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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2023-076607
Article Type:	Original research
Date Submitted by the Author:	12-Jun-2023
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Keywords:	COVID-19, Health Equity, Public health < INFECTIOUS DISEASES

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COVID-19-related disruption and resiliency in immunisation activities in LMICs: a rapid review

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June 12, 2023

Abstract

Objectives

Rapid review to determine the extent that immunisation services in LMICs were disrupted by the COVID-19 pandemic and what factors can be considered to build resilience in future.

Setting

We searched PubMed on 28th Feb 2023 for studies published after 1st December 2019 in English that focused on LMICs.

Participants

Screening and data extraction were conducted by two experienced reviewers with one reviewer vote minimum per study per stage. Of 3801 identified studies, 66 met the eligibility criteria.

Outcomes

Routine vaccine coverage achieved; Supplementary immunisation activity timing; Vaccine doses given; Timing of vaccination; Supply chain changes; factors contributing to disruption or resilience.

Results

Included studies showed evidence of notable declines in immunisation activities across LMICs related to the COVID-19 pandemic. These have included reductions in achieved routine coverage, cancellation or postponement of campaigns, and underimmunised cohorts. Immunisation was most disrupted in the early months of the pandemic, particularly March to May 2020; however, the amount of recovery seen varied by country, age-group, and vaccine. Though many countries observed partial recovery beginning after lockdown policies were lifted in 2020, disruption in many countries has also continued into 2021. It has

also been noted that clinician staff shortages and vaccine stock outs caused by supply chain disruptions contributed to immunisation delays but that concern over COVID transmission was a leading factor. Key resiliency factors included community outreach and healthcare worker support. Finally, whilst our search took place in February 2023, the latest dataset used across all studies was from November 2022 and many focused on 2020; as a result some of the study conclusions do not take recovery into account.

Conclusions

There is limited information on whether reductions in vaccination coverage or delays have persisted beyond 2021. Further research is needed to assess ongoing disruptions and identify missed vaccine cohorts.

Strengths and limitations of this study

- The rapid synthesis of findings related to immunization disruption and recovery to-date allows for key insights to target missed cohorts and identify research gaps.
- We include a narrative analysis of disruption across LMICs; this review benefits from the inclusion of barriers, enablers, and resilience to/in service provision.
- The search strategy was limited to studies published on PubMed up to February 28th, 2023, meaning not all relevant research meeting inclusion criteria may have been captured.

1 Introduction

The COVID-19 pandemic began on December 12th 2019 and quickly spread globally, adding to the strain on existing healthcare provision and creating unique problems in terms of service delivery [1]. Throughout 2020 there were disruptions to screening for cancer, maternal health services, care for chronic conditions such as diabetes, and immunisations [2]. This strain on health services has continued past 2020, as even those that have to recovered pre-COVID levels of visits and surveillance have to catch-up missed cohorts and delayed treatments.

LMICs disproportionately bear the burden of vaccine preventable diseases [3]; however, globally vaccination has seen a stagnation in coverage and zero-dose children are a concern. The issue of zero dose or underimmunised children is particularly important as it can hint at wider heterogeneity in healthcare access which may have been exacerbated by the pandemic [4]. It is estimated that 67 million children missed vaccinations between 2019 and 2021; of those, 48 million were zero-dose children [5]. Furthermore, targeting zero-dose children can be more difficult as they are often in harder-to-reach areas, particularly in LMICs where 1 in 6 children living in rural areas are zero-dose [5].

Resilient healthcare systems can withstand additional and unusual strains whilst maintaining priority services. Yet, is is still uncertain what factors contributed to disruption or resilience in light of the COVID-19 pandemic, which was a unique test on global healthcare systems. These factors and considerations may be instrumental in preparing for future healthcare strains such as those potentially caused by other epidemics, climate change, or antimicrobial resistance. As such, understanding the key factors for disruption due to the COVID-19 pandemic is critical for future planning in order to minimise the negative consequences of disruptions.

In order to understand the current state of vaccination coverage disruption, and highlight factors contributing to resilience, we undertook a rapid review of the existing literature. This focused on LMICs as they bear the majority of burden of vaccine preventable diseases. We included studies that not only discuss the quantitative measures of disruption such as reduced immunisation coverage and cancelled campaigns, but also more qualitative discussions of the factors contributing to disruption or characteristics of resilient systems.

2 Aim and research questions

The aim of this review was to understand the extent of disruptions in vaccination coverage due to the COVID-19 pandemic and what factors contributed to the disruption or resilience. Specifically, our research questions were:

RQ1: To what extent were immunisation services in LMICs disrupted by the COVID-19 pandemic?
RQ2: How did disruption vary by geography, demography or socioeconomic group?
RQ3: What factors contributed to coverage disruption or resilience?

3 Methods

A rapid review (RR) was conducted using streamlined systematic review methods and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6].

3.1 Procedure

We searched PubMed on 28th Feb 2023 for studies published after 1st December 2019 in English with search terms (((COVID-19) OR (SARS-CoV-2))) AND (immunisation OR vaccination) AND (disruption OR delay* OR postpon*). Studies were included if they focused on disruption to vaccination activities due to the COVID-19 pandemic in LMICs. Studies were excluded if they focused on high income countries only, examined disruption due to other factors ie. not related to the pandemic, or were reviews, commentaries or modelling studies without novel data.

3.2 Study selection, data extraction and quality assessment

Search results were imported into the Covidence (`www.covidence.org`) systematic review management tool where duplicates were removed. Titles and abstracts were screened by one reviewer, full text review was completed by two reviewers with conflicts resolved through consensus.

Each study was extracted by one reviewer into a Google sheet. We extracted information on i) last date of included data, ii) countries studied, iii) qualitative findings related to the research questions RQ1, RQ2 and RQ3, and iv) binary data on whether routine immunisation, SIAs, doses, schedule timing or supply chains were mentioned in the study. A second reviewer was consulted where there was uncertainty concerning the extracted data.

To expedite the review we did not use a formal quality assessment tool. instead, we focused on the scope of the study in terms of population, schedules considered and time window to assess the generalisability of the findings.

3.3 Synthesis

There were two main types of evidence to synthesise. Quantitative information on percentage drops in coverage achieved, doses administered or SIAs postponed, and more qualitative discussion on contributing factors informed by surveys or questionnaires. We grouped results by research question with the first question the most quantitative. Finally we collate characteristics of the studies themselves such as countries studied or dates of included data, for which we have prepared summary statistics.

3.4 Patient and public involvement

There was no patient or public involvement in this study.

4 Results

4.1 Characteristics of studies

We found 3801 studies where 66 met the inclusion criteria 1. The majority of studies were published in either 2021 (n = 30; 45.45%) or 2022 (n = 27; 40.91%), though most studies only reported on data from 2020 (n = 46; 69.70%). 10 studies (15.15%) included data during the first 6 months of 2021; a further 8 (12.12%) included data between July and December of 2021. Only 2 studies (3.03%) included data from 2022; the most recent of these covered data through November of 2022.

Most (n = 16; 24.24%) of the studies considered multiple LMICs. Of those that only considered one country, India (n = 8; 12.12%), Ethiopia (n = 5; 7.58%), Brazil (n = 4; 6.06%) and Pakistan (n = 4; 6.06%) were the most frequently studied. The African continent was the most represented.

Most (n = 47; 71.21%) studies examined the effect of the COVID-19 pandemic on routine immunisation coverage, with an additional 6 (9.09%) reporting pandemic effects on supplementary immunisation activities. The change in the number of administered doses (n = 13; 19.70%) or the timing of doses (n = 11; 16.67%) was also reported by several studies; 7 (10.61%) reported disruptions in the vaccine supply chain.

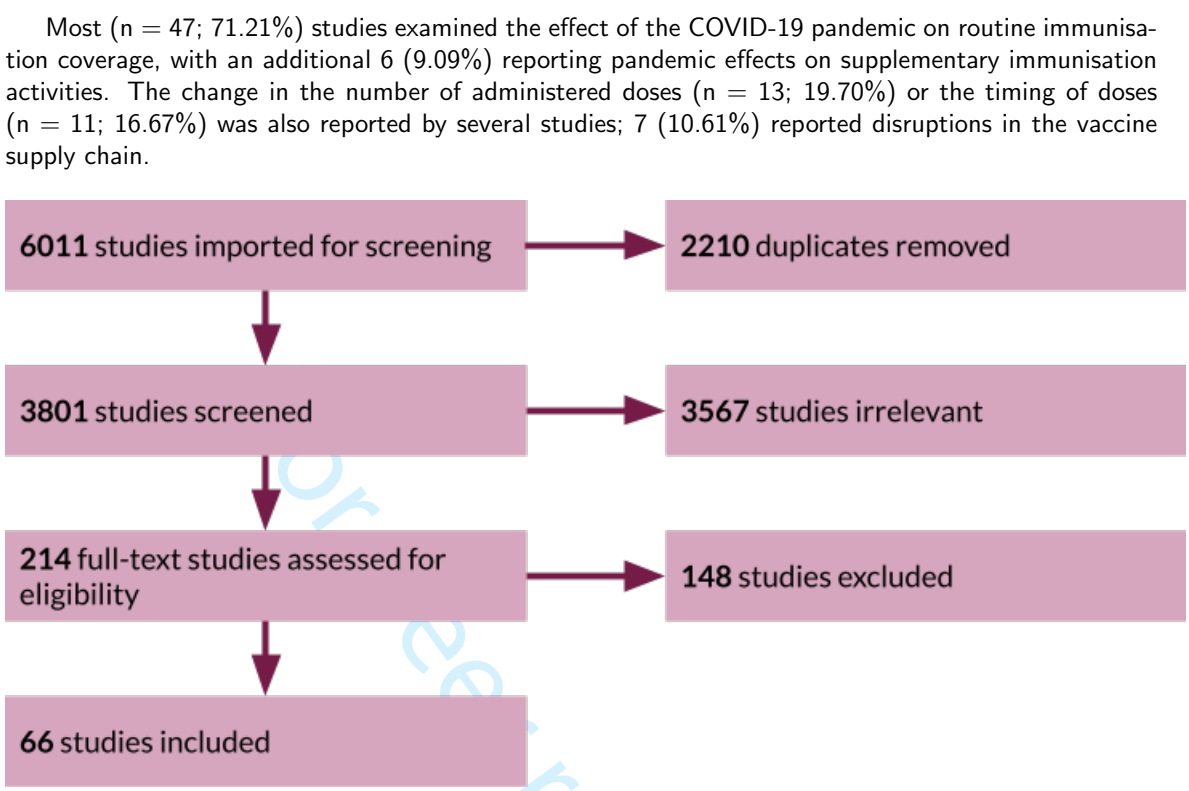

Figure 1: PRISMA flow of study selection. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

4.2 Extent of disruption

We divide this into a few main areas. Firstly, supply chains and vaccine availability, then the delivery of routine immunisation both in doses given and delays, then we examine supplementary immunisation activities, and finally, signs of recovery.

4.2.1 Vaccine supply

Following the declaration of COVID-19 as a pandemic, there was a reduction of vaccine sales and periods of stockout and low availability of vaccines in some countries [7, 8, 9]. Vaccine sales between April and August 2020 fell by 9.5% [10] but some losses were recouped by catch-up activities [8].

4.2.2 Routine immunisation

We divide insight by WHO region or country. In the WHO African Region there was a varied picture of disruption. In Ethiopia there were minimal disruptions up to August 2020 [11, 12, 13, 14]. Similarly, in DRC, disruptions in Kinshasa were minimal up to December 2020 [15] and in Kenya immunisation services were largely unaffected [16, 17, 18]. However, in South Africa full immunisation dropped in the first months of the pandemic, especially in April where it dropped by 30% [19, 20]. Ghana [21, 22, 23],

Nigeria [24], Uganda [8], Liberia [25] and Sierra Leone [26] all saw drops in coverage in 2020 and whilst some countries had begun to see recovery in coverage achieved, this was not enough to compensate for missed cohorts [27]. In the WHO region of the Americas, there were declines in coverage reported for Dominican Republic, Mexico, Ecuador and Brazil; Dominican Republic saw a drop of 10 percentage points [28], vaccinations reduced by 36% in Mexico [29, 30], there were 14% fewer doses administered in Ecuador [31], and in Brazil approximately 20% of children missed vaccinations with a 18% overall decline in dose administered in the first year of the pandemic [32, 33, 34]. Although one study found no significant evidence of COVID-19 isolation measures on vaccines per child in Brazil [35].

In the Eastern Mediterranean WHO region, drops in coverage were seen for Lebanon, Afghanistan, Jordan and Pakistan [36, 37, 38, 39, 40] of 31%, 21%, 6-16% and 30-48% respectively over the initial stages of the pandemic.

In the South East Asian WHO region, there were significant disruptions [41]. In India, there were substantial drops in coverage across the majority of districts (88% [42]) especially in lockdown and early in the pandemic [43, 44, 45, 46]; as a result children born in India after COVID-19 had a 2-10% lower probability of timely vaccination compared to earlier cohorts [47]. In Nepal and Bangladesh, the most severe disruptions were also seen earlier in the pandemic, particularly in Bangladesh where 20-25% of planned outreach immunisation was cancelled between April and May 2020 [48, 49].

In the WHO European region, in Armenia, there were only small declines in coverage achieved [50].

Globally, there were substantial drops in routine immunisations in 2020 [9]. Overall, it was an estimated that there were 31% fewer vaccine doses given [51], in middle-income countries 14% of individuals delayed or missed vaccinations in the first 6 months of the pandemic [52], and there was a 20% increase on children who had not completed the 3-dose DTP series [53]. Whilst disruption varied by vaccine [54, 55], most saw the most severe declines in the 6 months of the pandemic followed by variable recovery [56] which may affect control and elimination efforts [57].

It was not only the total number of doses administered that was affected, but also when those doses were given. In China and India, the majority of interviewed caregivers delayed vaccination [58, 59, 60, 47, 52] and in Ecuador and Sierra Leone this delay was worse for last doses [31, 26].

4.2.3 Supplementary immunisation activities

Overall, we found fewer studies focusing on supplementary immunisation activities (SIAs) or campaigns specifically; however, there are comprehensive records kept by the WHO campaign tracker as part of the immunisation repository [61]. SIAs were more disrupted in the early stages of the pandemic with 57% of planned campaigns globally postponed or cancelled because of COVID-19 by May 2020 [61]. By December 2020, this had fallen to 26% and many campaigns were reinstated from July 2020 onwards; by December 2021 this had fallen again to 16% of scheduled campaigns delayed or cancelled [61]. Overall, of those campaigns disrupted between March 2020 and December 2021, 59% had been reinstated [61]. Factors leading to postponement or cancellation of SIAs included non-pharmaceutical interventions [62] and stockouts or increased demand for general healthcare supplies [63, 8]. Additionally, whilst some SIAs had been reinstated, and there were plans for catchup activities, there are still large missed cohorts [44, 64, 57, 9].

4.2.4 Recovery

Information on recovery is limited by the date ranges of the included studies which mainly focused on 2020 and 2021. A key finding is that while there were signs of improvement in routine immunisation coverage achieved and reinstated vaccination campaigns, there was not the positive increase needed to

catch up missed cohorts [27, 51, 55, 49, 30, 65, 26]. It was also noted that pre-COVID levels of coverage had not been reached in many countries by the end of 2022 [57].

4.3 Heterogeneity in disruption

Heterogeneity in immunisation disruption was found across several factors, including geography, demography, wealth, and education; these are further detailed below. Variations in the extent of disruption by antigen were similarly reported in several studies [31, 37, 41, 10, 60].

4.3.1 Geographic Heterogeneity

Despite significant decreases in immunisation in LMICs, there was significant geographic heterogeneity in the extent of disruption and in the regions and/or individuals affected. On a national level, several studies reported differences in the extent of disruption as a result of economic income classification [52, 41, 53] by WHO Region [63, 54, 53], by global burden of disease super-region [51], or by Gavi eligibility [53], with greater pandemic impact observed in low- and middle-income countries compared to high-income countries, affecting the primarily African Region, the Americas, and Asia. The reverse trend was seen for vaccine sales early in the pandemic (i.e. April to August 2020), with high-income countries experiencing a 20% decline and low-income countries observing a 10% increase [10].

On a sub-national level, many countries observed statistically significant differences between regions and provinces in regards to the change in health service utilisation [66, 30, 42] or routine immunisation coverage [31, 37, 46]. In some countries, certain provinces reported increases in immunisation service provision or doses for some vaccines, such as in the Southern Province of Rwanda, where measles and rubella immunisation increased [66]. Geographic heterogeneity was also observed in the subsequent recovery of services [42, 20].

While some countries reported differences in disruption between urban and rural areas, there was significant heterogeneity in the extent of disruption. One study found that the odds of immunisation in Ethiopia were higher in rural areas [11], while another observed greater initial declines in urban and peri-urban areas in South Africa, followed by recovery in these areas and declines in rural areas as the pandemic progressed [20]. In Pakistan, lockdown affected rural areas more than urban areas[39]. Geographic heterogeneity was also observed between Ethiopia's hospitals and health centers, in which vaccine-related supplies were twice as likely to be affected by COVID-19 in hospitals [7], while in India children residing in "COVID-19 red zones" were more likely to face immunisation disruption [46]. Similarly, a study on polio outreach services in 33 African and Eastern Mediterranean countries found services necessary for "reaching their most vulnerable populations" were partially or severely disrupted [63].

4.3.2 Demographic Heterogeneity

Few studies focused on the effects of demographic heterogeneity on COVID-19 related immunisation disruption, including factors such as gender, age, birth order, or caste. Only two studies looked at differences by gender; one found greater declines in females than males, though this decline was not significant [37]. The second, conducted in Brazil, also found no significant differences, but did find that infants were less likely to experience immunisation disruptions or delays compared to one-year old children[32]. This finding was similar two studies, conducted in Eastern India and in China, where increasing age of the child was found to be associated with immunisation delays [59, 60]. A study conducted in South-East Asia and the Western Pacific found similar results, in which early-infancy was less disrupted than infancy, school-entry age, and adolescent immunisation [41]. However, greater disruption was seen among infants compared to adult/elderly immunisation [41]; additionally, one study in Jordan found that children older than 12 months were less likely to experience delays [38].

Only two studies stratified results by maternal or caregiver age; one finding that increasing maternal age was associated with delayed vaccination [59], the other finding no association[38].

Additionally, one study conducted in China found firstborn children were less likely to experience delays [60], while another paper in India examined heterogeneity as a result of ethnicity or caste, finding lower castes had lower likelihoods of full immunisation and greater immunisation disruption, though these findings were not significant [46].

4.3.3 Socioeconomic Heterogeneity

Contributors to socioeconomic heterogeneity in immunisation disruption largely included measures of household income and education. Two studies, one in Brazil and the other in India, found that missed vaccine doses were more likely in children from poorer households; in India it was additionally found that there were greater declines in immunisation among poorer subgroups [46, 32]. A study in South Africa found mixed results, finding declines in full immunisation and first dose of measles greater in wealthier quintiles at the start of the pandemic, but with faster positive recovery and continued declines among poorer subgroups as the pandemic progressed [20]. Only one study focused on education, similarly finding higher probability of incomplete immunisation and greater declines in households without formal education [46].

4.4 Factors contributing to coverage disruption and resilience

We divide this section into three key areas: health system barriers, vaccine demand and hesitancy, and resilience.

4.4.1 Health System Barriers

Many of the initial challenges in maintaining immunisation services in LMICs were the result of health system and supply barriers during the early stages of the pandemic. Many countries reported issues with vaccine supply delays or stockouts [30, 7, 67, 65, 25, 8, 9, 68] and lack of personal protective equipment (PPE) for healthcare workers (HCWs), including masks, gloves, and other drugs and supplies [7, 67, 25, 24, 69, 42, 68, 44, 45, 42]. Disruption caused by vaccine stockouts or supplies was found to vary by WHO region [9] or by geographical sub-region [24, 69, 41]; notably one study in Southeast Asia and the Western Pacific found vaccine stockouts to be among the least important reasons for service provision delays [41]. A lack of logistical support impacting routine services or outreach, such as a lack of fuel or water, was reported by three studies in the WHO African region [67, 25, 24].

Similarly, HCW availability posed a significant challenge, with countries citing difficulties due to the diversion of staff to COVID-19 response, staff illness, and transportation difficulties, among others [25, 9, 24, 68, 44, 45, 24, 42]. One study in Kenya further reported disruption due to a HCW strike from December 2020 to January 2021 [18]. On an individual level, HCWs reported that pandemic-related stigma, stress, or fears impacted service delivery [7, 24, 48, 45, 68, 42], with some additionally reporting harassment by law enforcement or by patients themselves[24, 42]. Only one study, conducted at a tertiary health centre in Ghana, found no disruptions to vaccine supply or in HCW availability [22].

COVID-19 lockdowns and restrictions also resulted in cancelled immunisation services, clinic closures, or reduced healthcare access or services available[7, 70, 25, 24, 39, 41, 52, 46, 62, 38], with some reporting difficulties maintaining COVID-19 prevention rules, such as social distancing, due to non-compliant patients or a lack of space[67, 24, 45].

Competing priorities also meant some countries faced declines in funding for immunisation services or supplies, resulting in financial constraints [44, 69].

4.4.2 Vaccine Demand and Acceptance

Many of the challenges in maintaining routine immunisation services during the COVID-19 pandemic also resulted from declining vaccine demand and increasing vaccine hesitancy among caregivers. Declines in vaccine demand were frequently attributed to travel barriers or difficulties in reaching immunisation services or clinics [46, 60, 14, 25, 9, 13, 45, 44, 48, 41], COVID-19 restrictions or requirements, including testing requirements, mask requirements, or lockdowns, [70, 67, 38, 40, 68, 48, 52], and financial constraints [13, 44, 48, 52]. One study, conducted in South East Asia and the Western Pacific, reported that while affordability issues contributed to immunisation service utilisation, it was among the lowest ranked reasons [41]. Some caregivers additionally reported low or no awareness of the availability of immunisation services, often believing clinics and hospitals were closed for routine immunisation services [67, 44, 22, 59].

Declines in vaccine demand due to fears of contracting COVID-19 at clinics or hospitals was pervasive, and one of the most reported causes across several studies [46, 52, 41, 48, 68, 44, 40, 13, 22, 45, 38, 9, 59, 67, 25]. Many others reported additional fear or stigma against healthcare providers, including fears that staff might be infected by the virus [22, 48, 45, 25, 68]. One survey of 100 caregivers at a tertiary health centre in Eastern India found that 83% of respondents agreed that "safety [was] more important than vaccination" [59]. Further unspecified declines in vaccine demand were noted by several studies [9, 65, 39].

Vaccine hesitancy factors were less commonly reported; misinformation and misbeliefs contributed to declines in demand in just two studies [9, 48], while fears specifically about vaccine side effects were found in just one study in a tertiary hospital in North Ghana [22]. One additional study in Liberia reported declines due to vaccine conspiracies, where parents believed their children would be injected with COVID-19 [25].

4.4.3 Resiliency

Though few papers highlighted resiliency factors or enablers to immunisation during the COVID-19 pandemic, two key focuses included the community outreach to address declining vaccine demand and acceptance and the importance of improved healthcare worker support to increase service provision. In Jordan and China, alternative arrangements for childhood vaccination (i.e. outside of the standard service provision within healthcare clinics) was found to be key to maintaining immunisation demand, though in Jordan this insight was based on a survey of caregiver beliefs[38, 58]. Similarly, a community intervention highlighting the importance of maintaining timely vaccination, despite the pandemic, was crucial in Jordan and in Ethiopia [38, 13]. Ethiopia additionally reported decreased fear of COVID-19 as an enabling factor [13]. In India, adequate access to PPE, overcoming barriers to transportation for HCWs, community and/or family support, and training on COVID-19 management was crucial support HCWs in maintaining immunisation service provision[68]. Similarly, proactive communication and coordination on all levels of the healthcare system was essential in Ethiopia in maintaining health system resiliency[69].

5 Discussion

Despite the challenges faced by health systems during the COVID-19 pandemic, the WHO has continued to emphasise the importance of routine immunisation, noting that the last effects of immunisation declines can lead to higher burdens of disease and/or excess deaths[71]. This review highlights the extent of disruption faced by LMICs, finding significant heterogeneity between and within regions, countries, and individual demographics, but nevertheless showing declines in routine immunisation in 2020 and 2021 that had not often not recovered to pre-COVID levels.

SIAs and campaigns were postponed with few regions reporting full recovery. Many LMICs rely on outreach services to reach vulnerable populations, especially where access to health clinics or services are limited[9]. COVID-19 response efforts or mitigation strategies, including lockdowns, resulted in additional disruption to transportation services, logistical support, or supplies, often hindering additional outreach activities and limiting the services that were available. This has resulted in a deepening of existing coverage inequalities, with studies noting greater disruptions among households with lower incomes, formal education, or those situated in informal housing or in some regions, rural areas, emphasising the heterogeneity that existed prior to the pandemic [72].

The findings in this study are limited by the data available — the majority of studies utilised data from 2020, limiting much of our understanding of how routine immunisation services have recovered since countries lifted lockdown or other COVID-19 response policies. Our study also does not include grey literature, only articles, with the search limited to one database. Nevertheless, this study expands upon the findings of a systematic review of available literature on childhood disruptions to immunisation using data from 2020, which included 39 studies and found an overall median decline of 10.8% [73]. Our study highlights the findings through 2022 and emphasises the ongoing heterogeneity in immunisation, alongside the barriers and enablers to service provision.

Our findings emphasise the urgency required to target individuals and cohorts who may have missed out on routine immunisation or campaigns during the COVID-19 pandemic, ensuring the barriers highlighted by staff and caretakers, including low staff or service availability, vaccine or supply stockouts, and transportation barriers are mitigated. Importantly, approaches to combat fears, misinformation, or misbeliefs, including those surrounding COVID-19 transmission and risk, are critical. Though few studies touched on vaccine hesitancy, declining vaccine acceptance has become a formative issue, and additional strategies are required to prevent additional backsliding[74].

Rebuilding immunisation services in LMICs will require a greater focus on healthcare resilience, so that the disruption caused by future epidemics or disasters on routine immunisation services is minimal, and that recovery and performance rapid and improved through an adaptation to real-world events[75]. Many of the countries that showed service delivery resilience during the COVID-19 pandemic highlighted the need for proactive and ongoing communication and coordination across multiple interconnected systems, especially between the community and healthcare system. One study, published in May of 2023, offers an updated framework to address the idea of epidemic-ready primary healthcare. Importantly, this framework offers solutions to many of the observed barriers found in this review, focusing on adequate training, compensation, and protection for HCWs, reliable logistic and supply-chain infrastructure, and linkages to the community[76]. Given the reliance on primary health care and outreach systems for immunisation in LMICs, this approach may be a beneficial starting point, though notably, it will require a shift in how healthcare currently interacts with public health, alongside strong political commitment and financing[76]. Further research will be required to understand how post-pandemic disruption and recovery in immunisation services has progressed, especially in regards to vulnerable communities.

6 Acknowledgements

This work was carried out as part of the Vaccine Impact Modelling Consortium (www.vaccineimpact.org), which is jointly funded by the Bill & Melinda Gates Foundation (Grant Numbers INV-034281 and INV-009125 / OPP1157270) and Gavi, the Vaccine Alliance. The views expressed are those of the authors and not necessarily those of the Consortium or its funders. The funders were given the opportunity to review this paper prior to publication, but the final decision on the content of the publication was taken by the authors.

AMH, XL, and KAMG also acknowledge funding from the MRC Centre for Global Infectious Disease

Analysis (reference MR/R015600/1), jointly funded by the UK Medical Research Council (MRC) and the UK Foreign, Commonwealth Development Office (FCDO), under the MRC/FCDO Concordat agreement and is also part of the EDCTP2 programme supported by the European Union; and acknowledge funding by Community Jameel.

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BMJ Open

COVID-19-related disruption and resiliency in immunisation activities in LMICs: a rapid review

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2023-076607.R1
Article Type:	Original research
Date Submitted by the Author:	20-Jun-2024
Complete List of Authors:	Hartner, Anna-Maria; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health; Robert Koch Institute, Centre for Artificial Intelligence in Public Health Research Li, Xiang; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health Gaythorpe, Katy; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Global health, Infectious diseases
Keywords:	COVID-19, Health Equity, Public health < INFECTIOUS DISEASES

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COVID-19-related disruption and resiliency in immunisation activities in LMICs: a rapid review

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April 19, 2024

Abstract

Objectives

We conducted a rapid review to determine the extent that immunisation services in low- and middle income countries (LMICs) were disrupted by the COVID-19 pandemic and synthesised the factors that can be used to build resilience in future.

Design

Rapid review reported in accordance with Preferred reporting for Systematic reviews and Meta-Analyses (PRISMA) guidelines.

Data sources

PubMed and Web of Science were searched through 6th October 2023.

Eligibility criteria for selecting studies

We included studies that focused on disruption to immunisation activities due to the COVID-19 pandemic in LMICs. Outcomes included were: Routine vaccine coverage; supplementary immunisation activities; Vaccine doses; Timing of vaccination; Supply chain changes; factors contributing to disruption or resilience.

Data extraction and synthesis

Two independent reviewers used standardised methods to search, screen, and code studies. Quality assessment was performed using a modified version of the Critical Appraisal Skills Programme (CASP) for qualitative research. Findings were summarised qualitatively.

Results

Of 4979 identified studies, 87 met the eligibility criteria. Included studies showed declines in immunisation activities across LMICs related to the COVID-19 pandemic. These included reductions in achieved routine coverage, cancellation or postponement of campaigns, and underimmunised cohorts. Immunisation was most disrupted in the early months of the pandemic; however, recovery varied by

country, age-group, and vaccine. Though many countries observed partial recovery in 2020, disruption in many countries continued into 2021. It has also been noted that clinician staff shortages and vaccine stock outs caused by supply chain disruptions contributed to immunisation delays but that concern over COVID transmission was a leading factor. Key resiliency factors included community outreach and healthcare worker support.

Conclusions

There is limited information on whether reductions in vaccination coverage or delays have persisted beyond 2021. Further research is needed to assess ongoing disruptions and identify missed vaccine cohorts.

Strengths and limitations of this study

- The rapid synthesis of findings related to immunisation disruption and recovery to-date allows for key insights to target missed cohorts and identify research gaps.
- We include a narrative analysis of disruption across LMICs; this review benefits from the inclusion of barriers, enablers, and resilience to/in service provision.
- The search strategy was limited to English-language studies identified from databases PubMed and Web of Science up to October 6th, 2023, meaning not all relevant research meeting inclusion criteria may have been captured.

1 Introduction

The coronavirus disease 2019 (COVID-19) pandemic began on December 12th, 2019 and quickly spread globally, adding to the strain on existing healthcare provision and creating unique problems in terms of service delivery [1]. Throughout 2020 there were disruptions to screening for cancer, maternal health services, care for chronic conditions, and immunisations [2]. This strain on health services has continued past 2020, as even those that have recovered to pre-COVID levels of visits and surveillance have to catch-up missed cohorts and delayed treatments.

Low- and middle-income countries (LMICs) disproportionately bear the burden of vaccine preventable diseases [3]; however, globally, vaccination has seen a plateau in coverage, with zero-dose children an ongoing concern. The issue of zero-dose or underimmunised children is particularly important, as it can hint at wider heterogeneity in healthcare access which may have been exacerbated by the pandemic [4]. It is estimated that 67 million children missed vaccinations between 2019 and 2021; of those, 48 million were zero-dose children [5]. Furthermore, targeting zero-dose children can be more difficult as they are often in harder-to-reach areas, particularly in LMICs, where 1 in 6 children living in rural areas are zero-dose [5].

Resilient healthcare systems can withstand additional and unusual strains whilst maintaining priority services. Yet, it is still uncertain what factors contributed to disruption or resilience in light of the COVID-19 pandemic, which was a unique test on global healthcare systems. These factors and considerations may be instrumental in preparing for future healthcare strains such as those potentially caused by other epidemics, climate change, or antimicrobial resistance. As such, understanding the key factors for disruption due to the COVID-19 pandemic is critical for future planning in order to minimise the negative consequences of disruptions.

In order to understand the current state of vaccination coverage disruption, and highlight factors contributing to resilience, we undertook a rapid review of the existing literature. This focused on LMICs as they bear the majority of burden of vaccine preventable diseases. We included studies that not only discuss the quantitative measures of disruption, such as reduced immunisation coverage and cancelled campaigns, but also more qualitative discussions of the factors contributing to disruption or characteristics of resilient systems.

2 Aim and research questions

The aim of this review was to understand the extent of disruptions in vaccination coverage due to the COVID-19 pandemic and the factors that contributed to the disruption or resilience. Specifically, our research questions were:

RQ1: To what extent were immunisation services in LMICs disrupted by the COVID-19 pandemic?
RQ2: How did disruption vary by geography, demography, or socioeconomic group?
RQ3: What factors contributed to coverage disruption or resilience?

3 Methods

A rapid review (RR) was conducted using streamlined systematic review methods and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6]. The full PRISMA checklist can be found in the supplementary material.

3.1 Procedure

We searched PubMed and Web of science up to 6th October 2023 for studies published after 1st December 2019 in the English-language with search terms (((COVID-19) OR (SARS-CoV-2))) AND (immunisation OR vaccination) AND (disruption OR delay* OR postpon*). Studies were included if they focused on disruption to vaccination activities due to the COVID-19 pandemic in LMICs. Studies were excluded if they focused on high-income countries only, examined disruption due to other factors, i.e. not related to the pandemic, or were reviews, commentaries, or modelling studies without novel data.

3.2 Study selection, data extraction and quality assessment

Search results were imported into the Covidence (www.covidence.org) systematic review management tool where duplicates were removed. Titles and abstracts were screened by one reviewer, full text review was completed by two reviewers with conflicts resolved through consensus.

Each study was extracted by one reviewer into a Google sheet. We extracted information on i) last date of included data, ii) countries studied, iii) qualitative findings related to the research questions RQ1, RQ2 and RQ3, and iv) binary data on whether routine immunisation, SIAs, doses, schedule timing or supply chains were mentioned in the study. A second reviewer was consulted where there was uncertainty concerning the extracted data.

The quality of studies was assessed through a modified version nine question checklist of the Critical Appraisal Skills Programme (CASP) for qualitative studies. Results were listed as N/A if not applicable for the study. All CASP results are available in the supplementary material.

3.3 Synthesis

There were two main types of evidence to synthesise. Quantitative information (i.e., percentage drops in coverage achieved, doses administered, or SIAs postponed), qualitative information on contributing factors informed by surveys or questionnaires. We grouped results by research question with the first question the most quantitative. Finally we collate characteristics of the studies themselves such as countries studied or dates of included data, for which we have prepared summary statistics. The full list of included studies and outcomes provided are included in the supplementary material.

3.4 Patient and public involvement

There was no patient or public involvement in this study.

4 Results

4.1 Characteristics of studies

We found 4978 studies where 85 met the inclusion criteria (Figure 1). The majority of studies were published in either 2021 (n = 30; 35.29%) or 2022 (n = 32; 37.65%), though most studies only reported on data from 2020 (n = 52; 61.18%). 14 studies (16.47%) included data during the first 6 months of 2021; a further 15 (17.64%) included data between July and December of 2021. Only 4 studies (4.71%) included data from 2022; the most recent of these covered data through November of 2022.

Most (n = 20; 23.53%) of the studies considered multiple LMICs. Of those that only considered one country, India (n = 12; 14.11%), Ethiopia (n = 7; 8.24%), Pakistan (n = 5; 5.88%) and Brazil (n = 4; 4.71%) were the most frequently studied. The African continent was the most represented.

Most (n = 57; 67.05%) studies examined the effect of the COVID-19 pandemic on routine immunisation coverage, with an additional 7 (8.24%) reporting pandemic effects on supplementary immunisation activities. The change in the number of administered doses (n = 19; 22.35%) or the timing of doses (n = 15; 17.64%) was also reported by several studies; 8 (9.41%) reported disruptions in the vaccine supply chain.

4.2 Extent of disruption

We divide this into a few main areas: supply chains and vaccine availability, the delivery of routine immunisation (as doses given, coverage, and/or delays), supplementary immunisation activities, and finally, signs of recovery (to pre-pandemic achieved coverage in any of the disrupted activities mentioned previously).

4.2.1 Vaccine supply

Following the declaration of COVID-19 as a pandemic, there was a reduction of vaccine sales and periods of stockout and low availability of vaccines in some countries [7, 8, 9, 10, 11], though one study in Northern Nigeria found that states experienced less stockouts in 2020 as compared to 2019 [12]. More globally, vaccine sales between April and August 2020 fell by 9.5% across 84 countries [13], but some losses in vaccine receipt after stockouts were recouped by catch-up activities, such as in Uganda [8].

4.2.2 Routine immunisation

We divide insight by WHO region or country.

In the WHO African Region there was a varied picture of disruption. In Ethiopia there were minimal disruptions up to August 2020 [14, 15, 16, 17, 10, 18]. Similarly, in DRC, disruptions in Kinshasa were minimal up to December 2020, with one study even finding increases in DTP3 and MCV1 doses administered [19, 20]. In Kenya [21, 22, 23] and Burkina Faso[24], immunisation services were largely unaffected. Zambia saw a mixed picture, in which estimates during the first 6 months of 2020 varied month-to-month with both disruptions and positive increases as compared to previous years; overall, however, the number of additional children missed was found to be minimal [25]. However, in South Africa full immunisation dropped in the first months of the pandemic, especially in April where it dropped by 30% [26, 27]. Ghana [28, 29, 30], Nigeria [31], Uganda [8, 20], Liberia [32], Sierra Leone [33, 20], and Somalia [11] all saw drops in coverage in 2020 and whilst some countries had begun to see recovery in coverage achieved, this was not enough to compensate for missed cohorts [34, 20].

In the WHO region of the Americas, there were declines in coverage reported for Dominican Republic, Mexico, Ecuador and Brazil; Dominican Republic saw a drop of 10 percentage points [35], vaccinations reduced by 36% in Mexico [36, 37], there were 14% fewer doses administered in Ecuador [38], and in Brazil approximately 20% of children missed vaccinations with a 18% overall decline in dose administered in the first year of the pandemic [39, 40, 41]. Although one study found no significant evidence of COVID-19 isolation measures on vaccines per child in Brazil [42].

In the Eastern Mediterranean WHO region, drops in coverage were seen for Lebanon, Afghanistan, Jordan and Pakistan [43, 44, 45, 46, 47] of 31%, 21%, 6-16% and 30-48% respectively over the initial stages of the pandemic. Pakistan additionally reported that as of September 2021, 18%

of parents had delayed routine immunisation for their children during the pandemic; an additional 2% received no immunisations [48].

In the South East Asian WHO region, there were significant disruptions [49, 50]. In India, six studies found substantial drops in coverage across the majority of districts (88% [51]) especially in lockdown and early in the pandemic [52, 53, 54, 55, 56]; as a result children born in India after COVID-19 had a 2-10% lower probability of timely vaccination compared to earlier cohorts [57, 58]. Two studies, one conducted among the Armed Forces population in Mumbai, the other across India, found disruptions continued into 2021 [58, 56]. Only one study found that the number of immunisation sessions in India increased in 2020 and 2021 compared to 2019 [59]. In Nepal and Bangladesh, the most severe disruptions were also seen earlier in the pandemic, particularly in Bangladesh where 20-25% of planned outreach immunisation was cancelled between April and May 2020 [60, 61]. In Indonesia, one study reported that 27.4% of parents delayed compulsory immunisation in 2020 [62].

In the WHO European region, in Armenia, there were only small declines in coverage achieved [63]. In the Western Pacific WHO Region, one study from China found that immunisation coverage dropped drastically in January 2020, but had recovered to pre-pandemic levels by June [64]. However, a second study conducted in Beijing found pandemic effects to continue into 2021, staying below 2019 levels despite catch-up activities [65].

Globally, there were substantial drops in routine immunisations in 2020 [9]. Overall, it was an estimated that there were 31% fewer vaccine doses given [66], in middle-income countries 14% of individuals delayed or missed vaccinations in the first 6 months of the pandemic [67], and there was a 20% increase on children who had not completed the 3-dose DTP series [68]. Whilst disruption varied by vaccine [69, 70], most saw the most severe declines in the 6 months of the pandemic followed by variable recovery [71] which may affect control and elimination efforts [72].

It was not only the total number of doses administered that was affected, but also when those doses were given. In China and India, the majority of interviewed caregivers delayed vaccination [73, 74, 75, 57, 67] and in Ecuador and Sierra Leone this delay was worse for last doses [38, 33].

4.2.3 Supplementary immunisation activities

Overall, we found fewer studies focusing on supplementary immunisation activities (SIAs) or campaigns specifically; however, there are comprehensive records kept by the WHO campaign tracker as part of the immunisation repository [76]. In 57 countries, SIAs were more disrupted in the early stages of the pandemic with 57% of planned campaigns globally postponed or cancelled because of COVID-19 by May 2020 [76]. By December 2020, this had fallen to 26% and many campaigns were reinstated from July 2020 onwards; by December 2021, in 54 countries, this had fallen again to 16% of scheduled campaigns delayed or cancelled [76]. Overall, of those campaigns disrupted between March 2020 and December 2021, 59% had been reinstated [76]. Factors leading to postponement or cancellation of SIAs included non-pharmaceutical interventions, such as national lockdowns, [77] and stockouts or increased demand for general healthcare supplies [78, 8]. One study found that the national policy guidance of Mozambique and Uganda recommend the halting of campaigns in 2020 [79]. Additionally, whilst some SIAs had been reinstated, and there were plans for catchup activities, there are still large missed cohorts [53, 80, 72, 9].

4.2.4 Recovery

Information on recovery is limited by the date ranges of the included studies which mainly focused on 2020 and 2021. A key finding is that while there were signs of improvement in routine immunisation coverage achieved and reinstated vaccination campaigns, there was not the positive increase needed to catch up missed cohorts, i.e. a sufficient return to pre-pandemic levels of immunisation [34, 66, 70, 61, 37, 81, 33, 65]. It was also noted that pre-COVID levels of coverage had not been reached in many countries by the end of 2022 [72].

4.3 Heterogeneity in disruption

Heterogeneity in immunisation disruption was found across several factors, including geography, demography, wealth, and education; these are further detailed below. Variations in the extent of

disruption by antigen were similarly reported in several studies [38, 44, 49, 13, 75, 20, 10, ?, 18, 65, 64].

4.3.1 Geographic Heterogeneity

Despite significant decreases in immunisation in LMICs, there was significant geographic heterogeneity in the extent of disruption and in the regions and/or individuals affected. On a national level, several studies reported differences in the extent of disruption as a result of economic income classification [67, 49, 68] by WHO Region [78, 69, 68], by global burden of disease super-region [66], or by Gavi eligibility [68], with greater pandemic impact observed in low- and middle-income countries compared to high-income countries, affecting the primarily African Region, the Americas, and Asia. The reverse trend was seen for vaccine sales early in the pandemic (i.e. April to August 2020), with high-income countries experiencing a 20% decline and low-income countries observing a 10% increase [13].

On a sub-national level, many countries observed statistically significant differences between regions, provinces, or districts in regards to the change in health service utilisation [82, 37, 51, 59, 56], routine immunisation coverage [38, 44, 55], or complete vaccination [24]. In some countries, certain provinces reported increases in immunisation service provision or doses for some vaccines, such as in the Southern Province of Rwanda, where measles and rubella immunisation increased [82]. Geographic heterogeneity was also observed in the subsequent recovery of services [51, 27].

While some countries reported differences in disruption between urban and rural areas, there was significant heterogeneity in the extent of disruption. One study found that the odds of immunisation in Ethiopia were higher in rural areas [14], while another observed greater initial declines in urban and peri-urban areas in South Africa, followed by recovery in these areas and declines in rural areas as the pandemic progressed [27]. In Pakistan, lockdown affected rural areas more than urban areas[46]. Geographic heterogeneity was also observed between Ethiopia's hospitals and health centres, in which vaccine-related supplies were twice as likely to be affected by COVID-19 in hospitals [7, 10], while in Nigeria, activities coordinated at the state level were impacted less than healthcare facilities [12]. In China, immunisation services continued in hospitals, even when immunisation clinics were suspended [64].

In India children residing in "COVID-19 red zones" were more likely to face immunisation disruption [55]. Similarly, a study on polio outreach services in 33 African and Eastern Mediterranean countries found services necessary for "reaching their most vulnerable populations" were partially or severely disrupted [78].

4.3.2 Demographic Heterogeneity

Few studies focused on the effects of demographic heterogeneity on COVID-19 related immunisation disruption, including factors such as gender, age, birth order, or caste. Only two studies looked at differences by gender; one found greater declines in females than males, though this decline was not significant [44]. The second, conducted in Brazil, also found no significant differences, but did find that infants were less likely to experience immunisation disruptions or delays compared to one-year old children[39]. This finding was similar to two studies, conducted in Eastern India and in China, where increasing age of the child was found to be associated with immunisation delays [74, 75]. A study conducted in South-East Asia and the Western Pacific found similar results, in which early-infancy was less disrupted than infancy, school-entry age, and adolescent immunisation [49]. However, greater disruption was seen among infants compared to adult/elderly immunisation [49]; additionally, one study in Jordan found that children older than 12 months were less likely to experience delays [45]. Finally, one study conducted in China found firstborn children were less likely to experience delays [75], while another paper in India examined heterogeneity as a result of ethnicity or caste, finding lower castes had lower likelihoods of full immunisation and greater immunisation disruption, though these findings were not significant [55].

While even fewer articles examined the demographic heterogeneity of disruption based on the characteristics of parents or caregivers, two studies stratified results by maternal or caregiver age; one finding that increasing maternal age was associated with delayed vaccination [74], the other finding no association[45]. Only one study examined other contributing factors of parents, finding that women

were more likely to delay vaccination for their children than men; presence of a chronic illness, prior flu vaccination, or experience with COVID-19 diagnosis were also associated with delays in childhood vaccination [62].

4.3.3 Socioeconomic Heterogeneity

Contributors to socioeconomic heterogeneity in immunisation disruption largely included measures of household income and education. Two studies, one in Brazil and the other in India, found that missed vaccine doses were more likely in children from poorer households [55, 39]; in India it was additionally found that there were greater declines in immunisation among poorer subgroups [55]. A study in South Africa found mixed results, finding declines in full immunisation and first dose of measles greater in wealthier quintiles at the start of the pandemic, but with faster positive recovery and continued declines among poorer subgroups as the pandemic progressed [27]. Another study in Iraq found that low socioeconomic status was associated with an increase in missed vaccine appointments [83]. Two studies, one conducted in Iraq and one conducted in Indonesia, similarly found that the type of employment changed the odds of vaccination during the pandemic [62, 83]; in Indonesia, healthcare workers especially were more likely to delay vaccination in their children [62].

Only two studies, one in India and one in Iraq, focused on education, similarly finding higher probability of incomplete immunisation and greater declines in households without formal education [55, 83].

4.4 Factors contributing to coverage disruption and resilience

We divide this section into three key areas: health system barriers, vaccine demand, and resilience.

4.4.1 Health System Barriers

Many of the initial challenges in maintaining immunisation services in LMICs were the result of health system and supply barriers during the early stages of the pandemic. Many countries reported issues with vaccine supply delays or stockouts [37, 7, 84, 81, 32, 8, 9, 85, 11, 58, 86] and lack of personal protective equipment (PPE) for healthcare workers (HCWs), including masks, gloves, and other drugs and supplies [7, 84, 32, 31, 87, 51, 85, 53, 54, 51, 12]. Disruption caused by vaccine stockouts or supplies was found to vary by WHO region [9] or by geographical sub-region [31, 87, 49, 10]; notably one study in Southeast Asia and the Western Pacific found vaccine stockouts to be among the least important reasons for service provision delays [49]. A lack of logistical support impacting routine services or outreach, such as a lack of fuel or water, was reported by three studies in the WHO African region [84, 32, 31].

Similarly, HCW availability posed a significant challenge, with countries citing difficulties due to the diversion of staff to COVID-19 response, staff illness, and transportation difficulties, among others [32, 9, 31, 85, 53, 54, 31, 51, 18, 12]. One study in Kenya further reported disruption due to a HCW strike from December 2020 to January 2021 [23]. On an individual level, HCWs reported that pandemic related stigma, stress, or fears impacted service delivery [7, 31, 60, 54, 85, 51], with some additionally reporting harassment by law enforcement or by patients themselves[31, 51]. Only one study, conducted at a tertiary health centre in Ghana, found no disruptions to vaccine supply or in HCW availability [29].

COVID-19 lockdowns and restrictions also resulted in cancelled immunisation services, clinic closures, or reduced healthcare access or services available[7, 88, 32, 31, 46, 49, 67, 55, 77, 45, 62, 89, 86, 83], with some reporting difficulties maintaining COVID-19 prevention rules, such as social distancing, due to non-compliant patients or a lack of space[84, 31, 54, 12].

Competing priorities also meant some countries faced declines in funding for immunisation services or supplies, resulting in financial constraints [53, 87, 12].

4.4.2 Vaccine Demand and Acceptance

Many of the challenges in maintaining routine immunisation services during the COVID-19 pandemic also resulted from declining vaccine demand and increasing fear or stigma surrounding COVID-19 among caregivers. Declines in vaccine demand were frequently attributed to travel barriers or difficulties in reaching immunisation services or clinics [55, 75, 17, 32, 9, 16, 54, 53, 60, 49, 65, 12, 83, 18, 48, 89], COVID-19 restrictions or requirements, including testing requirements, mask requirements, or lockdowns, [88, 84, 45, 47, 85, 60, 67], and financial constraints [16, 53, 60, 67]. One study, conducted in South East Asia and the Western Pacific, reported that while affordability issues contributed to immunisation service utilisation, it was among the lowest ranked reasons [49]. Some caregivers additionally reported low or no awareness of the availability of immunisation services, often believing clinics and hospitals were closed for routine immunisation services [84, 53, 29, 74].

Declines in vaccine demand due to fears of contracting COVID-19 at clinics or hospitals was pervasive, and one of the most reported causes across several studies [55, 67, 49, 60, 85, 53, 47, 16, 29, 54, 45, 9, 74, 84, 32, 12, 18, 58, 48, 89]. Many others reported additional fear or stigma against healthcare providers, including fears that staff might be infected by the virus [29, 60, 54, 32, 85]. One survey of 100 caregivers at a tertiary health centre in Eastern India found that 83% of respondents agreed that “safety [was] more important than vaccination” [74]. Further unspecified declines in vaccine demand were noted by several studies [9, 81, 46].

Vaccine hesitancy factors were less commonly reported; misinformation and misbeliefs contributed to declines in demand in just two studies [9, 60], while fears specifically about vaccine side effects were found in just one study in a tertiary hospital in North Ghana [29]. One additional study in Liberia reported declines due to vaccine conspiracies, where parents believed their children would be injected with COVID-19 [32]. Only one in Ethiopia study reported fewer declines in vaccine demand as a result of COVID-19 pandemic misinformation, including that they were not susceptible to the disease, the disease was not severe, or that the pandemic did not exist [18].

4.4.3 Resiliency

Though few papers highlighted resiliency factors or enablers to immunisation during the COVID-19 pandemic, two key focuses included the community outreach to address declining vaccine demand and acceptance and the importance of improved healthcare worker support to increase service provision. In Jordan and China, alternative arrangements for childhood vaccination (i.e. outside of the standard service provision within healthcare clinics) was found to be key to maintaining immunisation demand, though in Jordan this insight was based on a survey of caregiver beliefs[45, 73]. Similarly, a community intervention highlighting the importance of maintaining timely vaccination, despite the pandemic, was crucial in Jordan, India, and in Ethiopia [45, 16, 18, 58]. Ethiopia additionally reported decreased fear of COVID-19 as an enabling factor [16]. In India, adequate access to PPE, overcoming barriers to transportation for HCWs, community and/or family support, and training on COVID-19 management was crucial to support HCWs in maintaining immunisation service provision[85]. Similarly, proactive communication and coordination on all levels of the healthcare system was essential in Ethiopia in maintaining health system resiliency[87]. In India, capacity building to ensure a trained workforce assisted in maintaining immunisation programs [58, 89], while in Nigeria, one study found the supply chain logistics to be the most important factor for maintaining immunisation services [12]. Finally, in Zambia, community awareness through the National Immunization Campaign assisted in catching up pandemic declines [25].

5 Discussion

Despite the challenges faced by health systems during the COVID-19 pandemic, the WHO has continued to emphasise the importance of routine immunisation, noting that the last effects of immunisation declines can lead to higher burdens of disease and/or excess deaths[90]. This review highlights the extent of disruption faced by LMICs, finding significant heterogeneity between and within regions, countries, and individual demographics, but nevertheless showing declines in routine immunisation in 2020 and 2021 that had not often not recovered to pre-COVID levels.

SIAs and campaigns were postponed with few regions reporting full recovery. Many LMICs rely on outreach services to reach vulnerable populations, especially where access to health clinics or

services are limited[9]. COVID-19 response efforts or mitigation strategies, including lockdowns, resulted in additional disruption to transportation services, logistical support, or supplies, often hindering additional outreach activities and limiting the services that were available. This has resulted in a deepening of existing coverage inequalities, with studies noting greater disruptions among households with lower incomes, formal education, or those situated in informal housing or in some regions, rural areas, emphasising the heterogeneity that existed prior to the pandemic [91].

We utilised a rapid review format for this study, which includes some limitations. We included only two databases for the time period and only studies in English. As a result, we may be missing studies stored in other databases or in other languages. Additionally, rapid reviews may have additional risks of bias, given the single-reviewer extraction and synthesis of findings.

The findings in this study are limited by the data available — the majority of studies utilised data from 2020, limiting much of our understanding of how routine immunisation services have recovered since countries lifted lockdown or other COVID-19 response policies. Our study also does not include grey literature, only articles, with the search limited to one database. Nevertheless, this study expands upon the findings of a systematic review of available literature on childhood disruptions to immunisation using data from 2020, which included 39 studies and found an overall median decline of 10.8% [92]. Additionally, our study only focuses on LMICs; this is in contrast to high-income countries, which, according to one study on 26 middle- and high-income countries, saw considerably less missed vaccination [67]. Our study highlights the findings through 2022 and emphasises the ongoing heterogeneity in immunisation, alongside the barriers and enablers to service provision.

Our findings emphasise the urgency required to target individuals and cohorts who may have missed out on routine immunisation or campaigns during the COVID-19 pandemic, ensuring the barriers highlighted by staff and caretakers, including low staff or service availability, vaccine or supply stockouts, and transportation barriers are mitigated. Importantly, approaches to combat fears, misinformation, or misbeliefs, including those surrounding COVID-19 transmission and risk, are critical. Though few studies touched on vaccine hesitancy, declining vaccine acceptance has become a formative issue, and additional strategies are required to prevent additional backsliding[93].

Rebuilding immunisation services in LMICs will require a greater focus on healthcare resilience, so that the disruption caused by future epidemics or disasters on routine immunisation services is minimal, and that recovery and performance rapid and improved through an adaptation to real-world events[94]. Many of the countries that showed service delivery resilience during the COVID-19 pandemic highlighted the need for proactive and ongoing communication and coordination across multiple interconnected systems, especially between the community and healthcare system. One study, published in May of 2023, offers an updated framework to address the idea of epidemic-ready primary healthcare. Importantly, this framework offers solutions to many of the observed barriers found in this review, focusing on adequate training, compensation, and protection for HCWs, reliable logistic and supply-chain infrastructure, and linkages to the community[95]. Given the reliance on primary health care and outreach systems for immunisation in LMICs, this approach may be a beneficial starting point, though notably, it will require a shift in how healthcare currently interacts with public health, alongside strong political commitment and financing[95]. Further research will be required to understand how post-pandemic disruption and recovery in immunisation services has progressed, especially in regards to vulnerable communities.

6 Conclusion

This review highlights the extent and heterogeneity of immunisation disruption in LMICs as a result of the COVID-19 pandemic and the factors contributing to disruption and resilience in immunisation programs. Given there is limited information on whether reductions in vaccination coverage or delays have persisted beyond 2021, further research is needed to assess ongoing disruptions, identify missed vaccine cohorts, and examine factors contributing to resilience. Furthermore, these findings highlight the need for immunisation programs to provide support for healthcare workers and proactive communication within the health system and with the wider community to ensure the effect of future disasters on vulnerable communities is minimal.

7 Contributorship Statement

AMH: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing — Review and Editing. XL.: Conceptualization, Methodology, Writing — Review and Editing. KAMG: Supervision, Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing — Review and Editing

8 Competing Interests

Authors declare no other competing interests.

9 Funding

This work was carried out as part of the Vaccine Impact Modelling Consortium (www.vaccineimpact.org), which is jointly funded by the Bill & Melinda Gates Foundation (Grant Numbers INV-034281 and INV 009125 / OPP1157270) and Gavi, the Vaccine Alliance. The views expressed are those of the authors and not necessarily those of the Consortium or its funders. The funders were given the opportunity to review this paper prior to publication, but the final decision on the content of the publication was taken by the authors.

AMH, XL, and KAMG also acknowledge funding from the MRC Centre for Global Infectious Disease Analysis (reference MR/R015600/1), jointly funded by the UK Medical Research Council (MRC) and the UK Foreign, Commonwealth Development Office (FCDO), under the MRC/FCDO Concordat agreement and is also part of the EDCTP2 programme supported by the European Union; and acknowledge funding by Community Jameel. KAMG reports speaker fees from Sanofi Pasteur outside the submitted work.

10 Data Sharing Statement

All data relevant to the study are included in the article or uploaded as supplementary information.

11 Ethics Approval Statement

This study involved the use of secondary data and does not require ethics approval.

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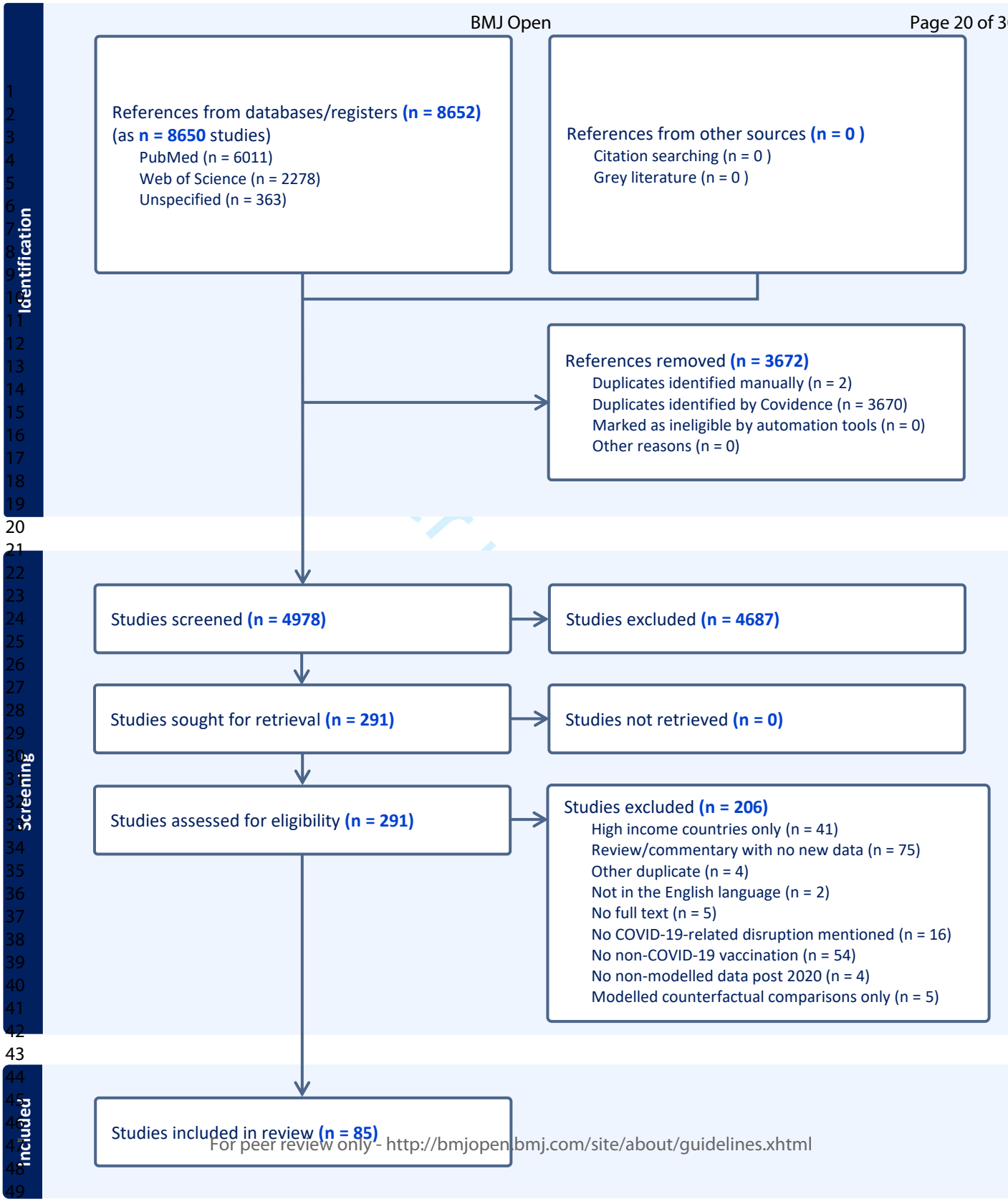

Supplementary Index: COVID-19-related disruption and resiliency in immunisation activities in LMICs: a rapid review

Anna-Maria Hartner, Xiang Li, Katy Gaythorpe

April 19, 2024

Search Strategy

We searched PubMed and Web of science on 6th October 2023 for studies published after 1st December 2019 in English. Our full list of search terms was as follows: (((COVID-19) OR (SARS-CoV-2))) AND (immunisation OR vaccination) AND (disruption OR delay* OR postpon*).

PRISMA Checklist

Section and Topic	Item	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title identifies study as a rapid review.
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract follows BMJ Open guidelines.
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Introduction
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Aim and research questions
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods: procedure.
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Methods: procedure.
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Methods: procedure and supplementary index.
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment

Section and Topic	Item	Checklist item	Location where item is reported
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods: Study selection, data extraction and quality assessment
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Methods: Study selection, data extraction and quality assessment
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	N/A; narrative synthesis only.
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item 5)).	All studies meeting inclusion criteria were synthesized.
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A; narrative synthesis only.
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	N/A
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Methods: Synthesis
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A; narrative synthesis only.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A; narrative synthesis only.
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	N/A; limitations in discussion.
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	N/A; narrative synthesis only.

Section and Topic	Item	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results: Characteristics of studies
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Results: Characteristics of studies
Study characteristics	17	Cite each included study and present its characteristics.	Results: Characteristics of studies; all studies are cited throughout.
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supplementary Index: additional tables
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	N/A; narrative synthesis only
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Results; bias in discussion.
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A; narrative synthesis only.
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A; narrative synthesis only.
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A; narrative synthesis only.
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Discussion
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Discussion
DISCUSSION			
	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion
	23b	Discuss any limitations of the evidence included in the review.	Discussion

Section and Topic	Item	Checklist item	Location where item is reported
Discussion	23c	Discuss any limitations of the review processes used.	Discussion
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Review was not registered.
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Protocol was not prepared.
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Acknowledgments
Competing interests	26	Declare any competing interests of review authors.	Acknowledgments
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Articles used in narrative synthesis are publicly available and given in citations.

Table 1: Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Checklist

Critical Appraisal Skills Program Quality Assessment

Study	Aims stated?	Appropriate methods?	Appropriate methods for aims?	Appropriate recruitment strategy for aims?	Data collected in way that addressed research question?	Relationship between researcher and participants?	Ethical consideration?	Rigorous Data Analysis?	Clear findings?
Hou et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Bose et al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Mansour et al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	No	Yes
Wanyana et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Saso et. al., 2020	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Carter et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Shapiro et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Desta et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	No	Yes	Yes
Jensen et. al., 2020	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Silveira et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	No	Yes
Harris et. al., 2021	Yes	Yes	No	No	Yes	Primary Data	Yes	Yes	Yes
Chandir et. al., 2020	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Shapira et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Abid et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Khan et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Zeitouny et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Cabral et. al., 2021	Yes	Yes	No	N/A	Yes	Secondary Data	Yes	Yes	Yes
Singh et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Patel et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Bekele et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Shet et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Nguyenet. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Mishra et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Wang et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Jain et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Avula et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	No	Yes
Nigus et. al., 2020	No	N/A	N/A	N/A	N/A	Secondary Data	No	No	Yes
Assefa et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Kawakatsu et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Adelekan et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
de Oliveira et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Shet et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Muhoza et. al., 2021	No	Yes	N/A	N/A	N/A	Secondary Data	No	N/A	Yes
Colomé-Hidalgo et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Santos et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Doubova et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Burt et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Hategeka et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Causey et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Alves et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Abu-Rish et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Babalola et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Evanset. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Khatiwada et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Suárez-Rodríguez et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Shaikh et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Rahman et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	No	Yes

Study	Aims stated?	Appropriate methods?	Appropriate methods for aims?	Appropriate recruitment strategy for aims?	Data collected in way that addressed research question?	Relationship between researcher and participants?	Ethical consideration?	Rigorous Data Analysis?	Clear findings?
Khan et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Bimpong et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Rana et. al., 2021	No	N/A	No	N/A	Yes	Secondary Data	No	No	Yes
Powelson et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Wambua et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Mariani et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Summan et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Thsehla et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Adilo et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Lucinde et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Connolly et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Burkholder et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Mbaeyi et. al., 2021	No	Yes	N/A	N/A	Yes	Secondary Data	No	Yes	Yes
Kiarie et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Doubova et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Ho et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Melkonyan et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Kissi et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	No
Minta et. al., 2022	No	Yes	No	N/A	Yes	Secondary Data	No	Yes	Yes
Plotkin et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Cooper et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Kasonia et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Winter et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Fahriani et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Orey et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	No
Sucharitha et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Manzoor et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Tawar et. al., 2022	Yes	No	Yes	Yes	Yes	Primary and Secondary Data	No	No	No
Wu et. al., 2020	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Owais et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	No	No
Rodo et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Chakrabarti et. al., 2023	Yes	Yes	No	N/A	Yes	Secondary Data	Yes	No	Yes
Berhane et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Zeidan et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	No	No	Yes
Aigbogun et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	No
Ji et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Endehabtu et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Sharma et. al., 2023	Yes	No	Yes	N/A	Yes	Secondary Data	Yes	No	No

Table 2: Modified Critical Appraisal Skills Program Quality Assessment for Qualitative Studies

Additional Supplementary Tables

OVERVIEW		OUTCOMES				
Study	**Countries**	**Routine coverage**	**SIA**	**Doses**	**Dose timing**	**Supply chain**
Hou et. al., 2021	China				TRUE	
Bose et al., 2022	Nepal		TRUE			
Mansour et al., 2021	Lebanon	TRUE		TRUE		
Wanyana et. al., 2021	Rwanda					
Saso et. al., 2020	Multiple	TRUE				
Carter et. al., 2022	Ethiopia	TRUE				
Shapiro et. al., 2022	Multiple	TRUE				
Desta et. al., 2021	Ethiopia	TRUE				
Jensen et. al., 2020	South Africa	TRUE				
Silveira et. al., 2021	Brazil	TRUE				
Harris et. al., 2021	SEAR/WPR	TRUE				
Chandir et. al., 2020	Pakistan	TRUE			TRUE	
Shapira et. al., 2021	Subsaharan Africa	TRUE		TRUE	TRUE	
Abid et. al., 2022	Afghanistan	TRUE				
Khan et. al., 2021	India			TRUE		
Zeitouny et. al., 2021	Multiple			TRUE		TRUE
Cabral et. al., 2021	Brazil and Portugal					
Singh et. al., 2021	Nepal	TRUE				
Patel et. al., 2022	India	TRUE				TRUE
Bekele et. al., 2022	Ethiopia					
Shet et. al., 2021	India	TRUE				
Nguyenet. al., 2021	India	TRUE				
Mishra et. al., 2023	India				TRUE	
Wang et. al., 2022	China				TRUE	
Jain et. al., 2021	India	TRUE		TRUE	TRUE	
Avula et. al., 2022	India					
Nigus et. al., 2020	Ethiopia					
Assefa et. al., 2021	Multiple	TRUE		TRUE		
Kawakatsu et. al., 2023	Ghana	TRUE				
Adelekan et. al., 2021	Nigeria	TRUE		TRUE		
de Oliveira et. al., 2022	Brazil			TRUE		
Shet et. al., 2022	Multiple	TRUE	TRUE			
Muhoza et. al., 2021	Multiple	TRUE				
Colomé-Hidalgo et. al., 2022	Dominican Republic	TRUE				
Santos et. al., 2021	Brazil	TRUE				
Doubova et. al., 2021	Mexico	TRUE				
Burt et. al., 2021	Uganda	TRUE	TRUE			TRUE
Hategeka et. al., 2021	DRC	TRUE				
Causey et. al., 2021	Multiple	TRUE				
Alves et. al., 2021	Brazil	TRUE				
Abu-Rish et. al., 2022	Jordan	TRUE			TRUE	

Babalola et. al., 2022	Liberia	TRUE				TRUE
Evanset. al., 2022	Multiple	TRUE				
Khatiwada et. al., 2021	Nepal				TRUE	TRUE
Suárez-Rodríguez et. al., 2022	Ecuador	TRUE		TRUE		
Shaikh et. al., 2021	Multiple	TRUE				
Rahman et. al., 2021	Pakistan	TRUE				
Khan et. al., 2022	Pakistan				TRUE	
Bimpong et. al., 2021	Ghana	TRUE				
Rana et. al., 2021	Bangladesh	TRUE				
Powelson et. al., 2022	Mozambique	TRUE		TRUE	TRUE	
Wambua et. al., 2022	Kenya	TRUE				
Mariani et. al., 2022	Sierra Leone			TRUE		
Summan et. al., 2023	India	TRUE			TRUE	
Thsehla et. al., 2023	South Africa	TRUE		TRUE		
Adilo et. al., 2022	Ethiopia					TRUE
Lucinde et. al., 2023	Kenya	TRUE				
Connolly et. al., 2022	Multiple	TRUE				
Burkholder et. al., 2021	Multiple	TRUE	TRUE			TRUE
Mbaeyi et. al., 2021	Pakistan					
Kiarie et. al., 2022	Kenya			TRUE		
Doubova et. al., 2022	Mexico	TRUE				
Ho et. al., 2022	Multiple		TRUE			
Melkonyan et. al., 2022	Armenia	TRUE				
Kissi et. al., 2022	Ghana	TRUE				
Minta et. al., 2022	Multiple	TRUE	TRUE			
Plotkin et. al., 2022	Multiple	TRUE	TRUE			
Cooper et. al., 2023	Burkina Faso	TRUE				
Kasonia et. al., 2023	Multiple			TRUE		
Winter et. al., 2023	Zambia	TRUE				
Fahriani et. al., 2021	Indonesia				TRUE	
Orey et. al., 2023	Somalia	TRUE				
Sucharitha et. al., 2022	India			TRUE		
Manzoor et. al., 2022	Pakistan				TRUE	
Tawar et. al., 2022	India	TRUE		TRUE		
Wu et. al., 2020	China	TRUE		TRUE		
Owais et. al., 2023	South Asia	TRUE				
Rodo et. al., 2022	Multiple	TRUE				
Chakrabarti et. al., 2023	India			TRUE		
Berhane et. al., 2023	Ethiopia			TRUE		
Zeidan et. al., 2023	Iraq				TRUE	
Aigbogun et. al., 2023	Nigeria	TRUE				TRUE
Ji et. al., 2023	China	TRUE			TRUE	
Endehabtu et. al., 2023	Ethiopia					TRUE
Sharma et. al., 2023	India					

Table 3: Overview of countries examined and outcomes reported (routine coverage, supplementary immunisation campaigns (SIAs), dose timing, or supply chain disruptions) by included papers.

BMJ Open

COVID-19-related disruption and resilience in immunisation activities in LMICs: a rapid review

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2023-076607.R2
Article Type:	Original research
Date Submitted by the Author:	04-Jul-2024
Complete List of Authors:	Hartner, Anna-Maria; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health; Robert Koch Institute, Centre for Artificial Intelligence in Public Health Research Li, Xiang; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health Gaythorpe, Katy; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Global health, Infectious diseases
Keywords:	COVID-19, Health Equity, Public health < INFECTIOUS DISEASES

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COVID-19-related disruption and resilience in immunisation activities in LMICs: a rapid review

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April 19, 2024

Abstract

Objectives

We conducted a rapid review to determine the extent that immunisation services in low- and middle income countries (LMICs) were disrupted by the COVID-19 pandemic and synthesised the factors that can be used to build resilience in future.

Design

Rapid review reported in accordance with Preferred reporting for Systematic reviews and Meta-Analyses (PRISMA) guidelines.

Data sources

PubMed and Web of Science were searched through 6th October 2023.

Eligibility criteria for selecting studies

We included studies that focused on disruption to immunisation activities due to the COVID-19 pandemic in LMICs. Outcomes included routine vaccine coverage, supplementary immunisation activities, vaccine doses, timing of vaccination, supply chain changes, and factors contributing to disruption or resilience.

Data extraction and synthesis

Two independent reviewers used standardised methods to search, screen, and code studies. Quality assessment was performed using a modified version of the Critical Appraisal Skills Programme (CASP) for qualitative research. Findings were summarised qualitatively.

Results

Of 4979 identified studies, 87 met the eligibility criteria. Included studies showed declines in immunisation activities across LMICs related to the COVID-19 pandemic. These included reductions in achieved routine coverage, cancellation or postponement of campaigns, and underimmunised cohorts. Immunisation was most disrupted in the early months of the pandemic; however, recovery varied by country, age-group, and vaccine. Though many countries observed partial recovery in 2020, disruption in many countries continued into 2021. It has also been noted that clinician staff shortages and vaccine stock-outs caused by supply chain disruptions contributed to immunisation delays, but that concern over COVID transmission was a leading factor. Key resiliency factors included community outreach and healthcare worker support.

Conclusions

There is limited information on whether reductions in vaccination coverage or delays have persisted beyond 2021. Further research is needed to assess ongoing disruptions and identify missed vaccine cohorts.

Strengths and limitations of this study

- The rapid synthesis of findings through the decision to structure the paper methodologically as a rapid review allows for key insights to target missed cohorts and identify research gaps related to immunisation disruption and recovery to-date.
- We include a narrative analysis of disruption across LMICs; this review benefits from the inclusion of barriers, enablers, and resilience to/in service provision.
- The search strategy was limited to English-language studies identified from databases PubMed and Web of Science up to October 6th, 2023, meaning not all relevant research meeting inclusion criteria may have been captured.

1 Introduction

The coronavirus disease 2019 (COVID-19) pandemic began on December 12th, 2019 and quickly spread globally, adding to the strain on existing healthcare provision and creating unique problems in terms of service delivery [1]. Throughout 2020, there were disruptions to screening for cancer, maternal health services, care for chronic conditions, and immunisations [2]. This strain on health services has continued past 2020, as even those that have recovered to pre-COVID levels of visits and surveillance have to catch-up missed cohorts and delayed treatments.

Low- and middle-income countries (LMICs) disproportionately bear the burden of vaccine preventable diseases [3]; however, globally, vaccination has seen a plateau in coverage, with zero-dose children an ongoing concern. The issue of zero-dose or underimmunised children is particularly important, as it can hint at wider heterogeneity in healthcare access which may have been exacerbated by the pandemic [4]. It is estimated that 67 million children missed vaccinations between 2019 and 2021; of those, 48 million were zero-dose children [5]. Furthermore, targeting zero-dose children can be more difficult as they are often in harder-to-reach areas, particularly in LMICs, where 1 in 6 children living in rural areas are zero-dose [5].

Resilient healthcare systems can withstand additional and unusual strains whilst maintaining priority services. Yet, it is still uncertain what factors contributed to disruption or resilience in light of the COVID-19 pandemic, which was a unique test on global healthcare systems. These factors and considerations may be instrumental in preparing for future healthcare strains such as those potentially caused by other epidemics, climate change, or antimicrobial resistance. As such, understanding the key factors for disruption due to the COVID-19 pandemic is critical for future planning in order to minimise the negative consequences of disruptions.

In order to understand the current state of vaccination coverage disruption, and highlight factors contributing to resilience, we undertook a rapid review of the existing literature. This focused on LMICs as they bear the majority of burden of vaccine preventable diseases. We included studies that not only discuss the quantitative measures of disruption, such as reduced immunisation coverage and cancelled campaigns, but also more qualitative discussions of the factors contributing to disruption or characteristics of resilient systems.

2 Aim and research questions

The aim of this review was to understand the extent of disruptions in vaccination coverage due to the COVID-19 pandemic and the factors that contributed to the disruption or resilience. Specifically, our research questions were:

RQ1: To what extent were immunisation services in LMICs disrupted by the COVID-19 pandemic?

RQ2: How did disruption vary by geography, demography, or socioeconomic group?
RQ3: What factors contributed to coverage disruption or resilience?

3 Methods

A rapid review (RR) was conducted using streamlined systematic review methods and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6]. The full PRISMA checklist can be found in the supplementary material.

3.1 Procedure

We searched PubMed and Web of science up to 6th October 2023 for studies published after 1st December 2019 in the English-language with search terms (((COVID-19) OR (SARS-CoV-2))) AND (immunisation OR vaccination) AND (disruption OR delay* OR postpon*). Studies were included if they focused on disruption to vaccination activities due to the COVID-19 pandemic in LMICs. Studies were excluded if they focused on high-income countries only, examined disruption due to other factors, i.e. not related to the pandemic, or were reviews, commentaries, or modelling studies without novel data.

3.2 Study selection, data extraction and quality assessment

Search results were imported into the Covidence (www.covidence.org) systematic review management tool where duplicates were removed. Titles and abstracts were screened by one reviewer, full text review was completed by two reviewers with conflicts resolved through consensus.

Each study was extracted by one reviewer into a Google sheet. We extracted information on i) last date of included data, ii) countries studied, iii) qualitative findings related to the research questions RQ1, RQ2 and RQ3, and iv) binary data on whether routine immunisation, SIAs, doses, schedule timing or supply chains were mentioned in the study. A second reviewer was consulted where there was uncertainty concerning the extracted data.

The quality of studies was assessed through a modified, nine question checklist of the Critical Appraisal Skills Programme (CASP) for qualitative studies. Results were listed as N/A if not applicable for the study. All CASP results are available in the supplementary material.

3.3 Synthesis

There were two main types of evidence to synthesise: quantitative information (i.e., percentage drops in coverage achieved, doses administered, or SIAs postponed) and qualitative information on contributing factors informed by surveys or questionnaires. We grouped results by research question. Finally, we collate characteristics of the studies themselves, such as countries studied or dates of included data. For these, we have prepared summary statistics. The full list of included studies and outcomes provided are included in the supplementary material.

3.4 Patient and public involvement

There was no patient or public involvement in this study.

4 Results

4.1 Characteristics of studies

We found 4978 studies where 85 met the inclusion criteria (Figure 1). The majority of studies were published in either 2021 (n = 30; 35.29%) or 2022 (n = 32; 37.65%), though most studies only reported on data from 2020 (n = 52; 61.18%). 14 studies (16.47%) included data during the first 6 months of 2021; a further 15 (17.64%) included data between July and

December of 2021. Only 4 studies (4.71%) included data from 2022; the most recent of these covered data through November of 2022.

Most (n = 20; 23.53%) of the studies considered multiple LMICs. Of those that only considered one country, India (n = 12; 14.11%), Ethiopia (n = 7; 8.24%), Pakistan (n = 5; 5.88%) and Brazil (n = 4; 4.71%) were the most frequently studied. The African continent was the most represented.

Most (n = 57; 67.05%) studies examined the effect of the COVID-19 pandemic on routine immunisation coverage, with an additional 7 (8.24%) reporting pandemic effects on supplementary immunisation activities. The change in the number of administered doses (n = 19; 22.35%) or the timing of doses (n = 15; 17.64%) was also reported by several studies; 8 (9.41%) reported disruptions in the vaccine supply chain.

4.2 Extent of disruption

We divide this section into a few main areas: supply chains and vaccine availability, the delivery of routine immunisation (as doses given, coverage, and/or delays), supplementary immunisation activities, and finally, signs of recovery (to pre-pandemic achieved coverage in any of the disrupted activities mentioned previously).

4.2.1 Vaccine supply

Following the declaration of COVID-19 as a pandemic, there was a reduction of vaccine sales and periods of stockout and low availability of vaccines in some countries [7, 8, 9, 10, 11], though one study in Northern Nigeria found that states experienced less stock-outs in 2020 as compared to 2019 [12]. More globally, vaccine sales between April and August 2020 fell by 9.5% across 84 countries [13], but some losses in vaccine receipt after stock-outs were recouped by catch-up activities, such as in Uganda [8].

4.2.2 Routine immunisation

We divide insight by WHO region or country.

In the WHO African Region, there was a varied picture of disruption. In Ethiopia, minimal disruptions were found up to August 2020 [14, 15, 16, 17, 10, 18]. Similarly, in DRC, disruptions in Kinshasa were minimal up to December 2020, with one study even finding increases in DTP3 and MCV1 doses administered [19, 20]. In Kenya [21, 22, 23] and Burkina Faso [24], immunisation services were largely unaffected. Zambia saw a mixed picture, in which estimates during the first 6 months of 2020 varied month-to-month, with both disruptions and positive increases as compared to previous years; overall, however, the number of additional children missed was found to be minimal [25]. In South Africa, however, full immunisation dropped in the first months of the pandemic, especially in April, where it dropped by 30% [26, 27]. Ghana [28, 29, 30], Nigeria [31], Uganda [8, 20], Liberia [32], Sierra Leone [33, 20], and Somalia [11] all saw drops in coverage in 2020, and whilst some countries had begun to see recovery in coverage achieved, this was not enough to compensate for missed cohorts [34, 20].

In the WHO region of the Americas, there were declines in coverage reported for the Dominican Republic, Mexico, Ecuador and Brazil. The Dominican Republic saw a drop of 10 percentage points [35], while vaccinations were reduced by 36% in Mexico [36, 37], and 14% fewer doses administered were in Ecuador [38]. In Brazil, approximately 20% of children missed vaccinations, with an 18% overall decline in doses administered in the first year of the pandemic [39, 40, 41]. However, one study found no significant evidence of COVID-19 isolation measures on vaccines per child in Brazil [42].

In the Eastern Mediterranean WHO region, drops in coverage were seen for Lebanon, Afghanistan, Jordan and Pakistan [43, 44, 45, 46, 47] of 31%, 21%, 6-16% and 30-48%, respectively, over the initial stages of the pandemic. Pakistan additionally reported that as of September 2021, 18% of parents had delayed routine immunisation for their children during the pandemic; an additional 2% received no immunisations [48].

In the South East Asian WHO region, there were significant disruptions [49, 50]. In India, six studies found substantial drops in coverage across the majority of districts (88% [51])

especially in lockdown and early in the pandemic [52, 53, 54, 55, 56]. As a result, children born in India after COVID-19 had a 2-10% lower probability of timely vaccination compared to earlier cohorts [57, 58]. Two studies, one conducted among the Armed Forces population in Mumbai, the other across India, found disruptions continued into 2021 [58, 56]. Only one study found that the number of immunisation sessions in India increased in 2020 and 2021 compared to 2019 [59]. In Nepal and Bangladesh, the most severe disruptions were also seen earlier in the pandemic, particularly in Bangladesh, where 20-25% of planned outreach immunisations were cancelled between April and May 2020 [60, 61]. In Indonesia, one study reported that 27.4% of parents delayed compulsory immunisation in 2020 [62].

In the WHO European region, in Armenia, there were only small declines in coverage achieved [63]. In the Western Pacific WHO Region, one study from China found that immunisation coverage dropped drastically in January 2020, but had recovered to pre-pandemic levels by June [64]. However, a second study conducted in Beijing found pandemic effects to continue into 2021, staying below 2019 levels despite catch-up activities [65].

Globally, there were substantial drops in routine immunisations in 2020 [9]. Overall, it was estimated that there were 31% fewer vaccine doses given [66]. In middle-income countries, 14% of individuals delayed or missed vaccinations in the first 6 months of the pandemic [67], and there was a 20% increase in children who had not completed the 3-dose DTP series [68]. Whilst disruption varied by vaccine [69, 70], most saw the most severe declines in the 6 months of the pandemic followed by variable recovery [71] which may affect control and elimination efforts [72].

It was not only the total number of doses administered that was affected, but also when those doses were given. In China and India, the majority of interviewed caregivers delayed vaccination [73, 74, 75, 57, 67] and in Ecuador and Sierra Leone, this delay was worse for last doses [38, 33].

4.2.3 Supplementary immunisation activities

Overall, we found fewer studies focusing on supplementary immunisation activities (SIAs) or campaigns specifically; however, there are comprehensive records kept by the WHO campaign tracker as part of the immunisation repository [76]. In 57 countries, SIAs were more disrupted in the early stages of the pandemic, with 57% of planned campaigns globally postponed or cancelled because of COVID-19 by May 2020 [76]. By December 2020, this had fallen to 26% and many campaigns were reinstated from July 2020 onwards. By December 2021, in 54 countries, this had fallen again to 16% of scheduled campaigns delayed or cancelled [76]. Overall, of those campaigns disrupted between March 2020 and December 2021, 59% had been reinstated [76]. Factors leading to postponement or cancellation of SIAs included non-pharmaceutical interventions, such as national lockdowns, [77] and stockouts or increased demand for general healthcare supplies [78, 8]. One study found that the national policy guidance of Mozambique and Uganda recommend the halting of campaigns in 2020 [79]. Additionally, whilst some SIAs had been reinstated, and there were plans for catchup activities, there are still large missed cohorts [53, 80, 72, 9].

4.2.4 Recovery

Information on recovery is limited by the date ranges of the included studies, which mainly focused on 2020 and 2021. A key finding is that while there were signs of improvement in routine immunisation coverage achieved and reinstated vaccination campaigns, there was not the positive increase needed to catch up missed cohorts, i.e. a sufficient return to pre-pandemic levels of immunisation [34, 66, 70, 61, 37, 81, 33, 65]. It was also noted that pre-COVID levels of coverage had not been reached in many countries by the end of 2022 [72].

4.3 Heterogeneity in disruption

Heterogeneity in immunisation disruption was found across several factors, including geography, demography, wealth, and education; these are further detailed below. Variations in the extent of disruption by antigen were similarly reported in several studies [38, 44, 49, 13, 75, 20, 10, 18, 65, 64].

4.3.1 Geographic Heterogeneity

Despite significant overall decreases in immunisation in LMICs, there was geographic heterogeneity in the extent of disruption and in the regions and/or individuals affected. On a national level, several studies reported differences in the extent of disruption as a result of economic income classification [67, 49, 68] by WHO Region [78, 69, 68], by global burden of disease super-region [66], or by Gavi eligibility [68], with greater pandemic impact observed in low- and middle-income countries compared to high-income countries, affecting the primarily African Region, the Americas, and Asia. The reverse trend was seen for vaccine sales early in the pandemic (i.e. April to August 2020), with high-income countries experiencing a 20% decline and low-income countries observing a 10% increase [13].

On a sub-national level, many countries observed statistically significant differences between regions, provinces, or districts in regards to the change in health service utilisation [82, 37, 51, 59, 56], routine immunisation coverage [38, 44, 55], or complete vaccination [24]. In some countries, certain provinces reported increases in immunisation service provision or doses for some vaccines, such as in the Southern Province of Rwanda, where measles and rubella immunisation increased [82]. Geographic heterogeneity was also observed in the subsequent recovery of services [51, 27].

While some countries reported differences in disruption between urban and rural areas, there was significant heterogeneity in the extent of disruption. One study found that the odds of immunisation in Ethiopia were higher in rural areas [14], while another observed greater initial declines in urban and peri-urban areas in South Africa, followed by recovery in these areas and declines in rural areas as the pandemic progressed [27]. In Pakistan, lockdown affected rural areas more than urban areas [46]. Geographic heterogeneity was also observed between Ethiopia's hospitals and health centres, in which vaccine-related supplies were twice as likely to be affected by COVID-19 in hospitals [7, 10]; in Nigeria, activities coordinated at the state level were impacted less than healthcare facilities [12]. In China, immunisation services continued in hospitals, even when immunisation clinics were suspended [64].

In India, children residing in "COVID-19 red zones" were more likely to face immunisation disruption [55]. Similarly, a study on polio outreach services in 33 African and Eastern Mediterranean countries found services necessary for "reaching their most vulnerable populations" were partially or severely disrupted [78].

4.3.2 Demographic Heterogeneity

Few studies focused on the effects of demographic heterogeneity on COVID-19 related immunisation disruption, including factors such as gender, age, birth order, or caste. Only two studies looked at differences by gender; one found greater declines in females than males, though this decline was not significant [44]. The second, conducted in Brazil, also found no significant differences, but did find that infants were less likely to experience immunisation disruptions or delays compared to one-year old children [39]. This finding was similar to two studies, conducted in Eastern India and in China, where increasing age of the child was found to be associated with immunisation delays [74, 75]. A study conducted in South-East Asia and the Western Pacific found similar results, in which early-infancy was less disrupted than infancy, school-entry age, and adolescent immunisation [49]. However, greater disruption was seen among infants compared to adult/elderly immunisation [49]. Additionally, one study in Jordan found that children older than 12 months were less likely to experience delays [45]. Finally, one study conducted in China found firstborn children were less likely to experience delays [75], while another paper in India examined heterogeneity as a result of ethnicity or caste, finding lower castes had lower likelihoods of full immunisation and greater immunisation disruption, though these findings were not significant [55].

While even fewer articles examined the demographic heterogeneity of disruption based on the characteristics of parents or caregivers, two studies stratified results by maternal or caregiver age; one finding that increasing maternal age was associated with delayed vaccination [74], the other finding no association [45]. Only one study examined other contributing factors of parents, finding that women were more likely to delay vaccination for their children than men; presence of a chronic illness, prior flu vaccination, or experience with COVID-19 diagnosis were also associated with delays in childhood vaccination [62].

4.3.3 Socioeconomic Heterogeneity

Contributors to socioeconomic heterogeneity in immunisation disruption largely included measures of household income and education. Two studies, one in Brazil and the other in India, found that missed vaccine doses were more likely in children from poorer households [55, 39]; in India it was additionally found that there were greater declines in immunisation among poorer subgroups [55]. A study in South Africa found mixed results, finding declines in full immunisation and first dose of measles greater in wealthier quintiles at the start of the pandemic, but with faster positive recovery and continued declines among poorer subgroups as the pandemic progressed [27]. Another study in Iraq found that low socioeconomic status was associated with an increase in missed vaccine appointments [83]. Two studies, one conducted in Iraq and one conducted in Indonesia, similarly found that the type of employment changed the odds of vaccination during the pandemic [62, 83]; in Indonesia, healthcare workers especially were more likely to delay vaccination in their children [62].

Only two studies, one in India and one in Iraq, focused on education, similarly finding higher probability of incomplete immunisation and greater declines in households without formal education [55, 83].

4.4 Factors contributing to coverage disruption and resilience

We divide this section into three key areas: health system barriers, vaccine demand, and resilience.

4.4.1 Health System Barriers

Many of the initial challenges in maintaining immunisation services in LMICs were the result of health system and supply barriers during the early stages of the pandemic. Many countries reported issues with vaccine supply delays or stock-outs [37, 7, 84, 81, 32, 8, 9, 85, 11, 58, 86] and lack of personal protective equipment (PPE) for healthcare workers (HCWs), including masks, gloves, and other drugs and supplies [7, 84, 32, 31, 87, 51, 85, 53, 54, 51, 12]. Disruption caused by vaccine stock-outs or supplies was found to vary by WHO region [9] or by geographical sub-region [31, 87, 49, 10]; notably one study in Southeast Asia and the Western Pacific found vaccine stockouts to be among the least important reasons for service provision delays [49]. A lack of logistical support impacting routine services or outreach, such as a lack of fuel or water, was reported by three studies in the WHO African region [84, 32, 31].

Similarly, HCW availability posed a significant challenge, with countries citing difficulties due to the diversion of staff to COVID-19 response, staff illness, and transportation difficulties, among others [32, 9, 31, 85, 53, 54, 31, 51, 18, 12]. One study in Kenya further reported disruption due to a HCW strike from December 2020 to January 2021 [23]. On an individual level, HCWs reported that pandemic related stigma, stress, or fears impacted service delivery [7, 31, 60, 54, 85, 51], with some additionally reporting harassment by law enforcement or by patients themselves [31, 51]. Only one study, conducted at a tertiary health centre in Ghana, found no disruptions to vaccine supply or in HCW availability [29].

COVID-19 lockdowns and restrictions also resulted in cancelled immunisation services, clinic closures, or reduced healthcare access or services available [7, 88, 32, 31, 46, 49, 67, 55, 77, 45, 62, 89, 86, 83], with some reporting difficulties maintaining COVID-19 prevention rules, such as social distancing, due to non-compliant patients or a lack of space [84, 31, 54, 12].

Competing priorities also meant some countries faced declines in funding for immunisation services or supplies, resulting in financial constraints [53, 87, 12].

4.4.2 Vaccine Demand and Acceptance

Many of the challenges in maintaining routine immunisation services during the COVID-19 pandemic also resulted from declining vaccine demand and increasing fear or stigma surrounding COVID-19 among caregivers. Declines in vaccine demand were frequently attributed to travel barriers or difficulties in reaching immunisation services or clinics [55, 75, 17, 32, 9, 16, 54, 53, 60, 49, 65, 12, 83, 18, 48, 89], COVID-19 restrictions or requirements, including testing requirements, mask requirements, or lockdowns, [88, 84, 45, 47, 85, 60, 67], and financial constraints [16, 53, 60, 67]. One study, conducted in South East Asia and

the Western Pacific, reported that while affordability issues contributed to immunisation service utilisation, it was among the lowest ranked reasons [49]. Some caregivers additionally reported low or no awareness of the availability of immunisation services, often believing clinics and hospitals were closed for routine immunisation services [84, 53, 29, 74].

Declines in vaccine demand due to fears of contracting COVID-19 at clinics or hospitals was pervasive, and one of the most reported causes across several studies [55, 67, 49, 60, 85, 53, 47, 16, 29, 54, 45, 9, 74, 84, 32, 12, 18, 58, 48, 89]. Many others reported additional fear or stigma against healthcare providers, including fears that staff might be infected by the virus [29, 60, 54, 32, 85]. One survey of 100 caregivers at a tertiary health centre in Eastern India found that 83% of respondents agreed that "safety [was] more important than vaccination" [74]. Further unspecified declines in vaccine demand were noted by several studies [9, 81, 46].

Vaccine hesitancy factors were less commonly reported; misinformation and misbeliefs contributed to declines in demand in just two studies [9, 60], while fears specifically about vaccine side effects were found in just one study in a tertiary hospital in North Ghana [29]. One additional study in Liberia reported declines due to vaccine conspiracies, where parents believed their children would be injected with COVID-19 [32]. Only one in Ethiopia study reported fewer declines in vaccine demand as a result of COVID-19 pandemic misinformation, including that they were not susceptible to the disease, the disease was not severe, or that the pandemic did not exist [18].

4.4.3 Resiliency

Though few papers highlighted resiliency factors or enablers to immunisation during the COVID-19 pandemic, two key focuses included community outreach to address declining vaccine demand and acceptance and the importance of improved healthcare worker support to increase service provision. In Jordan and China, alternative arrangements for childhood vaccination (i.e. outside of the standard service provision within healthcare clinics) was found to be key to maintaining immunisation demand, though in Jordan this insight was based on a survey of caregiver beliefs[45, 73]. Similarly, a community intervention highlighting the importance of maintaining timely vaccination, despite the pandemic, was crucial in Jordan, India, and in Ethiopia [45, 16, 18, 58]. Ethiopia additionally reported decreased fear of COVID-19 as an enabling factor [16]. In India, adequate access to PPE, overcoming barriers to transportation for HCWs, community and/or family support, and training on COVID-19 management was crucial to support HCWs in maintaining immunisation service provision[85]. Similarly, proactive communication and coordination on all levels of the healthcare system was essential in Ethiopia in maintaining health system resiliency[87]. In India, capacity building to ensure a trained workforce assisted in maintaining immunisation programs [58, 89], while in Nigeria, one study found the supply chain logistics to be the most important factor for maintaining immunisation services [12]. Finally, in Zambia, community awareness through the National Immunization Campaign assisted in catching up pandemic declines [25].

5 Discussion

Despite the challenges faced by health systems during the COVID-19 pandemic, the WHO has continued to emphasise the importance of routine immunisation, noting that the last effects of immunisation declines can lead to higher burdens of disease and/or excess deaths[90]. This review highlights the extent of disruption faced by LMICs, finding significant heterogeneity between and within regions, countries, and individual demographics, but nevertheless showing declines in routine immunisation in 2020 and 2021 that had not often not recovered to pre-COVID levels.

SIAs and campaigns were postponed with few regions reporting full recovery. Many LMICs rely on outreach services to reach vulnerable populations, especially where access to health clinics or services are limited[9]. COVID-19 response efforts or mitigation strategies, including lockdowns, resulted in additional disruption to transportation services, logistical support, or supplies, often hindering additional outreach activities and limiting the services that were available. This has resulted in a deepening of existing coverage inequalities, with studies noting greater disruptions among households with lower incomes, formal education,

or those situated in informal housing or in some regions, rural areas, emphasising the heterogeneity that existed prior to the pandemic [91].

We utilised a rapid review format for this study, which includes some limitations. We included only two databases for the time period and only studies in English. As a result, we may be missing studies stored in other databases or in other languages. Additionally, rapid reviews may have additional risks of bias, given the single-reviewer extraction and synthesis of findings.

The findings in this study are limited by the data available — the majority of studies utilised data from 2020, limiting much of our understanding of how routine immunisation services have recovered since countries lifted lockdown or other COVID-19 response policies. Our study also does not include grey literature, only articles. Nevertheless, this study expands upon the findings of a systematic review of available literature on childhood disruptions to immunisation using data from 2020, which included 39 studies and found an overall median decline of 10.8% [92]. Additionally, our study only focuses on LMICs; this is in contrast to high-income countries, which, according to one study on 26 middle- and high-income countries, saw considerably less missed vaccination [67]. Our study highlights the findings through 2022 and emphasises the ongoing heterogeneity in immunisation, alongside the barriers and enablers to service provision.

Our findings also emphasise the urgency required to target individuals and cohorts who may have missed out on routine immunisation or campaigns during the COVID-19 pandemic, ensuring the barriers highlighted by staff and caretakers, including low staff or service availability, vaccine or supply stockouts, and transportation barriers are mitigated. Importantly, approaches to combat fears, misinformation, or misbeliefs, including those surrounding COVID-19 transmission and risk, are critical. Though few studies touched on vaccine hesitancy, declining vaccine acceptance has become a formative issue, and additional strategies are required to prevent additional backsliding[93].

Rebuilding immunisation services in LMICs will require a greater focus on healthcare resilience, so that the disruption caused by future epidemics or disasters on routine immunisation services is minimal, and that recovery and performance rapid and improved through an adaptation to real-world events[94]. Many of the countries that showed service delivery resilience during the COVID-19 pandemic highlighted the need for proactive and ongoing communication and coordination across multiple interconnected systems, especially between the community and healthcare system. One study, published in May of 2023, offers an updated framework to address the idea of epidemic-ready primary healthcare. Importantly, this framework offers solutions to many of the observed barriers found in this review, focusing on adequate training, compensation, and protection for HCWs, reliable logistic and supply-chain infrastructure, and linkages to the community[95]. Given the reliance on primary health care and outreach systems for immunisation in LMICs, this approach may be a beneficial starting point, though notably, it will require a shift in how healthcare currently interacts with public health, alongside strong political commitment and financing[95]. Further research will be required to understand how post-pandemic disruption and recovery in immunisation services has progressed, especially in regards to vulnerable communities.

6 Conclusion

This review highlights the extent and heterogeneity of immunisation disruption in LMICs as a result of the COVID-19 pandemic and the factors contributing to disruption and resilience in immunisation programs. Given there is limited information on whether reductions in vaccination coverage or delays have persisted beyond 2021, further research is needed to assess ongoing disruptions, identify missed vaccine cohorts, and examine factors contributing to resilience. Furthermore, these findings highlight the need for immunisation programs to provide support for healthcare workers and proactive communication within the health system and with the wider community to ensure the effect of future disasters on vulnerable communities is minimal.

7 Contributorship Statement

AMH: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing — Review and Editing. XL.: Conceptualization, Methodology, Writing — Review and Editing. KAMG: Guarantor, Supervision, Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing — Review and Editing

8 Competing Interests

Authors declare no other competing interests.

9 Funding

This work was carried out as part of the Vaccine Impact Modelling Consortium (www.vaccineimpact.org), which is jointly funded by the Bill & Melinda Gates Foundation (Grant Numbers INV-034281 and INV 009125 / OPP1157270) and Gavi, the Vaccine Alliance. The views expressed are those of the authors and not necessarily those of the Consortium or its funders. The funders were given the opportunity to review this paper prior to publication, but the final decision on the content of the publication was taken by the authors.

AMH, XL, and KAMG also acknowledge funding from the MRC Centre for Global Infectious Disease Analysis (reference MR/R015600/1), jointly funded by the UK Medical Research Council (MRC) and the UK Foreign, Commonwealth Development Office (FCDO), under the MRC/FCDO Concordat agreement and is also part of the EDCTP2 programme supported by the European Union; and acknowledge funding by Community Jameel. KAMG reports speaker fees from Sanofi Pasteur outside the submitted work.

10 Data Sharing Statement

All data relevant to the study are included in the article or uploaded as supplementary information.

11 Ethics Approval Statement

This study involved the use of secondary data and does not require ethical approval.

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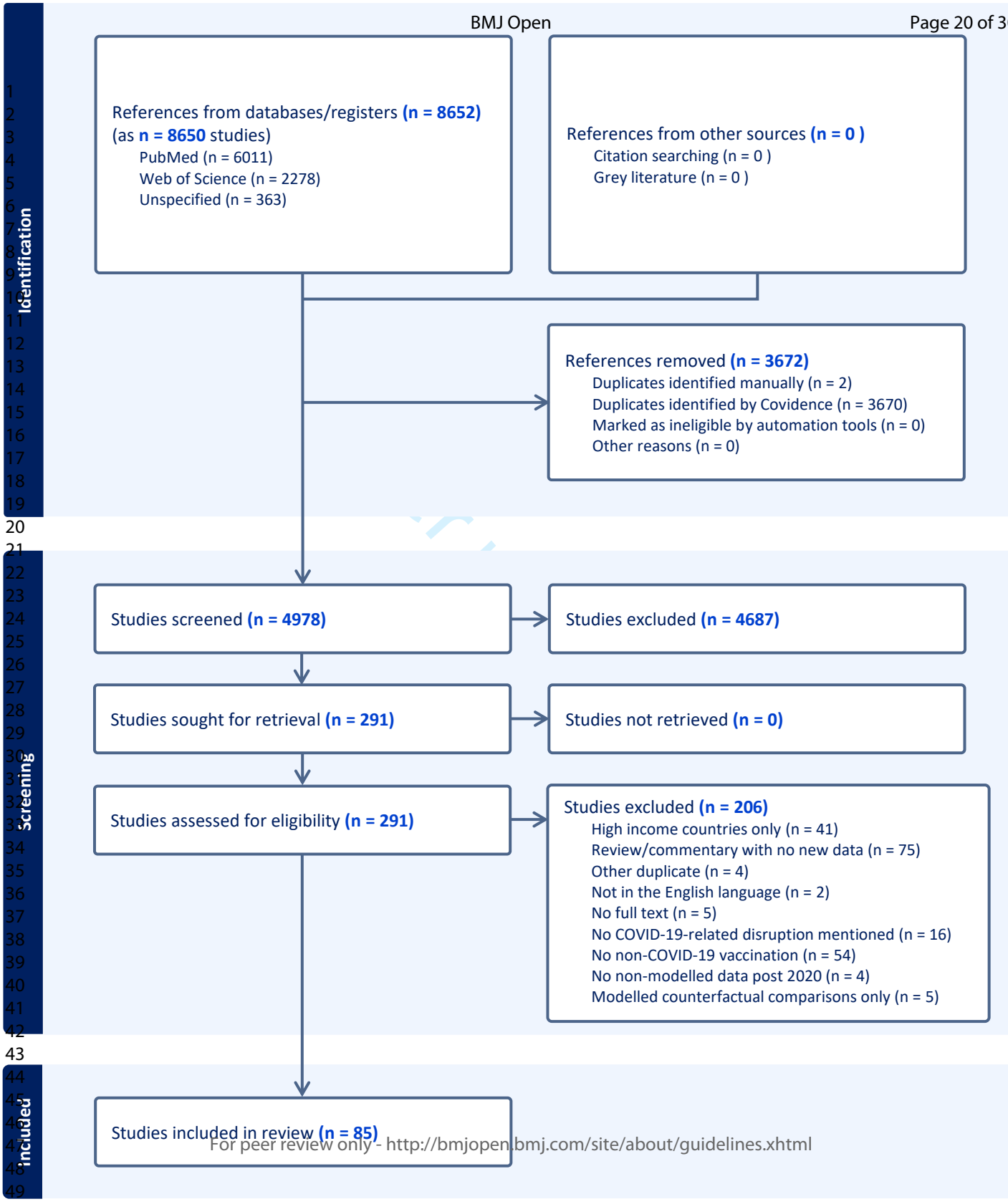

Supplementary Index: COVID-19-related disruption and resiliency in immunisation activities in LMICs: a rapid review

Anna-Maria Hartner, Xiang Li, Katy Gaythorpe

April 19, 2024

Search Strategy

We searched PubMed and Web of science on 6th October 2023 for studies published after 1st December 2019 in English. Our full list of search terms was as follows: (((COVID-19) OR (SARS-CoV-2))) AND (immunisation OR vaccination) AND (disruption OR delay* OR postpon*).

PRISMA Checklist

Section and Topic	Item	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title identifies study as a rapid review.
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract follows BMJ Open guidelines.
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Introduction
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Aim and research questions
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods: procedure.
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Methods: procedure.
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Methods: procedure and supplementary index.
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment

Section and Topic	Item	Checklist item	Location where item is reported
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods: Study selection, data extraction and quality assessment
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Methods: Study selection, data extraction and quality assessment
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	N/A; narrative synthesis only.
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item 5)).	All studies meeting inclusion criteria were synthesized.
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A; narrative synthesis only.
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	N/A
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Methods: Synthesis
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A; narrative synthesis only.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A; narrative synthesis only.
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	N/A; limitations in discussion.
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	N/A; narrative synthesis only.

Section and Topic	Item	Checklist item	Location where item is reported
RESULTS			
	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results: Characteristics of studies
Study selection	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Results: Characteristics of studies
Study characteristics	17	Cite each included study and present its characteristics.	Results: Characteristics of studies; all studies are cited throughout.
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supplementary Index: additional tables
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	N/A; narrative synthesis only
	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Results; bias in discussion.
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A; narrative synthesis only.
Results of syntheses	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A; narrative synthesis only.
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A; narrative synthesis only.
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Discussion
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Discussion
DISCUSSION			
	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion
	23b	Discuss any limitations of the evidence included in the review.	Discussion

Section and Topic	Item	Checklist item	Location where item is reported
Discussion	23c	Discuss any limitations of the review processes used.	Discussion
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Review was not registered.
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Protocol was not prepared.
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Acknowledgments
Competing interests	26	Declare any competing interests of review authors.	Acknowledgments
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Articles used in narrative synthesis are publicly available and given in citations.

Table 1: Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Checklist

Critical Appraisal Skills Program Quality Assessment

Study	Aims stated?	Appropriate methods?	Appropriate methods for aims?	Appropriate recruitment strategy for aims?	Data collected in way that addressed research question?	Relationship between researcher and participants?	Ethical consideration?	Rigorous Data Analysis?	Clear findings?
Hou et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Bose et al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Mansour et al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	No	Yes
Wanyana et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Saso et. al., 2020	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Carter et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Shapiro et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Desta et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	No	Yes	Yes
Jensen et. al., 2020	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Silveira et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	No	Yes
Harris et. al., 2021	Yes	Yes	No	No	Yes	Primary Data	Yes	Yes	Yes
Chandir et. al., 2020	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Shapira et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Abid et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Khan et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Zeitouny et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Cabral et. al., 2021	Yes	Yes	No	N/A	Yes	Secondary Data	Yes	Yes	Yes
Singh et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Patel et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Bekele et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Shet et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Nguyenet. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Mishra et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Wang et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Jain et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Avula et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	No	Yes
Nigus et. al., 2020	No	N/A	N/A	N/A	N/A	Secondary Data	No	No	Yes
Assefa et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Kawakatsu et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Adelekan et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
de Oliveira et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Shet et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Muhoza et. al., 2021	No	Yes	N/A	N/A	N/A	Secondary Data	No	N/A	Yes
Colomé-Hidalgo et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Santos et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Doubova et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Burt et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Hategeka et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Causey et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Alves et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Abu-Rish et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Babalola et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Evanset. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Khatiwada et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Suárez-Rodríguez et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Shaikh et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Rahman et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	No	Yes

Study	Aims stated?	Appropriate methods?	Appropriate methods for aims?	Appropriate recruitment strategy for aims?	Data collected in way that addressed research question?	Relationship between researcher and participants?	Ethical consideration?	Rigorous Data Analysis?	Clear findings?
Khan et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Bimpong et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Rana et. al., 2021	No	N/A	No	N/A	Yes	Secondary Data	No	No	Yes
Powelson et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Wambua et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Mariani et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Summan et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Thsehla et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Adilo et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Lucinde et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Connolly et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Burkholder et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Mbaeyi et. al., 2021	No	Yes	N/A	N/A	Yes	Secondary Data	No	Yes	Yes
Kiarie et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Doubova et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Ho et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Melkonyan et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Kissi et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	No
Minta et. al., 2022	No	Yes	No	N/A	Yes	Secondary Data	No	Yes	Yes
Plotkin et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Cooper et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Kasonia et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Winter et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Fahriani et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Orey et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	No
Sucharitha et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Manzoor et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Tawar et. al., 2022	Yes	No	Yes	Yes	Yes	Primary and Secondary Data	No	No	No
Wu et. al., 2020	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Owais et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	No	No
Rodo et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Chakrabarti et. al., 2023	Yes	Yes	No	N/A	Yes	Secondary Data	Yes	No	Yes
Berhane et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Zeidan et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	No	No	Yes
Aigbogun et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	No
Ji et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Endehabtu et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Sharma et. al., 2023	Yes	No	Yes	N/A	Yes	Secondary Data	Yes	No	No

Table 2: Modified Critical Appraisal Skills Program Quality Assessment for Qualitative Studies

Additional Supplementary Tables

OVERVIEW		OUTCOMES				
Study	**Countries**	**Routine coverage**	**SIA**	**Doses**	**Dose timing**	**Supply chain**
Hou et. al., 2021	China				TRUE	
Bose et al., 2022	Nepal		TRUE			
Mansour et al., 2021	Lebanon	TRUE		TRUE		
Wanyana et. al., 2021	Rwanda					
Saso et. al., 2020	Multiple	TRUE				
Carter et. al., 2022	Ethiopia	TRUE				
Shapiro et. al., 2022	Multiple	TRUE				
Desta et. al., 2021	Ethiopia	TRUE				
Jensen et. al., 2020	South Africa	TRUE				
Silveira et. al., 2021	Brazil	TRUE				
Harris et. al., 2021	SEAR/WPR	TRUE				
Chandir et. al., 2020	Pakistan	TRUE			TRUE	
Shapira et. al., 2021	Subsaharan Africa	TRUE		TRUE	TRUE	
Abid et. al., 2022	Afghanistan	TRUE				
Khan et. al., 2021	India			TRUE		
Zeitouny et. al., 2021	Multiple			TRUE		TRUE
Cabral et. al., 2021	Brazil and Portugal					
Singh et. al., 2021	Nepal	TRUE				
Patel et. al., 2022	India	TRUE				TRUE
Bekele et. al., 2022	Ethiopia					
Shet et. al., 2021	India	TRUE				
Nguyenet. al., 2021	India	TRUE				
Mishra et. al., 2023	India				TRUE	
Wang et. al., 2022	China				TRUE	
Jain et. al., 2021	India	TRUE		TRUE	TRUE	
Avula et. al., 2022	India					
Nigus et. al., 2020	Ethiopia					
Assefa et. al., 2021	Multiple	TRUE		TRUE		
Kawakatsu et. al., 2023	Ghana	TRUE				
Adelekan et. al., 2021	Nigeria	TRUE		TRUE		
de Oliveira et. al., 2022	Brazil			TRUE		
Shet et. al., 2022	Multiple	TRUE	TRUE			
Muhoza et. al., 2021	Multiple	TRUE				
Colomé-Hidalgo et. al., 2022	Dominican Republic	TRUE				
Santos et. al., 2021	Brazil	TRUE				
Doubova et. al., 2021	Mexico	TRUE				
Burt et. al., 2021	Uganda	TRUE	TRUE			TRUE
Hategeka et. al., 2021	DRC	TRUE				
Causey et. al., 2021	Multiple	TRUE				
Alves et. al., 2021	Brazil	TRUE				
Abu-Rish et. al., 2022	Jordan	TRUE			TRUE	

Babalola et. al., 2022	Liberia	TRUE				TRUE
Evanset. al., 2022	Multiple	TRUE				
Khatiwada et. al., 2021	Nepal				TRUE	TRUE
Suárez-Rodríguez et. al., 2022	Ecuador	TRUE		TRUE		
Shaikh et. al., 2021	Multiple	TRUE				
Rahman et. al., 2021	Pakistan	TRUE				
Khan et. al., 2022	Pakistan				TRUE	
Bimpong et. al., 2021	Ghana	TRUE				
Rana et. al., 2021	Bangladesh	TRUE				
Powelson et. al., 2022	Mozambique	TRUE		TRUE	TRUE	
Wambua et. al., 2022	Kenya	TRUE				
Mariani et. al., 2022	Sierra Leone			TRUE		
Summan et. al., 2023	India	TRUE			TRUE	
Thsehla et. al., 2023	South Africa	TRUE		TRUE		
Adilo et. al., 2022	Ethiopia					TRUE
Lucinde et. al., 2023	Kenya	TRUE				
Connolly et. al., 2022	Multiple	TRUE				
Burkholder et. al., 2021	Multiple	TRUE	TRUE			TRUE
Mbaeyi et. al., 2021	Pakistan					
Kiarie et. al., 2022	Kenya			TRUE		
Doubova et. al., 2022	Mexico	TRUE				
Ho et. al., 2022	Multiple		TRUE			
Melkonyan et. al., 2022	Armenia	TRUE				
Kissi et. al., 2022	Ghana	TRUE				
Minta et. al., 2022	Multiple	TRUE	TRUE			
Plotkin et. al., 2022	Multiple	TRUE	TRUE			
Cooper et. al., 2023	Burkina Faso	TRUE				
Kasonia et. al., 2023	Multiple			TRUE		
Winter et. al., 2023	Zambia	TRUE				
Fahriani et. al., 2021	Indonesia				TRUE	
Orey et. al., 2023	Somalia	TRUE				
Sucharitha et. al., 2022	India			TRUE		
Manzoor et. al., 2022	Pakistan				TRUE	
Tawar et. al., 2022	India	TRUE		TRUE		
Wu et. al., 2020	China	TRUE		TRUE		
Owais et. al., 2023	South Asia	TRUE				
Rodo et. al., 2022	Multiple	TRUE				
Chakrabarti et. al., 2023	India			TRUE		
Berhane et. al., 2023	Ethiopia			TRUE		
Zeidan et. al., 2023	Iraq				TRUE	
Aigbogun et. al., 2023	Nigeria	TRUE				TRUE
Ji et. al., 2023	China	TRUE			TRUE	
Endehabtu et. al., 2023	Ethiopia					TRUE
Sharma et. al., 2023	India					

Table 3: Overview of countries examined and outcomes reported (routine coverage, supplementary immunisation campaigns (SIAs), dose timing, or supply chain disruptions) by included papers.

BMJ Open

COVID-19-related disruption and resilience in immunisation activities in LMICs: a rapid review

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2023-076607.R3
Article Type:	Original research
Date Submitted by the Author:	16-Jul-2024
Complete List of Authors:	Hartner, Anna-Maria; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health; Robert Koch Institute, Centre for Artificial Intelligence in Public Health Research Li, Xiang; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health Gaythorpe, Katy; Imperial College London, MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Global health, Infectious diseases
Keywords:	COVID-19, Health Equity, Public health < INFECTIOUS DISEASES

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COVID-19-related disruption and resilience in immunisation activities in LMICs: a rapid review

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April 19, 2024

Abstract

Objectives

We conducted a rapid review to determine the extent that immunisation services in low- and middle income countries (LMICs) were disrupted by the COVID-19 pandemic and synthesised the factors that can be used to build resilience in future.

Design

Rapid review reported in accordance with Preferred reporting for Systematic reviews and Meta-Analyses (PRISMA) guidelines.

Data sources

PubMed and Web of Science were searched through 6th October 2023.

Eligibility criteria for selecting studies

We included studies that focused on disruption to immunisation activities due to the COVID-19 pandemic in LMICs. Outcomes included routine vaccine coverage, supplementary immunisation activities, vaccine doses, timing of vaccination, supply chain changes, and factors contributing to disruption or resilience.

Data extraction and synthesis

Two independent reviewers used standardised methods to search, screen, and code studies. Quality assessment was performed using a modified version of the Critical Appraisal Skills Programme (CASP) for qualitative research. Findings were summarised qualitatively.

Results

Of 4979 identified studies, 87 met the eligibility criteria. Included studies showed declines in immunisation activities across LMICs related to the COVID-19 pandemic. These included reductions in achieved routine coverage, cancellation or postponement of campaigns, and underimmunised cohorts. Immunisation was most disrupted in the early months of the pandemic; however, recovery varied by country, age-group, and vaccine. Though many countries observed partial recovery in 2020, disruption in many countries continued into 2021. It has also been noted that clinician staff shortages and vaccine stock-outs caused by supply chain disruptions contributed to immunisation delays, but that concern over COVID transmission was a leading factor. Key resiliency factors included community outreach and healthcare worker support.

Conclusions

There is limited information on whether reductions in vaccination coverage or delays have persisted beyond 2021. Further research is needed to assess ongoing disruptions and identify missed vaccine cohorts.

Strengths and limitations of this study

- The rapid synthesis of findings through the decision to structure the paper methodologically as a rapid review allows for key insights to target missed cohorts and identify research gaps related to immunisation disruption and recovery to-date.
- We include a narrative analysis of disruption across LMICs; this review benefits from the inclusion of barriers, enablers, and resilience to/in service provision.
- The search strategy was limited to English-language studies identified from databases PubMed and Web of Science up to October 6th, 2023, meaning not all relevant research meeting inclusion criteria may have been captured.

1 Introduction

The coronavirus disease 2019 (COVID-19) pandemic began on December 12th, 2019 and quickly spread globally, adding to the strain on existing healthcare provision and creating unique problems in terms of service delivery [1]. Throughout 2020, there were disruptions to screening for cancer, maternal health services, care for chronic conditions, and immunisations [2]. This strain on health services has continued past 2020, as even those that have recovered to pre-COVID levels of visits and surveillance have to catch-up missed cohorts and delayed treatments.

Low- and middle-income countries (LMICs) disproportionately bear the burden of vaccine preventable diseases [3]; however, globally, vaccination has seen a plateau in coverage, with zero-dose children an ongoing concern. The issue of zero-dose or underimmunised children is particularly important, as it can hint at wider heterogeneity in healthcare access which may have been exacerbated by the pandemic [4]. It is estimated that 67 million children missed vaccinations between 2019 and 2021; of those, 48 million were zero-dose children [5]. Furthermore, targeting zero-dose children can be more difficult as they are often in harder-to-reach areas, particularly in LMICs, where 1 in 6 children living in rural areas are zero-dose [5].

Resilient healthcare systems can withstand additional and unusual strains whilst maintaining priority services. Yet, it is still uncertain what factors contributed to disruption or resilience in light of the COVID-19 pandemic, which was a unique test on global healthcare systems. These factors and considerations may be instrumental in preparing for future healthcare strains such as those potentially caused by other epidemics, climate change, or antimicrobial resistance. As such, understanding the key factors for disruption due to the COVID-19 pandemic is critical for future planning in order to minimise the negative consequences of disruptions.

In order to understand the current state of vaccination coverage disruption, and highlight factors contributing to resilience, we undertook a rapid review of the existing literature. This focused on LMICs as they bear the majority of burden of vaccine preventable diseases. We included studies that not only discuss the quantitative measures of disruption, such as reduced immunisation coverage and cancelled campaigns, but also more qualitative discussions of the factors contributing to disruption or characteristics of resilient systems.

2 Aim and research questions

The aim of this review was to understand the extent of disruptions in vaccination coverage due to the COVID-19 pandemic and the factors that contributed to the disruption or resilience. Specifically, our research questions were:

RQ1: To what extent were immunisation services in LMICs disrupted by the COVID-19 pandemic?

RQ2: How did disruption vary by geography, demography, or socioeconomic group?
RQ3: What factors contributed to coverage disruption or resilience?

3 Methods

A rapid review (RR) was conducted using streamlined systematic review methods and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6]. The full PRISMA checklist can be found in the supplementary material on pages 1-5.

3.1 Procedure

We searched PubMed and Web of science up to 6th October 2023 for studies published after 1st December 2019 in the English-language with search terms (((COVID-19) OR (SARS-CoV-2))) AND (immunisation OR vaccination) AND (disruption OR delay* OR postpon*). Studies were included if they focused on disruption to vaccination activities due to the COVID-19 pandemic in LMICs. Studies were excluded if they focused on high-income countries only, examined disruption due to other factors, i.e. not related to the pandemic, or were reviews, commentaries, or modelling studies without novel data.

3.2 Study selection, data extraction and quality assessment

Search results were imported into the Covidence (www.covidence.org) systematic review management tool where duplicates were removed. Titles and abstracts were screened by one reviewer, full text review was completed by two reviewers with conflicts resolved through consensus.

Each study was extracted by one reviewer into a Google sheet. We extracted information on i) last date of included data, ii) countries studied, iii) qualitative findings related to the research questions RQ1, RQ2 and RQ3, and iv) binary data on whether routine immunisation, SIAs, doses, schedule timing or supply chains were mentioned in the study. A second reviewer was consulted where there was uncertainty concerning the extracted data.

The quality of studies was assessed through a modified, nine question checklist of the Critical Appraisal Skills Programme (CASP) for qualitative studies. The 10th question, “how valuable is the research,” was omitted given the aim to assess quality based on binary indicators and given no studies were excluded based on determinations of value. Results were listed as N/A if not applicable for the study. All CASP results are available in the supplementary material on pages 6-8.

3.3 Synthesis

There were two main types of evidence to synthesise: quantitative information (i.e., percentage drops in coverage achieved, doses administered, or SIAs postponed) and qualitative information on contributing factors informed by surveys or questionnaires. We grouped results by research question. Finally, we collate characteristics of the studies themselves, such as countries studied or dates of included data. For these, we have prepared summary statistics. The full list of included studies and outcomes provided are included in the supplementary material.

3.4 Patient and public involvement

There was no patient or public involvement in this study.

4 Results

4.1 Characteristics of studies

We found 4978 studies where 85 met the inclusion criteria (Figure 1). The majority of studies were published in either 2021 (n = 30; 35.29%) or 2022 (n = 32; 37.65%), though most studies only reported on data from 2020 (n = 52; 61.18%). 14 studies (16.47%) included data

during the first 6 months of 2021; a further 15 (17.64%) included data between July and December of 2021. Only 4 studies (4.71%) included data from 2022; the most recent of these covered data through November of 2022.

Most (n = 20; 23.53%) of the studies considered multiple LMICs. Of those that only considered one country, India (n = 12; 14.11%), Ethiopia (n = 7; 8.24%), Pakistan (n = 5; 5.88%) and Brazil (n = 4; 4.71%) were the most frequently studied. The African continent was the most represented.

Most (n = 57; 67.05%) studies examined the effect of the COVID-19 pandemic on routine immunisation coverage, with an additional 7 (8.24%) reporting pandemic effects on supplementary immunisation activities. The change in the number of administered doses (n = 19; 22.35%) or the timing of doses (n = 15; 17.64%) was also reported by several studies; 8 (9.41%) reported disruptions in the vaccine supply chain.

4.2 Extent of disruption

We divide this section into a few main areas: supply chains and vaccine availability, the delivery of routine immunisation (as doses given, coverage, and/or delays), supplementary immunisation activities, and finally, signs of recovery (to pre-pandemic achieved coverage in any of the disrupted activities mentioned previously).

4.2.1 Vaccine supply

Following the declaration of COVID-19 as a pandemic, there was a reduction of vaccine sales and periods of stockout and low availability of vaccines in some countries [7, 8, 9, 10, 11], though one study in Northern Nigeria found that states experienced less stock-outs in 2020 as compared to 2019 [12]. More globally, vaccine sales between April and August 2020 fell by 9.5% across 84 countries [13], but some losses in vaccine receipt after stock-outs were recouped by catch-up activities, such as in Uganda [8].

4.2.2 Routine immunisation

We divide insight by WHO region or country.

In the WHO African Region, there was a varied picture of disruption. In Ethiopia, minimal disruptions were found up to August 2020 [14, 15, 16, 17, 10, 18]. Similarly, in DRC, disruptions in Kinshasa were minimal up to December 2020, with one study even finding increases in DTP3 and MCV1 doses administered [19, 20]. In Kenya [21, 22, 23] and Burkina Faso [24], immunisation services were largely unaffected. Zambia saw a mixed picture, in which estimates during the first 6 months of 2020 varied month-to-month, with both disruptions and positive increases as compared to previous years; overall, however, the number of additional children missed was found to be minimal [25]. In South Africa, however, full immunisation dropped in the first months of the pandemic, especially in April, where it dropped by 30% [26, 27]. Ghana [28, 29, 30], Nigeria [31], Uganda [8, 20], Liberia [32], Sierra Leone [33, 20], and Somalia [11] all saw drops in coverage in 2020, and whilst some countries had begun to see recovery in coverage achieved, this was not enough to compensate for missed cohorts [34, 20].

In the WHO region of the Americas, there were declines in coverage reported for the Dominican Republic, Mexico, Ecuador and Brazil. The Dominican Republic saw a drop of 10 percentage points [35], while vaccinations were reduced by 36% in Mexico [36, 37], and 14% fewer doses administered were in Ecuador [38]. In Brazil, approximately 20% of children missed vaccinations, with an 18% overall decline in doses administered in the first year of the pandemic [39, 40, 41]. However, one study found no significant evidence of COVID-19 isolation measures on vaccines per child in Brazil [42].

In the Eastern Mediterranean WHO region, drops in coverage were seen for Lebanon, Afghanistan, Jordan and Pakistan [43, 44, 45, 46, 47] of 31%, 21%, 6-16% and 30-48%, respectively, over the initial stages of the pandemic. Pakistan additionally reported that as of September 2021, 18% of parents had delayed routine immunisation for their children during the pandemic; an additional 2% received no immunisations [48].

In the South East Asian WHO region, there were significant disruptions [49, 50]. In India, six studies found substantial drops in coverage across the majority of districts (88% [51]) especially in lockdown and early in the pandemic [52, 53, 54, 55, 56]. As a result, children born in India after COVID-19 had a 2-10% lower probability of timely vaccination compared to earlier cohorts [57, 58]. Two studies, one conducted among the Armed Forces population in Mumbai, the other across India, found disruptions continued into 2021 [58, 56]. Only one study found that the number of immunisation sessions in India increased in 2020 and 2021 compared to 2019 [59]. In Nepal and Bangladesh, the most severe disruptions were also seen earlier in the pandemic, particularly in Bangladesh, where 20-25% of planned outreach immunisations were cancelled between April and May 2020 [60, 61]. In Indonesia, one study reported that 27.4% of parents delayed compulsory immunisation in 2020 [62].

In the WHO European region, in Armenia, there were only small declines in coverage achieved [63]. In the Western Pacific WHO Region, one study from China found that immunisation coverage dropped drastically in January 2020, but had recovered to pre-pandemic levels by June [64]. However, a second study conducted in Beijing found pandemic effects to continue into 2021, staying below 2019 levels despite catch-up activities [65].

Globally, there were substantial drops in routine immunisations in 2020 [9]. Overall, it was estimated that there were 31% fewer vaccine doses given [66]. In middle-income countries, 14% of individuals delayed or missed vaccinations in the first 6 months of the pandemic [67], and there was a 20% increase in children who had not completed the 3-dose DTP series [68]. Whilst disruption varied by vaccine [69, 70], most saw the most severe declines in the 6 months of the pandemic followed by variable recovery [71] which may affect control and elimination efforts [72].

It was not only the total number of doses administered that was affected, but also when those doses were given. In China and India, the majority of interviewed caregivers delayed vaccination [73, 74, 75, 57, 67] and in Ecuador and Sierra Leone, this delay was worse for last doses [38, 33].

4.2.3 Supplementary immunisation activities

Overall, we found fewer studies focusing on supplementary immunisation activities (SIAs) or campaigns specifically; however, there are comprehensive records kept by the WHO campaign tracker as part of the immunisation repository [76]. In 57 countries, SIAs were more disrupted in the early stages of the pandemic, with 57% of planned campaigns globally postponed or cancelled because of COVID-19 by May 2020 [76]. By December 2020, this had fallen to 26% and many campaigns were reinstated from July 2020 onwards. By December 2021, in 54 countries, this had fallen again to 16% of scheduled campaigns delayed or cancelled [76]. Overall, of those campaigns disrupted between March 2020 and December 2021, 59% had been reinstated [76]. Factors leading to postponement or cancellation of SIAs included non-pharmaceutical interventions, such as national lockdowns, [77] and stockouts or increased demand for general healthcare supplies [78, 8]. One study found that the national policy guidance of Mozambique and Uganda recommend the halting of campaigns in 2020 [79]. Additionally, whilst some SIAs had been reinstated, and there were plans for catchup activities, there are still large missed cohorts [53, 80, 72, 9].

4.2.4 Recovery

Information on recovery is limited by the date ranges of the included studies, which mainly focused on 2020 and 2021. A key finding is that while there were signs of improvement in routine immunisation coverage achieved and reinstated vaccination campaigns, there was not the positive increase needed to catch up missed cohorts, i.e. a sufficient return to pre-pandemic levels of immunisation [34, 66, 70, 61, 37, 81, 33, 65]. It was also noted that pre-COVID levels of coverage had not been reached in many countries by the end of 2022 [72].

4.3 Heterogeneity in disruption

Heterogeneity in immunisation disruption was found across several factors, including geography, demography, wealth, and education; these are further detailed below. Variations

in the extent of disruption by antigen were similarly reported in several studies [38, 44, 49, 13, 75, 20, 10, 18, 65, 64].

4.3.1 Geographic Heterogeneity

Despite significant overall decreases in immunisation in LMICs, there was geographic heterogeneity in the extent of disruption and in the regions and/or individuals affected. On a national level, several studies reported differences in the extent of disruption as a result of economic income classification [67, 49, 68] by WHO Region [78, 69, 68], by global burden of disease super-region [66], or by Gavi eligibility [68], with greater pandemic impact observed in low- and middle-income countries compared to high-income countries, affecting the primarily African Region, the Americas, and Asia. The reverse trend was seen for vaccine sales early in the pandemic (i.e. April to August 2020), with high-income countries experiencing a 20% decline and low-income countries observing a 10% increase [13].

On a sub-national level, many countries observed statistically significant differences between regions, provinces, or districts in regards to the change in health service utilisation [82, 37, 51, 59, 56], routine immunisation coverage [38, 44, 55], or complete vaccination [24]. In some countries, certain provinces reported increases in immunisation service provision or doses for some vaccines, such as in the Southern Province of Rwanda, where measles and rubella immunisation increased [82]. Geographic heterogeneity was also observed in the subsequent recovery of services [51, 27].

While some countries reported differences in disruption between urban and rural areas, there was significant heterogeneity in the extent of disruption. One study found that the odds of immunisation in Ethiopia were higher in rural areas [14], while another observed greater initial declines in urban and peri-urban areas in South Africa, followed by recovery in these areas and declines in rural areas as the pandemic progressed [27]. In Pakistan, lockdown affected rural areas more than urban areas [46]. Geographic heterogeneity was also observed between Ethiopia's hospitals and health centres, in which vaccine-related supplies were twice as likely to be affected by COVID-19 in hospitals [7, 10]; in Nigeria, activities coordinated at the state level were impacted less than healthcare facilities [12]. In China, immunisation services continued in hospitals, even when immunisation clinics were suspended [64].

In India, children residing in "COVID-19 red zones" were more likely to face immunisation disruption [55]. Similarly, a study on polio outreach services in 33 African and Eastern Mediterranean countries found services necessary for "reaching their most vulnerable populations" were partially or severely disrupted [78].

4.3.2 Demographic Heterogeneity

Few studies focused on the effects of demographic heterogeneity on COVID-19 related immunisation disruption, including factors such as gender, age, birth order, or caste. Only two studies looked at differences by gender; one found greater declines in females than males, though this decline was not significant [44]. The second, conducted in Brazil, also found no significant differences, but did find that infants were less likely to experience immunisation disruptions or delays compared to one-year old children [39]. This finding was similar to two studies, conducted in Eastern India and in China, where increasing age of the child was found to be associated with immunisation delays [74, 75]. A study conducted in South-East Asia and the Western Pacific found similar results, in which early-infancy was less disrupted than infancy, school-entry age, and adolescent immunisation [49]. However, greater disruption was seen among infants compared to adult/elderly immunisation [49]. Additionally, one study in Jordan found that children older than 12 months were less likely to experience delays [45]. Finally, one study conducted in China found firstborn children were less likely to experience delays [75], while another paper in India examined heterogeneity as a result of ethnicity or caste, finding lower castes had lower likelihoods of full immunisation and greater immunisation disruption, though these findings were not significant [55].

While even fewer articles examined the demographic heterogeneity of disruption based on the characteristics of parents or caregivers, two studies stratified results by maternal or caregiver age; one finding that increasing maternal age was associated with delayed vaccination [74], the other finding no association [45]. Only one study examined other contributing factors of parents, finding that women were more likely to delay vaccination for

their children than men; presence of a chronic illness, prior flu vaccination, or experience with COVID-19 diagnosis were also associated with delays in childhood vaccination [62].

4.3.3 Socioeconomic Heterogeneity

Contributors to socioeconomic heterogeneity in immunisation disruption largely included measures of household income and education. Two studies, one in Brazil and the other in India, found that missed vaccine doses were more likely in children from poorer households [55, 39]; in India it was additionally found that there were greater declines in immunisation among poorer subgroups [55]. A study in South Africa found mixed results, finding declines in full immunisation and first dose of measles greater in wealthier quintiles at the start of the pandemic, but with faster positive recovery and continued declines among poorer subgroups as the pandemic progressed [27]. Another study in Iraq found that low socioeconomic status was associated with an increase in missed vaccine appointments [83]. Two studies, one conducted in Iraq and one conducted in Indonesia, similarly found that the type of employment changed the odds of vaccination during the pandemic [62, 83]; in Indonesia, healthcare workers especially were more likely to delay vaccination in their children [62].

Only two studies, one in India and one in Iraq, focused on education, similarly finding higher probability of incomplete immunisation and greater declines in households without formal education [55, 83].

4.4 Factors contributing to coverage disruption and resilience

We divide this section into three key areas: health system barriers, vaccine demand, and resilience.

4.4.1 Health System Barriers

Many of the initial challenges in maintaining immunisation services in LMICs were the result of health system and supply barriers during the early stages of the pandemic. Many countries reported issues with vaccine supply delays or stock-outs [37, 7, 84, 81, 32, 8, 9, 85, 11, 58, 86] and lack of personal protective equipment (PPE) for healthcare workers (HCWs), including masks, gloves, and other drugs and supplies [7, 84, 32, 31, 87, 51, 85, 53, 54, 51, 12]. Disruption caused by vaccine stock-outs or supplies was found to vary by WHO region [9] or by geographical sub-region [31, 87, 49, 10]; notably one study in Southeast Asia and the Western Pacific found vaccine stockouts to be among the least important reasons for service provision delays [49]. A lack of logistical support impacting routine services or outreach, such as a lack of fuel or water, was reported by three studies in the WHO African region [84, 32, 31].

Similarly, HCW availability posed a significant challenge, with countries citing difficulties due to the diversion of staff to COVID-19 response, staff illness, and transportation difficulties, among others [32, 9, 31, 85, 53, 54, 31, 51, 18, 12]. One study in Kenya further reported disruption due to a HCW strike from December 2020 to January 2021 [23]. On an individual level, HCWs reported that pandemic related stigma, stress, or fears impacted service delivery [7, 31, 60, 54, 85, 51], with some additionally reporting harassment by law enforcement or by patients themselves [31, 51]. Only one study, conducted at a tertiary health centre in Ghana, found no disruptions to vaccine supply or in HCW availability [29].

COVID-19 lockdowns and restrictions also resulted in cancelled immunisation services, clinic closures, or reduced healthcare access or services available [7, 88, 32, 31, 46, 49, 67, 55, 77, 45, 62, 89, 86, 83], with some reporting difficulties maintaining COVID-19 prevention rules, such as social distancing, due to non-compliant patients or a lack of space [84, 31, 54, 12].

Competing priorities also meant some countries faced declines in funding for immunisation services or supplies, resulting in financial constraints [53, 87, 12].

4.4.2 Vaccine Demand and Acceptance

Many of the challenges in maintaining routine immunisation services during the COVID-19 pandemic also resulted from declining vaccine demand and increasing fear or stigma surrounding COVID-19 among caregivers. Declines in vaccine demand were frequently

attributed to travel barriers or difficulties in reaching immunisation services or clinics [55, 75, 17, 32, 9, 16, 54, 53, 60, 49, 65, 12, 83, 18, 48, 89], COVID-19 restrictions or requirements, including testing requirements, mask requirements, or lockdowns, [88, 84, 45, 47, 85, 60, 67], and financial constraints [16, 53, 60, 67]. One study, conducted in South East Asia and the Western Pacific, reported that while affordability issues contributed to immunisation service utilisation, it was among the lowest ranked reasons [49]. Some caregivers additionally reported low or no awareness of the availability of immunisation services, often believing clinics and hospitals were closed for routine immunisation services [84, 53, 29, 74].

Declines in vaccine demand due to fears of contracting COVID-19 at clinics or hospitals was pervasive, and one of the most reported causes across several studies [55, 67, 49, 60, 85, 53, 47, 16, 29, 54, 45, 9, 74, 84, 32, 12, 18, 58, 48, 89]. Many others reported additional fear or stigma against healthcare providers, including fears that staff might be infected by the virus [29, 60, 54, 32, 85]. One survey of 100 caregivers at a tertiary health centre in Eastern India found that 83% of respondents agreed that “safety [was] more important than vaccination” [74]. Further unspecified declines in vaccine demand were noted by several studies [9, 81, 46].

Vaccine hesitancy factors were less commonly reported; misinformation and misbeliefs contributed to declines in demand in just two studies [9, 60], while fears specifically about vaccine side effects were found in just one study in a tertiary hospital in North Ghana [29]. One additional study in Liberia reported declines due to vaccine conspiracies, where parents believed their children would be injected with COVID-19 [32]. Only one in Ethiopia study reported fewer declines in vaccine demand as a result of COVID-19 pandemic misinformation, including that they were not susceptible to the disease, the disease was not severe, or that the pandemic did not exist [18].

4.4.3 Resiliency

Though few papers highlighted resiliency factors or enablers to immunisation during the COVID-19 pandemic, two key focuses included community outreach to address declining vaccine demand and acceptance and the importance of improved healthcare worker support to increase service provision. In Jordan and China, alternative arrangements for childhood vaccination (i.e. outside of the standard service provision within healthcare clinics) was found to be key to maintaining immunisation demand, though in Jordan this insight was based on a survey of caregiver beliefs[45, 73]. Similarly, a community intervention highlighting the importance of maintaining timely vaccination, despite the pandemic, was crucial in Jordan, India, and in Ethiopia [45, 16, 18, 58]. Ethiopia additionally reported decreased fear of COVID-19 as an enabling factor [16]. In India, adequate access to PPE, overcoming barriers to transportation for HCWs, community and/or family support, and training on COVID-19 management was crucial to support HCWs in maintaining immunisation service provision[85]. Similarly, proactive communication and coordination on all levels of the healthcare system was essential in Ethiopia in maintaining health system resiliency[87]. In India, capacity building to ensure a trained workforce assisted in maintaining immunisation programs [58, 89], while in Nigeria, one study found the supply chain logistics to be the most important factor for maintaining immunisation services [12]. Finally, in Zambia, community awareness through the National Immunization Campaign assisted in catching up pandemic declines [25].

5 Discussion

Despite the challenges faced by health systems during the COVID-19 pandemic, the WHO has continued to emphasise the importance of routine immunisation, noting that the last effects of immunisation declines can lead to higher burdens of disease and/or excess deaths[90]. This review highlights the extent of disruption faced by LMICs, finding significant heterogeneity between and within regions, countries, and individual demographics, but nevertheless showing declines in routine immunisation in 2020 and 2021 that had not often not recovered to pre-COVID levels.

SIAs and campaigns were postponed with few regions reporting full recovery. Many LMICs rely on outreach services to reach vulnerable populations, especially where access to health clinics or services are limited[9]. COVID-19 response efforts or mitigation strategies,

including lockdowns, resulted in additional disruption to transportation services, logistical support, or supplies, often hindering additional outreach activities and limiting the services that were available. This has resulted in a deepening of existing coverage inequalities, with studies noting greater disruptions among households with lower incomes, formal education, or those situated in informal housing or in some regions, rural areas, emphasising the heterogeneity that existed prior to the pandemic [91].

We utilised a rapid review format for this study, which includes some limitations. We included only two databases for the time period and only studies in English. As a result, we may be missing studies stored in other databases or in other languages. Additionally, rapid reviews may have additional risks of bias, given the single-reviewer extraction and synthesis of findings.

The findings in this study are limited by the data available — the majority of studies utilised data from 2020, limiting much of our understanding of how routine immunisation services have recovered since countries lifted lockdown or other COVID-19 response policies. Our study also does not include grey literature, only articles. Nevertheless, this study expands upon the findings of a systematic review of available literature on childhood disruptions to immunisation using data from 2020, which included 39 studies and found an overall median decline of 10.8% [92]. Additionally, our study only focuses on LMICs; this is in contrast to high-income countries, which, according to one study on 26 middle- and high-income countries, saw considerably less missed vaccination [67]. Our study highlights the findings through 2022 and emphasises the ongoing heterogeneity in immunisation, alongside the barriers and enablers to service provision.

Our findings also emphasise the urgency required to target individuals and cohorts who may have missed out on routine immunisation or campaigns during the COVID-19 pandemic, ensuring the barriers highlighted by staff and caretakers, including low staff or service availability, vaccine or supply stockouts, and transportation barriers are mitigated. Importantly, approaches to combat fears, misinformation, or misbeliefs, including those surrounding COVID-19 transmission and risk, are critical. Though few studies touched on vaccine hesitancy, declining vaccine acceptance has become a formative issue, and additional strategies are required to prevent additional backsliding[93].

Rebuilding immunisation services in LMICs will require a greater focus on healthcare resilience, so that the disruption caused by future epidemics or disasters on routine immunisation services is minimal, and that recovery and performance rapid and improved through an adaptation to real-world events[94]. Many of the countries that showed service delivery resilience during the COVID-19 pandemic highlighted the need for proactive and ongoing communication and coordination across multiple interconnected systems, especially between the community and healthcare system. One study, published in May of 2023, offers an updated framework to address the idea of epidemic-ready primary healthcare. Importantly, this framework offers solutions to many of the observed barriers found in this review, focusing on adequate training, compensation, and protection for HCWs, reliable logistic and supply-chain infrastructure, and linkages to the community[95]. Given the reliance on primary health care and outreach systems for immunisation in LMICs, this approach may be a beneficial starting point, though notably, it will require a shift in how healthcare currently interacts with public health, alongside strong political commitment and financing[95]. Further research will be required to understand how post-pandemic disruption and recovery in immunisation services has progressed, especially in regards to vulnerable communities.

6 Conclusion

This review highlights the extent and heterogeneity of immunisation disruption in LMICs as a result of the COVID-19 pandemic and the factors contributing to disruption and resilience in immunisation programs. Given there is limited information on whether reductions in vaccination coverage or delays have persisted beyond 2021, further research is needed to assess ongoing disruptions, identify missed vaccine cohorts, and examine factors contributing to resilience. Furthermore, these findings highlight the need for immunisation programs to provide support for healthcare workers and proactive communication within the health system and with the wider community to ensure the effect of future disasters on vulnerable communities is minimal.

7 Contributorship Statement

AMH: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing — Review and Editing. XL.: Conceptualization, Methodology, Writing — Review and Editing. KAMG: Guarantor, Supervision, Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing — Review and Editing

8 Competing Interests

Authors declare no other competing interests.

9 Funding

This work was carried out as part of the Vaccine Impact Modelling Consortium (www.vaccineimpact.org), which is jointly funded by the Bill & Melinda Gates Foundation (Grant Numbers INV-034281 and INV 009125 / OPP1157270) and Gavi, the Vaccine Alliance. The views expressed are those of the authors and not necessarily those of the Consortium or its funders. The funders were given the opportunity to review this paper prior to publication, but the final decision on the content of the publication was taken by the authors.

AMH, XL, and KAMG also acknowledge funding from the MRC Centre for Global Infectious Disease Analysis (reference MR/R015600/1), jointly funded by the UK Medical Research Council (MRC) and the UK Foreign, Commonwealth Development Office (FCDO), under the MRC/FCDO Concordat agreement and is also part of the EDCTP2 programme supported by the European Union; and acknowledge funding by Community Jameel. KAMG reports speaker fees from Sanofi Pasteur outside the submitted work.

10 Data Sharing Statement

All data relevant to the study are included in the article or uploaded as supplementary information.

11 Ethics Approval Statement

This study involved the use of secondary data and does not require ethical approval.

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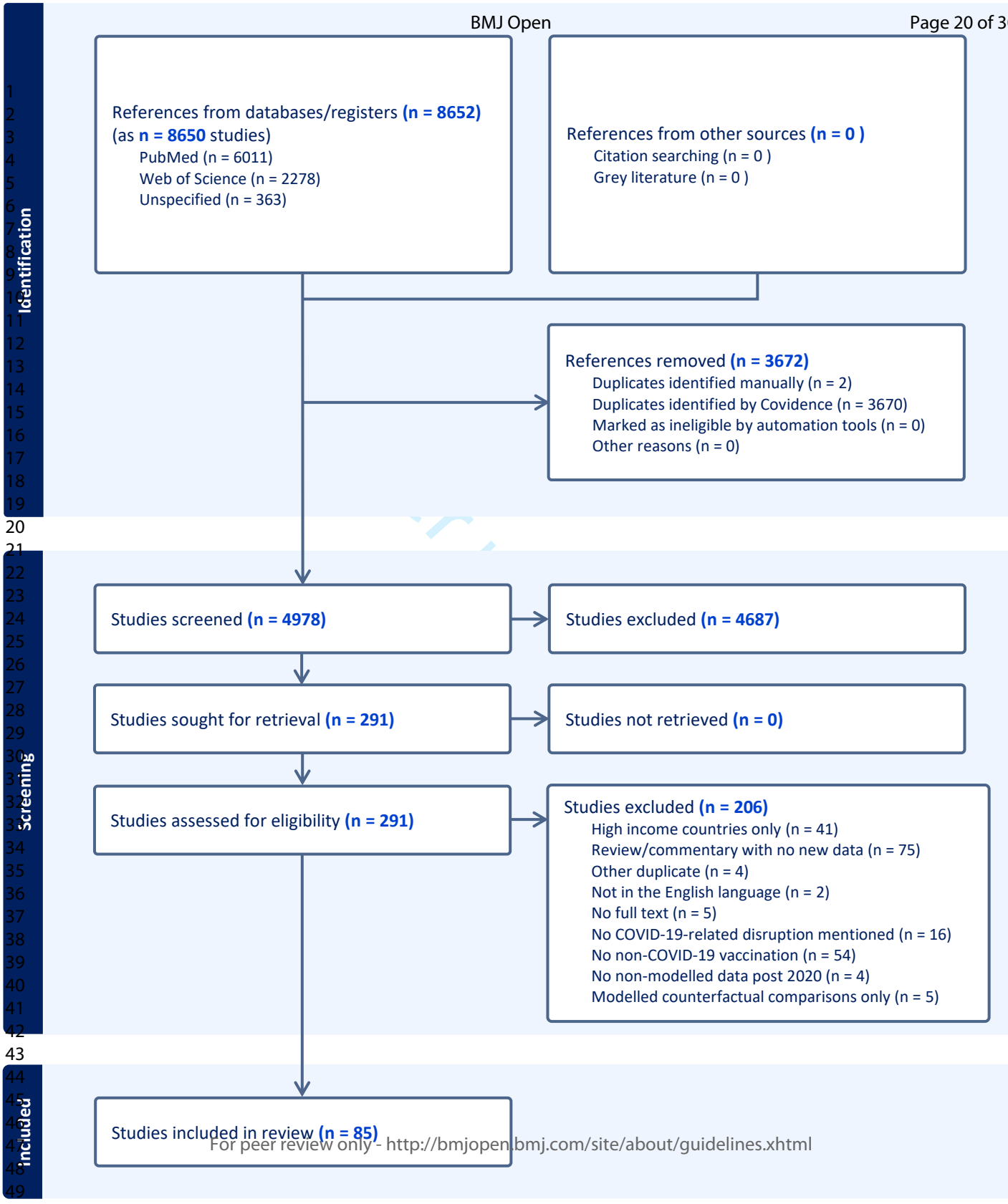

Supplementary Index: COVID-19-related disruption and resiliency in immunisation activities in LMICs: a rapid review

Anna-Maria Hartner, Xiang Li, Katy Gaythorpe

July 15, 2024

Search Strategy

We searched PubMed and Web of science on 6th October 2023 for studies published after 1st December 2019 in English. Our full list of search terms was as follows: (((COVID-19) OR (SARS-CoV-2))) AND (immunisation OR vaccination) AND (disruption OR delay* OR postpon*).

PRISMA Checklist

The PRISMA checklist is referenced in the main text on page 3.

Section and Topic	Item	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title identifies study as a rapid review (page 1).
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract follows BMJ Open guidelines (pages 1-2).
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Introduction (pages 2-3).
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Aim and research questions (page 3).
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods: procedure (page 3).
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Methods: procedure (page 3).
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Methods: procedure (page 3) and supplementary index (page 1).
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment (pages 3-4).
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment (pages 3-4).

Section and Topic	Item	Checklist item	Location where item is reported
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods: Study selection, data extraction and quality assessment (pages 3-4).
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Methods: Study selection, data extraction and quality assessment (pages 3-4).
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Methods: Study selection, data extraction and quality assessment (pages 3-4).
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	N/A; narrative synthesis only.
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item 5)).	All studies meeting inclusion criteria were synthesized.
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A; narrative synthesis only.
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	N/A
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Methods: Synthesis (page 4).
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A; narrative synthesis only.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A; narrative synthesis only.
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	N/A; limitations in discussion (pages 9-10).
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	N/A; narrative synthesis only.

Section and Topic	Item	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results: Characteristics of studies (page 4).
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Results: Characteristics of studies (page 4).
Study characteristics	17	Cite each included study and present its characteristics.	Results: Characteristics of studies (page 4); all studies are cited throughout.
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supplementary Index: pages 9-10
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	N/A; narrative synthesis only
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Results; bias in discussion (pages 4-10)
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A; narrative synthesis only.
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A; narrative synthesis only.
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A; narrative synthesis only.
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Discussion (pages 9-10).
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Discussion (pages 9-10)
DISCUSSION			
	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion (pages 9-10)
	23b	Discuss any limitations of the evidence included in the review.	Discussion (pages 9-10)
	23c	Discuss any limitations of the review processes used.	Discussion (pages 9-10)

Section and Topic	Item	Checklist item	Location where item is reported
Discussion			
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion (pages 9-10)
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Review was not registered.
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Protocol was not prepared.
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Acknowledgments
Competing interests	26	Declare any competing interests of review authors.	Acknowledgments
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Articles used in narrative synthesis are publicly available and given in citations.

Table 1: Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Checklist

Critical Appraisal Skills Program Quality Assessment

Study	Aims stated?	Appropriate methods?	Appropriate methods for aims?	Appropriate recruitment strategy for aims?	Data collected in way that addressed research question?	Relationship between researcher and participants?	Ethical consideration?	Rigorous Data Analysis?	Clear findings?
Hou et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Bose et al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Mansour et al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	No	Yes
Wanyana et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Saso et. al., 2020	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Carter et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Shapiro et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Desta et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	No	Yes	Yes
Jensen et. al., 2020	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Silveira et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	No	Yes
Harris et. al., 2021	Yes	Yes	No	No	Yes	Primary Data	Yes	Yes	Yes
Chandir et. al., 2020	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Shapira et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Abid et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Khan et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Zeitouny et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Cabral et. al., 2021	Yes	Yes	No	N/A	Yes	Secondary Data	Yes	Yes	Yes
Singh et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Patel et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Bekele et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Shet et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Nguyenet. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Mishra et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Wang et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Jain et. al., 2021	Yes	Yes	Yes	Yes	Yes	Secondary Data	Yes	Yes	Yes
Avula et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	No	Yes
Nigus et. al., 2020	No	N/A	N/A	N/A	N/A	Secondary Data	No	No	Yes
Assefa et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Kawakatsu et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Adelekan et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
de Oliveira et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Shet et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Muhoza et. al., 2021	No	Yes	N/A	N/A	N/A	Secondary Data	No	N/A	Yes
Colomé-Hidalgo et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Santos et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Doubova et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Burt et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Hategeka et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Causey et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Alves et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Abu-Rish et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Babalola et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Evanset. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Khatiwada et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Suárez-Rodríguez et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Shaikh et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Rahman et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	No	Yes

Study	Aims stated?	Appropriate methods?	Appropriate methods for aims?	Appropriate recruitment strategy for aims?	Data collected in way that addressed research question?	Relationship between researcher and participants?	Ethical consideration?	Rigorous Data Analysis?	Clear findings?
Khan et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Bimpong et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Rana et. al., 2021	No	N/A	No	N/A	Yes	Secondary Data	No	No	Yes
Powelson et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Wambua et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Mariani et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Summan et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Thsehla et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Adilo et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Lucinde et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Connolly et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Burkholder et. al., 2021	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Mbaeyi et. al., 2021	No	Yes	N/A	N/A	Yes	Secondary Data	No	Yes	Yes
Kiarie et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Doubova et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Ho et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Melkonyan et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	Yes
Kissi et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	No
Minta et. al., 2022	No	Yes	No	N/A	Yes	Secondary Data	No	Yes	Yes
Plotkin et. al., 2022	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Cooper et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Kasonia et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Winter et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	Yes	Yes
Fahriani et. al., 2021	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Orey et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	Yes	No	No
Sucharitha et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Manzoor et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Tawar et. al., 2022	Yes	No	Yes	Yes	Yes	Primary and Secondary Data	No	No	No
Wu et. al., 2020	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	Yes	Yes
Owais et. al., 2023	Yes	Yes	Yes	N/A	Yes	Secondary Data	No	No	No
Rodo et. al., 2022	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Chakrabarti et. al., 2023	Yes	Yes	No	N/A	Yes	Secondary Data	Yes	No	Yes
Berhane et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	Yes
Zeidan et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	No	No	Yes
Aigbogun et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary and Secondary Data	Yes	Yes	No
Ji et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	Yes	Yes
Endehabtu et. al., 2023	Yes	Yes	Yes	Yes	Yes	Primary Data	Yes	No	Yes
Sharma et. al., 2023	Yes	No	Yes	N/A	Yes	Secondary Data	Yes	No	No

Table 2: Modified Critical Appraisal Skills Program Quality Assessment for Qualitative Studies

Additional Supplementary Tables

OVERVIEW		OUTCOMES				
Study	**Countries**	**Routine coverage**	**SIA**	**Doses**	**Dose timing**	**Supply chain**
Hou et. al., 2021	China				TRUE	
Bose et al., 2022	Nepal		TRUE			
Mansour et al., 2021	Lebanon	TRUE		TRUE		
Wanyana et. al., 2021	Rwanda					
Saso et. al., 2020	Multiple	TRUE				
Carter et. al., 2022	Ethiopia	TRUE				
Shapiro et. al., 2022	Multiple	TRUE				
Desta et. al., 2021	Ethiopia	TRUE				
Jensen et. al., 2020	South Africa	TRUE				
Silveira et. al., 2021	Brazil	TRUE				
Harris et. al., 2021	SEAR/WPR	TRUE				
Chandir et. al., 2020	Pakistan	TRUE			TRUE	
Shapira et. al., 2021	Subsaharan Africa	TRUE		TRUE	TRUE	
Abid et. al., 2022	Afghanistan	TRUE				
Khan et. al., 2021	India			TRUE		
Zeitouny et. al., 2021	Multiple			TRUE		TRUE
Cabral et. al., 2021	Brazil and Portugal					
Singh et. al., 2021	Nepal	TRUE				
Patel et. al., 2022	India	TRUE				TRUE
Bekele et. al., 2022	Ethiopia					
Shet et. al., 2021	India	TRUE				
Nguyenet. al., 2021	India	TRUE				
Mishra et. al., 2023	India				TRUE	
Wang et. al., 2022	China				TRUE	
Jain et. al., 2021	India	TRUE		TRUE	TRUE	
Avula et. al., 2022	India					
Nigus et. al., 2020	Ethiopia					
Assefa et. al., 2021	Multiple	TRUE		TRUE		
Kawakatsu et. al., 2023	Ghana	TRUE				
Adelekan et. al., 2021	Nigeria	TRUE		TRUE		
de Oliveira et. al., 2022	Brazil			TRUE		
Shet et. al., 2022	Multiple	TRUE	TRUE			
Muhoza et. al., 2021	Multiple	TRUE				
Colomé-Hidalgo et. al., 2022	Dominican Republic	TRUE				
Santos et. al., 2021	Brazil	TRUE				
Doubova et. al., 2021	Mexico	TRUE				
Burt et. al., 2021	Uganda	TRUE	TRUE			TRUE
Hategeka et. al., 2021	DRC	TRUE				
Causey et. al., 2021	Multiple	TRUE				
Alves et. al., 2021	Brazil	TRUE				
Abu-Rish et. al., 2022	Jordan	TRUE			TRUE	

Babalola et. al., 2022	Liberia	TRUE				TRUE
Evanset. al., 2022	Multiple	TRUE				
Khatiwada et. al., 2021	Nepal				TRUE	TRUE
Suárez-Rodríguez et. al., 2022	Ecuador	TRUE		TRUE		
Shaikh et. al., 2021	Multiple	TRUE				
Rahman et. al., 2021	Pakistan	TRUE				
Khan et. al., 2022	Pakistan				TRUE	
Bimpong et. al., 2021	Ghana	TRUE				
Rana et. al., 2021	Bangladesh	TRUE				
Powelson et. al., 2022	Mozambique	TRUE		TRUE	TRUE	
Wambua et. al., 2022	Kenya	TRUE				
Mariani et. al., 2022	Sierra Leone			TRUE		
Summan et. al., 2023	India	TRUE			TRUE	
Thsehla et. al., 2023	South Africa	TRUE		TRUE		
Adilo et. al., 2022	Ethiopia					TRUE
Lucinde et. al., 2023	Kenya	TRUE				
Connolly et. al., 2022	Multiple	TRUE				
Burkholder et. al., 2021	Multiple	TRUE	TRUE			TRUE
Mbaeyi et. al., 2021	Pakistan					
Kiarie et. al., 2022	Kenya			TRUE		
Doubova et. al., 2022	Mexico	TRUE				
Ho et. al., 2022	Multiple		TRUE			
Melkonyan et. al., 2022	Armenia	TRUE				
Kissi et. al., 2022	Ghana	TRUE				
Minta et. al., 2022	Multiple	TRUE	TRUE			
Plotkin et. al., 2022	Multiple	TRUE	TRUE			
Cooper et. al., 2023	Burkina Faso	TRUE				
Kasonia et. al., 2023	Multiple			TRUE		
Winter et. al., 2023	Zambia	TRUE				
Fahriani et. al., 2021	Indonesia				TRUE	
Orey et. al., 2023	Somalia	TRUE				
Sucharitha et. al., 2022	India			TRUE		
Manzoor et. al., 2022	Pakistan				TRUE	
Tawar et. al., 2022	India	TRUE		TRUE		
Wu et. al., 2020	China	TRUE		TRUE		
Owais et. al., 2023	South Asia	TRUE				
Rodo et. al., 2022	Multiple	TRUE				
Chakrabarti et. al., 2023	India			TRUE		
Berhane et. al., 2023	Ethiopia			TRUE		
Zeidan et. al., 2023	Iraq				TRUE	
Aigbogun et. al., 2023	Nigeria	TRUE				TRUE
Ji et. al., 2023	China	TRUE			TRUE	
Endehabtu et. al., 2023	Ethiopia					TRUE
Sharma et. al., 2023	India					

Table 3: Overview of countries examined and outcomes reported (routine coverage, supplementary immunisation campaigns (SIAs), dose timing, or supply chain disruptions) by included papers.