Pediatric Vaccination During the COVID-19 Pandemic

Bradley K. Ackerson, MD, Lina S. Sy, MPH, Sungching C. Glenn, MS, Lei Qian, PhD, Claire H. Park, MPH,
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abstract

OBJECTIVES: The impact of the coronavirus disease 2019 pandemic on vaccination coverage, critical to preventing vaccine-preventable diseases, has not been assessed during the reopening period.

METHODS: Vaccine uptake and vaccination coverage for recommended vaccines and for measles-containing vaccines at milestone ages were assessed in a large cohort of children aged 0 to 18 years in Southern California during January to August 2020 and were compared with those in the same period in 2019. Differences in vaccine uptake and vaccination coverage (recommended vaccines and measles-containing vaccines) in pre-pandemic (January to March), stay-at-home (April to May), and reopening (June to August) periods in 2020 and 2019 were compared.

RESULTS: Total and measles-containing vaccine uptake declined markedly in all children during the pandemic period in 2020 compared with 2019, but recovered in children aged 0 to 23 months. Among children aged 2 to 18 years, measles-containing vaccine uptake recovered, but total vaccine uptake remained lower. Vaccination coverage (recommended and measles-containing vaccines) declined and remained reduced among most milestone age cohorts ≥24 months during the pandemic period, whereas recommended vaccination coverage in older children decreased during the reopening period in 2020 compared with 2019.

CONCLUSIONS: Pediatric vaccine uptake decreased dramatically during the pandemic, resulting in decreased vaccination coverage that persisted or worsened among several age cohorts during the reopening period. Additional strategies, including immunization tracking, reminders, and recall for needed vaccinations, particularly during virtual visits, will be required to increase vaccine uptake and vaccination coverage and reduce the risk of outbreaks of vaccine-preventable diseases.

WHAT’S KNOWN ON THIS SUBJECT: Childhood vaccine administrations declined markedly early in the coronavirus disease 2019 pandemic, later improving but remaining reduced in older children. Vaccination coverage has not been assessed since vaccine administrations partially recovered nor in older children during the pandemic.

WHAT THIS STUDY ADDS: During the first 6 months of the coronavirus disease 2019 pandemic, vaccine administrations remained lower in older children, complete vaccination coverage declined in all children, and measles vaccination coverage worsened in young children, markedly increasing the risk of vaccine-preventable diseases.
After a national state of emergency was declared in the United States on March 13, 2020, initial efforts to mitigate the pandemic spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) focused on social distancing and quarantine, severely limiting activity outside the home.\(^1\) California issued stay-at-home orders on March 19, 2020,\(^2\) and later issued guidelines on May 7, 2020, for partial reopening of lower-risk workplaces.\(^3\) Across the United States, in-person office visits plummeted but later partially recovered in some settings as businesses reopened and restrictions were lifted.\(^4\)

Anticipating disruptions in preventive health care, the Centers for Disease Control and Prevention (CDC) and the American Academy of Pediatrics (AAP) reaffirmed the importance of well-child care and immunization during the coronavirus disease 2019 (COVID-19) pandemic, particularly in children \(\leq 24\) months of age.\(^5,6\) Nonetheless, alarming decreases in vaccine administrations and vaccination coverage in children early in the pandemic were reported.\(^1,7,8\) Furthermore, another study found that although weekly vaccine administrations recovered to prepandemic levels in children <24 months of age by late May 2020, administrations in older children in 2020 remained approximately one-third fewer than what they were in the same weeks in 2019.\(^9\) Because of high levels of population immunity required to prevent outbreaks of many vaccine-preventable diseases (VPDs), reductions in vaccination coverage increase the risk of VPDs.\(^10\) Consequently, monitoring vaccination coverage and the possible need to increase vaccine uptake in children is essential. However, the impact of the pandemic on vaccination coverage during the reopening phase has not been assessed.\(^7\) Therefore, we evaluated the uptake of all recommended noninfluenza vaccines and of measles-containing vaccines before and during the first 6 months of the COVID-19 pandemic in 2020 and during the same period in 2019 among children aged 0 to 18 years in a large integrated health care delivery system in Southern California. We then assessed vaccination coverage for all recommended noninfluenza vaccines at milestone ages and measles vaccination coverage at 16 months and 7 years of age in this pediatric population before and during the COVID-19 pandemic in 2020 to compare with vaccination coverage during the same period in 2019.

**METHODS**

**Setting**

This observational, retrospective, open cohort study was conducted at Kaiser Permanente Southern California (KPSC), an integrated health care system providing prepaid services for 4.6 million members whose socio-demographics mirror the diverse Southern California population.\(^11\) KPSC uses electronic health records (EHRs) to integrate medical information, including immunizations. KPSC members are covered for the cost of recommended vaccines that can be given at any visit, providing incentive to receive vaccines within KPSC. Providers are encouraged to administer recommended vaccines flagged as due by the EHR at all encounters. Appropriately documented vaccines given outside KPSC are entered into the members’ EHRs.

**Study Population**

The study population consisted of children aged 0 to 18 years who were KPSC members or were vaccinated at KPSC facilities. KPSC membership was not required in calculating total vaccine doses given to children at KPSC or in assessing vaccination coverage at 1 month of age among infants born in KPSC facilities because the birth dose of the hepatitis B vaccine is given while the infant is hospitalized, before membership enrollment. However, membership was required at milestone ages 3 to 24 months, and at least 1-year membership was required at milestone ages \(\geq 7\) years for ascertainment of vaccination coverage. The study was approved by the KPSC Institutional Review Board.

**Recommended Vaccinations at Milestone Ages**

The EHR was used to assess vaccinations during January to August 2019 and 2020. Up-to-date status was assessed for milestone ages corresponding to the end of an Advisory Committee on Immunization Practices–recommended interval for recommended vaccines.\(^7,12\) Milestone age–based cohort assessments of up-to-date status for recommended immunizations received are detailed in Table 1.

**Analysis**

We described characteristics of KPSC members aged 0 to 18 years on January 1, 2019 and 2020. Distributions of age, sex, and race and/or ethnicity were compared between the 2019 and 2020 populations by using standardized difference.\(^13\)

To assess the impact of the COVID-19 pandemic on pediatric vaccination, weekly routine vaccine doses (ie, all noninfluenza routinely recommended vaccines) administered to children of each age group (0–23 months, 2–6 years, 7–12 years, and 13–18 years) from January to August 2019 and 2020 were plotted and compared.
percentage differences of routine vaccine doses administered during the prepanademic period (January 1, 2020, to March 12, 2020), stay-at-home period (March 13, 2020 to May 6, 2020), and reopening period (May 7, 2020 to August 31, 2020) were calculated by comparing to the same periods in 2019. To control for secular trends due to changes in population size and vaccination acceptance, we conducted difference-in-difference (DID) analyses and estimated adjusted percentage differences and 95% confidence intervals (CIs) during the stay-at-home and reopening periods using Poisson regression models, adjusting for the percentage difference in vaccine doses administered during January 1 to March 12 (the prepanademic period in 2020). Similar analyses were performed for measles-containing vaccines among children aged 0 to 23 months and 2 to 18 years and for all routine vaccine doses by race and/or ethnicity for children 0 to 18 years.

Complete vaccination coverage for all noninfluenza routinely recommended vaccines at each milestone age (1, 3, 5, 7, 16, 19, and 24 months and 7, 13, and 17 years) in a period was calculated by dividing the number of children who received all routine vaccine doses listed in Table 1 before a milestone age by the number of eligible children who reached that milestone age during the period. Complete vaccination coverage by month from January 2019 to August 2020 was plotted. The differences (rate ratios) of complete vaccination coverage during the prepanademic period (January 2020 to March 2020), stay-at-home period (April 2020 to May 2020), and reopening period (June 2020 to August 2020) were calculated by comparing to the same periods in 2019. To control for secular trends, we conducted DID analyses. The adjusted differences (ratios of rate ratios) of complete vaccination coverage and 95% CIs during the stay-at-home and reopening periods were estimated by using Poisson regression models with robust error variance, adjusting for the difference in complete vaccination coverage during the prepanademic period in 2020 compared with 2019. Similar analyses were also performed for measles-containing vaccines at 16-month and 7-year milestone ages.

All analyses were conducted by using SAS statistical software, version 9.4 (SAS Institute, Inc, Cary, NC).

RESULTS
There were 987 544 and 992 971 KPSC members 0 to 18 years of age on January 1, 2019 and 2020, respectively (Table 2). The age, sex, and race and/or ethnicity of the 2019 and 2020 pediatric populations were similar.

Vaccine Administrations
The weekly number of routine noninfluenza vaccine doses given in all age cohorts declined rapidly in early March 2020 compared with those given in the same weeks in March 2019 (Fig 1). Among children 0 to 23 months of age, the number of routine doses administered declined by 45% by the week beginning March 22 compared with the number given in the same week in 2019 (8398 vs 15 263, respectively; data not shown) but recovered to similar levels to those in 2019 in the week beginning April 26. In contrast, the decrease in the weekly number of routine doses given to children aged ≥2 years in 2020 compared with 2019 was more severe, decreasing by 94% in the week beginning March 22 (257 vs 3978 in 7–12-year-olds, respectively; data not shown), recovering more slowly, and remaining lower than 2019 levels.

Measles-containing vaccine administrations among children aged <24 months, depicted in Fig 2, decreased in the week beginning...
March 15, 2020, compared with the same week in 2019, with administrations decreasing by 60% the week beginning March 22, 2020, compared with the same week in 2019 (337 vs 836, respectively; data not shown). Measles-containing vaccine administrations subsequently increased but remained below the weekly administration levels in 2019 through the end of the

### TABLE 2 Demographic Characteristics of Children Aged 0–18 Years in KPSC on January 1, 2019 and 2020

<table>
<thead>
<tr>
<th>Age, n (%)</th>
<th>2019 (N = 987,544)</th>
<th>2020 (N = 992,971)</th>
<th>Standardized Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–23 mo</td>
<td>87,947 (8.9)</td>
<td>88,969 (9.0)</td>
<td>0.0025</td>
</tr>
<tr>
<td>2–6 y</td>
<td>242,625 (24.6)</td>
<td>244,432 (24.6)</td>
<td>—</td>
</tr>
<tr>
<td>7–12 y</td>
<td>317,352 (32.1)</td>
<td>318,874 (32.1)</td>
<td>—</td>
</tr>
<tr>
<td>13–18 y</td>
<td>339,620 (34.4)</td>
<td>340,896 (34.3)</td>
<td>—</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>483,088 (48.9)</td>
<td>485,610 (48.9)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Male</td>
<td>504,456 (51.1)</td>
<td>507,361 (51.1)</td>
<td>—</td>
</tr>
<tr>
<td>Race and/or ethnicity, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>243,325 (24.6)</td>
<td>240,380 (24.2)</td>
<td>0.0552</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>73,918 (7.5)</td>
<td>72,136 (7.3)</td>
<td>—</td>
</tr>
<tr>
<td>Hispanic</td>
<td>483,850 (49.0)</td>
<td>477,248 (48.1)</td>
<td>—</td>
</tr>
<tr>
<td>Non-Hispanic Asian American</td>
<td>98,945 (10.0)</td>
<td>99,073 (10.0)</td>
<td>—</td>
</tr>
<tr>
<td>Other</td>
<td>87,526 (8.9)</td>
<td>104,134 (10.5)</td>
<td>—</td>
</tr>
</tbody>
</table>

—, not applicable.

**FIGURE 1**

Routine childhood vaccine doses administered by week in KPSC, January to August 2019 and 2020.
observation period. Similarly, weekly measles-containing vaccine administrations among 2- to 18-year-olds decreased in early March 2020 compared with 2019, decreasing by 93% the week beginning April 5, 2020, compared with the same week in 2019 (91 vs 1349, respectively; data not shown) and remaining lower in 2020 than in 2019 through August.

Vaccination Coverage
Complete vaccination coverage declined markedly, then partially recovered, at milestone ages 5, 7, 16, and 19 months but declined steadily at 24 months compared with the same period in 2019 (Fig 3). Although complete vaccination coverage changed minimally at ages 7 and 13 years, it declined gradually at age 17 years.

Measles vaccination coverage at age 16 months decreased in April 2020 compared with April 2019 (Fig 2). It reached a low in July 2020 compared with July 2019 (81% vs 89%, respectively) and remained lower in August 2020 compared with August 2019. In contrast, the decrease in measles vaccination coverage at age 7 years was minimal.

In the adjusted analyses depicted in Table 3, the number of routine vaccine doses administered to children 0 to 23 months decreased by 25.2% (95% CI −26.0% to −24.4%) during the stay-at-home period in 2020 compared with 2019 but plummeted among children aged ≥2 years (−83.0% [95% CI −83.6% to −82.4%] and 87.6% [95% CI −88.2% to −86.9%] for 2- to 6-year-olds and 13- to 18-year-olds, respectively). On the other hand, during the reopening period in 2020, the adjusted number of routine vaccine doses given to children aged 0 to 23 months...
FIGURE 3
Complete vaccination coverage in children by milestone age in KPSC, January to August 2019 and 2020.
### TABLE 3 Comparison of Vaccine Doses Administered Before and During the COVID-19 Pandemic to Children 0–18 Years of Age at KPSC

<table>
<thead>
<tr>
<th>Age</th>
<th>All vaccines</th>
<th>Measles-containing vaccines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prepandemic Period (January 1 to March 12)</td>
<td>Stay-at-Home Period (March 13 to May 6)</td>
</tr>
<tr>
<td>0–23 mo</td>
<td>168 107</td>
<td>162 926</td>
</tr>
<tr>
<td>2–6 y</td>
<td>26 543</td>
<td>25 563</td>
</tr>
<tr>
<td>7–12 y</td>
<td>34 835</td>
<td>35 113</td>
</tr>
<tr>
<td>13–18 y</td>
<td>19 564</td>
<td>18 946</td>
</tr>
</tbody>
</table>

### TABLE 4 Comparison of Vaccination Coverage Before and During the COVID-19 Pandemic to Children 0–18 Years of Age at KPSC

<table>
<thead>
<tr>
<th>Age</th>
<th>All vaccines</th>
<th>Measles-containing vaccines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preparandemic Period (January to March)</td>
<td>Stay-at-Home Period</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 mo</td>
<td>92.6</td>
<td>91.0</td>
</tr>
<tr>
<td>3 mo</td>
<td>81.9</td>
<td>80.5</td>
</tr>
<tr>
<td>5 mo</td>
<td>79.7</td>
<td>78.7</td>
</tr>
<tr>
<td>7 mo</td>
<td>70.4</td>
<td>70.2</td>
</tr>
<tr>
<td>10 mo</td>
<td>70.1</td>
<td>68.8</td>
</tr>
<tr>
<td>19 mo</td>
<td>73.2</td>
<td>72.3</td>
</tr>
<tr>
<td>24 mo</td>
<td>67.0</td>
<td>66.8</td>
</tr>
<tr>
<td>7 y</td>
<td>88.7</td>
<td>88.2</td>
</tr>
<tr>
<td>13 y</td>
<td>53.3</td>
<td>52.1</td>
</tr>
<tr>
<td>17 y</td>
<td>45.4</td>
<td>41.8</td>
</tr>
</tbody>
</table>

* Adjusted % difference = (ratio of rate ratios - 1) × 100.
increased to nearly the same number given in 2019 (−5.2% [95% CI −6.0% to −4.4%]), whereas administrations remained substantially lower among children aged 2 to 18 years of age (−26.4% [95% CI −28.0% to −24.8%] and −49.3% [95% CI −50.6% to −48.0%] among 2- to 6- and 13- to 18-year-olds, respectively). Measles-containing vaccine administrations also decreased less in children aged <24 months during the stay-at-home period in 2020 than in those aged 2 to 18 years (−41.4% [95% CI −44.2% to −38.6%] vs −83.4% [95% CI −84.3% to −82.4%], respectively) and recovered more during the reopening period in 2020 among children aged <24 months than among those aged 2 to 18 years (−14.4% [95% CI −17.5% to −11.1%] vs −26.6% [95% CI −29.1% to −24.1%], respectively).

In the adjusted analyses depicted in Table 4, although complete vaccination coverage during the stay-at-home period did not change significantly compared with the same period in 2019 among children aged 7 to 17 years, it decreased among children aged ≤24 months, especially in the 5-, 7-, and 19-month cohorts (−12.6% [95% CI −14.6% to −10.6%], −17.6% [95% CI −20.0% to −15.2%], and −13.1% [95% CI −15.4% to −10.8%], respectively). Similarly, measles-containing vaccination coverage decreased during the same period in 2020 among 16-month-olds but not among 7-year-olds (−4.6% [95% CI −6.0% to −3.1%] vs 0.1% [95% CI −0.9% to 1.1%], respectively). However, during the reopening period, complete vaccination coverage recovered partially in most cohorts <24 months of age but continued to decline in 24-month-olds and started to decline in 13- and 17-year-olds. Complete vaccination coverage during the reopening period remained lower than it was during the same time in 2019 in all age cohorts, particularly among the 7-month-old and 17-year-old cohorts (−12.3% [95% CI −14.5% to −10.1%] and −11.9% [95% CI −15.4% to −8.3%], respectively).

**DISCUSSION**

This retrospective study, conducted in a large cohort of socio-demographically diverse children over the first 6 months of the COVID-19 pandemic, reveals that the dramatic decrease in routine vaccine doses administered to children during the pandemic results in significant declines in complete vaccination coverage in children at all milestone ages and substantial decreases in measles vaccination coverage in young children, markedly increasing the risk of VPDs. This report extends the period of observation of vaccine uptake and vaccination coverage in children during the pandemic longer than earlier reports, making it possible to assess trends in vaccine uptake and vaccination coverage in children as the response to the pandemic evolved and interventions to improve vaccine uptake were implemented.

Consistent with earlier reports, we found that the number of recommended vaccine doses and measles-containing vaccine doses administered to children decreased dramatically shortly after the declaration of a national state of emergency on March 13, 2020. Although this decrease was modest and recovered rapidly in children <24 months, it was more severe and persistent in older children.1,9 Much of the decrease in vaccine administration was likely due to early efforts to mitigate the pandemic spread and fear of acquiring SARS-CoV-2 during health care encounters, which resulted in markedly decreased office encounters4 and delayed access to care in children.15 The attenuated decline and rapid rebound in vaccinations given to children <24 months may have reflected efforts to improve vaccine uptake that were initially focused on children aged <24 months, as recommended by the CDC and AAP, including increased EHR tracking, with outreach and reassurance about enhanced safety measures for children due for immunizations; increased in-person encounter availability; and other measures, such as drive-through vaccination, when feasible, at each clinic (Table 5). On the other hand, the slower recovery in vaccine uptake in children aged ≥24 months likely reflected gradual broadening of these efforts to older children, including those who missed earlier visits and were overdue for vaccines, as well as relaxation of stay-at-home restrictions in May 2020.16 The decline in administrations resulted from the markedly decreased number of visits during the pandemic period in 2020 compared with 2019 (−35.5% and −71.6% decrease in well visits and other in-person visits, respectively; data not shown) despite more vaccine administrations per visit (0.31- and 0.15-dose increase per well visit and other in-person visit, respectively). As a result, the proportion of vaccinations at other in-person visits decreased during the pandemic period in 2020 compared with 2019 (23% vs 28%; data not shown). In addition, whereas administrations in all racial and ethnic groups plummeted during the stay-at-home period in 2020 compared with 2019, recovery was lower in non-Hispanic Black individuals than in other racial and ethnic groups during the reopening period (Supplemental Table 7), despite similar age distribution (Supplemental Table 6). Taken
Despite the less severe decrease and more rapid recovery in routine vaccine doses given to children aged <24 months compared with older children, the decline in vaccination coverage in this age group was immediate and more marked than it was in older children, reflecting shorter recommended vaccination intervals in young children and underscoring the importance of the CDC and AAP recommendation to focus initial efforts on vaccination of children <24 months of age.\(^5\)\(^6\) In contrast, vaccination coverage at 1 month did not change substantially, likely because the first dose of the hepatitis B vaccine is given in the hospital shortly after birth. Similarly, vaccination coverage in the 7-year cohort was only slightly decreased, likely because of California school immunization laws that require children to receive most Advisory Committee on Immunization Practices–recommended vaccines by 6 years of age.\(^2\) On the other hand, complete vaccination coverage among the 16-month cohort decreased slightly during the stay-at-home period then partially recovered during the reopening period, likely because most children received these vaccines at one-year visits a few months earlier. Therefore, the full impact of early decreases and subsequent increases in vaccine uptake on vaccination coverage was delayed by a few months in this age cohort. Similarly, vaccination coverage among the 13- and 17-year-olds did not change significantly during the stay-at-home period, reflecting vaccination in these cohorts before the pandemic, but decreased significantly during the reopening period, reflecting persistent decreases in vaccine uptake during the pandemic in children who subsequently turned 13 or 17 years of age. However, most worrisome is that although measles vaccination coverage was unchanged in the 7-year cohort, likely because of school vaccination requirements, there was a significant decrease in measles vaccination coverage among 16-month-olds that worsened over time, increasing the risk of measles outbreaks, particularly in day care settings, and underscoring the importance of catch-up vaccination in children who missed routine visits during the pandemic.\(^2\)\(^1\)\(^2\) Furthermore, although the severe decrease in adjusted measles-containing vaccine administrations among children improved, measles vaccine administrations remained substantially declined, and so the population of unvaccinated children is continuing to grow.\(^2\)\(^3\) This decrease is concerning because even small (2–5%) reductions in measles vaccination coverage are projected to result in

### TABLE 5 Measures Used to Increase Uptake of Recommended Vaccines in Children in KPSC During the COVID-19 Pandemic

<table>
<thead>
<tr>
<th>Measure</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize risk of exposure</td>
<td>Screen for symptoms of COVID-19 and contact with persons with possible COVID-19 before arrival and on arrival at the facility and isolate symptomatic patients as soon as possible. Limit and monitor points of entry to the facility and install physical barriers (plastic sneeze guards). Evaluate visitors and exclude as appropriate. Require cloth face covering in persons 2 y of age and older. Ensure adherence to respiratory hygiene, cough etiquette, and hand hygiene. Ensure staff adhere to prevention and control procedures. Employ standard precautions, including hand hygiene before and after all patient encounters and exposure to potentially infectious material and environment cleaning between patients. Require medical mask at all times, with mask type determined by potential for exposure. Use eye protection (goggles, face shield). Make spatial separation possible. Separate sick from well patients by time (eg, well visits in morning, sick visits in afternoon) or spatially (eg, different areas, different locations). Reduce crowding in waiting rooms. For example, patients remain outside (in vehicles if possible) until called into the facility for their appointment. This is also done in supporting departments, including pharmacy, laboratory, and radiology. Offer telemedicine visits for visits that do not require an in-person physical examination. Use hybrid telemedicine (history, virtual examination, discussion with parents) with in-person encounters for portions requiring face-to-face contact (vital signs, growth parameters, vaccinations, laboratory tests). Establish drive-through or parking lot vaccine clinics (facilities permitting) for older children (started with 11 y and older, now some areas seeing younger children). Outreach</td>
</tr>
</tbody>
</table>
exponential increases in measles outbreaks.\textsuperscript{24}

Reduction in vaccination coverage, particularly for highly contagious VPDs (such as measles), is of great public health concern because of the increased risk of outbreaks of VPDs that will likely worsen as measures taken to reduce the pandemic spread of SARS-CoV-2 are relaxed and as the risk of imported VPDs escalates because of the severe disruption of global vaccination during the COVID-19 pandemic.\textsuperscript{25,26} In addition, future decreases in vaccine uptake may be encountered if waves of SARS-CoV-2 infections recur and in-person visits again decline. Therefore, continued efforts to increase recommended vaccine uptake and ongoing monitoring of their impact on vaccination coverage in all pediatric age cohorts for possible improvements will be essential to preventing future outbreaks of VPDs.

The strengths of this study include demographic and comprehensive immunization data extracted from a large sample of children drawn from a racially and socioeconomically diverse population mirroring that of the Southern California population receiving care at multiple medical centers over a large geographic area.\textsuperscript{11} However, these results, drawn from a single health care organization in Southern California, may not be generalizable to all populations, including those with variably insured children with less access to health care or children from settings without EHRs that allow for active monitoring and outreach for needed recommended immunizations. Finally, although some children could be misclassified if they received vaccines outside of KPSC that were not entered into the EHR, the impact should be minimal because children are able to receive vaccines at KPSC without charge and providers are required to administer or document previous receipt of needed recommended vaccines at all encounters.

CONCLUSIONS

The number of vaccine doses, including the measles vaccine, given to children declined dramatically during the COVID-19 pandemic, resulting in decreases in complete vaccination coverage that persisted or worsened among several age cohorts as well as worsening decreases in measles vaccination coverage in young children. Although the number of vaccine doses given to children partially recovered during the reopening phase of the pandemic, pandemic waves are likely to recur, which will increase vaccine hesitancy and may severely limit health care resources and vaccination opportunities. Therefore, additional strategies, including intensive immunization tracking; reminders, particularly during virtual visits\textsuperscript{17}; and recall for needed vaccinations, especially in areas with high proportions of under-vaccinated children, will be required to increase vaccine uptake in all children, improve vaccination coverage, reduce disparities, and reduce the risk of outbreaks of VPDs.

ABBREVIATIONS

AAP: American Academy of Pediatrics
CDC: Centers for Disease Control and Prevention
CI: confidence interval
COVID-19: coronavirus disease 2019
DID: difference-in-difference
EHR: electronic health record
KPSC: Kaiser Permanente Southern California
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2
VPD: vaccine-preventable disease

FINANCIAL DISCLOSURE: Dr Ackerson and Ms Sy received research support from Moderna, GlaxoSmithKline, Dynavax, Seqirus, and Novavax for work unrelated to this study; Dr Qian received research support from Moderna, GlaxoSmithKline, Dynavax, and Genentech for studies unrelated to this study; Dr Jacobsen and Ms Park received research support from Dynavax for work unrelated to this study; and Ms Glenn and Dr Riewerts have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.

POTENTIAL CONFLICT OF INTEREST: Dr Ackerson and Ms Sy received research support from Moderna, GlaxoSmithKline, Dynavax, Seqirus, and Novavax for work unrelated to this study; Dr Qian received research support from Moderna, GlaxoSmithKline, Dynavax, and Genentech for studies unrelated to this study; Dr Jacobsen and Ms Park received research support from Dynavax for work unrelated to this study; and Ms Glenn and Dr Riewerts have indicated they have no potential conflicts of interest to disclose.

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Pediatrics  originally published online April 15, 2021; originally published online April 15, 2021;

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Pediatrics originally published online April 15, 2021; originally published online
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