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Determinants of immunization completeness among children under two years of age in the Malintang Public Health Center catchment area, Mandailing Natal Regency

Determinan kelengkapan imunisasi baduta di wilayah kerja Puskesmas Malintang Kabupaten Mandailing Natal

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Abstract

Background: Completion of vaccination during the second year of life is essential for sustained protection against vaccine-preventable diseases, yet local booster coverage remains suboptimal. Objective: To examine factors associated with complete booster immunization among children aged 18–24 months in the Malintang Public Health Center catchment area, Mandailing Natal Regency, Indonesia. Methods: A cross-sectional study included 81 mother–child pairs identified through total enumeration. Maternal education, household number of children, vaccination knowledge, and reported family and healthcare-worker support were assessed using structured interviews. Immunization status was determined from maternal and child health handbooks or health-center registers. Associations were estimated using Pearson's chi-square tests and crude odds ratios (ORs) with 95% confidence intervals (CIs). Results: Forty children (49.4%) had documentation of both recommended booster doses. Higher maternal education (OR 4.00; 95% CI 1.59–10.08), having no more than two children (OR 4.49; 1.62–12.45), better vaccination knowledge (OR 2.91; 1.17–7.23), family support (OR 3.21; 1.30–7.98), and healthcare-worker support (OR 5.06; 1.96–13.08) were associated with completion. The conventional multivariable model produced unstable coefficients, preventing valid adjusted inference. Conclusion: Booster completion was associated with multiple caregiver, household, and service-related characteristics. The findings support locally evaluated counseling and follow-up strategies, but do not establish independent causal effects.

Keywords: booster immunization; childhood vaccination; caregiver knowledge; family support; primary health care

Abstrak

Latar belakang: Imunisasi lanjutan pada tahun kedua kehidupan diperlukan untuk mempertahankan perlindungan terhadap penyakit yang dapat dicegah dengan imunisasi, tetapi cakupannya di tingkat pelayanan primer masih belum optimal. Tujuan: Menganalisis faktor yang berhubungan dengan kelengkapan imunisasi lanjutan pada anak usia 18–24 bulan di wilayah kerja Puskesmas Malintang, Kabupaten Mandailing Natal. Metode: Penelitian potong lintang melibatkan seluruh 81 pasangan ibu–anak yang memenuhi kriteria. Pendidikan ibu, jumlah anak, pengetahuan tentang imunisasi, serta dukungan keluarga dan petugas kesehatan diperoleh melalui wawancara terstruktur. Status imunisasi ditentukan berdasarkan buku kesehatan ibu dan anak atau register imunisasi puskesmas. Hubungan antarvariabel dianalisis menggunakan uji chi-kuadrat Pearson dan odds ratio (OR) kasar dengan interval kepercayaan (IK) 95%. Hasil: Sebanyak 40 anak (49,4%) tercatat telah menerima kedua dosis imunisasi lanjutan yang diteliti. Kelengkapan imunisasi berhubungan dengan pendidikan ibu lebih tinggi (OR 4,00; IK 95% 1,59–10,08), jumlah anak paling banyak dua (OR 4,49; 1,62–12,45), pengetahuan lebih baik (OR 2,91; 1,17–7,23), dukungan keluarga (OR 3,21; 1,30–7,98), dan dukungan petugas kesehatan (OR 5,06; 1,96–13,08). Model multivariat konvensional menghasilkan estimasi yang tidak stabil sehingga hubungan setelah penyesuaian tidak dapat disimpulkan. Kesimpulan: Kelengkapan imunisasi lanjutan berkaitan dengan karakteristik individu, keluarga, dan pelayanan kesehatan. Penguatan konseling serta penelusuran anak yang tertinggal jadwal imunisasi perlu dievaluasi pada konteks pelayanan setempat.

Kata kunci: imunisasi lanjutan; vaksinasi anak; pengetahuan ibu; dukungan keluarga; pelayanan kesehatan primer

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Introduction

Vaccination remains a cornerstone of child-survival programmes, but its preventive effectiveness at the population level depends on receiving age-appropriate doses throughout the recommended schedule. Analyses spanning low- and middle-income countries continue to demonstrate substantial inequalities in vaccine uptake across socioeconomic and maternal-education strata [1]. Indonesian household surveys likewise describe disparities in complete and timely childhood immunization [2,3], while more recent population-based studies identify maternal, reproductive-health and household characteristics associated with missed doses [4,5]. These findings indicate that routine coverage cannot be inferred solely from the availability of vaccination services. Assessment of the second-year schedule is particularly important because children who received primary immunization may still be underprotected if subsequent doses are missed.

In Indonesia, the routine programme recommends a diphtheria–pertussis–tetanus–hepatitis B–Haemophilus influenzae type b (DPT-HB-Hib) booster and a second measles–rubella (MR) dose at 18 months, with catch-up provision when scheduled vaccination has been missed [6]. These doses extend protection beyond infancy; consequently, complete primary vaccination and complete second-year booster vaccination are distinct outcomes. Studies in Indonesia have identified parental knowledge, health-service availability, and the perceived contribution of providers as correlates of immunization uptake [7]. Evidence specific to booster completion in Aceh [8], and analyses of incomplete basic immunization around Greater Jakarta [9] and among conditional cash-transfer beneficiaries [10], further indicate that vaccination behaviour is embedded within household circumstances and access to care. Media exposure and information sources may also influence vaccine decisions [11]. However, findings from infant immunization studies cannot automatically be generalized to booster doses administered later in childhood.

In the Malintang Public Health Center catchment area of Mandailing Natal Regency, administrative reports recorded DPT-HB-Hib booster coverage of 15.5% and MR booster coverage of 10.3% in 2023; the respective figures increased to 63.5% and 64.9% in 2024. Although this improvement was substantial, coverage remained uneven across villages. The causes of the year-to-year increase were not established by the available programme records, and the two administrative periods cannot be used to infer an effect of a particular outreach intervention. The persistence of coverage gaps despite the observed improvement underscores the need for empirical evidence on the mothers and households whose children do not complete the scheduled second-year doses. Such evidence is especially relevant to primary health-care settings where reminders, transportation, family decisions, and communication with frontline staff may determine whether a missed appointment is subsequently recovered.

The association between maternal education and childhood vaccination has been documented in systematic reviews, although its magnitude and direction may vary by setting [12]. Knowledge operates at a more proximate level: caregivers must recognize not only the benefits of vaccination, but also the timing of subsequent doses and the appropriate response to missed appointments or expected adverse events [13,14]. Concerns about safety, confidence in vaccines, and perceived practical barriers may further affect willingness to attend services [15,16]. Qualitative evidence indicates that trust in healthcare workers and the clarity of provider communication are central to caregiver decisions [17]. These influences may be mutually reinforcing: education may shape information access, family members may facilitate or hinder attendance, and healthcare workers may address uncertainty through individualized counseling rather than generic messages.

The number of children in a household may modify the time, transport and caregiving resources available for routine appointments. Similarly, family support may facilitate clinic attendance through practical

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assistance or encouragement, whereas healthcare-worker support may reduce uncertainty about eligibility and follow-up. Evidence from reminder interventions and broader comparisons of recipient-focused vaccination strategies supports combining communication with feasible access and appointment-support measures [18,19]. An Indonesian investigation specifically examining booster adherence among children younger than 24 months further highlighted the importance of behavioural and psychological factors [20]. Nevertheless, service-side and family-side constructs require precise measurement: an affirmative response to a single support question does not establish the frequency, quality, or multidimensional intensity of the support received.

Evidence from other Indonesian settings illustrates the heterogeneity of these relationships. A 2025 community study did not find statistically significant associations of maternal knowledge or family support with basic immunization compliance [21], whereas a national mixed-methods assessment reported that misinformation, family influences and encounters with health professionals shaped vaccination demand [22]. The apparent inconsistency across studies may reflect differences in age eligibility, the doses defining completion, local barriers and how explanatory variables were measured. In particular, evidence for complete booster receipt at 18–24 months in rural North Sumatra remains scarce. A locally focused analysis can therefore complement national surveys, provided that its cross-sectional design and measurement limitations are not interpreted as grounds for causal inference.

This study assessed associations between maternal education, number of children, immunization knowledge, reported family support and reported healthcare-worker support and the documented completion of second-year booster immunization among children aged 18–24 months in the Malintang Public Health Center catchment area. The analysis was intended to describe patterns relevant to primary-care follow-up, while acknowledging the limited sample size and the constraints of observational data.

Materials and Methods

Study design, setting, and participants

This analytical cross-sectional study was conducted in the catchment area of Malintang Public Health Center, Bukit Malintang District, Mandailing Natal Regency, North Sumatra, Indonesia. The study period extended from September 2025 through February 2026, encompassing preparation, fieldwork and statistical analysis. The study population comprised 81 mothers recorded in the local immunization or integrated community health post (Posyandu) registers as having children aged 18–24 months. Because the population was small, total enumeration rather than probability-based subsampling was used. All 81 mother–child pairs were included in the reported analytical tables. Eligibility required residence in the service catchment area, documentation of vaccination in the maternal and child health (MCH) handbook or a health-center register, and written informed consent. The protocol excluded mothers who could not complete the interview or could not be contacted after a repeat visit. In the absence of a separate recruitment log, eligibility screening and nonparticipation could not be quantified. The observational nature of the design permits the estimation of associations but not temporal or causal effects.

Outcome and explanatory variables

The primary outcome was documented completion of the DPT-HB-Hib booster and second MR dose recommended during the second year of life; children without documentation of both doses were classified as having incomplete booster immunization. The assessment referred to the 18-month schedule, rather than to completeness of all childhood vaccines or to exact dose timeliness [6]. Immunization status was abstracted from the MCH handbook or the health-center register. A standardized reconciliation procedure for discrepancies between record sources was not recorded. Consequently, doses administered elsewhere and incompletely entered in local registers could have led to outcome misclassification. Explanatory factors were maternal educational attainment (lower/higher in the analytical file), number of children (≤2/>2), maternal immunization knowledge (poorer/better), family support (absent/present) and healthcare-worker support (absent/present). Education and knowledge were analyzed using the reported dichotomous categories. The thresholds used when consolidating the original categories could not be independently recovered, which may limit reproducibility.

Maternal knowledge was assessed through 20 closed-response items addressing vaccine indications, schedules, missed visits, routine post-vaccination reactions and the purpose of booster doses. Family support

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was operationalized as a yes/no response to whether relatives supported immunization; healthcare-worker support was assessed by a yes/no question about information on vaccine importance and schedules. Questionnaire item validity was examined using Pearson item–total correlation, and internal consistency was evaluated using Cronbach's alpha, with a prespecified acceptability threshold of 0.70. Because each support indicator was measured with a single binary item, internal-consistency coefficients cannot establish reliability for those constructs. They represent reported presence of support rather than graded measures of its instrumental, emotional or informational components. This distinction is relevant when comparing associations with studies using multi-item validated scales.

Data collection, data quality, and statistical analysis

Mothers were interviewed using a structured questionnaire after written informed consent was obtained. Documentary vaccination information was drawn from MCH handbooks or the health-center immunization register. Responses were checked, coded and tabulated with IBM SPSS Statistics, version 27. The five reported two-by-two analyses each included 81 participants, with no missing values in the variables used for those comparisons. Because individual recruitment logs and records resolving discordant vaccination entries were unavailable, selection and classification errors could not be excluded. Descriptive statistics are presented as counts and percentages. Two-sided Pearson chi-square tests were used to assess crude associations at $\alpha = 0.05$. All five reported two-by-two tables met the expected-count requirement (minimum expected cell count >5); Fisher's exact test would be appropriate if this requirement were not met. Crude odds ratios (ORs) for complete booster immunization and their 95% confidence intervals (CIs) were calculated from the observed cell frequencies, with the less favourable category as reference. Reported p values were derived consistently from the uncorrected Pearson chi-square statistic.

Conventional multivariable logistic regression was explored to assess whether the crude associations persisted after mutual adjustment, with candidate selection described in the study plan as $p < 0.25$ at bivariate screening. However, model estimates included exceptionally large standard errors and implausible coefficients, indicating numerical non-identifiability compatible with complete or quasi-complete separation [23]. Although every marginal two-by-two table had nonzero counts, separation may arise from joint combinations of several predictors; those individual combinations cannot be identified using marginal tables alone. Moreover, family support was absent from the coefficient summary despite being considered among the five candidate factors. Firth's bias-reduced logistic regression is an appropriate approach to investigate separation [23], but a valid adjusted model cannot be reconstructed from marginal summaries and an unstable coefficient table without a complete participant-level predictor–outcome dataset. Accordingly, no adjusted ORs, dominant factor or multivariable significance claims are reported. Reporting follows the relevant principles of STROBE for observational research [24].

Ethical considerations

Ethical clearance and local institutional research authorization were obtained before fieldwork. All participating mothers provided written informed consent, and identifying information was kept confidential throughout analysis and reporting.

Results and Discussion

Characteristics of the study population

The analysis comprised 81 mother–child pairs. Complete second-year booster immunization was documented for 40 children (49.4%); 41 (50.6%) were classified as incomplete. Maternal education was classified as lower for 42 respondents (51.9%) and higher for 39 (48.1%). Fifty-four families (66.7%) had no more than two children. Poorer immunization knowledge was recorded for 45 mothers (55.6%); 42 (51.9%) reported no family support and 44 (54.3%) reported no healthcare-worker support. The distribution of explanatory variables is summarized in Table 1. All reported analytical denominators were 81, and no subgroup was excluded from the displayed comparisons.

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Table 1. Sociodemographic characteristics and immunization-related factors among participating mothers.

Variable	Category	n (%)
Maternal education	Lower	42 (51.9)
	Higher	39 (48.1)
Number of children	≤2	54 (66.7)
	>2	27 (33.3)
Maternal knowledge	Poorer	45 (55.6)
	Better	36 (44.4)
Family support	Absent	42 (51.9)
	Present	39 (48.1)
Healthcare-worker support	Absent	44 (54.3)
	Present	37 (45.7)
Booster immunization	Incomplete	41 (50.6)
	Complete	40 (49.4)

Fewer than half of the children in this complete local enumeration had both second-year doses documented. This estimate should not be compared directly with the 2023 and 2024 administrative coverage indicators because the denominator, period of observation and ascertainment approach differ. Nevertheless, it reinforces concerns about missed booster opportunities. Global and regional evidence indicates that gaps in routine vaccination remain concentrated in specific socioeconomic and service-access groups [1,25], but the local sample is insufficient to determine how closely this catchment area resembles other regions.

Maternal education and number of children

Of 39 mothers in the higher-education category, 26 (66.7%) had children with documented complete booster immunization, compared with 14 of 42 mothers (33.3%) in the lower-education category. Higher education was associated with fourfold greater crude odds of completion (OR 4.00, 95% CI 1.59–10.08; p = 0.003). The direction of this association is consistent with national Indonesian household studies and a systematic review of maternal schooling and childhood vaccination [2–5,12]. Schooling may facilitate interpretation of health messages and navigation of vaccination services, although health literacy, income and access were not jointly measured here. Accordingly, education should be understood as a marker of correlated social resources rather than as an isolated causal determinant.

Among families with no more than two children, 33 of 54 (61.1%) achieved complete booster documentation, compared with seven of 27 families (25.9%) with more than two children (OR 4.49, 95% CI 1.62–12.45; p = 0.003). Competing time demands, supervision of multiple children and transport arrangements provide plausible explanations, but none was directly measured. Prior experience with vaccination among larger families could also act in the opposite direction. The apparent household-size association therefore warrants prospective investigation with measures of caregiving burden and service availability before any specific mechanism is inferred.

Maternal knowledge and family support

Twenty-three of 36 mothers (63.9%) with better classified knowledge had children with complete booster immunization, compared with 17 of 45 (37.8%) in the poorer-knowledge category (OR 2.91, 95% CI 1.17–7.23; p = 0.020). In the knowledge-item results, correct answers were common for the role of booster vaccination and certain vaccine indications, while fewer mothers correctly identified several schedule-related questions and procedures after missed appointments. Such variation suggests that awareness of the general value of vaccines may not ensure knowledge sufficient to complete a time-dependent schedule. This interpretation is supported by caregiver studies and reviews emphasizing actionable information, perceived safety and follow-up advice [13–15]. However, item-specific effects could not be estimated, and uncertainty about the knowledge dichotomization threshold limits interpretability.

Twenty-five of 39 children (64.1%) whose mothers reported family support had complete booster documentation, versus 15 of 42 (35.7%) whose mothers did not report support (OR 3.21, 95% CI 1.30–7.98; p = 0.011). This pattern aligns with work addressing family involvement in booster vaccination [8]. In household decision-making, encouragement and practical assistance may reduce missed appointments, but the current single-item measure does not identify which forms of support were actually provided. The association thus concerns perceived presence of family support, not a validated score for its intensity or constituent domains.

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Some Indonesian studies have reported weaker or nonsignificant associations [21], further cautioning against a universal interpretation.

Healthcare-worker support

Healthcare-worker support was associated with the largest unadjusted OR of the five examined factors. Complete booster immunization was documented for 26 of 37 children (70.3%) when mothers reported healthcare-worker support, versus 14 of 44 (31.8%) when they did not (OR 5.06, 95% CI 1.96–13.08; p = 0.001). Provider communication may clarify the need for second-year doses, anticipated post-vaccination reactions and steps following a missed appointment [7,16,17]. However, this study assessed support through a single question on the provision of information and scheduling advice; it did not separately measure continuity, empathy, counseling duration or home visits. Its OR must therefore not be interpreted as a causal effect of a defined provider intervention.

Table 2 presents the five crude associations using consistent three-decimal p values and denominators. Figure 1 displays the corresponding ORs and uncertainty intervals; the vertical reference represents no difference in odds (OR = 1). Although all five Pearson tests were statistically significant, the magnitude of each unadjusted association is potentially confounded by the remaining maternal, household and service factors. The wide confidence intervals, particularly for healthcare-worker support, indicate limited precision rather than conclusive ranking of independent determinants.

Table 2. Unadjusted associations with complete second-year booster immunization among 81 mother–child pairs.

Factor	Favourable group: complete n/N (%)	Reference group: complete n/N (%)	Crude OR (95% CI)	p
Maternal education	Higher: 26/39 (66.7)	Lower: 14/42 (33.3)	4.00 (1.59–10.08)	0.003
Number of children	≤2: 33/54 (61.1)	>2: 7/27 (25.9)	4.49 (1.62–12.45)	0.003
Maternal knowledge	Better: 23/36 (63.9)	Poorer: 17/45 (37.8)	2.91 (1.17–7.23)	0.020
Family support	Present: 25/39 (64.1)	Absent: 15/42 (35.7)	3.21 (1.30–7.98)	0.011
Healthcare-worker support	Present: 26/37 (70.3)	Absent: 14/44 (31.8)	5.06 (1.96–13.08)	0.001

OR, odds ratio; CI, confidence interval. Pearson chi-square test (two-sided, no Yates correction); all minimum expected counts exceeded five. Crude ORs and 95% Wald CIs were calculated from the observed 2 × 2 tables. The displayed categories refer to the study's dichotomous classifications.

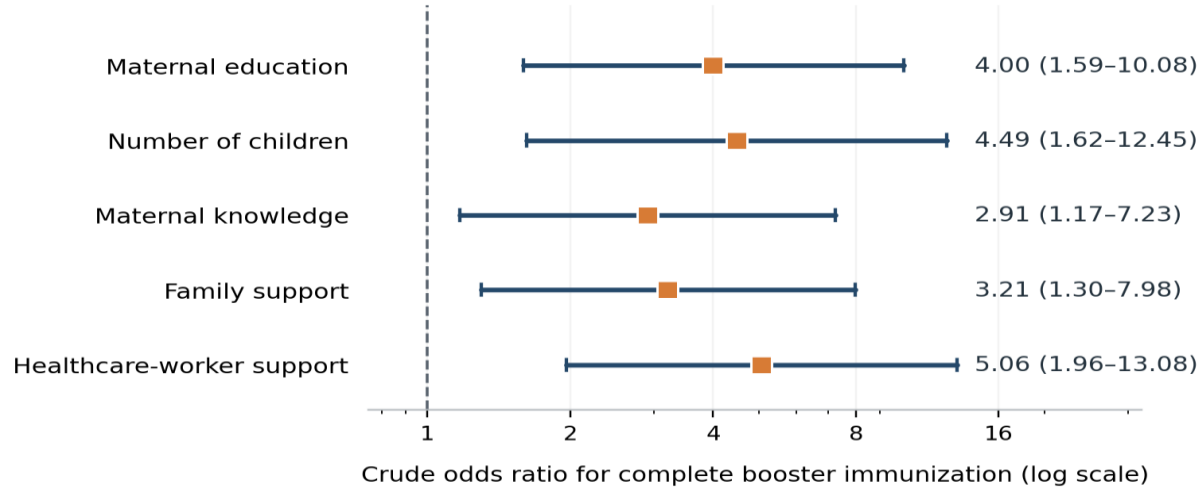


Figure 1. Forest plot of crude odds ratios for complete second-year booster immunization. Horizontal lines indicate 95% confidence intervals; the dashed line denotes OR = 1. Estimates were not adjusted for other factors.

Multivariable analysis and statistical limitations

The maximum-likelihood logistic model returned an omnibus chi-square of 102.826, Nagelkerke pseudo-R^2 of 0.959 and apparent classification accuracy of 98.8%. These striking figures were accompanied by a maternal-education coefficient near −24.916 (standard error 28,420.721) and other predictor standard errors exceeding 15,000, with individual p values close to 1.000. Such behaviour indicates severe instability of maximum-likelihood estimation consistent with separation or related rank deficiency [23]. Family support was absent from the final coefficient summary despite being included among the five candidate factors. No

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zero counts appeared in the individual two-by-two comparisons; thus the specific predictor combination responsible for potential separation cannot be established from the marginal two-by-two tables. High apparent classification accuracy in this setting cannot be interpreted as validated predictive accuracy, and Nagelkerke pseudo-R^2 cannot be treated as the percentage of outcome variance causally explained.

For separation-prone binary outcomes, Firth's penalized likelihood approach can yield finite, less-biased parameter estimates and may allow reporting of adjusted ORs and profile-likelihood CIs [23]. That method requires the joint individual-level observations, which were not available within the aggregate tabulations. Re-estimating a multivariable model from the five marginal two-by-two tables would be mathematically underdetermined: multiple individual-level datasets can produce the same marginal tables but different adjusted estimates. Consequently, neither a Firth-adjusted OR nor a statistically defensible "dominant factor" can be presented. The multivariable results are therefore reported only to document an estimation failure, while substantive conclusions remain limited to the crude comparisons. Reanalysis of the original dataset with convergence diagnostics, predictor cross-tabulations and a prespecified penalized model is required before independent associations can be asserted.

Public-health implications and study limitations

The coexistence of associations involving education, household size, knowledge and two sources of perceived support suggests that a multicomponent programme response is reasonable. Counseling delivered at routine contacts should specify the age for DPT-HB-Hib and MR boosters, ways to reschedule missed doses, and guidance on expected mild post-immunization reactions. Family-inclusive communication and reminder systems could help caregivers manage appointment demands; such approaches have evidence of benefit in reviews of reminder and recipient-focused interventions [18,19]. Community-based booster-adherence evidence from Indonesia also supports attention to caregiver motivation, prior experiences and service trust [20]. In Malintang, the increased administrative coverage between 2023 and 2024 may reflect service delivery, reporting or denominator changes; attribution to a specific intervention would require contemporaneous programme-evaluation data. Further audits of Posyandu outreach, vaccine availability and catch-up registers would help determine which local barriers are most amenable to intervention, and any proposed strategy should be evaluated using prospectively specified coverage indicators.

Several limitations temper interpretation. This single-centre study included only 81 mother–child pairs; with 40 children in the completed-outcome group and five candidate predictors, the ratio was approximately eight events per predictor, and sparse multivariable combinations may have contributed to unstable estimates. Although complete enumeration reduced sampling uncertainty within the registered target population, it did not confer representativeness beyond that service area. The cross-sectional design cannot establish temporality or causality. The two support indicators were binary single-item measures without documented reliability coefficients; item-level validity and reliability statistics for the knowledge scale were not available for independent verification. The thresholds linking the three-level operational classifications to dichotomous analytical categories were not fully recoverable. Vaccinations delivered outside the health-center system, incomplete MCH handbook entries or disagreement between records could have caused outcome misclassification; an independently verifiable reconciliation procedure was not available. Available cross-tabulations show 81 observations for each comparison, but a complete recruitment and missing-data audit was not available. Finally, large crude ORs with wide CIs may overstate true effects because confounding could not be controlled, and severe instability prevented credible adjusted modelling. These results are best considered exploratory and require confirmation in adequately powered, prospectively documented studies.

Conclusions

In this sample of 81 mother–child pairs, 40 children (49.4%) had documented completion of both routine second-year booster doses. In unadjusted analyses, higher maternal education, having no more than two children, better maternal knowledge, reported family support and reported healthcare-worker support were each associated with a greater likelihood of complete immunization. The conventional multivariable analysis was numerically unstable, and the available aggregate data were insufficient for defensible Firth-penalized re-estimation; independent associations or a dominant determinant could not be established. These findings favour locally evaluated counseling, family involvement and follow-up of children with missed doses rather than attribution of causality to any single factor.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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