ESJ Natural/Life/Medical Sciences Peer-reviewed

The Big Catch-up: Addressing Zero-Dose Children as a Surrogate of Vaccination Disruptions During Public Health Emergencies: A review of literature

Sadaf Khan
Independent Researcher
Gajendra Kumar Gupta
Deepika Agrawal
Syed Hasan Nawaz Zaidi
Jyoti Batra
Department of Community Medicine,
Santosh Deemed to Be University, Ghaziabad, India
Sabin Syed
International Consultant, Public Health
Lokesh Sharma
UNICEF NYHQ
Maureen Khambira
Health Specialist, Health Systems Strengthening, UNICEF, Malawi
Dereje Ayalew Haile
Ghanshyam Sethy
UNICEF Regional Office for East and Southern Africa, Kenya
Snehil Kumar Singh
Department of Community Medicine,
Santosh Deemed to Be University, Ghaziabad, India

Doi:10.19044/esj.2024.v20n36p19

Submitted: 20 August 2024
Accepted: 27 November 2024
Published: 31 December 2024

Cite As:
Khan S., Gupta G.K., Agrawal D., Nawaz Zaidi S.H., Batra J., Syed S., Sharma L., Khambira M., Haile D.A., Sethy G. & Singh S.K. (2024). *The Big Catch-up: Addressing Zero-Dose Children as a Surrogate of Vaccination Disruptions During Public Health Emergencies: A review of literature.* European Scientific Journal, ESJ, 20 (36), 19.
https://doi.org/10.19044/esj.2024.v20n36p19

Abstract

The COVID-19 pandemic triggered an unprecedented backslide in global immunization programs, increasing the number of zero-dose children-

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

those who have not received any vaccinations—from 13.3 million in 2019 to 18.1 million in 2021. This surge poses a significant threat to public health, especially in low- and middle-income countries (LMICs), where healthcare systems are already fragile. This scoping review focused on the impact of the pandemic on childhood immunization, with a focus on zero-dose children, and to identify effective interventions for rebuilding resilient immunization systems. Data from WHO, UNICEF, and Gavi were comprehensively reviewed. The IRMMA (Identify, Reach, Monitor, Measure, Advocate) framework was used to structure the analysis of evidence-based interventions across diverse settings. Consolidated findings show that in 2022, 20.5 million children missed one or more vaccines, with 14.3 million classified as zero-dose children. Despite improvements from 2021, these numbers remain higher than pre-pandemic levels. Countries such as Nigeria (2.3 million zero-dose children), India (1.1 million), and Ethiopia (1.1 million) are most affected.

Our review highlights the importance of strengthening health systems and leveraging innovative strategies such as drone delivery and digital health platforms for reaching zero-dose children. To ensure sustainability, policy interventions must focus on integrating immunization efforts into national healthcare frameworks. This includes prioritizing workforce development, enhancing supply chain management, and fostering partnerships with community leaders to rebuild trust and address vaccine hesitancy. Specific interventions, such as deploying mobile vaccination units, implementing culturally tailored health messaging, and utilizing real-time monitoring technologies, are recommended to target under-reached populations. The pandemic has exacerbated existing vulnerabilities in immunization systems but coordinated global efforts, like the "Big Catch-Up" campaign, offer a pathway to recovery and long-term sustainability. This scoping review underscores the urgent need for robust, context-specific policies and targeted interventions to bridge the immunization gap and protect vulnerable populations from vaccine-preventable diseases.

Keywords: Zero-Dose Children, COVID-19, Vaccination Disruption, Public Health, Immunization, Big Catch-Up Campaign

Introduction

The COVID-19 pandemic triggered a historic backslide in global immunization coverage, marking the worst decline in over three decades. In 2021, the number of zero-dose children—those who did not receive even a single dose of vital vaccines—grew from 13.3 million in 2019 to 18.2 million globally, representing a critical gap in child health and survival efforts (WHO et al., 2023). The World Health Organization (WHO) and UNICEF estimate that routine immunization services were suspended in over 68 countries,

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

leaving 25 million children under-vaccinated or entirely unprotected, including 80 million infants at high risk for preventable diseases (WHO, 2024). Countries like India saw a drop in DTP3 vaccine coverage from 91% to 85%, reflecting broader declines in Low- and Middle-Income Countries (LMICs) due to strained healthcare infrastructure (GAVI The Vaccine Alliance, 2022).

The pandemic exacerbated pre-existing challenges, including logistical hurdles like the demand for cold-chain storage for COVID-19 vaccines and the redirection of health resources toward pandemic response efforts (Fahrni et al., 2022). Consequently, many critical immunization campaigns, particularly for diseases such as measles, were delayed or canceled, leading to widespread outbreaks (Sharma et al., 2021). In response, global health agencies have stressed the urgent need to restore and strengthen immunization programs to prevent further escalation of vaccine-preventable diseases (Kapuria B et al., 2024).

This paper examines the profound impact of the pandemic on childhood vaccination efforts, with a particular focus on zero-dose children. Using the IRMMA (Identify, Reach, Monitor, Measure, Advocate) framework, we emphasize the importance of tailored, context-specific interventions to bridge the immunization gap. As part of the broader "Big Catch-Up" initiative, the focus must now shift to a coordinated recovery effort, aligned with the Immunization Agenda 2030 (WHO et al., 2023). This approach aims not only to recover lost ground but also to build a resilient, equitable system that ensures no child is left behind in the wake of the pandemic's disruptions.

This review is justified by the urgent need to address the rising number of zero-dose children globally, a consequence of the COVID-19 pandemic's disruptions to routine immunization programs. Ensuring that every child receives essential vaccinations is critical to reducing preventable diseases and deaths, particularly in low- and middle-income countries. By identifying innovative approaches to reach these vulnerable populations, this review aligns with several Sustainable Development Goals (SDGs). Specifically, it supports **SDG 3 (Good Health and Well-Being)**, which aims to ensure healthy lives and promote well-being for all by increasing immunization coverage and reducing child mortality. Additionally, it contributes to **SDG 10 (Reduced Inequalities)** by focusing on reducing disparities in healthcare access, particularly in remote, rural, and conflict-affected regions where zero-dose children are often concentrated. Addressing these gaps is essential to promoting equitable access to vaccines and achieving universal health coverage.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Materials and Methods

This study is designed as a **scoping review**, aimed at exploring innovative approaches for reaching and vaccinating zero-dose children. A scoping review was chosen due to the emergent nature of this topic, which requires a broad search for evidence, rather than limiting the review to specific interventions or populations as a systematic review would. This approach allows us to map the existing literature and identify gaps for future research.

Search Strategy

We conducted a comprehensive search across various databases, including PubMed, Scopus, and Google Scholar, using the following key terms: "zero-dose children," "unvaccinated children," "vaccination coverage gaps," and "DTP-specific campaigns." The search was supplemented by grey literature from WHO, UNICEF, and relevant policy papers, ensuring that our review captured the broadest possible evidence base. We applied the following i**nclusion criteria**:

- Articles published after 2010
- Articles available in English
- Peer-reviewed studies and grey literature focusing on zero-dose or DTP-specific vaccination efforts

Exclusion criteria:

- Duplicate articles
- Studies focused on unrelated vaccination programs or non-zero-dose populations
- Non-English language publications
- Articles published before 2010

Article Selection Process

The selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, as detailed in the PRISMA diagram. Initially, 500 records were identified through database searches, of which 150 were excluded due to duplication or irrelevance. The remaining 350 articles were screened for full-text review, resulting in the final selection of 30 articles. These articles were then analyzed using the snowball approach, where references from selected studies were reviewed for additional relevant sources.

A detailed PRISMA flow diagram is included to illustrate the selection process.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

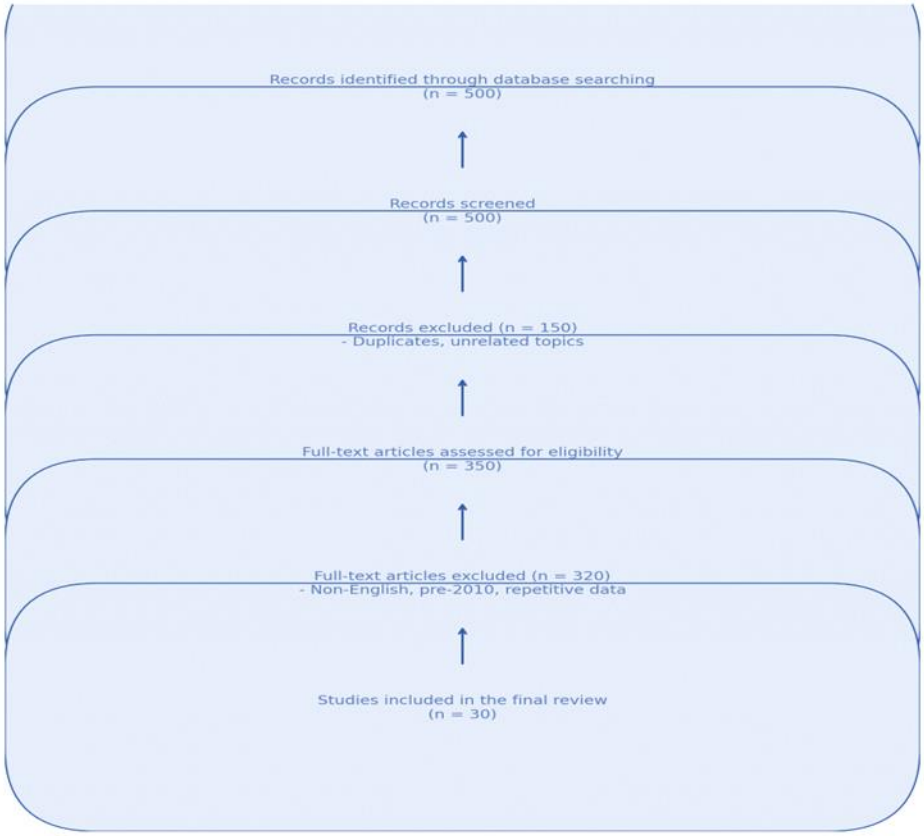


Figure 1: PRISMA diagram

Data Extraction and Categorization

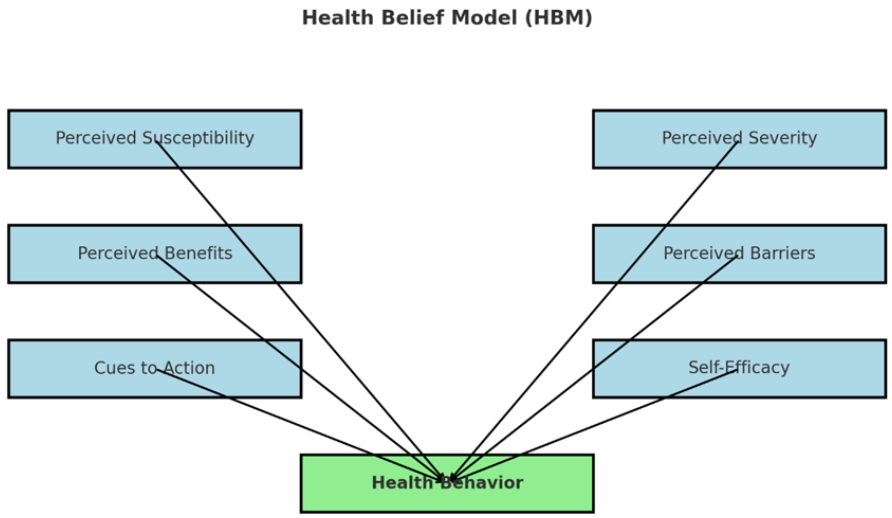
To ensure a structured and comprehensive analysis, the categorization involved grouping interventions into three thematic areas: community-based interventions, technological innovations, and strengthening health systems. Additionally, geographic contexts such as urban, rural, and conflict zones were considered to account for the diverse settings in which zero-dose children reside. Demographic factors, including socioeconomic status, cultural norms, and health service accessibility further refined each category.

Theoretical Framework

We applied the Health Belief Model (HBM) as the underlying theoretical framework for analyzing the socio-cultural and behavioral drivers that affect vaccine uptake. The HBM suggests that health behaviors are influenced by personal beliefs about health conditions and their severity, perceived benefits of action, barriers to action, and self-efficacy. This model is particularly useful for understanding the barriers and enablers of vaccination

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

uptake among zero-dose children, as it helps identify specific factors that drive or hinder access to immunization in different contexts.



Categorization by Setting

In line with the Equity Reference Group for Immunization (ERG) principles, which highlight that 40% of zero-dose children live in fragile or conflict settings, we categorized interventions based on settings such as remote rural areas, urban slums, and conflict zones. The findings were further grouped into predominant and emerging themes, such as community-based interventions, mobile vaccination units, and digital tracking systems for remote populations. These categorizations allowed us to focus on scalable solutions that are context-specific and effective in addressing zero-dose populations.

By employing a scoping review methodology, guided by the IRMMA framework and Health Belief Model, this study provides a comprehensive overview of the current strategies to reach zero-dose children across diverse settings. The inclusion of both published and grey literature ensures a broad evidence base and the PRISMA diagram provides transparency in our selection process.

Geographical Distribution

According to data published on 18th July'2023 by the World Health Organization (WHO) and UNICEF, in 2022, 20.5 million children missed out on one or more vaccines delivered through routine immunization services, compared to 24.4 million children in 2021 (UNICEF, n.d.). Despite this improvement, the number remains higher than the 18.4 million children who

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

missed out in 2019 before pandemic-related disruptions, underscoring the need for ongoing catch-up, recovery, and system-strengthening efforts. The geographic distribution of zero-dose children highlights concentrated vulnerabilities, with countries like Nigeria (2.3 million), India (1.1 million), and Ethiopia (1.1 million) being the most affected (Table 1).

Table 1: No DTP1 (zero dose) Children in 2022:

Country	No DTP1 (zero dose)
Nigeria	2.3 million
Ethiopia	1.1 million
DR Congo	753,000
India	1.1 million
Philippines	637,000
Angola	614,000
Indonesia	577,000
Brazil	431,000
Pakistan	431,000
Mozambique	377,000

The vaccine against diphtheria, tetanus, and pertussis (DTP) is used in the global market for immunization coverage. Of the 20.5 million children who missed out on one or more doses of their DTP vaccines in 2022, 14.3 million did not receive a single dose, so-called zero-dose children (Table 2). The figure represents an improvement from the 18.1 million zero-dose children in 2021 but remains higher than the 12.9 million children in 2019 (PAHO, n.d.).

Table 2: Global Vaccination Trends

Year	Total Children Missing Vaccines (millions)	Zero-Dose Children (millions)
2019	18.4	12.9
2021	24.4	18.1
2022	20.5	14.3

The early stages of recovery in global immunization have not occurred equally, with the improvement concentrated in a few countries. Progress in well-resourced countries with large infant populations, such as India and Indonesia, masks slower recovery or even continued declines in most low-income countries, especially for measles vaccination.

Of the 73 countries that recorded substantial declines in coverage during the pandemic, 15 have recovered to pre-pandemic levels, 24 are on the path to recovery, and, most concerningly, 34 have stagnated or continued declining. These trends reflect broader challenges in health metrics across

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

these countries. To effectively accelerate catch-up, recovery, and strengthening efforts, countries must consider the behavioral and social drivers influencing immunization uptake, as outlined in the Health Belief Model (HBM). The HBM emphasizes that perceived susceptibility to vaccine-preventable diseases, perceived severity of these diseases, perceived benefits of vaccination, and perceived barriers (, such as misinformation or logistical difficulties) play critical roles in shaping immunization behaviors. Cues to action, such as community health initiatives, and self-efficacy (the belief in one's ability to access and receive vaccines) are also key to improving vaccination uptake. By addressing these factors, countries can make more meaningful progress in ensuring that every child is reached with the vaccines they need. Furthermore, since routine immunization is a fundamental pillar of primary healthcare, this provides an opportunity to advance other related health sectors by strengthening the systems that support vaccine delivery.

Vaccination against measles - one of the most infectious pathogens - has not recovered as well as other vaccines, putting an additional 35.2 million children at risk of measles infection. First-dose measles coverage increased to 83 percent in 2022 from 81 percent in 2021 but remained lower than the 86 percent achieved in 2019. As a result, last year, 21.9 million children missed the routine measles vaccination in their first year of life - 2.7 million more than in 2019 – while an additional 13.3 million did not receive their second dose, placing children in under-vaccinated communities at risk of outbreaks. While some countries like India and Indonesia have shown faster recovery, progress has been slower in low-income countries, particularly for measles vaccination. (Table 3).

Table 3: Measles Vaccination Coverage

Year	First Dose Coverage (%)	Children Missing First Dose (millions)	Children Missing Second Dose (millions)
2019	86	N/A	N/A
2021	81	N/A	N/A
2022	83	21.9	13.3

Countries with steady, sustained coverage in the years before the pandemic have been better able to stabilize immunization services since the data indicates. For example, South Asia, which reported gradual, ongoing increases in coverage in the decade before the pandemic, has demonstrated a more rapid and robust recovery than regions that suffered longstanding declines, such as Latin America and the Caribbean. The African region, which is lagging in its recovery, faces an extra challenge. With an increasing child population, countries must scale up routine immunization services every year to maintain coverage levels.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

DTP3 vaccine coverage in the 57 lower-income countries supported by Gavi, the Vaccine Alliance increased to 81 percent in 2022 - a considerable increase from 78% in 2021 - with the number of zero-dose children who receive no basic vaccines also dropping by 2 million in these countries (WHO, n.d.). However, the increase in DTP3 coverage in Gavi-implementing countries was concentrated in lower-middle-income countries, with low-income countries not yet increasing coverage – indicating the work remaining to help the most vulnerable health systems rebuild (Table 4)

Table 4: DTP3 Vaccination in Gavi-supported Countries

Year	DTP3 Coverage (%)	Zero-Dose Children in Gavi-supported Countries (millions)
2021	78	N/A
2022	81	Reduction by 2 million

These tables provide a clear and concise overview of the critical vaccination data during the specified years, highlighting the trends in global vaccination, measles vaccination coverage, and DTP3 vaccination in Gavi-supported countries.

The interventions identified to reach zero-dose children vary based on the setting. In urban slums, strategies such as community-based outreach and religious leader involvement (e.g., Mobile Mullahs) have shown promise, while in remote rural areas, integrating immunization with other sectors such as agriculture and utilizing technologies like drone delivery have been effective. In conflict zones, ensuring healthcare worker safety and integrating vaccination efforts with humanitarian aid have been critical (Table 5)

Table 5. Examples of Interventions to Reach Zero-Dose Children Based on Thematic Areas in Each Setting

Setting	Community-Based Interventions	Health Systems Strengthening and Integration	Technological Innovations
Urban Slums	• Art for public health messaging (ex: GOAL Zimbabwe and M-pesa) • Community-based outreach • Utilizing religious leaders (Mobile Mullahs) • Women support groups/ Mother Meetings	• Incentives for CHWs/ASHAs • Slum health committees • Referral systems (ex: Roadmap for Achieving Universal Immunization Coverage) • Community mapping for timing and location (ex: Humara Bachpan) • Distribution of Vaccination Centers • Monitoring and Evaluation (India's urban immunization	• GIS for community mapping

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Setting	Community-Based Interventions	Health Systems Strengthening and Integration	Technological Innovations
		dashboard, Uganda's AEFI committee)	
Remote / Rural	• Culturally specific messaging (ex: drum beating)	• Electronic Immunization Registers (ex: family folders) • My Village My Home • Reach Every District (RED) • Integration with agricultural, animal health, and commercial sector services (ex: Project Last Mile, OneAcre Fund, Digital Green)	• Remote temperature monitoring devices (ColdTrace5, Microarray patches, solar direct-drive refrigerators) • Drone Delivery • Geospatial monitoring (ex: Reveal)
Conflict Zones	• Increase healthcare workers' communication and access to information through WhatsApp messaging or anonymous online hubs • Incentivize healthcare workers to acknowledge the risks in conflict zones	• Electronic Immunization Registers • IRC's mReach tracing data platform • Digital Health IDs • Monitoring facilities (WHO's Health Resources and Services Availability Monitoring System) • Integration with other humanitarian response services (ex: food supplement or formula distribution)	• Biometrics (ex: iRes)

Reasons for the Disparity:

Healthcare System Disruptions and Capacity

- **Low-income countries** have faced prolonged disruptions to healthcare services during the pandemic, which significantly delayed routine immunization programs, including measles vaccination. Many of these countries have fragile health systems, which were further strained by the COVID-19 response efforts.
- **Resource availability** in countries like India and Indonesia has allowed for a quicker recovery in vaccination campaigns because they were better equipped with infrastructure and healthcare personnel to reinstate programs. In contrast, countries with fewer resources and greater logistical challenges have lagged in restoring vaccination coverage.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

- **Supportive Literature**: Studies indicate that countries with stronger healthcare systems and higher health expenditure per capita are more likely to quickly recover from disruptions in routine services like immunization programs (Singh et al., 2024).

Vaccine Accessibility and Supply Chain Issues

- **Logistical barriers**, such as vaccine shortages and cold-chain failures, have disproportionately affected low-income countries. The transport of vaccines to remote and conflict-affected regions has also been a significant challenge.
- **Perceived Barriers** (, HBM): In the context of HBM, logistical difficulties are a key barrier perceived by both healthcare providers and parents in low-resource settings. These barriers hinder access to vaccines, leading to lower coverage rates. As a result, fewer children receive measles vaccines, particularly the second dose, which is critical for effective protection.
- **Supportive Literature**: A scoping review by Fahrni et al. (, 2022) highlights that vaccine distribution in low-resource settings was severely disrupted by pandemic-related supply chain issues, leading to uneven recovery in immunization rates.

Vaccine Hesitancy and Misinformation

- **Perceived Susceptibility and Severity** (, HBM): Parents' beliefs about the likelihood of their child contracting measles (, susceptibility) and the perceived seriousness of the disease (, severity) influence their decision to vaccinate. In some low-income countries, vaccine hesitancy driven by misinformation, fear of side effects, and mistrust in healthcare systems is more prevalent. This mistrust was exacerbated during the pandemic when false information about vaccines spread widely.
- **Supportive Literature**: Research shows that vaccine hesitancy disproportionately affects communities with lower healthcare literacy and access to reliable health information, contributing to disparities in vaccine coverage (Fahrni et al., 2022).

Cultural and Social Factors

- In some **remote and rural areas** in low-income countries, cultural beliefs about vaccinations and healthcare practices can discourage parents from seeking routine vaccinations for their children.
- **Cues to Action** (, HBM): In countries with slow recovery, a lack of strong community-based cues to action—such as public health campaigns or outreach by trusted community leaders—can result in

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

lower vaccination uptake. Conversely, in countries like India and Indonesia, active community engagement and outreach programs have helped to restore vaccination rates more rapidly.

- **Supportive Literature**: Research by Garnelo et al. (, 2020) underscores the importance of culturally specific health interventions that target vaccination uptake in rural populations. Countries with stronger community health outreach, like India, have been able to more effectively counter these barriers.

Discussion

We reviewed 63 relevant materials and conducted six key informant interviews to identify interventions aimed at vaccinating zero-dose children. Our key informants included representatives from non-governmental organizations (NGOs) such as PATH and VillageReach and academics. Much of the literature that guided our analysis came from grey sources, such as reports and articles by UNICEF, WHO, JSI, and the Equity Reference Group for Immunization (ERG). While peer-reviewed studies on zero-dose vaccination interventions were limited, the materials provided sufficient context for examining strategies across different settings where zero-dose children are prevalent: urban slums, remote rural areas, and conflict zones.

In line with the global efforts articulated in "The Big Catch-Up" campaign, our findings highlight the importance of adapting interventions to local contexts. The campaign emphasizes three core strategies—Catch-Up, Restore, and Strengthen—to mitigate the effects of the pandemic on global immunization (UNICEF, 2022). Our review supports this approach by identifying interventions across three key thematic areas including community engagement, health systems strengthening and integration, and technological innovation (Singh et al., 2024).

The data indicate that reaching zero-dose children in these priority settings requires interventions tailored to the specific sociocultural, economic, and political barriers faced by each community (Garg et al., Jan-Jun 2024). For instance, in urban slums, where mistrust in healthcare systems and logistical barriers are significant, community-based outreach and leveraging local leaders are crucial. Similarly, in remote rural settings, integrating health services with other sectors, such as agriculture, has shown promise. In conflict zones, ensuring the safety of healthcare workers and integrating vaccination efforts with humanitarian services are critical to reaching zero-dose children (Garnelo et al., 2020).

One recurring theme in our review was the need to avoid a "one-size-fits-all" approach. While global frameworks like the Zero Dose Guidelines provide a strong foundation, the interventions must be nuanced to address specific local challenges (Mahmoud et al., 2024). This is particularly relevant

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

in fragile contexts where zero-dose children are often hardest to reach due to ongoing conflict, displacement, and limited healthcare infrastructure.

Our review also revealed gaps in the existing evidence. First, there is limited data on the effectiveness of the interventions identified, particularly in relation to zero-dose children. While enthusiasm for these interventions is high, especially around innovative technologies like digital health records and vaccine delivery systems, their long-term impact on vaccine uptake remains unclear. Second, the cost-effectiveness of scaling these interventions in diverse contexts has not been adequately studied, which presents a challenge for policy implementation. Third, many interventions designed to reach zero-dose children also benefit under-vaccinated populations, making it difficult to assess the specific impact on zero-dose children.

Despite these limitations, our work underscores the importance of a multi-faceted approach that integrates community engagement, health systems strengthening, and technological innovation. The alignment with "The Big Catch-Up" campaign's strategic objectives emphasizes the need for urgent, equitable, and sustainable immunization efforts to recover from the setbacks caused by the COVID-19 pandemic.

The global push to vaccinate zero-dose children presents both challenges and opportunities. Our narrative review, informed by the principles of "The Big Catch-Up" campaign, highlights the critical need for context-specific interventions that reflect the unique barriers faced by missed communities. As global immunization efforts intensify, it will be essential to continue evaluating the effectiveness of these interventions and to ensure that they are integrated into resilient and sustainable health systems (Bhrigu Kapuria1 Randa S. Hamadeh et al., 2023).

*Gaps in Literature**:***

Limited Evidence on Interventions' Effectiveness: The manuscript notes the scarcity of evidence on the effectiveness of interventions aimed at increasing vaccine uptake among zero-dose children. Future research should focus on evaluating these interventions, particularly in diverse settings, to understand what works, for whom, and under what circumstances.

Cost-Effectiveness of Interventions: Another significant gap is the lack of data on the cost-effectiveness of scaling up these interventions. Research in this area is crucial for policymakers and practitioners to allocate resources efficiently and sustainably implement successful strategies.

Under-vaccinated vs. Zero-Dose Children: The distinction between under-vaccinated and zero-dose children needs further exploration. Understanding the barriers and facilitators unique to each group can help tailor interventions more effectively.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Cultural and Socio-political Factors: The review highlights the importance of adapting interventions to local contexts but does not delve deeply into how cultural, socio-economic, and political factors influence vaccine uptake. Future studies should examine these dimensions to design culturally sensitive and context-specific interventions.

Technological Innovations: While the manuscript mentions technological innovations as part of the solution, there is a gap in the literature regarding the adoption and impact of these technologies in different settings. Research focusing on the implementation challenges and effectiveness of technological solutions in enhancing vaccine coverage is needed.

Conclusion

The COVID-19 pandemic has exposed significant vulnerabilities within global health systems, notably through the sharp increase in zero-dose children who have missed essential vaccinations. This has heightened the risk of outbreaks of vaccine-preventable diseases, creating an urgent global public health threat. However, this crisis also provides a crucial opportunity for transformative changes in immunization efforts.

Our review, supported by data from WHO, UNICEF, and Gavi, emphasizes that recovery requires a comprehensive and adaptable approach. The "Big Catch-Up" campaign serves as a key framework to drive these efforts, with strategies focused on catching up, restoring, and strengthening immunization systems. This initiative aims not only to recover the millions of missed children but also to rebuild immunization coverage to pre-pandemic levels and beyond.

Ensuring the long-term sustainability of these interventions will require continuous investment in healthcare infrastructure and workforce capacity. Strengthening community-based health systems and integrating immunization efforts into broader healthcare services are critical for achieving lasting results. Establishing robust monitoring and evaluation frameworks can help track progress and ensure accountability while fostering community ownership through active participation can enhance trust and engagement. Furthermore, leveraging innovative technologies such as digital health platforms, drone delivery systems, and real-time monitoring tools can address logistical barriers and improve efficiency.

International collaboration and partnerships between governments, non-governmental organizations, and private sector stakeholders will be crucial in aligning immunization goals with broader health priorities. By promoting resilience and adaptability, these efforts can secure equitable healthcare access for vulnerable populations and safeguard immunization systems against future public health emergencies.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Recommendations

Addressing the low vaccine uptake requires a multifaceted approach informed by the Health Belief Model (HBM). First, increasing awareness of the risks associated with preventable diseases-such as measles-can raise perceived susceptibility and severity, motivating communities to take protective action. Educational campaigns should emphasize the individual and community benefits of vaccination to boost perceived benefits and reinforce the value of immunization. Additionally, addressing logistical and social barriers is critical. Policies that improve accessibility-such as mobile vaccination units, cost-reduction initiatives, and partnerships with trusted local leaders-can help reduce perceived barriers. Finally, cues to action and self-efficacy must be strengthened through regular community outreach, reminders, and support systems. By incorporating these HBM-based strategies, vaccination programs can more effectively promote immunization uptake, particularly in underserved and hesitant populations, supporting equitable healthcare access and improving public health outcomes.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

Funding Statement: The authors did not obtain any funding for this research.

References:

1. Bhrigu Kapuria1 Randa S. Hamadeh, Farah Mazloum1 Kassem Chaalan, Kyaw Aung, Ettie Higgins, Wafaa Kanaan, Tatiana Tohme, Doaa Kamal, Christina E. Khoury, Sabin Syed. (, 2023). Immunization as an entry point for primary health care and beyond healthcare interventions—Process and insights from an integrated approach in Lebanon. *Frontiers in Health Services*, *3*. https://doi.org/10.3389/frhs.2023.1251775
2. Fahrni, M. L., Ismail, I. A., Refi, D. M., Almeman, A., Yaakob, N. C., Saman, K. M., Mansor, N. F., Noordin, N., & Babar, Z. U. (, 2022). Management of COVID-19 vaccines cold chain logistics: A scoping review. Https://doi.org/10.1186/s40545-022-00411-5. *Journal of Pharmaceutical Policy and Practice, 15(, 1), 16.* https://doi.org/10.1186/s40545-022-00411-5
3. Garg, Rajat; Bhargava, Anita; Singh, Snehil Kumar. (, Jan-Jun2024). *Capacity Building in Public Health Emergency Management: A Crucial Pillar for Global Health Security.* 28–32. https://doi.org/10.4103/JNMO.JNMO_10_24

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

4. Garnelo, L., Parente, R.C.P., Puchiarelli, M.L.R. et al. (, 2020). Barriers to access and organization of primary health care services for rural riverside populations in the Amazon. *Int J Equity Health*, *19*(, 54). https://doi.org/10.1186/s12939-020-01171-x
5. GAVI The Vaccine Alliance. (2022, July 29). *Immunization in lower-income countries: Pandemic leads to a decline in coverage but signs of recovery emerge*. https://www.gavi.org/news/media-room/immunisation-lower-income-countries-pandemic-leads-decline-coverage-signs-recovery
6. Kapuria B, Sami Hamadeh R, Mazloum F, Korbane JA, Aung K, Kamal D, Chamoun N and Syed S. (, 2024). Achieving sustainable, environmentally viable, solarized vaccine cold chain system and vaccination program—An effort to move towards clean and green energy-driven primary healthcare in Lebanon. *Frontiers in Health Services*, *4*. https://doi.org/10.3389/frhs.2024.1386432
7. Mahmoud, Amina & Singh, Neha & Abdelmagid, Nada & Sabahelzain, Majdi & Checchi, Francesco & Mounier-Jack, Sandra & Nor, Barni. (, 2024). *Assessing Vaccination Delivery Strategies for Zero-Dose and Under-Immunized Children in the Fragile Context of Somalia. Vaccines. 12*(, 154). http://dx.doi.org/10.3390/vaccines12020154
8. PAHO. (, n.d.). *Factsheet: WHO/UNICEF Estimate of National Immunization Coverage 2022*. PAHO. https://www.paho.org/en/documents/factsheet-whounicef-estimate-national-immunization-coverage-2022
9. Sharma, Mohit; Singh, Snehil K.; Sharma, Lokesh, Dwiwedi, Manish K.; Agarwal, Deepika; Gupta, Gajendra K.; Dhiman, Ranjit. (, 2021). Magnitude and causes of routine immunization disruptions during the COVID-19 pandemic in developing countries. *Journal of Family Medicine and Primary Care*, *10*(, 11), 3991–3997. https://doi.org/10.4103/jfmpc.jfmpc_1102_21
10. Singh, S. K., Gupta, G. K., Agrawal, D., Zaidi, S. H. N., Batra, J., Sharma, L., Juneja, S., Joshi, K. J., Sethy, G., Haile, D. A., & Syed, S. (, 2024). Leveraging Resource Centers for Strengthening Immunization Supply Chain. *Cureus*, *16*(, 4). https://doi.org/10.7759/cureus.58966
11. UNICEF. (, n.d.). Zero-Dose Children: The alarming reality of missed vaccinations highlighted in UNICEF's 2023 World Immunization Week Dashboard. *UNICEF*.
12. UNICEF. (, 2022). *Every child survives and thrives -Global Annual Results Report*. UNICEF.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

https://www.unicef.org/media/143436/file/Global%20annual%20results%20report%202022%20:%20Goal%20Area%201.pdf

13. WHO. (, n.d.). *Childhood Immunization Post COVID-19*. WHO. https://www.who.int/news/item/18-07-2023-childhood-immunization-begins-recovery-after-covid-19-backslide
14. WHO. (2024, July 15). *Global childhood immunization levels stalled in 2023, leaving many without life-saving protection*. https://www.who.int/news/item/15-07-2024-global-childhood-immunization-levels-stalled-in-2023-leaving-many-without-life-saving-protection
15. WHO, & UNICEF, and Gavi, The Vaccine Alliance,. (2023, May). *The Big Catch-Up: An Essential Immunization Recovery Plan FOR 2023 AND BEYOND*. https://www.immunizationagenda2030.org/images/documents/9789240075511-eng.pdf

Appendix

Annex 1- Vaccine-dose combinations for which estimates are produced

		Vaccine-dose combinations for which estimates are produced
Years	**Number**	**Vaccine-dose**
1980–1984	6	BCG, DTP1, DTP3, MCV1, POL3, RCV1
1985–1989	7	… + HEPB3
1990–1996	8	… … + HIB3
1997–1999	9	… … … + YFV
2000–2005	12	… … … … + HEPBB + MCV2
2006–2007	13	…..... + ROTAC
2008–2014	15	…..... + PCV3
2015–2022	16	…..... + IPV1

BCG – Bacille Calmette-Guérin, DTP – Diphtheria-Tetanus-Pertussis containing vaccine, MCV – Measles containing vaccine, POL – Polio, RCV – Rubella containing vaccine, HEPB – Hepatitis B containing vaccine, HIB – Haemophilus influenzae type B containing vaccine, YFV – Yellow Fever vaccine, HEPBB – Hepatitis B birth dose, ROTAC – Rotavirus vaccine (, last dose), PCV – Pneumococcal conjugate vaccine, IPV – Inactivated polio vaccine.