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Immunization and Child Survival in Bihar: A Review of Coverage Trends, Inequities, and Mortality Outcomes

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ABSTRACT
Immunization is one of the most effective and cost-efficient public health interventions for reducing child morbidity and mortality. Despite national progress in India under the Universal Immunization Programme (UIP), substantial inter-state disparities persist. Bihar, a high-population and socioeconomically vulnerable state, continues to report lower immunization coverage and higher child mortality compared to national averages. This review aims to synthesize existing evidence on immunization coverage in Bihar, examine its role in reducing child mortality, and identify key gaps in implementation and research. A narrative review of published literature, national survey data (NFHS), government reports, and peer-reviewed studies was conducted. Evidence related to immunization coverage trends, determinants, health system performance, and associations with child mortality in Bihar was analyzed. Immunization coverage in Bihar has improved over the past two decades, driven by targeted initiatives such as Mission Indradhanush and health system strengthening efforts. However, full immunization coverage remains uneven across districts and population groups. Socioeconomic disadvantage, maternal education, health system constraints, and demand-side barriers significantly influence uptake. While reductions in infant and under-five mortality have coincided with improvements in immunization, direct causal evidence linking immunization to mortality reduction at the state level remains limited. Immunization has contributed to declining child mortality in Bihar, but coverage gaps and inequities persist. Strengthening routine immunization, improving equity, and generating robust mortality impact evidence are critical for achieving sustained reductions in child mortality.
Keywords: *Immunization, Child mortality, Bihar, Universal Immunization Programme, Public health, India*

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INTRODUCTION

Child mortality remains a major public health concern in India, particularly in economically and socially disadvantaged states. Immunization is globally recognized as a cornerstone intervention for preventing vaccine-preventable diseases (VPDs) such as measles, pertussis, tetanus, diphtheria, and polio, which historically contributed substantially to infant and under-five mortality. By interrupting disease transmission and preventing severe infections, immunization plays a critical role in improving child survival [1].

The World Health Organization (WHO) estimates that immunization averts approximately 2–3 million deaths annually worldwide. In India, the Universal Immunization Programme (UIP)— one of the largest public health initiatives globally—provides free vaccination against multiple VPDs and has been instrumental in reducing childhood morbidity and mortality. Despite significant national progress, immunization coverage and related health outcomes vary widely across states, reflecting persistent regional and socioeconomic disparities [2].

Bihar represents a particularly challenging public health context due to its high population density, predominantly rural population, widespread poverty, and historically weak health indicators. Although immunization coverage in the state has improved over recent years, it remains lower than that of high-performing states. These gaps contribute to preventable child morbidity and mortality, underscoring the

need for sustained programmatic efforts. This review examines the role of immunization in improving child survival in Bihar and highlights key gaps in evidence, implementation, and equity that must be addressed to achieve further mortality reductions.

IMMUNIZATION COVERAGE IN BIHAR: TRENDS AND DETERMINANTS

Historical and Recent Coverage Trends

Immunization coverage in Bihar has demonstrated a sustained upward trajectory since the early 2000s, reflecting incremental improvements in routine immunization delivery and broader health system strengthening efforts. Analysis of data from successive rounds of the National Family Health Survey (NFHS) reveals a consistent increase in the proportion of children aged 12–23 months who are fully immunized. Early NFHS rounds documented markedly low coverage levels, underscoring longstanding structural challenges such as inadequate health infrastructure, limited outreach capacity, and socioeconomic barriers to service utilization.

Recent NFHS estimates suggest that full immunization coverage in Bihar has reached approximately 70–75%, representing a substantial improvement compared to earlier decades. However, this level remains below the national target of 90% and lags behind high-performing states. The observed gains have been driven, in part, by targeted policy initiatives, most notably Mission Indradhanush and Intensified Mission Indradhanush, which were explicitly designed to identify and vaccinate left-out and drop-out children in low-performing districts. Evaluations of these initiatives indicate that intensified outreach, micro-planning, and enhanced monitoring contributed to measurable short-term improvements in coverage, particularly among marginalized and hard-to-reach populations [3].

Despite overall progress, immunization performance in Bihar continues to be characterized by substantial intra-state heterogeneity. District-level analyses reveal wide variation in coverage, with some districts approaching national averages while others persistently exhibit low immunization uptake. These disparities reflect differential health system capacity, geographic accessibility, socioeconomic conditions, and local governance effectiveness. The persistence of such heterogeneity highlights the limitations of uniform, state-wide strategies and underscores the necessity of localized, data-driven approaches tailored to district-specific contexts. Strengthening decentralized planning, improving district-level monitoring, and addressing context-specific supply- and demand-side barriers are therefore critical to sustaining and equitably extending immunization gains across Bihar [4].

SOCIO-DEMOGRAPHIC DETERMINANTS OF IMMUNIZATION

Multiple studies conducted in Bihar consistently identify socio-demographic factors as critical determinants of childhood immunization uptake, reflecting broader structural and social inequities in access to health services. Among these factors, maternal education emerges as one of the strongest and most consistently reported predictors of full immunization. Children born to mothers with secondary or higher levels of education are significantly more likely to be fully immunized compared to those whose mothers have no formal education. Maternal education enhances health literacy, improves awareness of immunization schedules and benefits, increases confidence in interacting with health systems, and is often associated with greater decision- making autonomy within households. These pathways collectively contribute to higher rates of timely and complete vaccination [5].

In addition to maternal education, several other socio-demographic and service-related factors significantly influence immunization coverage in Bihar. Place of delivery is a key determinant, with children born in institutional settings more likely to receive early vaccines and to be linked to follow-up immunization services than those born at home. Institutional delivery facilitates early contact with the health system, immediate administration of birth doses, and counseling of caregivers regarding subsequent vaccinations.

Socioeconomic status plays a central role in shaping immunization outcomes. Children from poorer households face multiple barriers, including indirect costs of accessing services, opportunity costs related to lost wages, and greater geographic constraints. These households are also more vulnerable to service disruptions, seasonal migration, and competing livelihood priorities, all of which increase the likelihood of missed or delayed vaccinations.

The availability and retention of immunization cards have been shown to be strongly associated with full immunization status. Immunization cards serve not only as records but also as reminders for caregivers and health workers, facilitating continuity of care. Loss or non-issuance of cards is associated with higher dropout rates, particularly for multi-dose vaccines.

Birth order and family size further influence immunization uptake. Higher birth order children and those from larger families are less likely to be fully immunized, reflecting resource constraints, caregiver fatigue,

and reduced attention to preventive care as family responsibilities increase.
Children from marginalized communities, including Scheduled Castes and economically disadvantaged households, are disproportionately represented among partially immunized or unvaccinated children in Bihar. These disparities reflect intersecting disadvantages related to poverty, social exclusion, lower educational attainment, and weaker engagement with formal health services. Such inequities have direct implications for child mortality risk, as under- immunized children remain more vulnerable to vaccine-preventable diseases that contribute significantly to infant and under-five mortality.
Overall, the persistence of socio-demographic disparities in immunization uptake underscores the need for equity-focused strategies that address the social determinants of health alongside improvements in service delivery. Targeted interventions aimed at low-literacy households, marginalized communities, and high-risk families are essential for closing immunization gaps and achieving sustained reductions in child mortality in Bihar [4].

IMMUNIZATION AND CHILD MORTALITY IN BIHAR

Burden of Vaccine-Preventable Diseases

Vaccine-preventable diseases (VPDs) have historically constituted a substantial share of infant and under-five mortality in Bihar, particularly in rural, remote, and socioeconomically disadvantaged settings. Prior to the scale-up of routine immunization, diseases such as measles, neonatal tetanus, pertussis, and diphtheria were major contributors to preventable child deaths in the state. Periodic measles outbreaks, in particular, accounted for significant morbidity and mortality among children under five, reflecting both low baseline immunization coverage and gaps in outbreak response capacity.
Neonatal tetanus has also been an important indicator of health system performance in Bihar, closely linked to inadequate maternal immunization, unsafe delivery practices, and poor access to institutional care. Similarly, pertussis and diphtheria—though underreported—have contributed to infant deaths, especially in settings with delayed or incomplete vaccination. These disease patterns disproportionately affected marginalized populations, reinforcing existing social and health inequities.
Immunization reduces child mortality through multiple, well-established mechanisms. By inducing individual immunity, vaccines directly prevent severe disease and death; by reducing pathogen circulation, they also confer indirect protection through herd immunity. At the population level, sustained immunization coverage interrupts transmission chains, prevents outbreaks, and lowers the overall disease burden. Although disease-specific mortality surveillance data at the state level remain limited in Bihar, extensive national and global evidence demonstrates that high immunization coverage is strongly associated with sharp declines in VPD incidence and mortality. The historical elimination of neonatal tetanus and the near-elimination of polio in India underscore the transformative potential of effective immunization programs [5].

Evidence Linking Immunization to Mortality Reduction

Trends observed in Bihar suggest that improvements in immunization coverage have occurred alongside notable declines in infant mortality rate (IMR) and under-five mortality rate (U5MR) over the past decade. Bihar's IMR has declined substantially, reflecting the cumulative impact of expanded immunization coverage, improved maternal and newborn care, enhanced institutional delivery rates, and strengthened neonatal health services. These parallel trends are consistent with national patterns, where states achieving higher immunization coverage have generally experienced faster reductions in child mortality.
At the national level, multiple studies have demonstrated strong associations between expanded vaccination coverage—particularly against measles—and reductions in child mortality. Large- scale analyses using nationally representative mortality data have shown that measles vaccination campaigns contributed significantly to declines in all-cause child mortality in India. While such studies provide compelling evidence of immunization's mortality-reducing effects, similar state-specific analyses for Bihar remain scarce.
Most of the available evidence linking immunization to child mortality reduction in Bihar is ecological or associative, relying on temporal correlations between coverage trends and mortality indicators rather than direct causal estimation. Few studies have employed longitudinal designs [6],
quasi-experimental methods, or cause-specific mortality attribution to quantify the proportion of mortality decline directly attributable to immunization. As a result, while immunization is widely recognized as a critical contributor to improved child survival, its precise contribution relative to other interventions—such as nutrition programs, sanitation improvements, and maternal health services—remains difficult to isolate in the Bihar context.
This lack of causal attribution represents a significant evidence gap with important policy implications. Without robust, state-specific estimates of immunization's mortality impact, prioritization and resource

allocation decisions rely heavily on indirect evidence and extrapolation from national or global studies.

Health System and Programmatic Factors

Supply-Side Constraints

Despite notable improvements under the Universal Immunization Programme (UIP) and initiatives such as Mission Indradhanush, Bihar's immunization system continues to face substantial supply-side and operational challenges. These constraints are particularly pronounced in rural, flood-prone, and socioeconomically disadvantaged districts.

One of the most persistent challenges is cold chain maintenance, which is critical for preserving vaccine potency. Evaluations of immunization infrastructure in Bihar have documented gaps in cold chain equipment availability, inconsistent electricity supply, and limited maintenance capacity, particularly at sub-centre and primary health centre levels. Studies assessing cold chain functionality in low-performing states have identified Bihar as having a higher proportion of cold chain points requiring repair or replacement compared to national averages, raising concerns about vaccine effectiveness in remote settings (UNICEF & MoHFW evaluations; ICMR-NCDIR reports).

Human resource constraints further undermine service delivery. Shortages of trained Auxiliary Nurse Midwives (ANMs), high staff turnover, and uneven distribution of health workers across districts have been consistently reported. Singh et al. (2019) found that staffing shortages and workload pressures limited the frequency and quality of outreach immunization sessions in low- performing blocks of Bihar. Inadequate training and limited opportunities for refresher courses also affect adherence to immunization schedules and recording practices.

Supervision and governance at the block and district levels remain weak. Ratna et al. (2024), in their immunization system strengthening roadmap for Bihar, highlighted limited supervisory capacity, irregular monitoring visits, and gaps in data use for decision-making. These systemic weaknesses reduce accountability and hinder timely identification of missed children and underperforming areas [3].

Geographic and environmental challenges further exacerbate supply-side barriers. Seasonal flooding, poor road connectivity, and dispersed settlements restrict access to immunization services, disrupt outreach activities, and contribute to session cancellations. Such logistical constraints disproportionately affect marginalized populations, reinforcing inequities in immunization coverage and child survival outcomes.

Demand-Side Barriers

In addition to supply-side limitations, demand-side factors play a crucial role in shaping immunization uptake in Bihar. Caregiver knowledge, attitudes, and trust in the health system strongly influence timely and complete vaccination.

Studies conducted in rural Bihar indicate that while overall acceptance of vaccines is relatively high, substantial knowledge gaps persist regarding immunization schedules, the importance of completing all doses, and the benefits of newer vaccines. Pandey et al. (2019) reported that incomplete understanding of vaccine schedules was a key reason for partial immunization among children aged 12–36 months. Lack of awareness about subsequent doses often results in dropouts after initial vaccinations.

Socioeconomic pressures further constrain demand. Seasonal migration for agricultural and informal labor is common in Bihar and has been identified as a significant contributor to missed or delayed immunizations. Children of migrant families are more likely to be partially immunized due to disrupted contact with health services and lack of continuity in care. National analyses of immunization inequities have shown that migration-related mobility disproportionately affects immunization completion in states like Bihar.

Gender norms and intra-household decision-making also influence immunization behavior. Multiple studies indicate that maternal autonomy, education, and support from family members—particularly male partners—are strongly associated with full immunization. In contexts where women have limited decision-making power or face competing domestic and livelihood responsibilities, immunization visits are more likely to be delayed or missed [7].

Trust in public health services and prior experiences with healthcare providers further shape demand. While overt vaccine hesitancy remains relatively low in Bihar compared to some other settings, perceptions of poor service quality, long waiting times, and irregular service availability can discourage caregivers from completing immunization schedules. Community-based qualitative studies emphasize the importance of consistent service delivery and respectful interactions with frontline health workers in sustaining caregiver engagement.

Fear of adverse events following immunization (AEFI) also acts as a significant, though often underreported, barrier to vaccine uptake. Caregivers may delay or avoid subsequent doses if a child experiences mild side effects such as fever or swelling, or due to misinformation and community-level rumors surrounding vaccine safety. In low-trust settings, even minor adverse events can disproportionately influence perceptions and reduce confidence in immunization services.In addition, the

indirect economic cost of accessing immunization services—particularly loss of daily wages—represents a critical constraint for low-income households. Many caregivers, especially those engaged in daily wage labor, face a trade-off between attending immunization sessions and securing their livelihood. This opportunity cost contributes to missed or delayed vaccinations, particularly for follow-up doses, and is more pronounced among marginalized and migrant populations [8].

Addressing these demand-side barriers is essential for achieving universal and equitable immunization coverage. Evidence suggests that community engagement, behavior change communication, and strengthened roles for frontline workers such as ASHAs and Anganwadi workers can significantly improve caregiver awareness and service utilization.

Evidence Gaps and Research Needs

Although immunization coverage data are regularly collected, there is a lack of:

- Longitudinal studies linking immunization exposure to mortality outcomes
- District-level disease surveillance data collected not available easily for research
- Vaccine-specific effectiveness and impact studies in Bihar

Strengthening data systems and integrating immunization data with mortality surveillance would allow more robust evaluation of immunization's role in child survival.

DISCUSSION

The evidence reviewed suggests that immunization has played a meaningful role in reducing child mortality in Bihar, although progress remains uneven and incomplete. Bihar's full immunization coverage (FIC) increased from single-digit levels in the early 1990s to around 71% by 2019–20, a transition that corresponded with declines in infant mortality rates in the state—IMR reportedly fell from about 42 in 2015 to 29 in 2019, a trend partially attributed to improved vaccination coverage alongside broader health system efforts.

Studies conducted within the state have documented substantial immunization uptake in specific settings; a community-based assessment of low-performing blocks reported corrected full immunization coverage of approximately 90.85% among children aged 12–23 months, although a noticeable proportion remained incompletely immunized due to factors such as vaccine hesitancy and missed vaccination opportunities due to operational gaps.

However persistent health system limitations—such as supply-side constraints, outreach challenges in urban, peri urban & rural areas, and inconsistent data quality—along with demand-side barriers like low caregiver awareness and operational barriers to accessing services, continue to restrict the full potential of immunization programs in Bihar. For example, a rural study in Bhojpur district found only 65% of children aged 12–36 months were fully immunized, with maternal education, place of birth, and possession of immunization cards strongly associated with coverage status—highlighting how socioeconomic and health service factors shape vaccine uptake.

Such disparities align with broader national evidence that socio-demographic determinants, including maternal education and health service access, significantly contribute to immunization inequalities across Indian districts, with low coverage clusters often concentrated in historically underserved regions like Bihar.

Despite improvements in immunization coverage, direct evidence attributing reductions in child mortality specifically to immunization programs in Bihar remains limited. Most current evidence relies on ecological associations between coverage trends and mortality declines rather than rigorous causal analyses. Nevertheless, national studies provide compelling evidence that immunization campaigns significantly reduce child deaths; for instance, analyses of measles immunization in India using large, nationally representative mortality datasets have demonstrated measurable declines in child mortality attributable to vaccination efforts.

Persistent health system limitations—such as supply-side constraints, outreach challenges in rural areas, and inconsistent data quality—along with demand-side barriers like low caregiver awareness and logistical barriers to accessing services, continue to restrict the full potential of immunization programs in Bihar.

These structural and equity issues underscore the need for integrated strategies that combine immunization with broader maternal and child health interventions while prioritizing data quality and targeted efforts to reach underserved populations.

CONCLUSIONS AND POLICY IMPLICATIONS

Immunization continues to be one of the most powerful and cost-effective strategies for reducing child mortality in Bihar. Although substantial gains in immunization coverage have been achieved over the past decade, progress remains uneven, with persistent disparities across districts, socioeconomic groups, and

hard-to-reach populations. These inequities, combined with health system constraints and limited availability of robust mortality attribution evidence, constrain the full potential of immunization programs to deliver sustained child survival gains.

To translate improvements in coverage into measurable and equitable reductions in child mortality, immunization efforts in Bihar must move beyond periodic campaign-driven approaches toward resilient, well-functioning routine systems. This will require sustained investment in health system capacity, targeted strategies for vulnerable populations, strengthened community engagement, and improved data systems that link immunization performance with child health outcomes. Generating high-quality, state-specific evidence on immunization impact will be critical for informing policy, guiding resource allocation, and accelerating progress toward national and global child survival goals.

AUTHOR CONTRIBUTIONS

All authors contributed equally to the conception, literature review, analysis, and preparation of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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