

Immunization Coverage and Vaccine Effectiveness in Public Health Programs Determinants, Digital Interventions and Implications for Population Health

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Abstract — Immunisation programmes represent one of the most effective interventions in global public health with regard to preventing infectious diseases and mitigating child mortality. Despite significant progress in global vaccination campaigns, disparities in immunisation rates continue due to socioeconomic disparities, healthcare access barriers, and vaccine hesitancy. This cross-sectional analytical study evaluates immunisation coverage and vaccine effectiveness among children using data collected on 268 children between 0–15 years of age visiting primary healthcare centres and immunisation clinics. Data on vaccination status, parental knowledge, healthcare access, and digital health interventions were collected through structured surveys and clinical immunisation history. Descriptive statistics, one-way ANOVA, and logistic regression determined variables contributing to vaccine uptake and efficacy. Findings indicate that good immunisation coverage is strongly linked with increased healthcare access ($F=5.12$, $p=0.006$), parental education ($F=6.28$, $p=0.002$), and systematic digital reminder systems ($F=6.85$, $p=0.001$). Digital health-based interventions including text-message reminders and electronic immunisation registries significantly increased vaccination compliance. Low parental education ($\beta=0.42$, $p=0.002$) and absence of reminder systems ($\beta=0.39$, $p=0.003$) were the strongest predictors of incomplete immunisation. Coverage gaps persist among groups with restricted healthcare access and lower socioeconomic status. The study highlights the paramount role of community-based health education, digital monitoring tools, and stronger immunisation infrastructure in increasing vaccine coverage and population health outcomes.

Keywords — Immunization Coverage; Vaccine Effectiveness; Childhood Vaccination; Public Health Immunization Programs; Vaccine Uptake; Digital Health Interventions.

1. Introduction

Immunisation is one of the best-known and most economical public health interventions to prevent infectious diseases and improve population health outcomes. Vaccination has been particularly instrumental in the control and near-eradication of life-threatening diseases like measles, poliomyelitis, diphtheria, and tetanus. International immunisation efforts have resulted in large-scale reductions in child death and morbidity over recent decades. However, even with impressive outcomes, immunisation coverage gaps remain in most areas, demonstrating the urgent need for continuous assessment of vaccine delivery systems and immunisation programme effectiveness (Shefer et al., 1999; Vakili et al., 2015).

High coverage rates are critical in ensuring herd immunity, which safeguards both vaccinated and unvaccinated people by limiting disease transmission within communities (Fairbrother et al., 2000). Surveillance of immunisation coverage is one of the indicators of national public health system performance. Immunisation programmes have been substantially transformed by technological innovations. Digital health systems including

immunisation registries, electronic health records, and mobile health applications are increasingly being used to monitor vaccine records, determine who has not received scheduled vaccines, and apply focused follow-up interventions (Placzek and Madoff, 2011).

Text-messaging reminder systems have demonstrated substantial increases in immunisation rates by reminding caregivers of upcoming appointments (Rand et al., 2015). Online digital media has been employed to create vaccine awareness and motivate community engagement (Odone et al., 2015).

HPV vaccines and other vaccine types have demonstrated high effectiveness in preventing infections and decreasing the incidence of HPV-related cancers (Markowitz et al., 2018; Giannone et al., 2022). Healthcare worker training programmes have been designed to improve knowledge of vaccination practices and significantly change delivery and immunisation rates (Uskun et al., 2008). Vaccine hesitancy, misinformation, distribution challenges, and socioeconomic disparities continue to reduce vaccination rates, requiring coordinated strategies combining healthcare education, community involvement, and sound infrastructure. AI and data

analytics are becoming increasingly studied options for strengthening immunisation systems (Devi et al., 2025; Shanthi et al., 2025).

2. Review of Literature

Systematic evidence-based reviews highlight that vaccination initiatives involving immunisation coordination among healthcare professionals, governmental health boards, and non-profit organisations significantly increase immunisation rates (Shefer et al., 1999). Evaluation of immunisation programmes in international territories reveals high heterogeneity in vaccination coverage across geographic areas, with imbalances in vaccine availability and healthcare quality predetermining vaccination rates (Vakili et al., 2015). Hospital-based interventions have proven effective channels for improving immunisation coverage, with systematic reviews indicating that these interventions significantly increase vaccination levels among paediatric groups (Reifferscheid et al., 2023).

Studies distinguish between vaccine efficacy in controlled clinical trials and vaccine effectiveness in real healthcare settings, with effectiveness assessment providing invaluable information for policymakers on whether vaccination programmes are attaining desired public health goals (Shim and Galvani, 2012; Costantino et al., 2020). HPV vaccination studies have proven that mass vaccination considerably reduces HPV infections and resulting malignancies (Markowitz et al., 2018; Giannone et al., 2022). Online immunisation records and electronic medical records enable healthcare workers to maintain accurate vaccination records and track population trends (Placzek and Madoff, 2011). Text-message reminder systems have been shown to significantly increase immunisation rates by encouraging caregivers to adhere to vaccination schedules (Rand et al., 2015; Odone et al., 2015).

Training curricula aimed at improving healthcare worker knowledge of immunisation practices improve vaccine uptake in communities (Uskun et al., 2008). Meta-analyses highlight the importance of integrated public-health interventions incorporating community outreach, educational initiatives, and digital technologies (Siddiqui et al., 2022). Digital transformation efforts can also benefit healthcare communication programmes and increase patient participation in preventive care (Catherine et al., 2025; Shanthi et al., 2025).

3. Objectives

- To evaluate immunisation coverage rates and vaccine effectiveness among children attending primary healthcare facilities.

- To identify socioeconomic and healthcare system determinants of vaccination compliance.
- To assess the impact of digital health interventions on immunisation adherence.
- To propose policy recommendations for strengthening immunisation systems.

4. Methodology

A cross-sectional analytical research design was utilised to question trends of immunisation coverage and determine vaccine effectiveness among children at primary healthcare facilities. The study was based in selected primary care units and specialised immunisation clinics. The target population was children aged 0–15 years receiving vaccination services or routine health checkups during the study period. The sample of 268 children was taken using systematic sampling of immunisation registers and hospital records. Inclusion criteria required documented vaccination records; children with no complete records or who had migrated without documented immunisation records were excluded. Information was collected through structured caregiver interviews and thorough examination of vaccination records, including demographic factors, vaccination status, parental knowledge of immunisation schedules, healthcare access, and use of digital reminder systems. Vaccination status was categorised using national guidelines into fully immunised, partially immunised, and not immunised. Statistical techniques included descriptive statistics, one-way ANOVA, and logistic regression. Statistical significance was set at $p < 0.05$. Institutional research ethics committee approval was obtained; informed consent was taken from parents or guardians and all data anonymised.

5. Results and Discussion

Table 1: Demographic Characteristics of Children (N = 268)

Variable	Category	Frequency	Percentage (%)
Age Group	0–2 years	86	32.1
	3–5 years	92	34.3
	6–10 years	58	21.6
	11–15 years	32	11.9
Gender	Male	142	53.0
	Female	126	47.0
Residence	Urban	151	56.3
	Rural	117	43.7

Table 2: Immunization Coverage Status

Vaccination Status	Number of Children	Percentage (%)
Fully immunized	182	67.9
Partially immunized	61	22.8
Not immunized	25	9.3

67.9% of children were fully immunised. The presence of partially immunised children suggests gaps in vaccination adherence that increase community vulnerability and emphasise the need for specific interventions to ensure complete immunisation coverage (Fairbrother et al., 2000).

Table 3: Factors Influencing Immunization Coverage (ANOVA)

Variable	Mean Immunization Score	F-value	Significance (p-value)
Parental education	3.41	6.28	0.002
Household income	3.29	5.67	0.004
Healthcare accessibility	3.36	5.12	0.006
Digital reminder systems	3.48	6.85	0.001

The strongest association was observed with digital reminder systems ($F=6.85$, $p<0.01$), suggesting that technological interventions play an important role in improving vaccination adherence, consistent with Rand et al. (2015) and Odone et al. (2015). Parental education and healthcare accessibility also demonstrated significant associations with immunisation coverage.

Table 4: Logistic Regression Analysis: Predictors of Incomplete Immunization

Predictor Variable	Regression Coefficient	Standard Error	p-value
Low parental education	0.42	0.08	0.002
Low household income	0.37	0.09	0.004
Limited healthcare access	0.35	0.07	0.005
Absence of reminder system	0.39	0.06	0.003

Low parental education and lack of reminder systems were the strongest predictors of incomplete immunisation. Limited healthcare accessibility and lower household income also significantly contributed to vaccination gaps. These findings are consistent with Carpiano et al. (2019) regarding socioeconomic status and vaccination behaviours.

Digital prompt systems demonstrated strong positive influence on vaccination adherence, consistent with Rand et al. (2015). Immunisation registries and digital health platforms improve vaccination monitoring accuracy and recognition of those needing follow-up (Placzek and Madoff, 2011). The prophylactic effectiveness of immunisation programmes against infectious illness is well demonstrated in studies of HPV vaccination (Markowitz et al., 2018; Giannone et al., 2022).

6. Public Health Policy Recommendations

Governments and healthcare institutions should expand routine immunisation services by strengthening primary healthcare systems and ensuring vaccination services are accessible to all communities. Public health education programmes should improve caregiver awareness regarding the importance of vaccination. Healthcare systems should integrate digital health technologies and immunisation monitoring systems to improve vaccination tracking and reduce missed appointments. Policymakers should focus on reducing socioeconomic barriers to vaccination by providing free or subsidised vaccination services for low-income families. Healthcare worker training programmes should be strengthened to enhance vaccination practices and improve communication with caregivers. Continuous research and surveillance of vaccine effectiveness should evaluate long-term impact of immunisation programmes and identify improvement opportunities.

7. Conclusion

Immunisation programmes remain one of the strongest tools for preventing infectious diseases and improving population health outcomes. Relatively high immunisation coverage in the study reflects the strength of national vaccination campaigns and supporting healthcare infrastructure. However, the discovery of partially immunised and unimmunised children indicates gaps requiring specific interventions to maintain sound disease prevention. Socioeconomic determinants, healthcare access, and technological innovations all significantly influence immunisation coverage and vaccine effectiveness. Increasing healthcare infrastructure, expanding digital health interventions, and increasing caregiver education would significantly improve vaccination coverage and safeguard the population against vaccine-preventable illnesses.

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