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Research Article

DETERMINANTS OF DELAYED AND MISSED CHILDHOOD IMMUNIZATION AMONG MOTHERS ATTENDING PRIMARY HEALTHCARE CENTERS IN AL-DIWANIYAH CITY, IRAQ: A CROSS-SECTIONAL STUDY

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Article History	ABSTRACT
Received: 19-07-2026 Revised: 14-08-2026 Accepted: 02-10-2026	Background: Childhood immunization is a cost-effective public health intervention; however, delayed and missed vaccinations remain significant challenges. This study aimed to determine the prevalence and key determinants of childhood immunization non-compliance among mothers attending primary healthcare centers (PHCs).
*Corresponding Author Durar Kamil Jabbar	Methods: A descriptive cross-sectional study was conducted among 300 mothers of children aged 0–24 months attending PHCs. Data were collected using structured, interviewer-administered questionnaires and verified through immunization cards. Non-compliance was defined as a delay of ≥ 4 weeks beyond the scheduled date or omission of a due vaccine dose. Binary logistic regression was performed using SPSS version 26 to identify independent predictors.
Keywords: Annexin A5; ANXA5 M2 haplotype; recurrent pregnancy loss; placental anticoagulant shield; thrombophilia; biomarker; Iraq.	Results: Immunization non-compliance was observed in 49.7% of children (n=149). The highest non-compliance rates were reported for IPV (35.7%), measles-rubella vaccine (34.3%), and the third dose of pentavalent vaccine (25.3%). Major barriers included child illness on vaccination day (45.0%), caregiver forgetfulness (38.9%), and fear of adverse effects (32.9%). Independent predictors included rural/peri-urban residence (aOR=3.21; p
	Keywords: Childhood immunization; Vaccine delay; Missed vaccination; Maternal determinants; Primary healthcare; Vaccine hesitancy; Immunization barriers; Cross-sectional study.

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INTRODUCTION

Childhood immunisation is one of the most effective and cost-effective public health tools in the world. Vaccines have been estimated to have saved at least 154 million deaths since the commencement of WHO's Expanded Program on Immunisation (EPI) in 1974, the majority of them among children under five years and have contributed to a 40% reduction in worldwide infant mortality [1]. Routine immunisation protects individual children against vaccine-preventable

diseases such as measles, diphtheria, pertussis, and poliomyelitis, but also provides community-level protection of children too young or medically ineligible to be vaccinated [2].

Despite these impressive advances, global immunisation coverage has plateaued in recent years. According to joint WHO-UNICEF data published in 2024 coverage with the three-dose diphtheria-tetanus-pertussis (DTP3) vaccine, the most important marker of immunisation programmatic performance, stayed at

84% in 2023, meaning around 14.5 million children worldwide did not receive even a single vaccine dose [3]. More than half of these zero-dose children live in fragile, conflict-affected environments, but there are also significant immunisation gaps in middle-income nations with functioning health systems [4]. This trend was further worsened by the COVID-19 pandemic, which disrupted normal immunisation programs around the world and created a backlog of children who were unvaccinated that health authorities are still trying to clear [5,6].

Delays in vaccination, defined as receiving a dose of vaccine well after the intended age, are just as important as missing doses. Children who are not vaccinated are exposed to the risk of illness, the time of opportunity for disease transmission in the community is extended, and the risk of subsequent missed doses and failure to complete the vaccine series is increased [7]. There are a number of reasons at the individual, household, community and health system levels can lead to delays and omissions in immunisation. Maternal education, socioeconomic position, geographic access to facilities, parity, fear of harmful consequences and provider-related constraints have all been implicated to different degrees, in different situations [8,9,10].

Childhood immunisation delivery is mostly through primary healthcare centers (PHCs) which are the frontline delivery site in most low- and middle-income nation settings [11]. Consequently, it is especially crucial to understand the reasons for non-compliance with immunisation regimens among mothers who are already in contact with the health system. These are the people who are most likely to be reached by focused educational and logistical interventions. Still important are local and contextualized studies, as factors of non-compliance are profoundly different across health systems, cultural contexts and geographic surroundings, as information on immunisation obstacles increases regionally and globally. In this study, the magnitude of delayed and missed kid vaccination and their independent predictors among mothers attending PHCs were assessed.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

This was a descriptive cross-sectional study conducted in Al-Diwaniyah City across 12 primary health care centers affiliated with Al-Diwaniyah Maternity and Children Teaching Hospital. The PHCs were chosen to represent urban, peri-urban and rural catchment areas and sociodemographic variety in the sample. Data were collected from February 2024 to July 2025. In this setting, PHCs are the initial contact point for routine immunization delivery as per the national EPI schedule, which comprises BCG and hepatitis B at birth; pentavalent (DTP-HepB-Hib), OPV, and PCV at 6, 10, and 14 weeks; IPV at 14 weeks; and measles-rubella (MR) at 9 months [12].

2.2 Participants and Eligibility

Mothers of children aged 0–24 months, who came to PHC for any health-related visit were eligible for inclusion both primary immunisation visits and additional attendances (growth monitoring, sick child consultations) were eligible recruitment opportunities. Inclusion criteria were: (i) Mother being the main career and aged ≥ 18 years; (ii) Mother having verifiable vaccination card of kid; and (iii) Mother giving informed written consent. Mothers with children who had documented contraindications to any specific vaccine, those with incomplete or unreadable cards and those who moved from outside the research area in the last six months were excluded. Recruitment was based on a consecutive convenience sampling scheme: in each participating PHC, all eligible mothers who presented during the scheduled data-collection sessions were invited to participate until the target quota for that center was attained, and refusals and ineligibility were recorded to characterise potential selection bias.

2.3 Sample Size

The sample size was determined by applying the method for the estimation of a single proportion $n = Z^2 \cdot p \cdot (1-p) / d^2$ where $Z=1.96$ at 95% confidence level, $d=0.05$ and $p=0.45$ based on non-compliance rates reported in similar regional studies [5,10]. This computation resulted in 381 individuals with the assumption of $\pm 5\%$ of absolute-precision [13]. The achieved sample of 300 mother-child pairs is equivalent to $\pm 5.7\%$ of absolute accuracy at $p=0.5$, which was considered acceptable for a single-center descriptive study. Two supplementary criteria further validated the adequacy to the analytical objectives. First, post-hoc power analysis indicated that the achieved sample provided $\geq 90\%$ statistical power to detect an adjusted odds ratio of 2.0 at $\alpha=0.05$, given the observed exposure prevalence's of 25–50%. Second, the 149 observed non-compliance events yielded an events-per-variable (EPV) ratio of approximately 21 for the seven-predictor logistic regression model, comfortably exceeding the conventional minimum of 10 EPV recommended to avoid over-fitting and to ensure stable maximum-likelihood coefficient estimates [14]. The final enrolled sample therefore comprised 300 mother-child pairs.

2.4 Data Collection Instrument

A structured, interviewer-administered questionnaire was developed in three sections. Section A collected sociodemographic data (maternal age, education, employment, parity, residence, and monthly household income). Section B documented vaccination status by verifying each vaccine dose against the child's immunization card; non-compliance was defined as any vaccine dose delayed by ≥ 4 weeks beyond the EPI-scheduled date or completely absent at the time of data collection. Section C explored self-reported barriers to timely vaccination using a list of ten pre-defined options (child illness, forgetfulness, fear of side effects, distance, long waiting time, vaccine stock-outs,

lack of schedule awareness, work obligations, mistrust of vaccine safety, and religious/cultural objections) plus an open-ended 'other' category. Content validity was established through expert review by a panel of two pediatricians and a public health specialist. A pilot test among 25 mothers yielded a Cronbach's alpha of 0.71 for the barrier subscale.

2.5 Ethics Approval

Ethical approval was obtained from the Institutional Review Board of the College of Medicine, University of Al-Qadisiyah, and approval number (QU-IRB-2024-07). All participants provided written informed consent. Participation was voluntary and carried no implication for clinical care. Data were anonymized prior to entry and analysis. The study conformed to the principles of the Declaration of Helsinki.

2.6 Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Frequencies and percentages were computed for categorical variables. The chi-square test (χ^2) was used to examine bivariate associations between sociodemographic factors and vaccination compliance status. All variables significant at $p < 0.20$ in bivariate analysis were entered into a binary logistic regression model, with non-compliance as the dependent variable, to compute crude and adjusted odds ratios (OR) and 95% confidence intervals (CI). Multicollinearity among candidate predictors was screened prior to model fitting using variance inflation factors (VIF), with a threshold of $VIF < 5$ considered acceptable. Model fit was assessed using the Hosmer–Lemeshow test, and overall discrimination was quantified with Nagelkerke's R^2 . Statistical significance was defined as $p < 0.05$ throughout.

3. RESULTS

3.1 Sociodemographic Characteristics

All 300 recruited mother-child pairs supplied complete data (response rate 100%). The mean age of the mothers was 28.9 ± 7.1 years. The largest age cohort was the 25–34 year group (51.3%). Close to half (49.0%) had attained at most a secondary level of education and 26.7% possessed a bachelor's degree or a higher certification. Most of the mothers characterized themselves as housewives or unemployed (68.7%). In terms of parity 26.3% were first time mothers, 46.3% had 2–3 children and 27.3% had four or more. The sample was predominantly urban (66.3%). Regarding child age, nearly half (49.7%) were aged 13–24 months. Full sociodemographic details are presented in Table 01.

Table 01: Sociodemographic characteristics of study participants (N=300)

Variable	n (%)	Cumulative %
Maternal age (years)		
<25	68 (22.7)	22.7

25–34	154 (51.3)	74.0
≥35	78 (26.0)	100.0
Educational level		
Primary or below	56 (18.7)	18.7
Secondary	91 (30.3)	49.0
Diploma/Technical	73 (24.3)	73.3
Bachelor's or above	80 (26.7)	100.0
Maternal employment		
Employed	94 (31.3)	31.3
Unemployed/Housewife	206 (68.7)	100.0
Number of children		
1	79 (26.3)	26.3
2–3	139 (46.3)	72.7
≥4	82 (27.3)	100.0
Residence		
Urban	199 (66.3)	66.3
Rural/Peri-urban	101 (33.7)	100.0
Child age (months)		
0–6	62 (20.7)	20.7
7–12	89 (29.7)	50.3
13–24	149 (49.7)	100.0

Note: Percentages may not sum to 100.0 due to rounding.

3.2 Prevalence and Pattern of Delayed and Missed Vaccination

Overall, 149 children (49.7%, 95% CI: 44.0–55.3%) had at least one delayed or missed vaccine dose, meeting the study definition of non-compliance. Considering vaccination status by antigen, birth-dose vaccines (BCG, hepatitis B, OPV-0) showed the lowest rates of non-compliance (9.3–11.7%). Non-compliance increased with advancing schedule age: pentavalent doses 1–3 showed progressive deterioration in coverage (19.7%, 23.0%, and 25.3% non-compliance, respectively). The highest non-compliance rates were observed for IPV at 14 weeks (35.7%) and measles-rubella at 9 months (34.3%). A complete breakdown of compliance by vaccine and dose is presented in Table 02.

Table 02: Vaccination status by vaccine and dose (N=300; eligible denominators vary by child age)

Vaccine/Antigen	On Schedule n (%)	Delayed n (%)	Missed n (%)
BCG (birth dose)	272 (90.7)	20 (6.7)	8 (2.7)
Hepatitis B (birth dose)	258 (86.0)	27 (9.0)	15 (5.0)
OPV-0 (birth dose)	260 (86.7)	24 (8.0)	16 (5.3)
Pentavalent-1 (6 weeks)	241 (80.3)	43 (14.3)	16 (5.3)
Pentavalent-2 (10 weeks)	231 (77.0)	49 (16.3)	20 (6.7)
Pentavalent-3 (14 weeks)	224 (74.7)	53 (17.7)	23 (7.7)
PCV (all three doses)	218 (72.7)	56 (18.7)	26 (8.7)
Measles-Rubella (9	197	68	35

months)	(65.7)	(22.7)	(11.7)
IPV (14 weeks)	193 (64.3)	72 (24.0)	35 (11.7)
Overall (any vaccine delayed or missed)	151 (50.3)	89 (29.7)	60 (20.0)

Note: Non-compliance defined as ≥ 4 weeks delay beyond scheduled date or complete absence of due dose. Children below the age of eligibility for a given dose were excluded from that dose's denominator. OPV = Oral Poliovirus Vaccine; BCG = Bacillus Calmette-Guérin; PCV = Pneumococcal Conjugate Vaccine; IPV = Inactivated Poliovirus Vaccine; MR = Measles-Rubella.

3.3 Self-Reported Barriers to Vaccination

Among the 149 mothers with non-compliant children, multiple overlapping barriers were frequently reported. The most common reason was child illness on the scheduled vaccination day (45.0%), followed by caregiver forgetfulness or carelessness (38.9%), fear of vaccine-related adverse effects (32.9%), and transport difficulties due to distance (28.2%). Long waiting times at the PHC were reported by 26.2% and vaccine stock-outs by 20.8%. Lack of knowledge about the immunization schedule (19.5%), competing work or domestic obligations (17.4%), mistrust of vaccine safety (12.1%), and religious or cultural objections (6.0%) were also identified, albeit less frequently. Reported barriers are summarized in Table 3.

Table 03: Self-reported barriers to timely vaccination among non-compliant mothers (n=149; multiple responses permitted)

Reason	n	% of non-compliant (n=149)
Child was ill on vaccination day	67	45.0
Caregiver forgetfulness or carelessness	58	38.9
Fear of side effects / adverse reactions	49	32.9
Distance/transport difficulties to PHC	42	28.2
Long waiting time at the center	39	26.2
Vaccine stock-out reported at PHC	31	20.8
Lack of knowledge about schedule	29	19.5
Work/domestic obligations	26	17.4
Mistrust of vaccine safety	18	12.1
Religious or cultural objections	9	6.0

Note: Responses are not mutually exclusive; total exceeds 100%. PHC = Primary Healthcare Center.

3.4 Bivariate Analysis

Chi-square analysis identified statistically significant associations between vaccine non-compliance and: educational level $\leq$ secondary ($\chi^2=28.34$, $p<0.001$), maternal age below 25 years or 35 and above ($\chi^2=11.73$, $p=0.003$), large family size ≥ 4 children ($\chi^2=13.47$, $p<0.001$), rural/peri-urban residence ($\chi^2=17.81$, $p<0.001$), fear of vaccine side effects ($\chi^2=10.12$, $p=0.002$), and distance to PHC exceeding 5 km ($\chi^2=19.44$, $p<0.001$). Maternal employment status did not reach statistical significance in bivariate analysis ($p=0.11$). Results are detailed in Table 04.

Table 04: Bivariate association between sociodemographic and attitudinal factors and vaccine non-compliance (N=300)

Variable	Compliant n (%)	Non-compliant n (%)	χ^2	p-value
Educational level				
Primary/Secondary	62 (42.2)	85 (57.8)	28.34	<0.001*
Diploma or above	89 (58.2)	64 (41.8)		
Maternal age (years)				
<25	29 (42.6)	39 (57.4)	11.73	0.003*
25–34	89 (57.8)	65 (42.2)		
≥ 35	33 (42.3)	45 (57.7)		
Number of children				
1	53 (67.1)	26 (32.9)	13.47	<0.001*
2–3	74 (53.2)	65 (46.8)		
≥ 4	24 (29.3)	58 (70.7)		
Residence				
Urban	122 (61.3)	77 (38.7)	17.81	<0.001*
Rural/Peri-urban	29 (28.7)	72 (71.3)		
Fear of vaccine side effects				
Yes	28 (38.4)	45 (61.6)	10.12	0.002*
No	123 (54.4)	104 (45.6)		
Distance to PHC (>5 km)				
Yes	31 (33.3)	62 (66.7)	19.44	<0.001*
No	120 (57.7)	88 (42.3)		

Note: * Statistically significant at $p < 0.05$ (chi-square test). Non-compliance defined as any delayed or missed dose.

3.5 Logistic Regression Analysis

The binary logistic regression model incorporating all variables significant in bivariate analysis demonstrated adequate fit (Hosmer–Lemeshow $\chi^2 = 7.14$, $p = 0.521$; Nagelkerke $R^2 = 0.34$). Multicollinearity among predictors was not a concern (all VIF < 2). The strongest predictor of vaccine non-compliance was large family size of ≥ 4 children (OR=3.54, 95% CI: 1.90–6.59, $p < 0.001$), followed by rural/peri-urban residence (aOR=3.21, 95% CI: 1.84–5.61, $p < 0.001$) and distance to the PHC exceeding 5 km (aOR=2.33, 95% CI: 1.34–4.05, $p = 0.003$). Fear of vaccine side effects was independently predictive (aOR=2.18, 95% CI: 1.22–3.89, $p = 0.008$), as was low educational level primary or secondary only compared to diploma-holder or university-educated mothers (aOR=2.08, 95% CI: 1.27–3.41, $p = 0.004$). Maternal age younger than 25 years and unemployed status did not independently predict non-compliance after adjusting for confounders ($p = 0.115$ and $p = 0.311$, respectively). Full regression results are presented in Table 05.

Table 05. Binary logistic regression: independent predictors of childhood vaccine non-compliance (N=300)

Predictor Variable	Crude OR (95% CI)	Adjusted OR (95% CI)	SE	P-value
Primary/Secondary education (vs. diploma+)	2.41 (1.51 – 3.84)	2.08 (1.27 – 3.41)	0.25	0.004*
Rural/Peri-urban residence (vs. urban)	3.93 (2.31 – 6.68)	3.21 (1.84 – 5.61)	0.28	<0.001*
≥ 4 children (vs. 1 child)	4.17 (2.30 – 7.55)	3.54 (1.90 – 6.59)	0.32	<0.001*
Fear of side effects (yes vs. no)	2.51 (1.44 – 4.38)	2.18 (1.22 – 3.89)	0.30	0.008*
Distance >5 km to PHC (yes vs. no)	2.74 (1.63 – 4.60)	2.33 (1.34 – 4.05)	0.28	0.003*
Maternal age <25 years (vs. 25–34)	1.83 (1.04 – 3.22)	1.61 (0.89 – 2.91)	0.30	0.115
Unemployed/housewife (vs. employed)	1.47 (0.93 – 2.32)	1.29 (0.79 – 2.11)	0.25	0.311

Note: * Statistically significant at $p < 0.05$. OR = Odds Ratio; CI = Confidence Interval; SE = Standard Error of regression coefficient. Reference categories: diploma/university education; urban residence; 1 child; no fear of side effects; distance ≤ 5 km; age 25–34 years; employed. Model fit: Hosmer–Lemeshow $\chi^2 = 7.14$, $p = 0.521$; Nagelkerke $R^2 = 0.34$.

A composite figure integrating the prevalence of non-compliance by antigen, the frequency and ranking of reported barriers and the forest plot of adjusted odds ratios is presented in Figure 01.

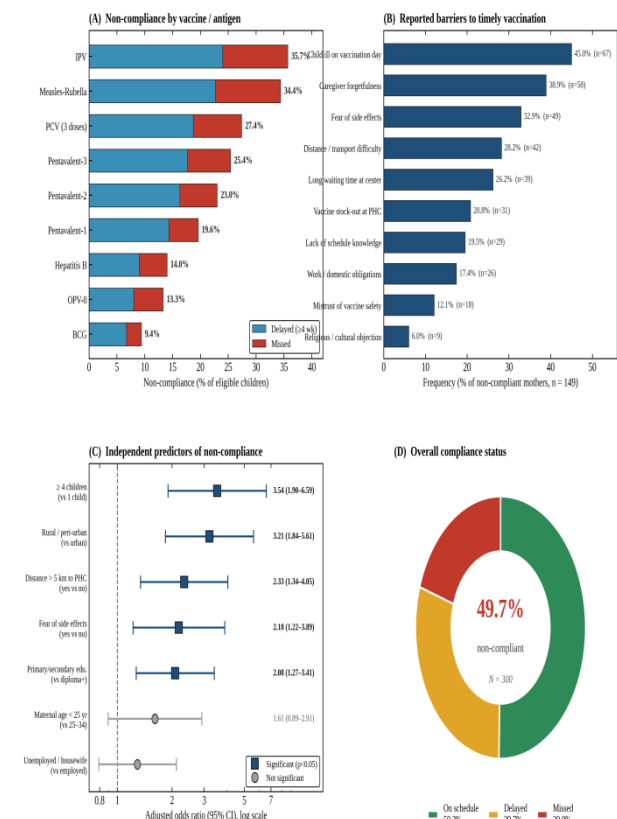


Figure 01: Composite summary of vaccination non-compliance patterns, barriers, and independent predictors (N=300). Panel A: non-compliance prevalence by antigen. Panel B: reported barriers among non-compliant mothers. Panel C: adjusted odds ratios from logistic regression. Panel D: overall compliance status distribution.

4. DISCUSSION

This cross-sectional study found that nearly half (49.7%) of children attending PHCs had at least one delayed or missed vaccine dose a figure that is both clinically significant and consistent with the range reported from comparable settings. A study conducted at PHCs in Riyadh, Saudi Arabia, identified 7.1% delayed vaccination, predominantly affecting IPV, OPV, and meningococcal vaccine, with child illness and caregiver carelessness as principal causes [5]; however, that study's lower rate likely reflects the higher baseline healthcare utilization and shorter average

distances to facilities in an urban Gulf context. In contrast, studies from sub-Saharan Africa and South Asia report non-compliance rates exceeding 40–60% [8,9], and a retrospective chart review from a PHC in Hila, Iraq, found that a substantial proportion of children missed routine doses during the 2020–2021 data collection period [15].

The progressive deterioration in compliance with advancing schedule age from relatively high adherence for birth-dose vaccines to over a third of children missing or delaying the measles-rubella and IPV doses mirrors a well-documented global pattern [7, 10]. Birth-dose vaccines are typically administered in the maternity ward immediately after delivery, where adherence is almost structural. Later dosages, however, require the mother to deliberately go back to a health institution at certain times, providing repeated chances for logistical, attitudinal, and informational hurdles to develop. Particularly high non-compliance for IPV has been seen across the region, in part owing to parents' relative unfamiliarity with this newer schedule addition compared to the well-known OPV [5, 10].

45.0% of non-compliant mothers reported child illness on vaccination day as the reason for delay, which represents a true clinical problem (contraindications to vaccination) and more frequently, a false perception that small illness precludes safe immunisation. The sole absolute contraindication to immunisation is severe febrile illness according to current WHO and national criteria. Minor illnesses such as moderate fever, rhinorrhoea and mild diarrhoea are not a contraindication for immunisation [16]. This barrier thus partly reflects missed opportunities for provider counselling by PHC clinicians who may have advised that most children with minor ailments could safely receive their scheduled immunisations. High career amnesia (38.9%) was commonly observed. Systems-level reminders via SMS, reinforcement of the vaccination card at every clinic visit, and follow-up by community health workers may lead to large gains in schedule adherence.

Fear of vaccine side effects (32.9%) is one of the significant attitudinal barriers in our population in accordance with international literature. In the US, substantial levels of parental concerns about the safety of vaccinations have been found as early as 2009 [17], and the fear of side effects has been established as a near-universal antecedent of vaccine hesitancy in both developed and developing contexts in following systematic reviews [18,19]. In developing nation setups, this fear is usually compounded by misinformation through social media, informal community networks and past poor healthcare experiences [18]. Our logistic model demonstrated an independent association between fear of side effects and non-compliance ($aOR=2.18$, $p=0.008$), which emphasises the necessity for targeted communication strategies that address

specific parental concerns about side effects in a credible and culturally appropriate manner.

On the characteristics related to structure, two of the three most important independent predictors of non-compliance were the place of living (rural/peri-urban) ($aOR=3.21$) and the distance to the PHC (>5 km) ($aOR=2.33$). The geographic inaccessibility of health services is one of the most commonly cited barriers to children immunisation in the literature [8, 10]. When transit expenses are high and the number of PHCs is low, the time and financial burden of several clinic visits for a full series of immunisations may be simply prohibitive for households with already-stretched budgets. Large family size ($aOR=3.54$) was the strongest predictor in our model and may operate via multiple pathways, including conflicting caregiving responsibilities across multiple children, increased per-family transportation costs, and the potential dilution of parental attention and record-keeping capacity. This finding is in accord with those from Iraq [15] and the broader Middle Eastern literature, where large family size has been identified as a reliable indication of incomplete immunisation [20].

Low maternal education ($aOR=2.08$) was a predictor of non-compliance independent of the structural and attitudinal factors mentioned above. This finding is in line with studies done in Ethiopia [9], Saudi Arabia [5] and Bangladesh [21]. Education influences vaccination practice through multiple pathways such as health literacy (awareness of the importance of each dose), knowledge of vaccination schedule (awareness of the timing of doses) and self-efficacy in navigating the health systems. However, non-compliance was not substantially linked with mother employment status, which may be predicted to limit attendance for immunisation due to time restrictions. This may be related to the fact that our sample was mostly composed of housewives (68.7%) or that employed mothers may have more social capital and access to the health system that makes up for conflicting time demands.

A few limitations should be pointed up. The cross-sectional design prevents causal inference and is vulnerable to simultaneity bias. We rely on self-reported barriers subject to social desirability effects, notably for attitudinal factors such as scepticism in vaccine safety. Immunisation card data, while more objective than recall, may not record dosages received elsewhere. The sample was well powered but was selected from moms already attending PHCs which may not have included the most difficult-to-reach groups who had the greatest burden of non-compliance. Because the study was restricted to Al-Diwaniyah city, findings may not fully generalize to other Iraqi governorates with different socio-economic profiles or immunisation delivery infrastructure. Finally, our sampling was of a convenience nature, limiting generalizability to a carefully defined reference population.

5. CONCLUSION

The present study reports that vaccine non-compliance among children attending primary health care clinics in the study area affects roughly half of the children with the greatest impact in vaccines delivered at subsequent schedule ages. Major modifiable variables of non-compliance include rural residence, big family size, and geographical distance to amenities, low mother education and fear of deleterious effects. Collectively, these findings point to an urgent need for multi-level interventions: mobile and outreach vaccination services to overcome geographic barriers; SMS-based reminder systems and engagement of community health workers to overcome forgetfulness and non-adherence to schedules; and targeted health communication campaigns delivered through trusted community channels to address misconceptions about vaccine safety. Healthcare providers at PHCs should be trained to use every contact of a mother as an opportunity to assess vaccination status, give necessary doses where clinically indicated (including when the child is mildly unwell) and counsel on the immunisation schedule. Policymakers should recognize geographic accessibility as a critical component of immunisation equality and distribute resources appropriately, prioritizing rural and peri-urban regions with proven gaps in coverage. These interventions need to be evaluated through future longitudinal studies, and vaccine coverage patterns need to be monitored in a more granular, context-sensitive manner.

6. DECLARATIONS

Ethics Approval and Consent to Participate

Approval number (QU-IRB-2024-07). Written informed consent was obtained from all participants prior to enrollment. The study conformed to the principles of the Declaration of Helsinki.

7. CONFLICT OF INTEREST

The authors declare no conflict of interest.

9. FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

10. Data Availability

De-identified data are available from the corresponding author upon reasonable request and subject to institutional data-sharing agreements.

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