

Research Article

Community-Based Assessment of Childhood Immunization Coverage and Associated Risk Factors in Pakistan

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ABSTRACT

Background: Pakistan has been making progress in its Expanded Programme on Immunization but still, incomplete immunization among children is a tremendous challenge especially in the underserved population. Knowing local coverage and barriers to completing routine immunization schedules is crucial to improving routine immunization completion. The present study evaluated the immunization status of children and the factors related to inadequate immunization status in a community based population.

Methods: It was a cross sectional study done at community level involving 400 children of 12-23 months age in selected urban and rural communities of Pakistan. Data were collected on the sociodemographic characteristics, maternal health care services used, immunisation status, knowledge of the caregivers, problems accessing health care, and reasons for failure to immunise using a structured questionnaire. Vaccination status was determined as full, partial or no vaccination for age. The analysis of the data was done with the IBM SPSS Statistics version 27 software. The influences of these factors on having an incomplete immunization were examined using univariable and multivariable binary logistic regression analyses.

Outcome: Of all the children, 67.0% were fully vaccinated, 27.5% were partially vaccinated, and 5.5% were unvaccinated. Coverage was found to be highest for the first doses of vaccines, and lower for the subsequent doses, with 9.4% drop off in coverage for pentavalent doses 1-3. At the multivariable level, the lack of understanding of the EPI schedule, vaccine hesitancy, missed vaccination opportunities, rural residence, low level of maternal education, inadequate antenatal care, and more distant healthcare facilities from vaccination services were independently associated with incomplete immunization status. The most common reasons for default were the lack of knowledge about the next immunization date, temporary childhood illness, difficulties with access, and fear of vaccine adverse effects.

The conclusion: Incomplete immunization was linked to a mix of informational, socioeconomic, access-related and behavioral factors. Better caregiver counselling, rural outreach, reminder tools and opportunistic vaccination can help to meet childhood vaccination timelines.

Keywords: Childhood Immunization, Vaccination Coverage, Incomplete Immunization, Vaccine Hesitancy, Expanded Programme on Immunization, Pakistan.

INTRODUCTION

Immunization is one of the most successful and cost-effective public health interventions that can prevent morbidity, disability and death due to vaccine-preventable diseases in children. Vaccination programs have been a major

contribution to child survival worldwide but there remain significant deficits in routine immunization coverage, especially in low- and middle-income countries, with millions of children not vaccinated or receiving incomplete vaccination [1]. This is a challenge that

continues to pose risks to Pakistan despite the implementation of an established Expanded Programme on Immunization (EPI) [2,3] with a structured age-based vaccination programme to immunise children against 12 vaccine-preventable diseases.

In the past few decades, Pakistan has also added more vaccines to the routine immunization program such as hepatitis B, Haemophilus influenzae type b, pneumococcal disease, rotavirus, typhoid and rubella, along with established vaccines for tuberculosis, poliomyelitis, diphtheria, pertussis, tetanus, and measles [4]. However, coverage is still not equitable and timely due to the large birth cohort in the country, geographical diversity, uneven healthcare facilities, and socioeconomic differences. Despite significant drop from previous years, it was estimated that about 390,000 zero dose children remained in Pakistan in 2023 [5].

Past studies at both national and regional levels have shown that there is significant variation in completion of vaccinations. The results of analysis of Pakistan Demographic and Health Survey data indicated that there were significant gaps in timeliness, completeness and coverage in the childhood immunization, and that the maternal tetanus vaccination rate, household wealth, and maternal education were important factors affecting completion and timeliness of childhood immunization [6]. Parental education, media exposure, household wealth and community-level maternal education were positively associated with full immunization in another study conducted in Pakistan with children [7].

Socio-economic and health-care access barriers seem to be more significant. In Pakistan, prior studies showed that the non-immunisation was mainly seen in children residing in rural areas and the factors associated with it were low parental literacy, poverty, increased family size, and the distance from healthcare centers [8]. A similar analysis in Sindh resulted in variables related to parental education, household wealth, number of living children, use of antenatal-care services, delivery assistance, and maternal and child health information all being found to affect completion of childhood vaccinations [9].

Coverage estimates at the national level can mask significant local variation, therefore, evidence at the community level is important. In rural Pakistan, maternal education, knowledge of vaccination, accessibility of EPI services, misconceptions, and outreach services

have been reported to be a significant determinant in vaccine uptake [10]. More recent data from Khyber Pakhtunkhwa also indicated that rural living, low parental awareness, culture, misconceptions, migration and poor health access were factors associated with immunization default [11].

In this context, community-based assessment can help to better understand the immunization coverage and barriers to immunization that can be modified at the local level. Hence, the present study was undertaken to estimate immunization coverage among childhood population in a community based population in Pakistan and to know the demographic, socioeconomic, parental and healthcare related factors associated with under-immunization or no immunization.

MATERIALS AND METHODS

Study Design and Setting

To determine the status of childhood vaccination and factors influencing incomplete vaccinations, a cross sectional study was conducted in selected urban and rural communities of Pakistan using community based approach. A structured questionnaire was used for data collection with trained data collectors by visiting the households over a predetermined study period.

Study Population

Children 12–23 months who lived in selected communities with their parents/caregivers were included in the study. This age group was chosen because the majority of childhood vaccines recommended for the primary series are delivered by the end of infancy, thus providing a meaningful opportunity to measure the completion of the primary series of childhood vaccines.

Children with missing parent/carers after repeated visits, children who were short-term visitors to the selected household, and for whom vaccination status could not be confirmed from a vaccination card and/or reliably be established based on the history of the caregivers were not included.

Sample Size and Sampling Technique.

A sample size was determined using the single-population proportion formula: $n = Z^2 p(1-p)/d^2$. The n was the required sample size, Z was set to 95% (confidence level), p was set according to previous data obtained in Pakistan and d was the margin of error desired. The number of additional proportions was added in

due to non-response and incomplete questionnaires.

A multi-stage cluster sampling technique was used. Selected districts or administrative areas were stratified based on urban and rural residents. Communities/Clusters were then selected followed by systematic selection of households within each cluster. If there were multiple eligible children in a household, one child was chosen by a simple random selection method that is predetermined to avoid clustering in the household level.

Data Collection Procedure

Data have been gathered by face-to-face interviews with mothers or main caregivers with a pretested semi-structured questioner. The questionnaire consisted of information related to the child, characteristics of the family, parental factors, access to health care, access to vaccines, and parent knowledge and attitudes about routine immunization.

The child's age, sex, birth order, sibling size, nutrition status (if available) and past serious illness were noted. Household characteristics consisted of place of residence, family size, family income category, socioeconomic status, distance from the nearest vaccination facility and means of transportation.

Maternal factors considered were age, education, occupation, frequency of antenatal services, place of delivery and use of postnatal services. Paternal education and occupation also were recorded. Caregivers were questioned on their awareness of the vaccination schedule, their perception of the benefits and harms of vaccination, the availability of vaccines, missed opportunities, vaccine hesitancy, and delayed or incomplete immunization.

Determine the Immunization Status of the Child

Assessment of the vaccination status was done mainly using the child's vaccination/EPI card. If the card was not available, information about vaccinations was obtained from the caregivers using the vaccine names, doses, age at vaccination, and vaccine-related information that could be recognized.

No vaccine reactions: there were no reported adverse reactions to the vaccines. Partially immunized: Child has had one or more vaccines but failed to receive all the required age appropriate doses. Unimmunized/zero-dose: the child had not been given any of the routine childhood vaccines. When a binary outcome

was specified for regression analysis, "partially immunized" and "unimmunized" children were merged to form the category "incompletely immunized."

Operational Definitions

Complete immunization coverage was defined as the number of children who were fully immunized (Fever Vaccination status 0 or 1) divided by the number of children who were eligible for the survey (Fever Vaccination status 0-3) x 100.

Dropout rate between selected vaccine doses was calculated using:

Dropout rate = (first dose recipients – final dose recipients/first dose recipients) x 100

Maternal education was defined based on the educational category determined in the study, and socioeconomic status was determined based on the occupation, education and household asset indicators as well as household income recorded on the study proforma.

Access difficulty was described as when the caregiver reported an issue accessing routine immunization services due to distance, transportation, cost, inconvenient time or a shortage of vaccination staff.

Study Variables

Childhood immunization status was the primary outcome variable, defined by a child being fully immunized or incompletely immunized. Child age and gender, birth order, family size, number of siblings, urban or rural residence, parent education level, parental occupation, maternal age, socioeconomic status, attendance at antenatal care, institutional delivery, distance from immunization center, having a vaccination card, caregiver knowledge, exposure to information about vaccination, vaccine hesitancy, perceived adverse effects, and availability of EPI services were considered potential explanatory variables.

Quality Assurance

The questionnaire was checked for clarity and content validity and was also pre-tested in a population having characteristics similar to that of the study population. Standardized training was provided to data collectors prior to field work. Completed questionnaires were reviewed each day to verify that they were complete, logical and that there were no missing responses. Key data on a proportion of households was checked again by the field supervisors.

Statistical Analysis

IBM SPSS Statistics for Windows (Version 27.0, Armonk, NY, USA) was used to enter and analyze data. The continuous variables were presented as mean and standard deviation or median and interquartile range as per their distribution. Categorical data were described as frequencies and percentages. Immunization coverage was estimated and with 95% confidence intervals as appropriate for each and every subgroup.

When the expected cell frequencies were less than five, the associations between immunization status and categorical explanatory variables were analyzed by the Pearson chi-square test or Fisher's exact test. The independent-samples t-test or Mann-Whitney U test was used to compare continuous variables as appropriate.

Univariable binary logistic regression were conducted to determine factors associated with incomplete immunization. Variables with p-values <0.20 on univariable analysis and clinically/epidemiologically important variables

were included in a multivariable binary logistic regression model. Both crude odds ratios and adjusted odds ratios along with 95% CIs were reported. To assess multicollinearity, the tolerance statistics and variance inflation factors were used, and to evaluate the model fit, the Hosmer–Lemeshow goodness-of-fit test was used. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

Table 1 shows that there were higher rates of not being fully immunised amongst children of rural and socially disadvantaged families. Incompletely immunized children were significantly more likely to be rural residents (66.7% vs 47.0%, $p < 0.001$) and low maternal education and low socioeconomic status were strongly associated with incomplete vaccination. Higher birth order and family size were associated with similar trends, indicating that family structure and social disadvantage are factors that may be involved in missed childhood vaccines.

Table 1. Sociodemographic Characteristics According To Childhood Immunization Status

Variable	Overall (N=400)	Fully immunized (n=268)	Incompletely immunized (n=132)	Test statistic	p-value
Child age, months, mean $\pm$ SD	17.4 $\pm$ 3.5	17.6 $\pm$ 3.4	17.0 $\pm$ 3.6	t = 1.63	0.104
Male sex, n (%)	218 (54.5)	143 (53.4)	75 (56.8)	$\chi^2 = 0.42$	0.518
Rural residence, n (%)	214 (53.5)	126 (47.0)	88 (66.7)	$\chi^2 = 13.72$	<0.001
Birth order ≥ 4 , n (%)	111 (27.8)	61 (22.8)	50 (37.9)	$\chi^2 = 10.32$	0.001
≥ 4 children in household, n (%)	156 (39.0)	89 (33.2)	67 (50.8)	$\chi^2 = 11.50$	<0.001
Maternal education $\leq$ primary	182 (45.5)	102 (38.1)	80 (60.6)	$\chi^2 = 18.21$	<0.001
Paternal education $\leq$ primary	145 (36.3)	82 (30.6)	63 (47.7)	$\chi^2 = 11.37$	<0.001
Mother employed outside home	61 (15.3)	43 (16.0)	18 (13.6)	$\chi^2 = 0.40$	0.528
Low socioeconomic status	174 (43.5)	99 (36.9)	75 (56.8)	$\chi^2 = 14.17$	<0.001

Overall, 67.0% of children were fully immunized for age, while 27.5% were partially immunized and 5.5% were completely unimmunized. Coverage was highest for BCG (95.5%) and declined across later doses, with measles-rubella second-dose coverage

reaching 69.3%. The pentavalent first-to-third dose dropout rate was 9.4%, indicating that retention within the immunization schedule remained an important challenge despite high initial vaccine uptake (Table 2).

Table 2. Childhood Immunization Coverage and Vaccine-Specific Completion

Immunization indicator	n	%
Fully immunized for age	268	67.0

Partially immunized	110	27.5
Zero-dose/unimmunized	22	5.5
BCG received	382	95.5
Pentavalent-1 received	371	92.8
Pentavalent-3 received	336	84.0
PCV-3 received	331	82.8
OPV-3 received	342	85.5
Rotavirus series completed	326	81.5
Measles/MR first dose received	315	78.8
Measles/MR second dose received*	277	69.3
Vaccination card available	302	75.5

Maternal healthcare use, caregiver knowledge, and access to immunization services were strongly related to vaccination completion. Adequate knowledge of the EPI schedule was present in 76.5% of fully immunized children compared with 47.7% of incompletely immunized children ($p < 0.001$), while vaccination counseling and card retention were

also markedly higher in the fully immunized group. In contrast, distance from vaccination centers, transport difficulties, missed vaccination opportunities, and vaccine hesitancy were substantially more common among incompletely immunized children (Table 3).

Table 3. Maternal and Healthcare-Related Factors Associated With Incomplete Immunization

Factor	Fully immunized (n=268)	Incompletely immunized (n=132)	Test statistic	p-value
≥4 antenatal care visits	211 (78.7)	76 (57.6)	$\chi^2 = 19.41$	<0.001
Institutional delivery	227 (84.7)	91 (68.9)	$\chi^2 = 13.91$	<0.001
Vaccination counseling received	216 (80.6)	76 (57.6)	$\chi^2 = 23.69$	<0.001
Adequate knowledge of EPI schedule	205 (76.5)	63 (47.7)	$\chi^2 = 33.58$	<0.001
Vaccination card retained	224 (83.6)	78 (59.1)	$\chi^2 = 29.30$	<0.001
Vaccination center >30 min away	58 (21.6)	52 (39.4)	$\chi^2 = 14.33$	<0.001
Transport difficulty	51 (19.0)	47 (35.6)	$\chi^2 = 13.38$	<0.001
Missed vaccination opportunity	37 (13.8)	41 (31.1)	$\chi^2 = 17.07$	<0.001
Concern regarding vaccine adverse effects	49 (18.3)	47 (35.6)	$\chi^2 = 14.92$	<0.001
Vaccine hesitancy	30 (11.2)	36 (27.3)	$\chi^2 = 16.95$	<0.001

The most frequently reported reason for incomplete immunization was lack of awareness regarding the next vaccination date (37.1%), followed by illness of the child at the scheduled visit (31.8%) and difficulty reaching vaccination services (29.5%). Fear of adverse effects was reported by 27.3% of caregivers,

while vaccine or session unavailability was also common. These findings indicate that incomplete immunization resulted from a combination of informational, access-related, service-delivery, and attitudinal barriers rather than a single cause (Table 4).

Table 4. Reported Reasons for Partial or Absent Childhood Immunization

Reported reason*	Partially/unimmunized children (n=132)	%
Caregiver unaware of next vaccination date	49	37.1

Child was ill at scheduled visit	42	31.8
Vaccination center too far/transport difficulty	39	29.5
Fear of adverse effects	36	27.3
Vaccine/session unavailable on visit	31	23.5
Family commitments/lack of time	27	20.5
Misconceptions regarding vaccines	25	18.9
Migrated or changed residence	21	15.9
Family opposition	18	13.6
Previous adverse event following vaccination	13	9.8

After adjustment for potential confounders, inadequate caregiver knowledge of the EPI schedule remained one of the strongest predictors of incomplete immunization (aOR 2.47, 95% CI 1.45–4.20), followed by vaccine hesitancy (aOR 2.21, 95% CI 1.21–4.04) and missed vaccination opportunities (aOR 2.05,

95% CI 1.14–3.69). Rural residence, lower maternal education, inadequate antenatal care, and greater distance from vaccination services also remained independently associated with incomplete immunization, whereas socioeconomic status and institutional delivery lost significance after adjustment (Table 5).

Table 5. Univariable and Multivariable Logistic Regression of Factors Associated With Incomplete Childhood Immunization

Predictor	Crude OR (95% CI)	Wald χ^2	p-value	Adjusted OR (95% CI)	Wald χ^2	p-value
Rural residence	2.25 (1.45–3.50)	13.2	<0.001	1.72 (1.03–2.87)	4.31	0.038
Maternal education $\leq$ primary	2.51 (1.63–3.87)	17.9	<0.001	1.89 (1.13–3.15)	5.90	0.015
Low socioeconomic status	2.25 (1.47–3.46)	14.0	<0.001	1.42 (0.85–2.37)	1.79	0.181
Birth order ≥ 4	2.07 (1.32–3.25)	10.2	0.001	1.41 (0.83–2.40)	1.61	0.205
<4 antenatal visits	2.72 (1.72–4.30)	18.5	<0.001	1.84 (1.08–3.13)	4.98	0.026
Inadequate EPI knowledge	3.58 (2.31–5.54)	32.5	<0.001	2.47 (1.45–4.20)	10.9	0.001
Vaccination center >30 min away	2.36 (1.49–3.73)	13.8	<0.001	1.78 (1.04–3.05)	4.43	0.035
Missed vaccination opportunity	2.81 (1.69–4.68)	15.7	<0.001	2.05 (1.14–3.69)	5.73	0.017
Vaccine hesitancy	2.98 (1.75–5.08)	15.9	<0.001	2.21 (1.21–4.04)	6.65	0.010
Institutional delivery	0.40 (0.25–0.65)	14.0	<0.001	0.67 (0.37–1.19)	1.86	0.173

DISCUSSION

Findings from the present community-based study confirm that roughly one-third of children were fully immunized by their age, almost one-third were partially immunized and a smaller portion were not routinely immunized. This is broadly aligned with national evidence that the gaps in completing vaccinations are evident despite relatively high uptake of the first doses. The coverage achieved was highly variable, with coverage of full vaccination at 76.5%, and coverage at later doses and delayed vaccination also being common, according to a large national household survey of over 110,000 children aged 12–23 months [12]. The slightly lower overall coverage found in the present study might be attributable to local socioeconomic factors, representation of rural areas and variations in the definition of age appropriate completion.

The current study showed that there was progressive reduction in coverage in the successive doses of vaccines with high BCG coverage and low pentavalent and measles-rubella completion. This trend was observed in a village in the north of Pakistan, where vaccine completeness severely dropped when the measles dose was added to the schedule, despite a relatively high early-dose coverage rate [13]. Similarly, national survey data showed that doses were not as often given as the initial vaccinations [12]. The results suggest that getting children started may not be the major problem; keeping them on schedule until they complete their vaccinations could be just as critical.

In the present analysis, the rural residence was independently related to incomplete immunization. A previous study conducted in

Peshawar revealed a significant urban-rural immunization gap of 76.5% for urban areas versus 48.8% for rural areas, with various factors like poor accessibility, parental awareness and misconceptions being major barriers [14]. Additional studies from Khyber Pakhtunkhwa showed higher rates of defaulters among those living in rural areas, and identified poor access, migration, cultural issues and lack of parental knowledge as factors associated with defaulters [15]. The continuity of this rural disadvantage highlights the key role of geographical accessibility and continuity of outreach in vaccine equity in Pakistan.

In the current study, maternal education was another significant factor, as children with mothers who lack education were significantly more likely to be incompletely immunized. Another national study on the Pakistan Demographic and Health Survey (PDHS) 2017–18 found that the likelihood of not being fully vaccinated among children was significantly lower in educated mothers and large differences existed between provinces and regions [16]. A second geospatial analysis of the same survey confirmed maternal education and place of delivery as important determinants; the odds of mothers being poorly immunized were about half as great for those who were educated as for those who were not [17]. Maternal education could help her understand the vaccination schedule, understand the value of getting timely vaccinations, and determine to navigate the health service system more effectively.

Use of healthcare services before and around birth was also associated with completion of childhood vaccinations. Inadequate antenatal care was associated with incomplete immunization among children, but no longer significant after multivariable adjustments; institutional delivery was also a significant association factor, but not after multivariable adjustments. Several past studies in Pakistan have found antenatal care use and institutional delivery to be strongly linked to greater odds of having received routine immunization [18]. Clinically plausible because the relation of antenatal services to delivery services, which generates repeated opportunities for providing education to caregivers, initiating immunisation, giving an EPI card and follow-up with preventive services.

One of the most significant results was the relationship between low knowledge of caregivers and lack of immunisation. The caregivers of incompletely vaccinated children

were significantly less likely to be aware of the EPI schedule and not knowing the date of the next vaccination was the most common reported cause of default. In a study done in Karachi, lack of knowledge about the immunization schedule was also the most frequently reported barrier among the children who missed the vaccine doses, followed by fear of vaccine side effects and childhood illness [11]. In a qualitative study conducted in Swat, the lack of knowledge regarding completion of the schedule, illness of the children, belief of adverse side effects, misunderstanding and failure due to the caregivers' issues were found to be significant factors contributing to default [19]. These results indicate that while enhancing the availability of services is important, enhancing caregiver communication and recall mechanisms, too, may be required. In the current study, vaccine hesitancy and concerns about vaccine side effects were independently related to underimmunization. This has also been reported in slum communities in the city of Karachi, where parents' refusal to vaccinate children was attributed to misconceptions, parental concerns about the safety of vaccines, and mistrust [20]. Some previous studies in Pakistan further revealed that 23% of caregivers reported concerns about the adverse effects, and other barriers were lack of awareness, time constraints among caregivers and distance from vaccination facilities [21,22]. The results suggest that in Pakistan, this reluctance is often intermingled with real barriers to uptake, such as lack of access to health services and information about vaccines, and not just an ideological refutation of vaccination.

Other factors associated with failure to complete immunization were missed vaccination opportunities. Pakistani children's status in relation to pentavalent and measles doses was recently analysed in over 100,000 eligible children and approximately one-quarter of them had not received any of the doses [23,24]. The evidence from multicountry studies has also revealed a high prevalence of missed opportunities for immunisation for vaccine eligible children who attend healthcare facilities – including data from Pakistan [25, 26]. This is significant for the programs because each clinical visit is a time to check the immunisation status of the child and provide appropriate vaccines where appropriate.

Based on the present findings, it can thus be concluded that there is a need to look at a multifactorial explanation in relation to

incomplete child immunization in Pakistan. Rural status, lower maternal education, less antenatal contact, poor knowledge of vaccination schedule, geographic access barriers, missed opportunities and vaccine hesitancy continued to be important even when these were adjusted for. Important, socioeconomic status and institutional delivery ceased to be independent in the final model, indicating that some other social disadvantage may be mediated by the more proximal factors of limited knowledge and reduced healthcare contact as well as poor access to vaccination services. Enhancing outreach to underserved communities, building caregiver education, minimizing missed opportunities at health-system interactions, and responding to safety concerns by way of trusted communication could, therefore, be more effective than a single intervention.

Strengths and Limitations

The strengths of this study were the community-based design which enabled measurement of immunization coverage and barriers beyond the hospital environment and a larger representation of children who receive routine preventative care. Multivariable analysis also allowed for several demographic, socioeconomic, maternal and health care-related factors to be adjusted. The cross sectional design restricted the ability to measure temporality and causality, however. Immunization information was partially based on caregiver recall if immunization cards were not available, and thus may have included some recall and misclassification biases. The findings of the study may not apply to all communities of Pakistan, especially those with varying health-service access, cultural practices, or security environments. Reporting bias was also present for self-reported barriers including vaccine hesitancy and difficulty getting to vaccination sites and missed opportunities.

CONCLUSION

Childhood incomplete immunisation continued to be a public health problem in the community studied. While most children had started routine immunizations, coverage rates dipped each dose and a significant number were partially or fully unimmunized. Lower maternal education, rural residence, poor knowledge of the EPI schedule by caregivers, greater distance from vaccination services, missed opportunities for vaccination and vaccine hesitancy were independent factors associated

with under-immunization. The results suggest several approaches to increasing vaccine acceptance, such as continuing to offer vaccines, enhancing caregiver education and outreach, providing follow-up, and leveraging all health care visits to discuss and refresh vaccination status.

Future Perspective

Geographically tailored interventions, digital reminder systems, improved outreach, and opportunistic vaccine delivery strategies should be tested in future multicenter and longitudinal studies to see which are most effective in ensuring timely and complete childhood vaccination in Pakistan.

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