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A multilevel analysis of individual and community-level factors associated with childhood immunisation in Bangladesh: Evidence from a pooled cross-sectional survey

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ABSTRACT

Introduction: Previous studies on childhood vaccinations in Bangladesh relied on single-level analyses and ignored the clustering and hierarchical structure of data collected from people living in different geographical units. This study, therefore, aimed to investigate the association between individual and community-level factors of full childhood immunisation with an improved analytical approach.
Methods: Participants were 13,752 children aged 12–59 months. Data were extracted from the Bangladesh Demographic and Health Survey (BDHS) conducted in 2007, 2011, 2014, and 2017–18. A two-level multilevel logistic regression method was used to analyse the data.
Results: Approximately 87% of the children were fully immunised. In the fully adjusted model, at the individual level, mothers who had primary and above education (Adjusted odds ratio [AOR] = 1.78; 95% Confidence Interval [CI]: 1.57, 2.01), mass media exposure (AOR = 1.14; 95% CI: 1.00, 1.30), having vaccination cards (AOR = 3.65; 95% CI: 3.23, 4.14), and having at least 4 antenatal care (ANC) visits (AOR = 1.24; 95% CI: 1.06, 1.44) were strongly associated with full childhood immunisation. At community-level, rural residency (AOR = 1.25; 95% CI: 1.08, 1.44), community women's education (AOR = 1.24; 95% CI: 1.07, 1.43), and community ANC utilisation (AOR = 1.38; 95% CI: 1.19, 1.61) were significantly associated with full childhood immunisation.
Conclusion: Along with individual-level factors, community-level factors have a significant effect on childhood immunisation. Policymakers should target improving community-level characteristics, such as community poverty, education levels, and the number of community-level ANC visits, to increase the national level of childhood immunisation. Public health intervention programs aiming at increasing awareness of childhood immunisation should include elements at both individual and community levels.

1. Background

Childhood immunisation has been one of the most critical contributors to child's health worldwide. Immunisation is a biological process that provides immunity against a particular infectious disease [1]. World Health Organisation (WHO) established the Expanded Program on Immunisation (EPI) in 1974 with the aim to immunise every child and protect them from vaccine-preventable diseases (VPD) [2], including diphtheria, tetanus, pertussis, influenza, and measles. WHO estimates that immunisation prevents nearly 2 to 3 million deaths per year caused by these diseases. Despite this, approximately 1.5 million children die every year from VPD worldwide [3]. Furthermore, nearly 20 million children, most of them from South Asia, did not receive lifesaving measles, diphtheria, and tetanus vaccines in 2018 [4].

According to the World Bank's World Development Indicators (WDI), the deaths of children under five in Bangladesh declined from 87 to 34 per 1000 live births in 2014 due to a strong national commitment by the Bangladesh government to achieve the Millennium Development Goals (MDG) [4]. According to the Global Alliance for Vaccine and Immunization (GAVI), the Bangladesh government estimated 92% of diphtheria-tetanus-pertussis

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(DPT3) coverage among children in 2013 [5]. The full vaccination rate among 12 to 23-month-old children rose from 76% in 2007 to 86% in 2018 [6]. However, the full immunisation rate fell by 8% in 2014 [7]. Although Bangladesh has reduced its child mortality rate by two-thirds since 1990 [8], a previous study reported that the majority of child deaths could be prevented through immunisation [9,10].

Existing studies have outlined that socioeconomic, and demographic factors, and healthcare utilisation have impacted childhood vaccination in Bangladesh [8,11]. Previous studies on childhood vaccination have reported estimates utilising the single-level binary logistic regression model based on cross-sectional data. These single-level analytical techniques were the main weakness of earlier studies, which also ignored clustering and hierarchical structure of data collected from people living in different geographical units, such as households, cities, and enumeration areas (EAs). Furthermore, the community levels factors such as place of residence, community poverty level, community women's education, community unemployment, community ANC utilization, community institutional delivery, and community media exposure are significant factors in child immunization [12-14]. The individual-level factors are deep-seated inside community-level factors in the Demographic and Health Survey (DHS). A biased result could have occurred when estimating the determinants of childhood immunisation coverage without considering the community-level factors [15], and without adjusting for clustering and hierarchical structure of the data. Even the influence of community-level factors on child immunization status has been given less notice, and there exists a confusion. This study, therefore, used multilevel modeling and offered a more robust analysis of the factors associated with child vaccination in Bangladesh [15].

2. Methods and materials

2.1. Data source and study design

This study used the nationally representative BDHS data, collected from 2007 (n = 3,507), 2011 (n = 5,345), 2014 (n = 2,801), and 2017–18 (n = 2,099) BDHS rounds. Taking data from four different points allowed a comparison of the trend of childhood immunisations. Mitra and Associates in Bangladesh conducted the survey under the authority of the National Institute of Population Research and Training (NIPORT), Ministry of Health and Family Welfare, Bangladesh. A DHS collects information on fertility, childhood mortality, fertility preferences, awareness, approval and use of family planning methods, maternal and child health, knowledge and attitudes toward human immunodeficiency virus (HIV) and acquired immunodeficiency syndrome (AIDS) and other sexually transmitted infections (STI). It also collects information on community-level data, such as the accessibility and availability of health and family planning services. A two-stage stratified cluster sample design was used in the DHS based on the EAs. Clusters were selected in the first stage from a complete list of EAs, and households were assigned to each selected cluster in the second stage. Households were then systematically selected for participation in the survey, with women aged 15–49 years and those who have children aged 12–59 months is the target participants of our study. A total of 13,752 children, after excluding the missing and unnecessary observations from the pooled data, were included in the analyses. Of the 13,752 samples, approximately 26%, 39%, 20%, and 15% were from BDHS 2007, 2011, 2014, and 2017–18, respectively.

2.2. Study variables

2.2.1. Dependent variable

The outcome variable in this study is full childhood immunisation, which was assessed based on children's immunisation records and information reported by their mothers. If a child received three doses of diphtheria, pertussis, and tetanus (DTP), four doses of polio, one dose of measles, one dose of Bacillus Calmette–Guérin (BCG), and four doses of hepatitis B vaccine by the age of 12 months, it would be considered as full immunisation [3].

2.2.2. Independent variables

Individual and community-level factors were potential predictors of full childhood immunisation. Some specific potential risk factors of childhood immunisation were selected based on previous studies [8-11,14,16-20]. Child and parent-specific characteristics were considered as individual-level factors, including children's age [8,21], place of delivery [14,20,22] and having a vaccination card [20], and mother's education [14,21,23], household wealth index [11,18,22,24], mass media exposure [8,9,23], family size [8,24], and ANC visit [11,22,24].

Direct community-level and collective community-level independent variables were considered in the analysis. Direct community-level variables were considered without any changes, while collective community-level variables were generated in binary form by aggregating individual-level variables. The clusters were used as the proxies of the community level. Place of residence [14,17,20,24], community poverty status [17,20,21], community women's education [17,20,21], community unemployment [17,20,21], community ANC utilisation [17,18,20], community institutional delivery [17,18,20] and community mass media exposure [18,20] were considered as community-level factors. The BDHS collects data on the place of residence that describes the characteristics of the clusters. Other community-level variables were generated by aggregating the individual factors of interest in a cluster. The aggregates were calculated using the proportion of a given variable's sub-category as the aggregate value for some generated variables was not normally distributed. However, all the community-level variables were categorised into two groups using the median.

2.3. Statistical analysis

Firstly, the software Stata 15 was used to perform the statistical analysis of the considered data [25]. The distributions of various individual-level and community-level factors were reported using descriptive statistics. Bivariate associations between the outcome variable and confounders were identified using chi-square tests. The significantly associated ($p < 0.05$) factors from the bivariate analyses were included in the multivariate multilevel regression analysis. This study used the multilevel technique since the DHS data was hierarchical, where individual (Level 1) factors were nested inside the community (Level 2) factors. The association between individual-level factors and children's full immunization coverage was determined in Level 1. The association between community-level factors and children's full immunization coverage was evaluated in Level 2. The multilevel analysis was performed separately in four regression models. Model 1 was an empty model to check the variability among the communities without inserting any independent variables. The random effects at the community level were assessed by this empty model (Model 1). Model 2 included individual-level factors that were statistically significant (<0.05) in the bivariate analyses. Similarly, statistically significant (<0.05) community-level factors in the bivariate analyses were included in Model 3. The final model (Model 4), known as

the mixed model, considered individual and community-level factors simultaneously.

The fixed and random effect parameters were estimated from multivariate multilevel modeling. The fixed and random effects models measured the adjusted odds ratios and community-level variance, respectively. Intraclass correlation (ICC) and Proportional Change in Variance (PCV) were used to measure the random effects, with ICC calculating the variance in percentage explained by the community-level factors and PCV evaluating the proportional difference in the community level variance among the models (Model 1 to 4). Finally, the best model was selected using some vital model fit statistics, such as log-likelihood and Akaike's Information Criterion (AIC).

2.4. Patient and public involvement

The study was conducted using secondary data. Patients or the public were not directly involved in the design, or analysis, or reporting, or no plans to disseminate the results of the research.

3. Results

Table 1 presents the distribution of childhood immunisation coverage by individual factors in Bangladesh. The full childhood immunisation coverage was more than 87%. The full childhood immunisation rate was more than 91% for mothers having a primary and higher level of education and for approximately 93% of children from the richest family. The immunisation rate among children aged 24 to 59 months was nearly 89%.

Mass media exposure contributed to a higher proportion of full immunisation. About 89% of children from families having 1–4 members were fully immunised. A total of 13,752 children, about 85.20%, were delivered in the home, but 92.41% of children who were born in a health facility were fully immunised. The highest, 85% of children had vaccination card, and 90.38% of children received all doses of vaccine. About 71% of children had experienced 0–3 visits to ANC, whereas the percentages of fully immunised children were highest among the mothers who had four or more ANC visits (92.66%). All individual-level factors were significantly associated with full immunisation at a 5% level of significance.

Table 2 presents the distribution of childhood immunisation coverage among 12–59 month-old children according to community-level factors in Bangladesh. Among the community-level factors, about two-thirds (66.91%) of the total number of children lived in rural areas. More than half of the community's mothers belonged to the low proportion of poverty (51.78%) and education (50.41%). Similarly, 52.49%, 51.88%, and 55.85% of the total number of children were from communities with low unemployment, ANC utilisation, and institutional delivery rates, respectively. Furthermore, 50.83% of the children were from communities with higher media exposure rates.

In rural areas, full childhood immunisation was lower compared to urban areas (86.44% versus 88.68%). Similarly, approximately 90% of children from mothers with higher education at community-level and about 84.31% of those with low levels of education were fully immunised. Furthermore, 84.04% of children with low ANC utilisation and 90.57% of children with high ANC utilisation were fully vaccinated. Over 90% of children from high institutional delivery utilisation coverage were fully immunised. Similarly, over 85.27% of children living in communities with low media exposure were fully vaccinated, whereas around 90% of children living in communities with a higher mass media exposure had full immunisation. Fig. 1 also presents the overall prevalence of full immunisation in different survey years. The prevalence of full immunisation was 84.58% in 2007, but this prevalence was 88.38% in 2017–18. However, there was a little fluctuation among the considered survey years.

Table 3 describes the multivariate multilevel regression analysis results for empty, individual, community, and individual-community factors accounting for the random effect of community

Table 1
Distribution of immunisation coverage among children aged 12–59 months old according to individual-level background characteristics in Bangladesh in 2007–2018 (n = 13,752).

Variables	Full immunisation status Total, n (%)	Yes, n(%)	No, n(%)	p-value
Childhood Immunisation	13,752 (100%)	11,989 (87.18)	1,763 (12.82)	
Mothers' education				<0.001
No education	5,008(36.42)	3,996(79.79)	1,012(20.21)	
Primary and above	8,744(63.58)	7,993(91.41)	751(8.59)	
Wealth index				<0.001
Poorest	2,968(21.58)	2,397(80.76)	571(19.24)	
Poorer	2,692(19.58)	2,310(85.81)	382(14.19)	
Middle	2,587(18.81)	2,268(87.67)	319(12.33)	
Richer	2,686(19.53)	2,382(88.68)	304(11.32)	
Richest	2,819(20.50)	2,632(93.37)	187(6.63)	
Children age (months)				<0.001
12–23	5,150(37.45)	4,367(84.80)	783(15.20)	
24–59	8,602(62.57)	7,622(88.61)	980(11.39)	
Mass media exposure				<0.001
No	6,528(47.47)	5,459(83.62)	1,069(16.38)	
Yes	7,224(52.53)	6,530(90.39)	694(9.61)	
Family size				<0.001
1–4	4,471(32.51)	3,975(88.91)	496(11.09)	
5 and above	9,281(67.49)	8,014(86.35)	1,267(13.65)	
Place of delivery				<0.001
Home	9,971(72.51)	8,495(85.20)	1,476(14.80)	
Health facility	3,781(27.49)	3,494(92.41)	287(7.59)	
Children's vaccination card				<0.001
No cards	2,115(15.38)	1,472(69.60)	643(30.40)	
Have cards	11,637(84.62)	10,517(90.38)	1,120(9.62)	
Mothers' ANC visit				<0.001
0–3	9,760(70.97)	8,290(84.94)	14,701(15.06)	
4 and above	3,992(29.03)	3,699(92.66)	293(7.34)	

Table 2
Distribution of immunisation coverage among children aged 12–59 months old according to community-level background characteristics in Bangladesh in 2007–2018 (n = 13,752).

Variable	Full immunisation status			p-value
	Total, n (%)	Yes, n (%)	No, n (%)	
Place of residence				<0.001
Urban	4,551(33.09)	4,036(88.68)	515(11.32)	
Rural	9,201(66.91)	7,953(86.44)	1,248(13.56)	
Community poverty status				<0.001
Low	7,121(51.78)	6,304(88.53)	817(11.47)	
High	6,631(48.22)	5,685(85.73)	946(14.27)	
Community women education				<0.001
Low	6,933(50.41)	5,845(84.31)	1,088(15.69)	
High	6,819(49.59)	6,144(90.10)	675(9.90)	
Community unemployment				<0.001
Low	7,218(52.49)	6,380(88.39)	838(11.61)	
High	6,534(47.51)	5,609(85.84)	925(14.16)	
Community ANC utilisation				<0.001
Low	7,135(51.88)	5,996(84.04)	1,139(15.96)	
High	6,617(48.12)	5,993(90.57)	624(9.43)	
Community institutional delivery				<0.001
Low	7,680(55.85)	6,505(84.70)	1,175(15.30)	
High	6,072(44.15)	5,484(90.32)	588(9.68)	
Community media exposure				<0.001
Low	6,762(49.17)	5,766(85.27)	996(14.73)	
High	6,990(50.83)	6,223(89.03)	767(10.97)	

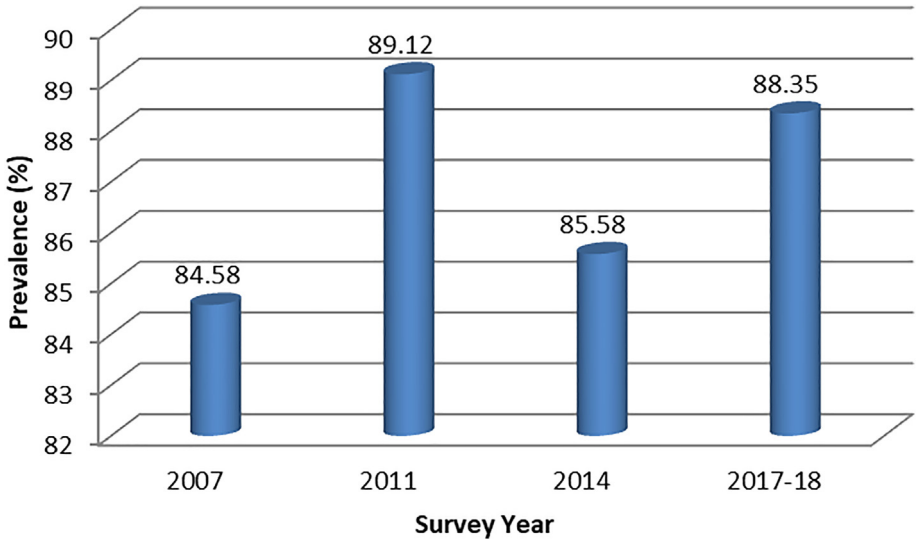

Fig. 1. The prevalence of full vaccination in different survey years.

and fixed effect of factors associated with full immunisation among 12–59 month-old children in Bangladesh.

The empty model (Model 1) illustrated that significant variability exists in the odds of full immunisation across communities (τ = 0.64; 95% CI: 0.56–0.72; p < 0.001). Likewise, significant variations in full immunisation remained in Model 2 (τ = 0.53; 95% CI: 0.45–0.62; p < 0.001) and Model 3 (τ = 0.55; 95% CI: 0.48–0.64; p < 0.001). For this reason, after controlling the effect of both individual and community-level factors, the variance at the community level had a significant impact (τ = 0.49; 95% CI: 0.41–0.58; p < 0.001) in Model 4. The empty model (Model 1) showed that an overall 11.08% variation in the odds of full immunisation coverage was reported by involving the cluster difference of the characteristics (ICC = 11.08%). The variability between clusters declined over consecutive models, from 11.08% in the empty model (Model 1) to 8.57% in the community-level model (Model 3), 7.89% in the individual-level model (Model 2), and 6.93% in the final model (Model 4). The PCV specified that the accumulation of forecasters to the empty model clarified an increased proportion of variation in full immunisation coverage. Parallel to the ICC values, the PCV showed higher values in the combined model, i.e., 23.44% of the variation in full childhood immunisation could be explained by the combined individual and community level factors. Thus, the combined model of individual and community-level factors was favoured in forecasting full childhood immunisation coverage.

Adjusting the individual and community-level factors in the final model, the mothers' education, wealth index, the children's age, mass media exposure, the children's having vaccination card, the mothers' ANC visits, place of residence, community poverty, community women's education and community ANC visits and community institutional delivery facilities were associated with full immunisation among children.

Considering education, the odds of full childhood immunisation were 1.78 (AOR = 1.78; 95% CI: 1.57–2.01) times higher in children whose mothers had primary and above education compared to the mothers with no education. The odds of full immunisation among

Table 3
Multivariate multilevel logistic regression analysis of individual and community-level factors with children's full immunisation among children aged 12–59 months old in Bangladesh in 2007–2018 (n = 13,752).

Covariates	Model 1 AOR (95% CI)	Model 2 AOR (95% CI)	Model 3 AOR (95% CI)	Model 4 AOR (95% CI)
Individual-level factors				
Mothers education				
No education (ref)				
Primary and above		**1.82 (1.62, 2.05)*****		**1.78 (1.57, 2.01)*****
Wealth index				
Poorest (ref)				
Poorer		**1.18 (1.01, 1.37)***		**1.18 (1.01, 1.38)***
Middle		**1.23 (1.03, 1.47)***		**1.28 (1.08, 1.53)****
Richer		1.15 (0.96, 1.39)		**1.25(1.03, 1.52)****
Richest		**1.78 (1.42, 2.23)*****		**1.97(1.54, 2.52)*****
Children age (month)				
12–23 (ref)				
24–59		**1.78 (1.59, 2.00)*****		**1.75 (1.56, 1.96)*****
Mass media exposure				
No (ref)				
Yes		**1.14 (1.00–1.29)***		**1.14 (1.00, 1.30)***
Family size (number)				
1–4 (ref)				
5 and above		0.89 (0.80, 1.01)		0.89 (0.97, 1.34)
Place of delivery				
Home (ref)				
Health facility		**1.17 (1.00, 1.34)***		1.14(0.97, 1.34)
Children's vaccination card				
No cards (ref)				
Have cards		**3.68 (3.25, 4.17)*****		**3.65 (3.23, 4.14)*****
ANC visit				
0–3 (ref)				
4 or above		**1.34 (1.15, 1.57)*****		**1.24 (1.06, 1.44)*****
Level-2 variables				
Residence				
Urban (ref)				
Rural			0.93 (0.82, 1.07)	**1.25 (1.08, 1.44)***
Community poverty status				
Low (ref)				
High			1.09 (0.91, 1.30)	**1.22 (1.02, 1.47)***
Community women education				
Low (ref)				
High			**1.34 (1.16, 1.55)*****	**1.24 (1.07, 1.43)****
Community unemployment				
Low (ref)				
High			0.96 (0.83, 1.12)	1.00 (0.86, 1.16)
Community ANC utilisation				
Low (ref)				
High			**1.62 (1.40, 1.88)*****	**1.38 (1.19, 1.61)***
Community institutional delivery				
Low (ref)				
High			**1.21 (1.03, 1.41)***	1.11 (0.94, 1.31)
Community media exposure				
Low (ref)				
High			1.05 (0.89, 1.25)	0.97 (0.82, 1.15)
Intercept	8.08 (7.45, 8.75)***	1.07 (0.88, 1.28)	5.02 (4.06, 6.20)***	0.62 (0.47,0 0.82)*
Model summary (Random effect)				
Communities variances (SE)	0.64 (0.04) (0.56,0 0.72)	0.53 (0.04) (0.45, 0.62)	0.55 (0.04) (0.48,0 0.64)	0.49 (0.04) (0.41, 0.58)
ICC%	11.08	7.89	8.57	6.93
PCV%	Ref			
Log likelihood	−5171.454	−4716.4734	−5106.3848	−4690.845
AIC	10346.91	9458.947	10230.77	9421.69

* $p < 0.05$,
** $p < 0.01$,
*** $p < 0.001$.

children from the richest households were 1.97 times (AOR = 1.97; 95% CI: 1.54–2.52) higher than children from the poorest households. Likewise, the odds of full immunisation among the children aged 24–59 months were 1.75 (AOR = 1.75; 95% CI: 1.56–1.96) times higher compared to the children aged 12–23 months old. Children whose families had access to mass media were 1.14 (AOR = 1.14; 95% CI: 1.00–1.30) times more likely to be fully immunised than those whose families had no access to mass media. Furthermore, children having a vaccination card had a 3.65 (AOR = 3.65; 95% CI: 3.23–4.14) times higher likelihood of being fully immunised when compared to the children having no vaccination card. Mothers who made ANC visits four or more times (AOR = 1.24; 95% CI: 1.06–1.44) had significantly higher odds of their children being fully immunised than mothers with 0–3 ANC visits. Among the community-level factors, rural children had higher odds (AOR = 1.25; 95% CI: 1.08–1.44) of full childhood

immunisation compared to urban children. Among the other community-level factors, a high rate of poverty (AOR = 1.22; 95% CI: 1.02–1.47), the women's education (AOR = 1.24; 95% CI: 1.07–1.43), and ANC utilisation (AOR = 1.38; 95% CI: 1.19–1.61) had a significant positive association with full immunisation among 12–59 months-old children.

The model fit statistics from Table 3 showed that Model 4′s Akaike information criterion (AIC) values were lower than Model 1, Model 2, and Model 3. Based on the log-likelihood and AIC values, Model 4 performed better than the other models. As a result, Model 4′s integrated individual and community level factors were preferred to forecast full childhood immunisation among 12–59-month-old children.

4. Discussion

This study found that full immunisation was 87% (2007–2018) in Bangladesh, which was higher than the rate in 2004, which was approximately 62% [11]. The main reason behind the underlying coverage is the national and community-level health system of Bangladesh, where health facilities (both government and non-government organisations) dynamically connect to provide healthcare services. Furthermore, community health workers have brought vaccination coverage to remote regions in Bangladesh [26]. However, significant disparities in vaccination coverage have been observed. For example, vaccination coverage is comparatively low among children belonging to uneducated mothers, those from the poorest households, and those with no vaccination card.

Our results demonstrated that individual and community-level factors were significantly associated with full childhood immunisation in Bangladesh. This study found that individual-level factors, such as the mothers' education, wealth index, children's age, having children's vaccination card, and ANC visits were significantly associated with full childhood vaccination. This study also revealed that community-level variables, such as place of residence, community poverty, community women's education, and community ANC utilisation, were significantly associated with full childhood immunisation in Bangladesh.

These findings indicate that the mother's education is a crucial factor in full childhood immunisation and is positively associated with increased full immunisation of their children compared with peers having no formal education, which is consistent with the findings from previous studies conducted in Bangladesh [8,11], India [26], and several other countries [8,14,21,24,27]. Educated parents have better awareness and understanding of the suggested immunisation schedule, along with access to health facilities, compared with non-educated parents [3,28]. However, studies from Ethiopia and Uganda have claimed that the mothers' education was not significantly associated with the children's full vaccination coverage [16,22].

This study showed that children from the wealthiest households had higher odds of having full immunisation compared with children from poorer households. Studies from India [24], Nigeria [29], Burkina Faso [30], Swaziland [31], Congo [17], and Ethiopia [16] also reported similar results. Wealthier people are aware of the healthcare services needed for their children and usually have better access to these services [32,33]. Another possible reason could be that poor parents often neglect to immunise their children on time [34]. Furthermore, long distances to health facilities and higher travel costs impede low-income families from vaccinating their children [35].

Having children's vaccination cards was significantly associated with higher odds of childhood immunisation compared to children without a vaccination card. This finding is in line with past studies conducted in Ghana [36], Senegal [37], Cameroon [38], and Ethiopia [16,19,20]. The possible reason could be that a vaccination card helps the mothers to remember their children's vaccination schedule and, thus, helps them to complete the vaccinations [23].

This study has revealed that four or more ANC visits by the mother were associated with higher odds of full childhood vaccination occurring compared to mothers who haven't had ANC visits, and this finding is consistent with earlier studies conducted in China [39], Indonesia [40] and Ethiopia [41]. A higher number of ANC visits may help mothers obtain proper healthcare support, institutional delivery, postnatal care, vaccinations, and family planning services [27]. A study conducted in India found that ANC visits made mothers aware of getting their children immunised and became more serious [42].

This study mainly focuses on community-level factors and has investigated the impact of these factors on childhood immunisation in Bangladesh. Place of residence, community poverty status, community women's education, and community ANC utilisation were significant factors of full childhood immunisation. In our study, rural children were more likely to be immunised than urban children. In contrast, another study reported that urban children have improved immunisation compared with rural children [24]. This could be explained by the fact that approximately 33% of urban people in developing countries live in slums, and health-related facilities and services are limited in those areas [40]. Children from urban slum areas had a lower chance of being immunised because of the limited access to health-related facilities and services. However, high community poverty has a significant positive effect on full childhood vaccination compared with the low proportion of community poverty. The probable cause for this may be that vaccination in Bangladesh is free of cost and available in all government hospitals [18]. This study revealed that a higher proportion of educated women in the community is significantly associated with higher odds of full childhood vaccination compared with the low proportion of women's higher education in the community, indicating the positive effect of higher education on childhood immunisation coverage. The possible reason for this could be that the mothers' higher education at the community level is positively associated with increased access to information, health literacy, and family planning awareness [17].

This study's findings have also revealed that community ANC utilisation is significantly positively associated with full childhood immunisation in Bangladesh, which is corroborated by the findings of the study carried out in Nigeria [43]. The plausible reasons for this finding might be that women lack prenatal care and have lower knowledge about childhood immunisation and other health promotion programs. A different possible explanation for this result could be the improved reliance on the importance of child immunisation and higher institutional delivery among women who meet ANC services [3].

The findings of this study have immense public health implications for improving immunisation coverage in Bangladesh. Policymakers should pay special attention to illiterate mothers. Similarly, interventions are needed for children and women living in the poorest rural families to implement timely immunisation practices. This study suggests that the circulation of the benefits of immunisation should take the place of the merits and demerits of childhood immunisation in rural areas to make people aware of family planning, the necessity of ANC visits, and the disbursement of health facilities.

This study has made several contributions to the literature. Using multilevel modeling, this study handles the fixed effects and random effects to explain the cluster variations simultaneously. Prior studies that have used BDHS data have yet to describe the clusters properly, except for the variables, region, and place of residence. To overcome the limitations, this study has generated factors by aggregating individual information into cluster values,

which helps in identifying the association between cluster-level factors and full childhood immunisation. Furthermore, this study pooled the BDHS data set collected at three different time points to achieve a large sample size and provide more precise estimates. Additionally, this study employed several diagnostic tests that explain the model fit.

This study, however, has some limitations. Self-reported data are subjected to recall bias which may underestimate or overestimate the actual rate of full childhood vaccination. Furthermore, this study defines the community-level variables using clusters, and a cluster might not be truly representative of a real community because of its arbitrary boundary. Another limitation of this study is over estimated rate of full vaccination in different survey years compare to the report. Some crucial factors, such as the mothers' employment status, distance from the health facility, transportation to the health facility, pregnancy intention, preceding birth space, the mother's age at delivery, the women's decision-making power etc., were not analyzed in this study due to unavailability of the data.

5. Conclusions

Individual and community-level factors were significantly associated with full childhood immunisation. Among the individual-level factors, mothers' education level, wealth index, children's age, exposure to mass media, family size, having children's vaccination card, and at least 4 ANC visits had a strong association with full childhood immunisation. Furthermore, this study identified that the place of residence, poverty, women's education, and ANC utilisation at the community-level were associated with full childhood immunisation. Addressing the risk factors of full childhood immunisation and protecting children from infectious diseases are needed. Therefore, the vaccination rate is still low in Bangladesh, so it is essential to increahe child vaccination coverage by promoting institutional delivery and maternal care visits, as well as maternal education. Further, community people initiatives necessary to increase child vaccination and husband's education, media advertisement and additional development of health care services for women should be made to continue further progresses in child vaccination. Furthermore, strategies and programs intended at addressing cluster disparities in child vaccination want to be conveyed.

Strengths and limitations of this study

- This study explored cross-sectional data pooled from the recent four rounds of Bangladesh Demographic and Health Survey (BDHS) to investigate the associations between individual and community-level factors of full childhood immunisation.
- Individual-level and community-level factors were analysed, accounting for the clustering and hierarchical structure of data collected from people living in different geographical units
- After adjusting for individual-level factors, community-level factors such as community poverty, community women's education, community ANC utilisation, and community institutional delivery had a significant impact on full childhood immunisation.
- A causal relationship cannot be drawn due to the cross-sectional design of the surveys, and the vaccination coverage was recorded based on children's immunization cards and interviews with mothers.

Contributors

MAS and BA contributed to the design of the study, literature review and data analysis. MAS, KYL, SAK and BA wrote the manuscript. SAK, KYL, RH, MKA and BA critically reviewed and revised the manuscript for its intellectual content. All authors read and approved the final manuscript.

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Patient and Public Involvement statement

Not required.

Ethical approval

The Bangladesh Demographic and Health Survey (BDHS) was conducted under the authority of the National Institute of Population Research and Training (NIPORT) of the Ministry of Health and Family Welfare (MOHFW). Since BDHS data is a secondary and publicly available data, so further research ethical approval was not required.

Provenance and peer review

Not commissioned; externally peer-reviewed.

Data availability statement

Data are available at: https://dhsprogram.com/data/available-datasets.cfm.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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