




REVIEW

Impact of COVID-19 pandemic on routine vaccination coverage of children and adolescents: A systematic review

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Abstract

Background and Aims: Scientists and healthcare workers have expressed their concerns on the impacts of the COVID-19 pandemic on vaccination coverage in children and adolescents. Therefore, we aimed to systematically review the studies addressing this issue worldwide.

Methods: We conducted a systematic search of relevant studies using the keywords on databases of PubMed, Web of Science, and Cochrane on May 22, 2021. The identified records were imported into EndNote software and underwent a two-phase screening process consisting of title/abstract and full-text screenings against inclusion criteria. The data of the included studies were summarized into a table and the findings were analyzed in a systematic approach.

Results: From 26 eligible studies, 21 studies demonstrated decreased vaccination rates in the children during the COVID-19 pandemic, while three studies found increased or no significant changes only in influenza vaccination. The two remaining studies from Brazil and Sweden also showed no significant changes in vaccination rates in the children during the pandemic.

Conclusion: Most of the reports worldwide reported a decline or delay in vaccination at the time of the COVID-19 pandemic. A sustained catch-up program seems to be necessary, especially in low-income countries, to avoid any vaccine dose missing. Facilitating the vaccination process is recommended, such as decreasing the waiting time for vaccination at the health center, addressing the fear and concerns related to COVID infection for parents, and enhancing vaccine availability, and promoting access in remote areas. Countries should ensure proper vaccination to prevent future pandemics related to vaccine-preventable diseases.

KEYWORDS

children, COVID-19, pediatrics, SARS-CoV-2, vaccination coverage, vaccine

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1 | INTRODUCTION

The coronavirus disease 2019 (COVID-19) represents one of the most challenging and concerning public health crises of the last century.^{1,2} The COVID-19 pandemic is a multifaceted health crisis that severely affected essential health services provision, placing an enormous burden on healthcare systems and economies of countries.^{3,4} The unprecedented spread of COVID-19 and its characteristics have highlighted the need for quick solutions.⁵⁻⁷ All countries have initiated measures to reduce the outbreak, including social-distancing mandates, closure of nonessential businesses, quarantine, and shifting healthcare resources to the COVID-19 response.⁸⁻¹⁰ This will have widespread implications for the control of other chronic diseases and preventable illnesses.¹¹ Childhood immunization is one of the most cost-effective and successful public health

measures that could reduce the morbidity and mortality rates for vaccine-preventable diseases (VPDs).¹²

The COVID-19 pandemic is disrupting routine child immunization services around the world and threatening the gains made in the control of VPDs for the past two decades.^{3,13} The World Health Organization (WHO) has stated that routine immunization programs have been substantially disrupted in at least 68 countries, affecting more than 80 million children worldwide, especially in poor countries.^{14,15} The reduction of child vaccination coverage, even for brief periods during emergencies, could cause an increased number of susceptible individuals and raise the risk of outbreak-prone VPDs such as measles, polio, and pertussis.^{14,16}

Outbreaks of VPDs could be dreadful for a health system that is already battling the impacts of COVID-19, and substantively increase morbidity and mortality in the age groups most at risk.¹ For this



PRISMA 2009 Flow Diagram

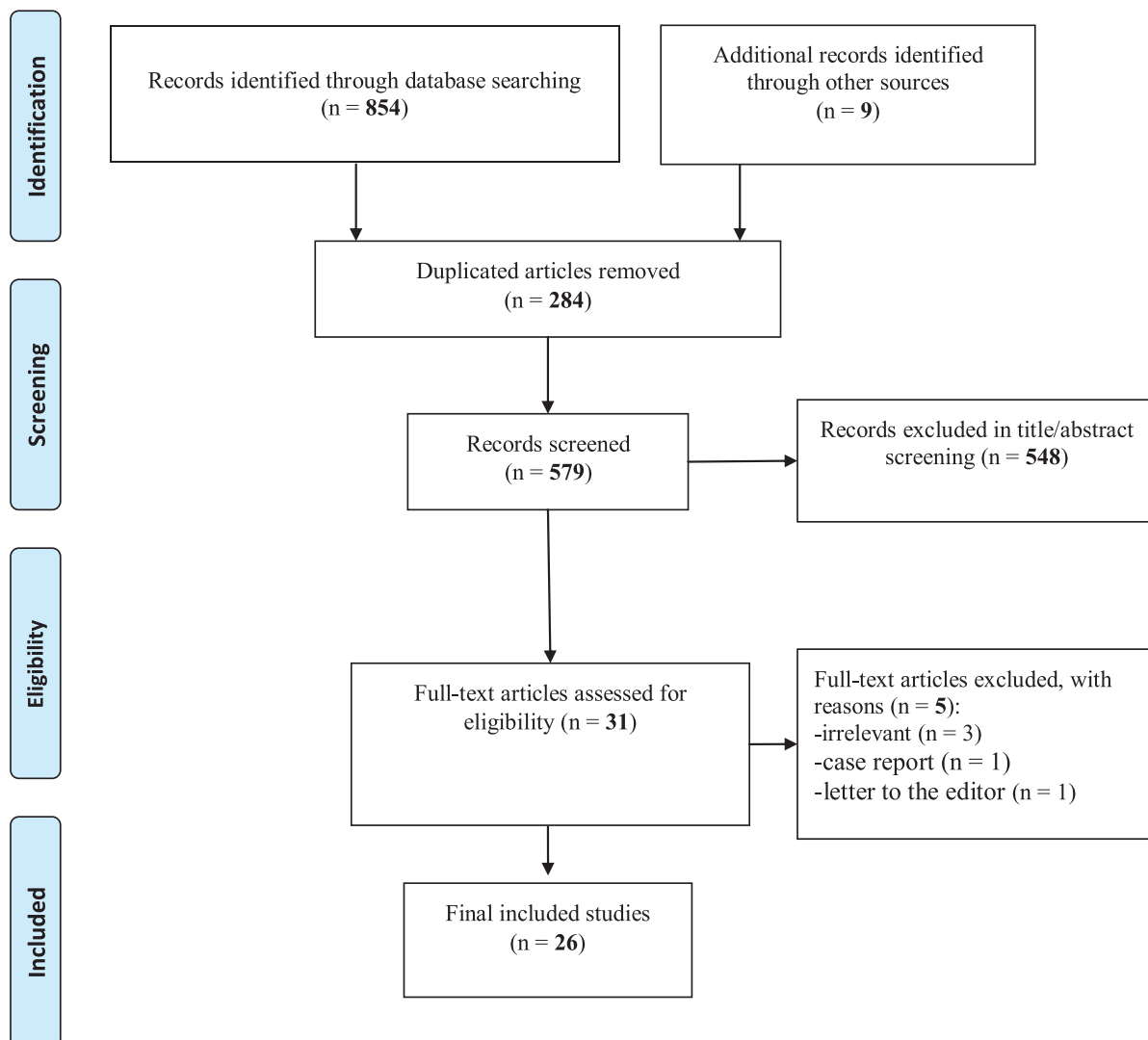


FIGURE 1 PRISMA flow diagram of the study's selection process. PRISMA, Preferred Reporting Items for Systematic Reviews

reason, maintaining vaccination services to prevent the outbreak of VPDs which could be potentially life-threatening is vital for all countries.⁸ Several barriers are contributing to child immunization services during the pandemic, including parental and provider concerns of exposure to COVID infection, transportation restrictions, and redeployment of healthcare resources to COVID-19.¹¹ The WHO recommends routine immunizations programs to be continuously provided to maintain high levels of coverage under safe conditions.^{1,17} The pandemic must not be seen as an obstacle to compliance with routine immunizations, but rather as a reminder of the importance of vaccination as an essential public health strategy for disease prevention.^{18,19}

Among the financial consequences of VPDs can be diarrhea in children under 5 years of age²⁰ and febrile illness among under-five children.²¹ A significant financial burden is borne by the families themselves for the treatment of diarrhea in children under five due to a lack of medical insurance.²⁰ It is important to monitor the cost of health care in different types of health centers. The high cost of treatment requires adequate financial support for all as provided in the Global Health Coverage. There is room for indirect cost reduction through appropriate policy decisions to increase access to and availability of healthcare services.²¹

We hypothesized that the routine vaccinate rates might have declined due to the pandemic and its possible effects, such as fear of getting infected and limited accessibility related to the quarantines. Therefore, The objective of this systematic review was to identify and summarize the impacts of the COVID-19 pandemic on routine vaccination coverage of children and adolescents.

2 | METHODS

2.1 | Overview

This study was conducted according to the Preferred Reporting Items for Systematic Reviews 2020 guidelines. We conducted a systematic search for relevant studies using the keywords on databases of PubMed, Web of Science, and Cochrane on May 22, 2021. The relevant records, based on the inclusion criteria, were retrieved and imported into the EndNote software for further screening. The screening process consisted of two phases: first, the researchers identified the eligible studies based on their title and abstract. Then, they carefully read the full-texts of the studies and included the eligible articles for this systematic review. A summary of included studies was then extracted into a table.

2.2 | Search strategy

We searched the title/abstract for a combination of relevant keywords such as “COVID-19,” “vaccination,” and “pediatrics, adolescent.” The final search strategy is illustrated in line [D].

A. [COVID-19] OR [SARS-CoV-2] OR [SARS-CoV2] OR [2019-nCoV]
 B. [Vaccine] OR [Vaccination] OR [Immunization] OR [Active immunization]

C. [Pediatrics] OR [Child] OR [Children] OR [Adolescent] OR [Teen] OR [Teens] OR [Teenager] OR [Teenagers] OR [Youth]
 D. [A] AND [B] AND [C]

2.3 | Study selection

We included the original articles that evaluated the effects of the COVID-19 pandemic on vaccine coverage of children and adolescents. Articles from any languages and from the start of the pandemic (December 2019) until May 22 were included. The exclusion criteria were as follows:

1. Reviews, meta-analyses, and any studies without original data;
2. Abstracts or other studies lacking available full texts;
3. Case reports;
4. Studies on the adult population;
5. Pure laboratory or animal studies without clinical data;
6. Studies not related to routine vaccinations, for example, those related to COVID-19 vaccines.

2.4 | Data extraction

We extracted and summarize the following information into a table: authors' names, study type (eg, cross-sectional), country of study, study population, patient mean age and sex, type of vaccines, vaccine coverage before and after the COVID pandemic, a summary of main findings. Measured viral load, and disease outcome, and gathered them in a specifically designed sheet. Data extraction was performed by three independent researchers and another researcher reviewed the tables and resolved any possible discrepancies.

3 | RESULTS

In this review, 863 documents were identified using a systematic search strategy. In the preliminary review, 284 duplicates were removed, and the title and abstract of the remaining were reviewed during which 548 studies were excluded. Finally, after full-text articles were assessed for eligibility, 26 studies were included (Figure 1). These studies explored the impact of the COVID-19 pandemic on vaccination coverage of children and were conducted in the USA ($n = 4$), Saudi Arabia ($n = 3$), Japan ($n = 2$), Brazil ($n = 2$), Ethiopia ($n = 2$), the Republic of Korea ($n = 1$), Singapore ($n = 1$), China ($n = 1$), Morocco ($n = 1$), Italy ($n = 1$), the African region ($n = 1$), Switzerland ($n = 1$), Pakistan ($n = 1$), Sweden ($n = 1$), Sierra Leone ($n = 1$), Turkey ($n = 1$), India ($n = 1$), and between countries ($n = 1$). From 26 included studies, 21 reported decreasing in vaccination due to the COVID-19 pandemic, three studies show increases or no major changes in the influenza vaccination rate,²²⁻²⁴ and two studies from Brazil²⁵ and Sweden²⁶ did not provide strong evidence that the COVID-19 pandemic affected the immunization of children (Table 1).

TABLE 1 Details of the included studies

First author ID (reference)	Type of study	Country	Study population (N)	Mean Age (% years)	Female (%)	Type of vaccine	Vaccination coverage before 2019 (%)	Vaccination coverage after 2019 (%)	Summary of findings
1 Ahmed, T. ²⁷	Cohort	Bangladesh, Nigeria, and South Africa	Data from the national health management information system of Bangladesh and 2 teaching hospitals both in Nigeria & South Africa	N/A	N/A	Measles and rubella	113.5% in March 150.4% in April		There was a reduction in utilization of antenatal care and immunization during April/May 2020
2 Almoosa, Z. ²⁸	Cross-sectional study	Saudi Arabia	378 children	0-6 years	47.4%	Birth vaccine, 2, 4, 6, 9, 12, 18 months 2 and 4-6 years vaccine	25.4% have previously delayed their child vaccination 74.6% not delayed	66.9%	Almost 33% of parents did not vaccinate their children during the pandemic There might be an association between the educational level of parents and adherence to routine vaccination of children
3 Alrabiaah, A. ²⁹	Retrospective cohort	Saudi Arabia	15 870 children	0-1 year	N/A	Birth vaccine, 2, 4, 6, 9, 12 months vaccines	4712 vaccination visits	1735 vaccination visits 149.93% in March 171.9% in April 168.5% in May	Reduction of vaccinations for birth 2, 4, 6, 9, and 12 months were 1.65%, 80.5%, 74.7%, 72.9%, 80%, and 74.1%, respectively
4 Alsuhailani, M. ³⁰	Cross-sectional study	Saudi Arabia	749 parents	0-2 years Parents: 49.8% (31-40 years)	Mothers: 82.6% Children: N/A	Birth vaccine, 2, 4, 6, 9, 12, 18, 24 months vaccines		73.2%	The COVID-19 pandemic affected the timelines of immunization in Saudi Arabia
5 Alves, J. ²⁵	Short communication	Brazil	N/A	0-1 year	N/A	Vaccination program of children under 1 year	The maximum number of doses per child was 13 in March 2017		This analysis did not provide strong evidence that the COVID-19 pandemic affect the immunization of Brazilian children at the national level
6 Bramer, C. ³¹	Cohort	US	9269 average for each cohort	0-2 years	N/A	1, 3, 5, 7, 16, 19, and 24 months	For age 5 month: average 66-67% 16 months: 76.1%	5 months: 49.7% 16 months: 70.9%	Vaccination coverage declined in all age cohorts except for the birth dose of hepatitis B coverage (which is administered in the hospital at birth)
7 Buonsenso, D. ³²	Retrospective cross sectional study	Sierra Leone	About 5000	0-5 years	N/A	Vaccination program of children under 5 years		150-80%	50-80% drop in vaccination in 2020 compared to 2019
8 Carias, C. ³³	Cohort	US	N/A	N/A	N/A	Measles	85%	50%	Measles vaccination coverage decreased
9 Chandir, S. ³⁴	Cross sectional study	Pakistan	>3.1 million children enrolled	0-23 month	N/A	BCG, Polio, penta, PCV10, rotavirus, and measles		152.5%	There was a 52.5% decline in vaccinations and the highest decline was seen for BCG (40.6%)
10 Russo, R. ³⁵	Cross sectional study	Rome, Italy	1474	0-11 years	N/A	cholera, measles, meningitis, polio, tetanus, typhoid, and yellow fever		North of Italy (33.89), Centre of Italy, ²⁶⁻⁴² South of Italy (40.09)	More than one third (34%) of them skipped the vaccine appointment as they were afraid of SARS-CoV-2-virus (44%), vaccination services postponed the appointment (42%) or was closed to the public (13%)

TABLE 1 (Continued)

First author ID (reference)	Type of study	Country	Study population (N)	Mean Age (% years)	Female (%)	Type of vaccine	Vaccination coverage before 2019 (%)	Vaccination coverage after 2019 (%)	Summary of findings
11 Seiler, M. ²²	Cross sectional study	Switzerland	662	N/A	N/A	Influenza	7.2% (47/654)	20.4% (134/657)	The majority of children (92%; 602/654) were up-to-date on their vaccination schedule. In 2019/2020, 7.2% (47/654) were vaccinated against influenza. Children with chronic illnesses were more frequently vaccinated than healthy children (19.2% vs 5.6%; $P = .002$)
12 Silveira M. F. ³⁶	Cross-sectional study	Brazil	2439	0–3 years	1180	(BCG), diphtheria, tetanus, pertussis, hemophilus influenza B and hepatitis B, polio, measles, mumps, and rubella vaccine	80%	60%	The overall response rate in the nationwide survey was 55%, due to logistic difficulties during the lockdown period. No family members were at home in 22% of the households and in another 23% the residents refused to undergo a test for COVID antibodies
13 Sokol R. L. ²³	Cross sectional study	US	1893	ages 6 months to 5 years	912	Influenza	25%	38%	The COVID-19 pandemic alone does not appear sufficient to encourage the uptake of pediatric seasonal influenza vaccination.
14 Tegegne A. W. ³⁷	Cross sectional study	Ethiopia	1300	Aged 10–23 months	N/A	(BCG), diphtheria, tetanus, pertussis, hemophilus influenza B and hepatitis B, polio, measles, mumps, and rubella vaccine	From all the respondents, 1110 (85.4%) took both BCG and OPV vaccines, from 1110 BCG started children only 798 (71.8%) of the children complete their immunization. Of the total 1300 children, 190 (14.6%) of them were not taking any vaccine at all. Overall 1088 (83.7%) of them received both PCV one and Penta one, 1082 (83.2%) received rotavirus and 798 (61.4%) received measles vaccine.	Variables significantly associated with incomplete immunization among children aged 10–23 months were time waiting at a health facility, place of delivery, educational status of the women, not understanding the separation care of COVID-19	
15 Yu J. H. ³⁸	Cross-sectional study	Republic of Korea	N/A	Under the age of 6 years	N/A	(BCG), diphtheria, tetanus, pertussis, Hepatitis B, polio, measles, mumps, rubella, DTaP, IPV, PIVC, MMIR, JE	(97%)	The vaccination rate in children aged 0–35 months in Korea did not decrease significantly, whereas the vaccination rate for children aged 4–6 years decreased by 1.4–1.9%. The overall incidence of VPDs decreased by 10–50%	

(Continues)

TABLE 1 (Continued)

First author ID (reference)	Type of study	Country	Study population (N)	Mean Age (% years)	Female (%)	Type of vaccine	Vaccination coverage before 2019 (%)	Vaccination coverage after 2019 (%)	Summary of findings
16 Zhong Y. ³⁹	Multicenter retrospective cohort	Singapore	N/A	12-month to 2-year-olds	N/A	MMRV vaccine, the pentavalent Diphtheria-Tetanus-Pertussis-inactivated Polio-Haemophilus influenza (5-in-1) vaccine, including the hexavalent Diphtheria-Tetanus-Pertussis-inactivated Polio-Haemophilus influenza-hepatitis B (6-in-1), and the 13-valent Pneumococcal conjugate vaccine			between 2019 and 2020, especially with varicella The authors found a 25.6% to 73.6% drop in MMR uptake rates, 0.4–10.3% drop for Diphtheria-Tetanus-Pertussis-inactivated Polio-Haemophilus influenza (5-in-1), and 8.0–67.8% drop for PCV across all 3 sites. Consequent herd immunity reduces coverage that is protective for measles
17 N. Chekhab ⁴⁰	Cross-sectional study	Morocco	103 pediatricians	39	82.5%	1, 2, 3, 4, 9, 12, 18 months		82.5% of parents were hesitant to come to the office to get the vaccine, 6% refused to do the vaccine during the COVID 19 period and 11.5% of parents, on the other hand, insisted on doing the vaccine on time	Pediatricians quickly changed their vaccination strategy in favor of strengthening and catching up in order to compensate for this slackening
18 Falkenstein Hagander K. ²⁶	Cross-sectional	Sweden	21 Regional child health offices			Measles mumps rubella vaccine diphtheria-tetanus-pertussis-polio		90%	The Swedish immunization program was resilient during the early COVID-19 pandemic, thanks to sustainable organization coordinated by Sweden's network of regional child health offices.
19 Hou Z. ²⁴	Cross-sectional online survey study	China	1655 children aged 3 to 17 years	3–17	50%	Influenza	During the 2019 flu season, 54.7% (905/1655) of families had taken their children or adolescents to receive the influenza vaccination	80.9% (1339/1655) of parents intended to vaccinate their children or adolescents against influenza in the future after the epidemic, a rate much higher than that before the epidemic	Prevention behaviors and attitudes toward influenza vaccination have improved during the COVID-19 epidemic. Public health prevention measures should be continuously promoted, particularly among girls, parents with lower education levels, and larger families. Meanwhile, misinformation about COVID-19 remains a serious challenge and needs to be addressed by public health stakeholders

TABLE 1 (Continued)

First author ID (reference)	Type of study	Country	Study population (N)	Mean Age (% years)	Female (%)	Type of vaccine	Vaccination coverage before 2019 (%)	Vaccination coverage after 2019 (%)	Summary of findings
20 Kara A. ⁴¹	Retrospective cross-sectional study	Turkey	Family practitioners, pediatricians, and pediatric infectious disease specialists					Vaccination rates in Ankara have decreased 2–5% during the pandemic, and the greatest decrease was observed for vaccines administered after 18 months of age	
21 Kitano T. ⁴²	Cross sectional	Japan	Japanese population			<i>Haemophilus influenzae</i> type b	97%	73%	The persistent decline of the Hib vaccination rate due to COVID-19 causes an incremental disease burden irrespective of the possible decline of the Hib transmission rate by COVID-19 mitigation measures. Rapid recovery of vaccination coverage rate can prevent this possible incremental disease burden
22 Kitano T. ⁴³	Cross-sectional	Japan	Japanese population			Pneumococcal vaccine			A persistent decline in the childhood pneumococcal vaccination rate due to the impacts of COVID-19 could result in an increase in the IPD incidence and an incremental disease burden. These increases are primarily because of an increase in VT IPD. A rapid recovery in the vaccination coverage rate could prevent this possible increase in the disease burden. Sustaining a high pneumococcal vaccination rate is important for minimizing the disease burden of childhood IPD, even though the impact of vaccination appears to be minimal due to serotype replacement
23 Masresha B. G. ⁴⁴	Cross-sectional	African countries	African population			Diphtheria-pertussis-tetanus measles		13 of the 15 countries showed a decline in the monthly average number of vaccine doses provided, with 6 countries having more than 10% decline. Nine countries had a lower monthly mean of recipients of first dose measles vaccination in the second quarter of 2020 as compared to the first quarter. Guinea,	Countries with lower immunization coverage in the pre-COVID period experienced larger declines in the number of children vaccinated immediately after the COVID-19 pandemic was declared. Prolonged and significant reduction in the number of children vaccinated poses a serious risk for outbreaks such as measles. Countries should monitor coverage trends at national and subnational levels, and undertake catch-up vaccination activities to ensure that children

(Continues)

TABLE 1 (Continued)

First author ID (reference)	Type of study	Country	Study population (N)	Mean Age (% years)	Female (%)	Type of vaccine	Vaccination coverage before 2019 (%)	Vaccination coverage after 2019 (%)	Summary of findings
24 Miretu D. G. ⁴⁵	Cross-sectional	Ethiopia	633 children aged 15–23 months				Nigeria, Ghana, Angola, Gabon, and South Sudan experienced a drop in the monthly number of children vaccinated for DPT3 and/or MCV1 of greater than 2 standard deviations at some point in the second quarter of 2020 as compared to the mean for the months January–June of 2018 and 2019	who have missed scheduled vaccines receive them at the earliest possible time	
25 O'Leary S. T. ⁴⁶	Cross sectional	USA	0-18 years old			(Haemophilus influenzae type b; 13-valent pneumococcal conjugate; and measles, mumps, and rubella vaccines)			Age-eligible vaccination coverage during the COVID-19 outbreak was 12.5% lower than before the outbreak In individuals aged 0–2 years, the rate of immunizations dropped by 4581 (95% CI, 2965–6196) immunizations per week ($P < .001$). In individuals aged 3 to 9 years, it dropped by 2486 (95% CI, 568–4408) immunizations per week ($P > .99$), and in individuals aged 10 to 17 years, it dropped by 4060 (95% CI, 2156–5965) immunizations per week ($P < .001$)
26 Jain, R ⁴⁷	Retrospective cross-sectional study	India	2144 Children under 1 year old (children that turned At least 12 months old between January and October 2020)	48%		First year immunization like measles	74.5% during lockdown	9.7% to 14.0% reduction during lockdown	9.7% to 14.0% reduction of first year immunization during lockdown Decline is larger in poorer & less educated families During lock down children were less likely to be immunized at or before 9 months but more likely to be immunized at 10–12 months Coverage dropped to 70.4% and 64.1% in partially exposed and heavily exposed children respectively and increased to 71% in postexposure children

Abbreviations: COVID-19, coronavirus disease 2019; IPD, invasive pneumococcal disease; MMRV, measles-mumps-rubella-varicella; PCV, pneumococcal conjugate vaccine; VPDs, vaccine-preventable diseases.

The present study results showed that the COVID-19 pandemic significantly decreased the vaccination coverage in children.

4 | DISCUSSION

This review aimed to evaluate the vaccination coverage of pediatrics and the potential decline due to the COVID-19 pandemic. Twenty-one of 26 studies included in this review revealed a decrease in the children vaccination rate during the pandemic or delay in vaccination,^{24,27–37,39–46} up to 80% decrease in some cases compared to the time before the pandemic.²⁹ The COVID-19 pandemic influenced the public health priorities and changed their directions inadvertently; thus, many preventive programs failed to continue and function properly as they did before.²⁷ Our findings suggest the following reasons for this event:

1. Parental hesitation in well-child visits existed in almost all the studies reporting decreased immunization. Parents refused to bring their children to vaccination centers due to fear of COVID infection^{32,39}; some mothers even preferred to labor at home; therefore, the first vaccine doses were missed.³² COVID-19 fear overshadowed the importance of routine immunization in the public eye in the UK during the pandemic.⁴⁸ In a survey in Italy, 44% of parents skipped their child's immunization program due to uncertainties about the safety of the immunization centers and the risk of contacting COVID-19.³⁵ Moreover, in a study from Saudi Arabia, the main reason for vaccination delay was the unwillingness of the parents to get their children vaccinated.³⁰ Similar behavior was observed in Singapore, Pakistan, and African countries.^{34,39,49} Reluctance toward health services has been reported in past epidemics, and apparently the COVID-19 pandemic is not an exception.⁵⁰ Fear of contagion mixed with lack of information or misinformation concerning both vaccination and COVID-19 raise the vaccine hesitancy.⁵¹ Prepandemic awareness-raising campaigns regarding the importance of vaccination were suspended due to some countries' quarantine, further expanding the public uncertainties toward vaccination.⁴⁴
2. Social distancing policies and lockdown implementation contributed to disrupted immunization in high-income countries as many healthcare centers were shut down. The US studies demonstrated a decline in vaccination uptake after implementing the stay-at-home orders and quarantine policies.^{18,33,52} A study in Colorado showed a sharp decline in vaccination rate immediately after the release of social distancing guidance.⁴⁶ Canceled vaccine appointments due to closed health centers were reported in African countries, Pakistan, China, and Saudi Arabia.^{30,34,49,53} In Pakistan, suspended transportation and cease in the outreach vaccination program was reported to be the reason for vaccination delay.³⁴ While in countries like Sweden, vaccine-providing centers were primarily open during the lockdown, and in China, the 75% delay in vaccination was due to the closure of vaccination centers alongside the public concerns about COVID-19.⁵³ In this regard, Sweden provided sustained national immunization programs during the pandemic, while China did not have such programs for some time, which may correlate to the observed changes in the subsequent vaccination rates.²⁶
3. Severe shortages of healthcare providers and disruptions in the supply chain due to border closures and travel restrictions, contribute to disrupted immunization programs in many countries, especially developing countries.¹³ Developing countries with weaker health systems are at greater risk of health service disruptions.⁵⁴ Redistribution of health workers and the budget was a major contributing factor in declined vaccination rate in Pakistan and some African countries.^{34,49} Some reports in developing countries showed that most of the health budget and centers were diverted on COVID-19, leaving little focus on other health services, including vaccination.⁴⁹ In Pakistan, postpandemic policies eliminated outreach vaccination services by not sending vaccinators out. As a result, a 79% decline in the vaccination rate of children using these services happened, who were already at greater risk of missing vaccination before the pandemic.³⁴
4. The absence of clear guidelines and recommendations for non-COVID-19 issues and ineffective communication between healthcare staff and policy makers lead to confusion and heterogeneous decision making in health centers in some countries, including Pakistan, Bangladesh, and Nigeria.^{34,49} Lack of personal protective equipment, including masks, shields, and hand sanitizers for health workers in the absence of comprehensive guidelines, made the staff reluctant to engage with patients in primary health centers.
5. Despite the drop in uptake of most pediatric vaccines, influenza vaccine demand increased in some countries.^{22,53} In a postpandemic survey in Switzerland, parents expressed tremendous enthusiasm for influenza vaccination of their children, more than double the rate from the last year.²² Similar behavior was observed in China, with 80% of parents in a study declaring their willingness for the influenza vaccine.⁵³ Moreover, a study in the USA reported that parents with a history of vaccinating their children against influenza intended to continue influenza vaccination during pandemic.²³ The global issue of COVID-19 seems to change public behavior toward influenza vaccination in countries overwhelmed by COVID-19 the most.^{22,24,55}

A significant drop in vaccination rate, especially in the low-income countries, may result in dangerous sequels regarding child health.^{32,34} It can potentially increase the mortality and morbidity from polio, measles, and other VPDs, particularly in countries with low coverage.³⁴ Subsequent outbreaks may occur when the vaccination coverage drops and this would impose an additional burden on the already overloaded health system in the COVID-19 era.³⁵ Concerning the importance of immunization in children, not disrupting it even for a short time, the WHO declared the immunization guideline during the pandemic in the document "Guidance on routine immunization services during COVID-19 pandemic in the WHO European Region".⁵⁶ In a study by Zhong et al., as high as 25.6% to 73.6% decline in measles-mumps-rubella (MMR) vaccination was observed.³⁹ The

vaccine coverage among 1-2 years old infants will be less than the target for herd immunity (95% coverage) given a missed MMR dose. Thus, the emergence of measles outbreaks is not unimaginable, as experienced before in not highly vaccinated populations.^{39,57} Also, Kitano et al. warned about the consequences of a decline in Hib and pneumococcal conjugate vaccine and projected an increase in the incidence of Hib and invasive pneumococcal disease (IPD) and the related burden of the disease if the decline in vaccination persists during the pandemic.^{42,43}

While most of our studies reported disruptions in routine pediatric vaccination schedules, some countries sustained their immunization program via catch-up strategies, only facing brief periods of decline in immunization rate. In the Republic of Korea, the pediatric vaccination program remained sustained due to the high-powered national vaccination program and minimal cost of vaccination. Similarly, the pediatric immunization program was proceeding on the usual schedule in Switzerland and Sweden.²² In other studies, this sustained vaccination was due to the fact that these studies merely evaluated vaccination rate of newborns and infants. Given the fact that their vaccines, including BCG and hepatitis B are administered at the labor room, missing them seemed less likely.^{25,36}

It appeared that the infants were less likely to miss their vaccination than older toddlers during the COVID pandemic.^{26,53} This may suggest that parents put the vaccination of their infants at priority. Besides, toddlers are more active than infants, thus at greater risk of catching VPDs. Consequently, missed vaccinations and greater exposure to diseases make older children a target population for potential future outbreaks.

To avert the reported vaccination disruptions, World Health Organization released guiding principles suggesting compensation strategies for the disrupted immunization plan.⁵⁸ Re-opening health centers while gaining public trust in vaccination clinics is a milestone. Several measures minimize the possibility of COVID-19 exposure in the vaccination process. These include devoting places and times to vaccination-only services, using safety protocols by the vaccinators, limiting the number of people in clinics, and changing public perception of vaccination and consequences of the delay. Vaccination sites can expand by adding in-car and in-home vaccination programs to the routine in-clinic immunization or establishing mobile vaccination centers.^{26,59,60} Skipped pediatric vaccinations can be detected in electronic health records. By implementing the Reminder/Recall system, parents can be informed via email, text messages, or phone calls during the pandemic.^{61,62}

Our study faced limitations mainly due to included studies' limitations. Most of the included studies have a retrospective or cross-sectional design, making it difficult to compare the vaccination coverage before and after the COVID-19 pandemic. In some included studies, parents involved in the study were not representatives of all parents at the research site. Also, some studies reported a low rate of response from the study population. In addition, the time period of studies was short and only represented a specific period. In this regard, studies are unable to differentiate between postponed or canceled vaccination. The trend of immunization among children and

fluctuation of vaccination is also different during multiple periods of the pandemic.

5 | CONCLUSION

Most of the reports worldwide represent a decline or delay in vaccination during the COVID-19 pandemic. Continuation of childhood vaccination programs is essential to the child's health and must be prioritized and sustained even during pandemics. A sustained catch-up program is necessary, especially in low-income countries, to avoid any vaccine dose missing. Facilitating the vaccination process is recommended, such as decreasing the waiting time for vaccination at the health center, addressing the concerns and fears related to the COVID-19 for parents, and enhancing vaccine availability, and promoting access in remote areas. Timely and persistent vaccination is the key to preventing future inadvertent epidemics from VPDs.

ACKNOWLEDGMENT

The present study was conducted in collaboration with Khalkhal University of Medical Sciences, and Iranian Research Center for HIV/AIDS, Tehran University of Medical Sciences, Tehran, Iran.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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TRANSPARENCY STATEMENT

Esmail Mehraeen affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

AVAILABILITY OF DATA AND MATERIAL

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT TO PUBLICATION

Not applicable.

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How to cite this article: SeyedAlinaghi S, Karimi A, Mojdeganlou H, et al. Impact of COVID-19 pandemic on routine vaccination coverage of children and adolescents: A systematic review. *Health Sci Rep*. 2022;5:e00516. doi:10.1002/hsr2.516