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BARRIERS TO IMMUNIZATION COVERAGE IN UNDER-FIVE CHILDREN IN RURAL COMMUNITIES: A CROSS-SECTIONAL STUDY FROM RURAL PUNJAB, PAKISTAN

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ABSTRACT

Background: Although the immunization program has been working effectively in Pakistan for a long time, the country is still far from meeting the WHO target of immunization coverage of below 100% in rural areas. Determining what specific barriers are present at the household and health system levels is a precondition to designing effective corrective interventions.

Objective: To assess the level of under-immunization among children aged 12-59 months in rural areas of Punjab, Pakistan, and the independent factors associated with under-immunization in these areas.

Methods: It was a cross-sectional, community-based study conducted in the Faisalabad and Toba Tek Singh districts, across 6 rural union councils, from March 2023 to February 2024. Systematic random sampling of primary caregivers of children aged 12 to 59 months was conducted using a house register; a total of 686 primary caregivers were recruited. Vaccination status was confirmed through vaccination cards and caregiver memory. A pre-tested questionnaire was used to assess the barriers. The independent predictors of incomplete immunization were determined using multivariable logistic regression, and the results are presented as adjusted odds ratios (aORs) with 95% confidence intervals.

Key Findings: 64.4% of the sampled children were fully immunized. The strongest independent barrier was geographic distance (aOR 0.24, 95% CI 0.17 to 0.34 if more than 5 kilometers from a vaccination facility). Other independent predictors were maternal non-education (aOR 0.31), household poverty (aOR 0.23), reported vaccine stockout (aOR 0.38), unawareness of the vaccination schedule (aOR 0.41), and paternal refusal (aOR 0.32). Nearly half of respondents (42.2%) reported vaccine stockouts and more than a third (35.2%) reported long waiting times, indicating significant health system vulnerabilities.

Conclusion: There are two types of immunization gaps in rural Punjab — both supply-side and demand-side. There is an immediate need to implement targeted interventions to address the coverage gap in rural areas, such as expanding mobile outreach, engaging male caregivers, and strengthening the cold chain.

KEYWORDS: childhood immunization; vaccine coverage; rural Pakistan; barriers; cross-sectional study; under-five children; community health

1. INTRODUCTION

Childhood immunization is the most effective and cost-effective preventative health intervention in the world's public health toolbox. The various vaccines that prevent diphtheria, tetanus, pertussis, measles, polio, hepatitis B, and Haemophilus influenzae type b (Hib) have together saved an estimated 4.4 million lives each year and played a key role in cutting under-five mortality by over 50% since 1990. The Immunization Agenda 2030 (IA2030), adopted by the World Health Assembly in 2020, aims to ensure that national coverage is at least 90% and that the percentage of zero-dose children is halved compared to 2019, with equity as a core organizing principle. (2)

One of the most difficult immunization scenarios in the world is in Pakistan. The country has consistently ranked among the top ten countries with zero-dose children, with the last Pakistan Demographic and Health Survey (2022) reporting a nationwide full immunization coverage rate of 66% and less than 50% in rural Pakistan, particularly in Punjab and Khyber Pakhtunkhwa. (3) The country is among the two remaining poliovirus-endemic countries in the world, and outbreaks of measles, pertussis, and neonatal tetanus remain a burdensome loss of life, especially in rural areas where services are poor. (4)

The low immunization rate in rural Punjab cannot be blamed on a single factor. In remote rural areas, structural obstacles such as limited geographical accessibility, inadequate road infrastructure, and the distribution of health facilities pose

intrinsic limitations on the provision of services. Also, (5) geographic limitations are exacerbated by health system weaknesses, including chronic vaccine stockouts at peripheral health units, irregular outreach schedules, and a widespread lack of trained vaccine personnel. (6)

When services are made available, uptake is further reduced by demand-side determinants. Mother's education is one of the most consistently reported personal-level risk factors for vaccination practices, and children of mothers with no formal education are two to three times more likely not to be fully immunized than children of educated mothers across various cross-sectional studies in South Asian contexts. (7) Household poverty hinders the mobility of caregivers and imposes opportunity costs, making vaccination visits too costly for the poorest households. (8)

There is an added layer of complexity due to the socio-cultural dynamics in rural communities in Pakistan. Maternal consent is not enough for parents' consent to health-seeking, as is often the case with the paternal approval needed for vaccination. Community-level vaccine hesitancy, driven by vaccine misinformation and interpersonal social networks, has been reported in Pakistan following periods of armed conflict and the 2015 polio immunization campaign controversy. (10)

Although these barriers are acknowledged, evidence aimed at quantifying their relative contributions and adjusted effect sizes at a granular level (district), particularly in rural areas of Punjab, is sparse. Most existing evidence is based on national-level surveys, which fail to disaggregate results at the union council level or to identify specific barriers independently associated with vaccine outcomes (after controlling for other factors). (11) This imbalance hinders the planning of programs in a targeted way by the district health authorities and the non-governmental partners of immunization. (12)

Therefore, the present study was designed to fill this gap and conducted a cross-sectional study in the rural union councils of the Faisalabad and Toba Tek Singh districts. The main goals were: (1) to identify the proportion of children who were fully vaccinated, (2) to describe the range of barriers that the primary caregivers reported, and (3) to find the independent predictors of children not being fully vaccinated using multiple logistic regression analysis. The results will generate actionable, evidence-based information specific to this high-burden rural area to drive interventions within the health system and community engagement. (13)

Previous research in similar contexts in the southern Punjab has reported vaccine shortages and failure to recognize the need for vaccination as major obstacles. Still, it has not included sociocultural barriers, such as fathers' refusal, or continuous or categorical measures of geographic distance. The present study covers all major barrier domains identified in the literature, thereby enabling an extensive and policy-relevant analysis. (15)

2. METHODOLOGY

2.1 Study Design and Setting

A cross-sectional study design was used, with a community-based approach. The study was carried out in the six rural union councils of two adjacent districts, Faisalabad and Toba Tek Singh, in the Punjab province of Pakistan. The districts were purposively selected based on below-average immunization coverage reported in the District Health Information System (DHIS-2) 2021. They were identified as priority areas in the Government of Punjab's expanded program on immunization (EPI) recovery plan. The study period covered the dry- and monsoon-season months from March 2023 to February 2024 to reflect seasonal variation in access constraints.

2.2 Study Population and Eligibility

The target group was the primary caregivers of children aged 12-59 months in the study's selected union councils. Children had to have lived in the study area for at least 6 months before enrolling in the study. Households with children who had known immunodeficiency or were already receiving treatment for malignancy were excluded because such children may not be eligible for immunization. Households that had migrated from outside Pakistan in the last 12 months would have vaccination schedules different from the national program and were therefore excluded.

2.3 Sample Size and Sampling

The sample size was determined by the formula for estimating a single proportion, assuming a 55% immunization coverage rate based on DHIS-2 district data, a design effect of 1.5 (due to cluster sampling), and a 10% non-response adjustment. The minimum sample size was determined to be 624 households, with a target of 700 households. Households were selected systematically through random sampling, using the household registers maintained by the lady health workers in each union council. Each 4th entry on the register was taken, and if the main caregiver could not be visited after 2 attempts, the next household was used instead. An overall interview response rate of 98.0% was achieved, as 686 families completed the interview.

2.4 Data Collection Instrument

The structured, interviewer-led questionnaire was developed iteratively through reviewing validated questionnaires from similar settings, expert panel review by two pediatricians and a public health specialist, and pilot testing with 40 caregivers in a non-study union council. The questionnaire collected sociodemographic data, child vaccination status (based on the vaccination card and confirmed by the caregiver if the vaccination card was not available), and the results of a 22-item module on barriers to vaccination across the 4 domains: geographic, financial, health system, and sociocultural. A child

was considered fully vaccinated when they received all vaccines recommended by the national EPI schedule for their age at the time of the interview.

2.5 Statistical Analysis

EpiData, version 3.1, was used to enter the data twice, and SPSS, version 26.0, was used for data analysis. Categorical variables were presented as frequencies and percentages, and continuous variables as means and standard deviations. The main outcome – full immunization coverage – was reported as a proportion with 95% CI. A chi-square test was used in bivariate analyses to find candidate predictors for logistic regression. Variables with p-values < 0.20 in bivariate analyses were included in a multivariable logistic regression model, selected using backward elimination. Crude odds ratios (cORs), adjusted odds ratios (aORs), and 95% CIs are reported. The Hosmer-Lemeshow goodness-of-fit test was used to assess model calibration. The level of statistical significance was set at $p < 0.05$.

2.6 Ethical Considerations

The study was approved by the Institutional Review Board (IRB) of King Edward Medical University, Lahore (Ref: KEMU-IRB-2023-114). All participants gave informed written consent before starting the interview. The response was voluntary, and there were no negative consequences for withdrawing. The data was anonymized using anonymous codes to ensure confidentiality throughout. Data storage and management complied with relevant national data protection laws.

3. RESULTS

3.2 Family Background of Respondents

Finally, 686 caregiver-child pairs were analyzed. Children's mean age was 31.4 months (SD 13.8). The female children made up 48.4% of the sample. Most of the respondents (88.3%) were mothers, and 11.7% were grandmothers or other women caregivers. The average maternal age was 27.6 years (SD 5.3). The most common maternal educational attainment level was primary education (36.9%), followed by no formal education (31.8%) and secondary or higher education (31.4%). The majority of households (56.8%) lived up to 5km away from the nearest health care facility for vaccination. The sociodemographic characteristics and their distribution by vaccination status groups are detailed in Table 1.

Table 1. Sociodemographic Characteristics of Study Participants by Immunization Status (N = 686)

Variable	n (%)	Fully Vaccinated n (%)
Maternal age < 25 years	312 (45.5)	178 (57.1)
Maternal age 25–34 years	291 (42.5)	205 (70.4)
Maternal age ≥ 35 years	83 (12.1)	61 (73.5)
No formal education	218 (31.8)	89 (40.8)
Primary education	253 (36.9)	167 (66.0)
Secondary or above	215 (31.4)	188 (87.4)
Poorest wealth quintile	174 (25.4)	68 (39.1)
Second quintile	168 (24.5)	109 (64.9)
Middle quintile	145 (21.2)	108 (74.5)
Fourth quintile	113 (16.5)	96 (84.9)
Wealthiest quintile	86 (12.5)	63 (73.3)
Distance < 5 km to facility	389 (56.8)	311 (79.9)
Distance ≥ 5 km to facility	297 (43.3)	133 (44.8)

cOR = crude odds ratio; CI = confidence interval. Values represent n (%) unless stated otherwise.

3.2 Immunization Coverage

Full immunization coverage was observed in 444 of 686 children (64.7%; 95% CI 61.0 to 68.3%). The majority of incompletely vaccinated children (n = 242; 35.3%) were not given the diphtheria-tetanus-pertussis-hepatitis B-Hib pentavalent vaccine (Penta-3), and 38.4% were not given the second dose of the measles-rubella vaccine (MR-2). 8.2% (n = 56) were considered zero-dose children, those with no documented vaccination. For 71.3% of children, the source used for verifying the availability of a vaccination card was caregiver recall, which is standard WHO practice for sites reporting low vaccine card retention.

3.3 Barriers to Immunization Reported by Caregivers

Most caregivers identified more than one barrier, with a mean of 2.8 barriers per household (SD 1.4). The most common barrier was geographic distance (5 or more kilometers) from the nearest vaccination facility (58.1%). Secondly, the most frequent barriers were transportation costs (50.7%), vaccination schedule stockouts at the facility (42.2%), awareness of the vaccination schedule (40.3%), and long waiting times (35.2%). 31.2% of caregivers reported fear of adverse events. The incidence of paternal refusal was recorded at 27.3% across households. The least common individual barrier was religious/cultural objection (14.3%). The full frequency distribution of reported barriers is presented in Table 2.

Table 2. Frequency and Ranking of Barriers to Immunization Reported by Caregivers (N = 686)

Barrier	Frequency n (%)	Rank
Distance to vaccination facility	398 (58.1)	1
Transportation cost	347 (50.7)	2
Vaccine stockout	289 (42.2)	3
Unawareness of vaccination schedule	276 (40.3)	4
Long waiting time at facility	241 (35.2)	5
Fear of adverse events	214 (31.2)	6
Paternal refusal	187 (27.3)	7
Health worker shortage	163 (23.8)	8
Religious or cultural objection	98 (14.3)	9
Misinformation from social network	77 (11.2)	10

Multiple barriers could be reported per respondent. Percentages are of total sample.

3.4 Predictors of Incomplete Immunization — Logistic Regression

Six variables were independently associated with incomplete immunization after adjustment for all other covariates in multivariable logistic regression. Geographic distance to a vaccination center, defined as ≥ 5 km, had the strongest association (aOR 0.24, 95% CI 0.17 to 0.34, $p < 0.001$). The second strongest predictor was living in the poorest fifth of the wealth scale (aOR 0.23, 95% CI 0.15 to 0.34, $p < 0.001$). Maternal non-education conferred an aOR of 0.31 (95% CI 0.21 to 0.45, $p < 0.001$). The association of vaccine stock-out with incomplete vaccination was independent (aOR 0.38, 95% CI 0.27 to 0.53, $p < 0.001$). Unawareness of the vaccination schedule was associated with an aOR of 0.41 (95% CI, 0.30 to 0.56; $p < 0.001$). Paternal refusal was independently predictive, with an aOR of 0.32 (95% CI, 0.22 to 0.48; $p < 0.001$). The Hosmer-Lemeshow test indicated a good fit of the model (chi-square = 6.41, df = 8, $p = 0.60$). Full regression results are presented in Table 3.

Table 3. Crude and Adjusted Odds Ratios for Predictors of Incomplete Immunization (N = 686)

Variable	cOR (95% CI)	p-value	aOR (95% CI)	p-value
Distance ≥ 5 km	0.21 (0.15–0.30)	< 0.001	0.24 (0.17–0.34)	< 0.001
No formal education	0.27 (0.19–0.39)	< 0.001	0.31 (0.21–0.45)	< 0.001
Poorest wealth quintile	0.19 (0.13–0.28)	< 0.001	0.23 (0.15–0.34)	< 0.001
Vaccine stockout reported	0.33 (0.24–0.45)	< 0.001	0.38 (0.27–0.53)	< 0.001
Unaware of schedule	0.35 (0.26–0.47)	< 0.001	0.41 (0.30–0.56)	< 0.001

Paternal refusal	0.28 (0.19–0.40)	< 0.001	0.32 (0.22–0.48)	< 0.001
Secondary+ maternal education (ref)	1.00	—	1.00	—

cOR = crude odds ratio; aOR = adjusted odds ratio; CI = confidence interval. Reference category for maternal education is secondary or above.

4. DISCUSSION

4.1 Overall Coverage Levels in Context

The study has achieved a higher immunization coverage rate of 64.7 percent, which is slightly better than the national EPI survey estimate for rural Punjab in 2022 (61.3 percent), but significantly lower than the recommended coverage target of 90 percent by WHO and IA2030, highlighting that most rural communities in this region still have programmatically unacceptable immunization coverage. Of particular concern is the proportion of zero-dose children (8.2%) who will be completely vulnerable to all vaccine-preventable diseases and will be considered the most vulnerable group for the spread of an outbreak. This finding is corroborated by data from the 2022 Pakistan Demographic and Health Survey (PDHS), which revealed that districts in the southern and central parts of Punjab were persistently high-burden districts for zero-dose children, with these children mainly concentrated in agricultural and peri-urban rural communities. (3)

The performance of rural immunization in Pakistan is relatively weak compared with other South Asian countries, despite per capita health expenditure on immunization being relatively similar or higher over the past few years. Adopting a structural program redesign at district and sub-district levels is an essential condition for improving coverage. The gap between national targets and the results achieved in this study indicates that further financial investment alone is not enough. Analogous districts in Sindh and Khyber Pakhtunkhwa have also conducted health system assessments, revealing that merely introducing program inputs does not improve health coverage without adequate attention to last-mile delivery systems and community outreach. (6)

4.2 Geographic Distance as Primary Independent Barrier

In this study, geographic distance of 5 or more kilometers to the nearest vaccination facility was the strongest independent predictor of incomplete immunization (aOR 0.24); children living further from a vaccination facility were 76% less likely to be fully vaccinated than those living closer to a facility after controlling for all the other predictors. The effects are similar to those observed in rural areas of Ethiopia and Nigeria, where distance thresholds of 5 kilometers have been associated with 60-80% variation in the odds of completing vaccinations. The finding of this threshold across different geographical contexts in LMICs indicates that 5km is a critical operational threshold: when crossed, passive facility service delivery does not provide adequate population coverage. (9)

Distance reduces immunization for several reasons. The quantitative association was confirmed in this study, with 31.4% of caregivers reporting physical inaccessibility at distant households during the monsoon months. (10) Travel time > 2 h was associated with reduced completion of appointments despite no difference in transportation costs, meaning that travel time burden is a barrier on its own. Mobile vaccination teams operating on a fixed, schedule-announced basis have proven effective in improving coverage in similar contexts in rural Sindh and highland Ethiopia, increasing coverage by 18 to 26 percentage points in communities with only fixed coverage. (12)

4.3 Quality of Healthcare and the Poverty-Vaccination Gradient

In this study, household poverty (as measured by wealth quintile) was the second-strongest independent predictor of incomplete vaccination (aOR 0.23 for the poorest quintile). The dose-response pattern across quintiles – with increasing vaccination rates from poorer to richer quintiles – reflects the gradient observed in nationally representative surveys in Pakistan, Bangladesh and sub-Saharan Africa. This gradient does not so much reflect the direct costs of vaccines because vaccines are free in the EPI program. Still, rather than the indirect costs of vaccine access, such as transportation, lost daily wages, and the opportunity cost of accompanying a child to a distant facility. (14)

Qualitative information gathered during the structured interview with caregivers included in this study, though not reported here, indicated that on days when a vaccination visit was made, transportation costs averaged 20-35% of the household's daily income for caregivers in the lowest wealth category. This result is similar to findings from an indirect cost study in rural Nigeria, where indirect costs for the poorest families were estimated at 15-40% of the daily wage, despite vaccines being free. Conditional incentive models tested in Bangladesh and the home-grown Lady Health Worker (LHW) program in Pakistan have shown that even small financial incentives, such as transportation subsidies, have a significant effect on improving coverage for health appointments in the poorest households, and scaling up these models in the study districts could be considered in policy decisions. (16)

4.4 Maternal education and its mediating role

Results were consistent with education being one of the most robust individual-level correlates of child health behavior worldwide, as maternal non-education was an independent predictor of incomplete immunization (aOR 0.31). There was a significant difference in full vaccination between children whose mothers had secondary or higher education (87.4% vaccinated) and those whose mothers had no formal education (40.8% vaccinated; difference 46.6%, $p<0.001$), which remained after adjustment for wealth and other covariates. (7) This level of association suggests that maternal education

may work in ways other than socioeconomic factors, such as health literacy, the capacity to make decisions autonomously, and the capacity to manage health system interactions effectively. (18)

This suggests that direct communication to low-education caregiver groups through immunization programs needs to be targeted to low literacy, such as pictorial vaccination schedules, radio-based reminder systems, and home visits by community health workers. Antenatal care contacts provide a systematic opportunity to deliver immunization schedule education before delivery; research in Punjab demonstrated that EPI counseling during ANC visits is associated with a 19-24 percentage-point increase in the proportion of babies receiving full immunization. The low-cost, high-impact systematic implementation of this integration within the Lady Health Worker and Basic Health Unit networks in the study districts would constitute an intervention.

4.5 Health System Failures and Supply-Side Constraints

The high percentage of vaccine stockouts (42.2%) and long waiting times (35.2%) reported in this study indicate significant supply chain failures that limit the potential for effective vaccine coverage, even among motivated caregivers. Vaccine stockouts reported by over 2 in 5 respondents indicate failures in cold chain management and logistics planning. They are unlikely to be the result of funding shortages, since EPI vaccines are fully donor-supported in Pakistan. What is more likely, but not recorded here, is that logistical issues at the tehsil and union council levels, such as poor stock rotation, unreliable transport from district vaccine stores, and inadequate forecasting, contributed to the observed logistical problems. This finding is similar to observations made during the EPI cold chain assessment conducted by UNICEF Pakistan in the Faisalabad division in 2023. (4)

Waiting times were cited by 35.2% of caregivers and are a modifiable health system barrier that is not widely discussed in discussions about program planning. In this study, where most caregivers had traveled long distances to reach the facility, more than two hours of waiting time was cited as an exit criterion in 18.7% of cases in which caregivers arrived at the facility but did not receive vaccination. Timed appointment systems and specific vaccination time slots during facility hours (10) have been introduced and tested successfully in urban health care settings in Pakistan. Their implementation in rural basic health units would be a practical and effective improvement. (11)

4.6 Communicating with Parents and Children about Vaccination.

An independent predictor of incomplete vaccination was unawareness of the vaccination schedule (aOR 0.41), with 40.3% of caregivers reporting being unaware. The study corresponds with a survey conducted in the neighboring districts of Jhang and Sargodha in 2023, which reported the inability to be present on schedule as the most modifiable demand-side barrier in this context, with 38.6% of rural caregivers indicating they were not present on schedule. The national EPI program provides vaccination cards with the vaccination schedule. Still, among the children studied, only 71.3% had a vaccination card kept at home, the primary information tool that is missing in almost one-third of households. (19)

Of the caregivers, 31.2% reported fear of adverse events after vaccination, which was associated with discontinuing vaccines after the first vaccine contact in 23.4% of incompletely vaccinated children. It has been demonstrated that pre-vaccination counseling that explicitly informs caregivers about anticipated post-vaccination symptoms, such as transient fever, local tenderness, and mild irritability, could significantly reduce discontinuation rates in Pakistan and similar South Asian contexts. The lack of this counseling in basic health units (BHUs), reported by 44.8% of caregivers who received at least one vaccination visit, is an unexploited opportunity to mitigate a behavior that can be modified at little additional program cost.

4.7 Impact of Paternal Refusal and Sociocultural Factors

Paternal refusal was an independent predictor of incomplete immunization (aOR 0.32), reported by 27.3% of caregivers, and was the fourth most common sociocultural barrier in this study. This is consistent with a formative research study conducted in rural Khyber Pakhtunkhwa and southern Punjab in 2022, where 24-31% of households with mothers who reported being willing to vaccinate their children had paternal veto authority over health-seeking behavior. Implication (16): Essentially, almost one-third of the children in this sample were not fully vaccinated because their mothers were willing to vaccinate them, but their homes had a structural barrier that couldidual health communication. (9) could not address

Programs specifically designed for male engagement, including community mobilization and mosque outreach, and engagement of male Lady Health Workers have been found to reduce rates of paternal refusal in trials in Pakistan's Federally Administered Tribal Areas and in rural Bangladesh. (8) These interventions should not be considered as add-on or experimental, but rather be part of the EPI social mobilization strategy, in districts where paternal refusal is reported at this level. The use of religious messaging by locally credible religious scholars has been documented as an effective strategy to overcome vaccine hesitancy rooted in religious beliefs in rural areas of Pakistan. It should be integrated into community engagement strategies. (5)

5. FUTURE DIRECTIONS AND RECOMMENDATIONS

The subsequent evidence-based recommendations to district health authorities, Expanded Program on Immunization, and community health stakeholders are based on the results of this study:

Health System Strengthening

● District EPI managers should develop dedicated mobile vaccination team schedules for all Union Councils that are at least 5 kilometers away from a permanent health facility, and the frequency of visits should be advertised in the community regularly and predictably, not less than twice a month.

● A targeted cold chain audit should be undertaken in every basic health unit where the frequency of stock-outs is >20%, and corrective action plans should be developed, involving the implementation of better forecasting procedures and accountability measures for district vaccine store managers.

● Appropriately pilot the facility-level scheduling change, such as appointment windows for routine immunization, in at least two union councils, followed by proper evaluation before scale-up.

Demand Generation and Community Engagement

● Male involvement sessions facilitated by community religious leaders and health educators should be institutionalized as a part of EPI social mobilization activities in districts where there is evidence of paternal refusal rates > 20%.

● Guidelines on the types of adverse events that may occur after immunization should be standardized and provided at all first-dose immunization visits to basic health units.

Policy and Financing

● The district health department should experiment with a transportation incentive program, which will involve offering a set amount of money (round-trip transportation costs) to caregivers in the poorest two wealth quintiles presenting vaccination cards for having completed the series.

● The maternal education status, household wealth quintile, and distance from the facility should be disaggregated in DHIS-2 to facilitate monitoring and targeted allocation of resources for immunization coverage reporting at the union council level and at the household level.

Research

● Policy and intervention recommendations from this survey should include a longitudinal cohort study of children identified as zero dose to test catch-up vaccination rates and the effectiveness of targeted intervention to bring children to full vaccination status within 12 months.

● Qualitative research to understand the sociocultural context of vaccine decision-making by fathers and the best ways to engage them in the process would directly guide the design of the intervention for male engagement in vaccines in rural Punjab.

6. CONCLUSION

This cross-sectional study in rural Punjab, Pakistan, shows that high proportions of children are still not immunized (35.3%), incompletely immunized (35.3%), and not immunized at all (8.2%). Each of the four variables (geographic distance, household poverty, maternal non-education, vaccine stockout, and schedule unawareness), and each alone, is a significant and independent predictor of incomplete vaccination after adjustment for confounders. Each of the four variables is a significant and independent predictor of incomplete vaccination after adjustment for confounders. The results in this context confirm that coverage gaps do not trace back to a single impediment but result from the combined presence of supply-side failures and demand-side deficits at the household and health system levels. A programmatic approach in Punjab is needed, shifting from passive, facility-based service delivery to active, community-integrated service delivery that includes structured male engagement, low-literacy communication, and accountable cold-chain management to close the immunization gap in rural Punjab. Political will, equity-sensitive monitoring, and community partnership are essential to bringing these recommendations to fruition and to measurable child health outcomes.

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