on elective procedures and in-person preventative care in Minnesota [10]) was anticipated and measured [11], this decrease in administration persisted past the initial months of the pandemic and the ongoing immunization gap in these age groups continues to garner concern [12, 13]. In this study, both Iowa and Minnesota saw overall decreases in vaccine uptake in both 2020 and 2021 compared to the 2017–19 average, although there was some rebound in 2021. Conversely, North Dakota experienced much smaller declines in 2020 but uptake worsened in 2021. Iowa's and Minnesota's trend was likely due to initial pandemic restrictions with a later return to standard preventative care and in-person schooling while it took longer for the impact of the pandemic to be seen in immunization rates in North Dakota.

During the pandemic, trends in routine vaccine uptake appeared to be influenced by the standard immunization schedule [9], with previously recommended vaccinations bearing the brunt of the decline particularly in the first year. For 2020 in all three states, the 15-year-olds experienced the largest decline in doses administered followed by the 6-year-old age group. Similarly, the 15-year-olds had the largest decline followed by the 2-year-olds in 2021 for Iowa and Minnesota, while the 12-year-olds saw the largest

decline in North Dakota followed by the 2-year-olds and 15-year-olds. This decline reflects patterns of standard vaccination, with 15-year-olds only being recommended for the measured vaccines when catch-up is needed, 2-year-olds normally recommended for all studied vaccines, and 6- and 12-year-olds having a combination of recommended and catch-up vaccines analyzed in this study [9].

Further breakdown of uptake by vaccine type within the age groups supports these trends, particularly in adolescents. For both years in all three states, 12-year-olds experienced notably larger percent declines in HepB, MMR, and varicella vaccination, which are all vaccines that should be received in childhood. This decline was generally the pattern for the 15-year-olds, although there was more variation from the pattern as Tdap, MenACWY, and HPV are also catch-up vaccines by this age. HPV vaccination in 12-year-olds was also a consistent trend across all three states, faring the best and experiencing a percent increase for both years for two out of the three states. This finding agrees with a National Immunization Surveys (NIS) study that reported an increased nationwide HPV rate in 2020 [14]. One potential explanation for this finding is that the HPV vaccine, while routinely recommended for that age group, is not required for attending school. As schools transitioned to online learning in 2020, MenACWY and Tdap may have experienced larger decreases if school requirements were the primary motivator of vaccination, whereas parents vaccinating their children for HPV were already doing so independently of any requirements and were less impacted.

There was much more variation in childhood vaccine uptake during the pandemic. Generally, MMR and HepB experienced the greatest decline in vaccine administration, followed by varicella and PCV. The larger decline in MMR vaccination is consistent with other US studies [4, 6, 15], with the pandemic potentially exacerbating vaccine hesitancy. Minnesota also had a vaccination spike in 2017 following their measles outbreak [16, 17], meaning MMR could have an apparent larger decline than other vaccines that did not have an abnormal surge in their comparison years. Additionally, varicella is often administered with MMR, both in tandem and as the combination vaccine Proquad, which may have contributed to the reduced administration of that vaccine. HepB and PCV, though routinely recommended for 2-year-olds, are catch-up vaccinations for 6-year-olds which may have further contributed to their overall larger declines, as parents already late or hesitant to vaccinate their children may not have wanted to deal with the additional pandemic barriers to vaccination. Conversely, Hib generally fared the best, experiencing a few percent increases throughout the two years across all three states. Other state-specific trends stood out: Iowa experienced larger polio declines; Minnesota had lower DTaP uptake, consistent with a known

fourth-dose gap that requires further analysis to understand; and North Dakota experienced some large increases in Tdap and DTaP in 2020.

There were less consistent patterns of pandemic impact on vaccine coverage between the three states, possibly because UTD coverage reflects vaccination practice for the cohort's entire lifetime and unmeasured pre-pandemic routine state differences could have diluted any trends. Unlike vaccine uptake, 2021 2-year-old coverage declined for both Iowa and Minnesota. Unlike the other age groups, North Dakota's 2-year-old coverage improved in 2021 compared to 2020, but declined from the average of 2017–19, which was also observed in the other two states. Declines in coverage rates for the 2-year-olds, despite uptake faring better in this age group compared to the other three analyzed, is likely because this age cohort had more expected vaccination appointments during the early days of COVID-19 pandemic (i.e., when states were under Stay at Home orders, etc.) with fewer recommended vaccines prior to the pandemic. For 6-year-olds, rates were generally higher, but one or more states did experience lower coverage rates in 2021, almost entirely in vaccines recommended for that age group (i.e., DTaP, polio, MMR, varicella). While the uptake results suggested that administration of catch-up vaccination potentially fared worse during the pandemic, this group might make up a small enough portion of the overall population that the impact was not reflected in the overall coverage rates. Smaller declines in vaccines routinely recommended for the assessment age may have applied to a much larger portion of the population, resulting in depressed rates. Another possibility is that reduced administration of catch-up vaccines was due in part to more timely vaccination of those cohorts prior to the pandemic, meaning there would not be a resulting decrease in coverage.

Similarly, in all three states, MenACWY and Tdap UTD coverage generally had larger declines for the adolescent age groups compared to the other three catch-up vaccines. HPV, the third standard recommended vaccine for adolescents, experienced some of the highest increases in Minnesota and North Dakota. These increases were particularly apparent in 15-year-olds, although their high coverage could also be the result of most adolescents in the cohort receiving timely, pre-pandemic vaccinations as 12-year-olds. Conversely, Iowa saw a large percent decrease in HPV coverage for 12-year-olds in 2020 and 2021 compared with the 2017–19 average.

The coverage differences within the childhood and adolescent age groups also suggests the importance of school requirements. Excluding HPV, students are required to be UTD for the studied vaccines before entering school each fall [18–20]. The 15-year-old age cohort experienced few declines and generally high increases in coverage, even in

2020, but all adolescents had been recommended to receive these vaccines prior to the pandemic and required to receive most before entry into school several grades earlier. Similarly, 6-year-olds and 12-year-olds vaccine coverage tended to rebound in 2021, with both age groups already recommended to receive many vaccines for previous school years and likely rebounding in 2021 for the return to in-person learning for some states and a return to enforcing vaccine requirements for school. Gaps in 2-year-old vaccinations were the most pronounced, and while coverage rates may improve as this cohort reaches school age, targeted outreach could be conducted to get them UTD sooner. Importantly, delays in vaccination can lower the vaccine efficacy [21], have economic impacts [22], and reduce population-level protection resulting in more frequent disease outbreaks [23–25].

Decrease in routine childhood and adolescent vaccine administration was further measured by provider type with some notable patterns. Private practices and LPH were two of the top vaccinators pre-pandemic, joined by hospitals in Iowa and Minnesota, SBHCs in Iowa, and IHS in Minnesota and North Dakota. Most of these organization types remained top vaccinators of routine immunizations throughout the pandemic despite seeing large percent declines in vaccine administrations compared to the 2017–19 average. LPH experienced some of the largest declines with generally poor rebound, suggesting that these agencies might have had limited capacity with their ongoing COVID-19 response work. The COVID-19 vaccine was made available in December 2020, which shifted the focus from routine pediatric vaccination to COVID-19 vaccine rollout and services. This decline is particularly concerning as LPH are important safety net providers, a service that will be vital in lessening the current immunization gaps. In Iowa and Minnesota, private practices and hospitals also generally had large declines in 2020 but improved in 2021. North Dakota generally had percent increases for those provider types, although private practice vaccine administration declined in 2021.

Other provider types saw more variation in pandemic effects across the three jurisdictions and there were several instances of rapid change due to shifts in vaccination practice. In Iowa, administration by SBHCs experienced a percent increase for the childhood age groups in 2020 and saw improvement in 2021 but declined for the adolescent age groups. In Minnesotan SBHCs, all the school-aged (6-, 12-, and 15-year-old) groups saw large percent decreases in 2020 and then percent increases in 2021, the rebound likely attributed to the return to in-person learning. Routine administration by pharmacies was variable with small numbers in most groups, but generally experienced a decrease in adolescents in Iowa compared to increases in Minnesotan

and North Dakotan adolescents. Increases with this provider was unsurprising due the expansion of pharmacy administration ability by the US Department of Health & Human Services, issued in response to the decline in routine vaccinations [26]. Minnesota also separately analyzed administration by convenience/retail clinics, which saw increases in 2020 and marked improvement in 2021.

### Adult Seasonal Influenza Vaccination

Adult influenza uptake and coverage improved during the pandemic, consistent with previously published reports [27, 28]. For all three states, 2020–21 coverage was better than 2021–22 although North Dakota did have a slight percent decrease in 2021–22. This improvement is likely due to increased promotion and a variety of strategies [29] public health agencies employed to improve influenza vaccination rates and subvert a ‘twindemic’. The focus on COVID-19 vaccination, which allows for influenza vaccine coadministration [30, 31], could have also contributed to increased coverage rates during the pandemic.

Similar to routine childhood and adolescent vaccination, LPH was a top vaccinator that experienced the most consistent percent declines in adult influenza immunization across all three states. Private practices and hospitals, two other top vaccinators, experienced consistent pandemic declines in at least two states while pharmacies and convenience/retail clinics increased. Pharmacies surpassed private practices in administered vaccines in Iowa, possibly due to the widespread availability of COVID-19 vaccines at pharmacies. Many other provider types experience a decline at least one year in at least one state, but there was much more variation likely due to jurisdictional differences and smaller populations being vaccinated.

### Limitations

This analysis is limited in its scope and ability to fully consider all potential variables that impact immunization rates. This study looks at data from three Midwestern states which limits its generalizability, as it acts as a small-scale look at the impact of the pandemic but cannot fully characterize the impact in other states. This retrospective analysis is also limited by the lack of previous and complete address data and relied on individuals’ current address to determine eligibility. The inability to accurately determine whether a client was previously a resident of the state for which the analysis was conducted may have inappropriately excluded some eligible individuals from the study. Additionally, recommendations outside of the standard vaccine schedule were not taken into account when calculating UTD coverage.

State-specific differences also limited the comparability of results within the study. Each state has their own process and criteria that defines which patients are considered ‘active’ and each state has their own policy around patients opting in and out of the system. Differences in reporting requirements across the three states also may result in some states having a more complete population or immunization history.

### Conclusions

This study adds to the growing body of literature on the effects of the COVID-19 pandemic on routine preventative care. All three Midwestern states reported notable decreases in childhood and adolescent vaccine administration, consistent with many previously published reports both national and globally. The magnitude of effects appeared to vary across vaccine type, age group, and provider type, although some patterns emerged, suggesting particularly the importance of school vaccine requirements. Further analysis would be needed to explain the variation more comprehensively or to determine if these effects differ across other demographic variables (i.e., urban vs. rural residence, race and ethnicity categories, etc.).

As public health moves away from the emergency response, identifying and improving gaps in coverage will be important in the shift back to routine work. Coverage differences by vaccine type will help direct immunization program outreach, while data on vaccine administration by provider type can help inform coordination and resource distribution across public health agencies. Timely immunization is critical to maintaining the safety and efficacy of routinely recommended vaccines and for achieving sufficient coverage to prevent vaccine-preventable disease outbreaks and protect our most vulnerable populations.

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## Declarations

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