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

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Abstract

The COVID-19 pandemic has significantly disrupted global immunization programs, resulting in a sharp increase in the number of zero-dose children-those who have not received any vaccinations. This disruption

poses a critical threat to public health, exacerbating the risk of vaccine-preventable disease outbreaks. This paper investigates the pandemic's impact on routine childhood immunization, with a particular focus on zero-dose children. Through a comprehensive review of data from WHO, UNICEF, Gavi, and key informant interviews, we highlight evidence-based interventions aligned with the strategic framework of the Zero Dose Guidelines. Our findings emphasize the importance of context-specific approaches, particularly in vulnerable settings such as urban slums, remote rural areas, and conflict zones. We identified key thematic areas for intervention: community engagement, health systems strengthening, and technological innovations. These strategies are critical for reaching zero-dose children and rebuilding resilient immunization systems. However, gaps remain in the evidence surrounding the long-term effectiveness and cost-efficiency of these interventions, especially in low- and middle-income countries. This study underscores the urgency of addressing the growing number of zero-dose children through coordinated global efforts like "The Big Catch-Up" campaign, which aims to recover and strengthen immunization coverage worldwide. By focusing on equity, innovation, and tailored strategies, we can mitigate the pandemic's long-term effects and ensure that no child is left unprotected.

Keywords: Zero-Dose Children, COVID-19, Vaccination Disruption, Public Health, Immunization Programs, 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, & UNICEF and Gavi, The Vaccine Alliance, 2023). The World Health Organization (WHO) and UNICEF estimate that routine immunization services were suspended in over 68 countries, 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, 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). Consequently, many critical immunization campaigns, particularly for diseases such as measles, were delayed or cancelled, leading to widespread outbreaks(Sharma, Mohit; Singh, Snehil K.; Sharma, Lokesh,; Dwiwedi, Manish K.; Agarwal, Deepika; Gupta, Gajendra K.; Dhiman, Ranjit, 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, Sami Hamadeh R, Mazloum F, Korbane JA, Aung K, Kamal D, Chamoun N and Syed S, 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, & UNICEF and Gavi, The Vaccine Alliance, 2023). This approach aims not only to recover lost ground but to build a resilient, equitable system that ensures no child is left behind in the wake of the pandemic's disruptions.

Materials and Methods

The authors conducted a comprehensive literature review to explore innovative approaches for reaching and vaccinating zero-dose children. Using search terms such as "zero dose" and "unvaccinated," we identified relevant articles and organizations actively working in this field. Given the scarcity of data and sources specific to this topic, few sources were excluded from the review. The exclusion criteria applied were repetition of information, non-English language, and publications predating 2010. Additionally, we excluded sources that focused on vaccination efforts not directly related to zero-dose or DTP-specific campaigns.

Relevant articles that met the inclusion criteria were assessed further using a snowball approach, following references in primary sources identified as highly pertinent to our topic. Both published literature and grey literature were included, ensuring a broad evidence base. This approach captured diverse types of evidence, including peer-reviewed publications, policy papers, and reports, all deemed relevant to our focus on zero-dose children.

In conducting the review, we incorporated the principles of the IRMMA (Identify, Reach, Monitor, Measure, and Advocate) framework to structure our search and analysis of innovative solutions. Recognizing the diverse socio-cultural and economic barriers in different regions, our review centered on evidence-based interventions that align with the strategic

priorities outlined in the Zero Dose Guidelines. This included a focus on methodologies that prioritize equity, gender inclusion, and a strong understanding of local community dynamics.

WHO and UNICEF review reports submitted by Member States annually—primarily through the Joint Reporting Form on Immunization (eJRF)—on national immunization coverage. These reports, along with finalized surveys, as well as published and grey literature, informed our understanding of zero-dose children. Using these data, WHO and UNICEF strive to distinguish between situations where empirical data accurately reflect immunization system performance and those where data might be compromised. The most likely coverage levels for each country are estimated annually, considering potential biases and the expertise of local stakeholders.

In line with the Equity Reference Group for Immunization (ERG) principles, which highlight that approximately 40% of zero-dose children live in fragile or conflict settings, we categorized evidence based on setting types such as remote rural areas, urban slums, and conflict zones. This categorization was integral to identifying the most appropriate interventions tailored to these contexts. Using Excel, we organized the information into predominant and emerging intervention themes, allowing us to focus on scalable solutions for each setting.

Our methodology reflects the principles of the "Big Catch-Up" campaign, with a commitment to restoring and strengthening immunization systems by addressing the gaps in coverage created by the pandemic. By maintaining focus on equity, the review serves as a guide for developing tailored interventions that ensure zero-dose children are reached across diverse settings.

Result

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 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 as the global marker 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 recovered to pre-pandemic levels, 24 are on route to recovery and, most concerningly, 34 have stagnated or continued declining. These concerning trends echo patterns seen in other health metrics. Countries must ensure they are accelerating catch-up, recovery, and strengthening efforts, to reach every child with the vaccines they need and - because routine immunization is a fundamental pillar of primary healthcare - take the opportunity to make progress in other, related health sectors.

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 per cent in 2022 from 81 per cent in 2021 but remained lower than the 86 per cent 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. Measles coverage remains lower than pre-pandemic levels, with 21.9 million children missing the first dose in 2022, and an additional 13.3 million not receiving their second dose, placing many at risk of outbreaks (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 stabilise immunization services since, the data indicates. For example, South Asia, which reported gradual, ongoing increases in coverage in the decade prior to 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 in order to maintain coverage levels.

DTP3 vaccine coverage in the 57 lower-income countries supported by Gavi, the Vaccine Alliance increased to 81 per cent 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 dashboard, Uganda's AEFI committee)	- GIS for community mapping
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,	- Remote temperature monitoring devices (ColdTrace5, Microarray patches, solar direct-drive refrigerators) - Drone Delivery - Geospatial monitoring

Setting	Community-Based Interventions	Health Systems Strengthening and Integration	Technological Innovations
		and commercial sector services (ex: Project Last Mile, OneAcre Fund, Digital Green)	(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

Discussion

In total, 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, as well as 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, 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).

The data indicate that reaching zero-dose children in these priority settings requires interventions tailored to the specific socio-cultural, economic, and political barriers faced by each community(Garg, Rajat; Bhargava, Anita; Singh, Snehil Kumar, Jan-Jun2024). 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, L., Parente, R.C.P., Puchiarelli, M.L.R. 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, Amina & Singh, Neha & Abdelmagid, Nada & Sabahelzain, Majdi & Checchi, Francesco & Mounier-Jack, Sandra & Nor, Barni., 2024). This is particularly relevant 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, Farah Mazloum1 Kassem Chaalan, Kyaw Aung, Ettie Higgins, Wafaa Kanaan, Tatiana Tohme, Doaa Kamal, Christina E. Khoury, Sabin Syed, 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.

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 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 Pandemic has laid bare the vulnerabilities within global health systems, with its most striking consequence being the surge in zero-dose children who have missed critical vaccinations. This has escalated the risk of outbreaks of vaccine-preventable diseases, posing a serious threat to global public health. However, this crisis also presents an opportunity for transformative change in immunization efforts worldwide.

As illuminated through this review, supported by data from WHO, UNICEF, and Gavi, as well as insights from key informants, the road to recovery requires a multi-faceted and nuanced approach. The "Big Catch-Up" campaign serves as a vital framework to guide global efforts in addressing this gap. Its strategy of *Catch-Up, Restore, and Strengthen* not

only aims to reach the millions of missed children but also to restore and solidify global immunization coverage to pre-pandemic levels and beyond.

Moving forward, it is critical to intensify community engagement, ensuring that trust is rebuilt in communities that have historically faced barriers to vaccination. Strengthening health systems is equally crucial—both in terms of infrastructure and human resources—to ensure that vaccines reach every corner of the globe, and that skilled healthcare professionals are equipped to administer them and engage with communities. Finally, leveraging innovative technologies, such as drone delivery systems and digital health platforms, offers the potential to overcome logistical hurdles, ensuring that no child is left behind.

While the findings from this review underscore the urgency of the challenge, they also reveal gaps in the literature and practice. The lack of robust evidence on the long-term effectiveness and cost-efficiency of interventions in low- and middle-income countries remains a barrier to scaling these efforts. To address this, future research must focus on evaluating interventions in diverse contexts, with a strong emphasis on equity, efficiency, and sustainability. Rigorous monitoring and evaluation will be essential to ensure that the gains achieved through the "Big Catch-Up" campaign are not just short-term successes but contribute to lasting resilience in immunization systems.

In conclusion, the pandemic has highlighted the fragility of global immunization systems but also offers a pivotal moment for recovery and reform. By adhering to the principles of equity, innovation, and system strengthening, as set forth in the "Big Catch-Up" campaign, we can turn this crisis into an opportunity. The global community must seize this moment to ensure that zero-dose children become a phenomenon of the past, and that no child is left unprotected against vaccine-preventable diseases.

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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.