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Socio-demographic determinants of timely adherence to BCG, Penta3, measles, and complete vaccination schedule in Burkina Faso

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ABSTRACT

Objective: To identify the determinants of timely vaccination among young children in the North-West of Burkina Faso.
Methods: This study included 1665 children between 12 and 23 months of age from the Nouna Health and Demographic Surveillance System, born between September 2006 and December 2008. The effect of socio-demographic variables on timely adherence to the complete vaccination schedule was studied in multivariable ordinal logistic regression with 3 distinct endpoints: (i) complete timely adherence, (ii) failure, and (iii) missing vaccination. Three secondary endpoints were timely vaccination with BCG, Penta3, and measles, which were studied with standard multivariable logistic regression.
Results: Mothers' education, socio-economic status, season of birth, and area of residence were significantly associated with failure of timely adherence to the complete vaccination schedule. Year of birth, ethnicity, and the number of siblings was significantly related to timely vaccination with Penta3 but not with BCG or measles vaccination. Children living in rural areas were more likely to fail timely vaccination with BCG than urban children (OR = 1.79, 95%CI = 1.24–2.58 (proximity to health facility), OR = 3.02, 95%CI = 2.18–4.19 (long distance to health facility)). In contrast, when looking at Penta3 and measles vaccination, children living in rural areas were far less likely to have failed timely vaccinations than urban children. Mother's education positively influenced timely adherence to the vaccination schedule (OR = 1.42, 95%CI 1.06–1.89). There was no effect of household size or the age of the mother.
Conclusions: Additional health facilities and encouragement of women to give birth in these facilities could improve timely vaccination with BCG. Rural children had an advantage over the urban children in timely vaccination, which is probably attributable to outreach vaccination teams amongst other factors. As urban children rely on their mothers' own initiative to get vaccinated, urban mothers should be encouraged more strongly to get their children vaccinated in time.

1. Background

The success and cost-effectiveness of vaccination as public health intervention is widely acknowledged [1–3]. Vaccination has contributed to major global reductions in morbidity and mortality [4,5]. Despite its overwhelming success, vaccine preventable diseases remain a major health problem among children in developing countries. The World Health Organization (WHO) and the United Nations Children's Funds (Unicef) estimate that 1.5 million children worldwide continue to die from vaccine-preventable diseases every year because of inadequate vaccination coverage (delayed vaccination, incomplete or non-vaccination) mainly in Sub-Sahara Africa (SSA) and South-East Asia [6,7]. This underlines the particular need for continued monitoring of vaccination program performance to detect potential problems and to identify appropriate solutions in the above regions.

There has been a significant increase in vaccination coverage in SSA during the last decades [7,8]. However, it has been demonstrated that high vaccination coverage does not imply that children are vaccinated according to the schedule [9–16]. Furthermore, vaccines can have non-specific effects on morbidity and mortality among children, particularly in high mortality areas [17–19]. These effects can be influenced by the timeliness of vaccination, with potential negative consequences of delayed vaccination [12,20,21].

Abbreviations: BCG, Bacillus Calmette-Guérin; CRSN, Centre de Recherche en Santé; CSPS, peripheral health centre; HDSS, Health and Demographic Surveillance System; OPV, Oral Polio Vaccine; Penta, Pentavalent Vaccine; SES, socio-economic status; SSA, Sub-Saharan Africa; Unicef, United Nations Children's Funds; WHO, World Health Organization.

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At the same time, vaccine doses given early are said to be invalid and must be repeated with administrative, programmatic, and cost implications. Furthermore, vaccines administrated too early contribute to overall coverage figures, leading to an overestimation of actual population immunity [9,22,23]. Thus, timely administration of vaccines has important implications for the success of child immunization programs [15]. However, only limited knowledge exists about factors determining delay in vaccination, particularly in SSA [14,24,25]. This study aims to identify the determinants of timely vaccination among young children in the North-West of Burkina Faso.

2. Methods

2.1. Study area

This study was conducted in the area of the Nouna Health and Demographic Surveillance System (HDSS). In 2010, the Nouna HDSS comprised about 88,650 inhabitants residing in Nouna town and 58 surrounding villages. The study area is a Sub-Sahelian dry orchard savannah with one dry (November–May) and one rainy (June–October) season [6].

The routine vaccination program in Burkina Faso recommends five different vaccines for the prevention of nine infections: (i) Bacillus Calmette-Guérin (BCG), (ii) Oral Polio Vaccine (OPV), (iii) Pentavalent Vaccine for diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b (Penta), (iv) yellow fever vaccine, and (v) measles vaccine. The recommended vaccination schedule in Burkina Faso is BCG and first dose of OPV (OPV0) at birth, first dose of Penta (Penta1) and OPV1 at 8 weeks, Penta2 and OPV2 at 12 weeks, Penta3 and OPV3 at 16 weeks, and measles and yellow fever vaccination at 9 months (270 days) of age. We considered timely vaccination as receiving the respective vaccines within 3 days prior and 28 days after the recommended vaccination date. If vaccination was received more than 3 days prior to or 28 days after the recommended schedule, vaccination was considered early or delayed, respectively (Supplementary Fig. 1).

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Children living in villages with a peripheral health centre (CSPS) have the opportunity to receive routine vaccinations during monthly vaccination sessions. Children living in the other villages in the catchment area of respective CSPS are visited once per month by governmental vaccination teams.

2.2. Data collection

Households of the Nouna HDSS are visited every 3–4 months by trained field workers of the *Centre de Recherche en Santé de Nouna* (CRSN) to register vital events such as births, deaths, and in- and out-migration. With these data, all individuals can be linked to their parents, children, and siblings. The detailed procedures are described elsewhere [6,26].

Since September 2008 an additional questionnaire has been added to the routine visits to derive data on vaccination coverage [14]. Interviewers include all children, who are below five years of age at the time of the visit. Mothers or fathers or, if absent, other household members are asked, if they have a health card for the child. If the card is available, information on all vaccinations is copied into the prepared questionnaire, which also includes a question for the mother's highest educational attainment.

Apart from the routine HDSS data collection, a census was performed in the year 2009, in which data on household assets and housing characteristics were collected [27]. By the HDSS-specific individual identification number, data from the routine HDSS rounds, vaccination survey, and the census have been linked for the purpose of analysis.

The protocol for this study was approved by the local Ethical Committee in Burkina Faso and the Ethical Commission of the Medical School at the Heidelberg University. Informed community consent was sought for the implementation of the additional survey questionnaire on vaccination during routine HDSS procedures.

2.3. Study population

For the present analysis, data from the first round of interviews conducted between September 2008 and December 2009 were considered. This study included children who were between 12 and 23 months old at the time of the visit. This age span was chosen as it is the youngest age group which is likely to have received all basic immunizations according to the Burkinian vaccination schedule. Including children older than 2 years of age would increase the risk of missing health cards or recall bias because the last vaccination dates back some time. Applying exclusion criteria led to a total of 2152 children between 12 and 23 months of age, of whom 1665 could be included in the analysis because the health card had been seen by the interviewer (Supplementary Fig. 2).

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2.4. Statistical analysis

A multivariable ordered logistic regression model was applied to study the effect of the independent variables on timely completion of the total vaccination schedule [28]. The outcome variable was divided into three categories: (1) complete timely adherence, (2) failure, and (3) missing vaccination. If all vaccinations were administered in the time frame of 3 days prior to and 28 days after the recommended age, children were assigned to the category complete timely adherence. The children, who received vaccinations too early or too late, but within the first year of life, were assigned to the category failure. The outcome variable took the value missing vaccination if children had not received one or more vaccinations until their first birthday. For the ordered model, an inherent order was assumed with complete timely adherence as the most favorable outcome and missing vaccination as the most undesirable outcome. In the ordered logistic model, outcome category 3 is compared to categories 1 and 2 and additionally, outcome categories 2 and 3 are compared to category 1.

The effects of different independent predictors on timely fulfillment of the specific vaccinations (i) BCG, (ii) Penta3, and (iii) measles were analyzed in three separate standard multivariable logistic regression models. The outcome could attain two different values: if the respective vaccine was given within 3 days prior to and 28 days after the recommended age, timely vaccination was considered fulfilled and failed otherwise. Penta3 and measles vaccinations could be timely fulfilled, even if this was not the case for any of the preceding vaccinations in the schedule.

Independent variables considered in the multivariable analysis were sex of the child, year of birth (2007/2008 versus 2006), season of birth (dry–rainy), religious affiliation (Christian–Muslim–Animist/other), ethnicity (indigenous–migrant), household size (<11 to 11–20 to >20 members), mother's education (none–any), household socio-economic status (SES) (in quintiles Q1 (lowest) to Q5 (highest)), area of residence (urban–rural and 5 or less kilometers to walk to the closest health facility–rural and more than 5 km to the closest health facility), number of siblings (1–2/3–4 or more), and age of mother at birth of child (<20 to 20–35 to 36+ to unknown).

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The household socio-economic status was created by principal components analysis, including variables on asset ownership, housing characteristics, and ownership of animals and farming material. This was done separately for rural and urban households. Rural and urban households were then divided into quintiles according to the socio-economic status score, respectively [29].

We performed a number of sensitivity analyses: we included those children without health cards into the category of severe failure in the ordered logistic regression, we tested the effect of different cut-offs for timely vaccination (i.e. within 2 weeks prior to and 8 weeks after the recommended schedule), and we used a different variable for mother's education, which also separated between higher education levels. All tests were two-sided and analyses were performed with SAS, version 9.3 (PROC LOGISTIC) software (SAS Institute, Inc., Cary, NC).

3. Results

Vaccination coverage among those 1665 children with a health card was 97% for BCG, 93% for Penta3, and 78% for measles (Table 1). Timely adherence to vaccination schedule was about 70% for BCG vaccination but only 48% for Penta3 and 46% for measles. Most children failed because they received the vaccinations too late or not at all. However, several children failed by receiving vaccines too early, mostly Penta1/OPV1 or measles/yellow fever. At age 140 days, the last possible day to receive timely Penta3 and OPV3 vaccination, about 47% of children were still missing Penta3 (Supplementary Fig. 3) and almost 70% of the study children had failed to adhere to the complete vaccination schedule (Supplementary Fig. 4). Previously, similar numbers have been reported from Burkina Faso and the study area [14,16,30].

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The availability of the health cards varied according to specific factors such as area of residence and mother's education (Supplementary Table 1). Of the 1665 children with available health cards, 307 (18.4%) received all vaccinations within 3 days prior to and 28 days after the recommended schedule. Of the remaining 1358 children who failed to follow the schedule, 431 (25.9%) missed vaccinations at their first birthday (Table 2). Children who lived in the rural area but within 5 km to the closest health facility had the highest timely vaccination proportion (25%). This proportion was much lower in the rural population living at a greater distance to the closest health facility (16%) and lowest in the urban area (15%). Timely vaccination with BCG/OPV0, however, was highest in the urban area (data not shown).

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Area of residence, season of birth, mother's education, and socio-economic status were significant predictors for incomplete adherence to the whole vaccination schedule (Table 3). Children of mothers without any formal education were more likely to fail the timely vaccination schedule than mothers who possessed some reading ability (OR = 1.42, 95%CI 1.06–1.89). Household wealth had a significant influence on vaccination failure. Compared to the least deprived children in quintile 5, all other children were more likely to fail timely vaccination for all recommended vaccines. Surprisingly, the strongest difference was seen between children from quintile 3 and quintile 5 (OR = 1.72, 95%CI 1.26–2.34).

Living in an urban area was strongly associated with failing to adhere to the vaccination schedule. Rural children living within 5 km to the closest health facility were least likely to fail timely completion of the vaccination schedule (OR = 0.58, 95%CI 0.43–0.77). Season of birth was significantly related to complete timely vaccination with children born in the dry season being at higher risk for failure than children born in the rainy season (OR = 1.31, 95%CI 1.08–1.59). Number of household members or number of siblings was not associated with timely vaccination coverage of the complete schedule. Children of older mothers appeared to be less likely to fail the vaccination schedule but this difference was not statistically significant.

The effect of the studied factors on timely vaccination was very heterogeneous for BCG, Penta3, and measles vaccination (Table 4). Children living in rural areas were more likely to fail timely vaccination with BCG than urban children (ORs = 1.79, 3.02). In contrast, when looking at Penta3 and measles vaccination, children living in rural areas were far less likely to have failed timely vaccinations.

The effect of education on timely vaccination was strongest for Penta3 and still significant for measles vaccination. Children of mothers with some education were less likely to fail timely vaccination as compared to mothers without any reading ability. For BCG, there was no effect of mothers' education. Girls were more likely to fail timely vaccination with BCG as compared to boys (OR = 1.24, 95%CI 1.00–1.54). The number of siblings or household members and the age of the mother at birth of the child were in general unrelated to vaccination failure, except that children with one or more sisters or brothers were more likely to fail timely vaccination of Penta3.

Table 1
Adherence to the vaccination schedule for recommended vaccines in 1665 children with a health card seen from the Nouna Health and Demographic Surveillance System, 2008/09.

	Time of vaccination					
	Too early *n* (%)	In time[a] *n* (%)	Delayed *n* (%)	Out of sequence[b] *n* (%)	Missing[c] *n* (%)	Overall coverage[d] (%)
BCG	NA	1159 (69.6)	383 (23.0)	65 (3.9)	58 (3.5)	96.5
Polio0	NA	1245 (74.8)	362 (21.7)	NA	58 (3.5)	96.5
Penta1	156 (9.4)	1101 (66.1)	299 (18.0)	65 (3.9)	44 (2.6)	97.4
Polio1	171 (10.3)	1140 (68.5)	313 (18.8)	NA	41 (2.5)	97.5
Penta2	130 (7.8)	956 (57.4)	520 (31.2)	NA	59 (3.5)	96.5
Polio2	129 (7.7)	958 (57.5)	520 (31.2)	NA	58 (3.5)	96.5
Penta3	93 (5.6)	794 (47.7)	632 (38.0)	29 (1.7)	117 (7.0)	93.0
Polio3	91 (5.5)	811 (48.7)	660 (39.6)	NA	103 (6.2)	93.8
Measles	214 (12.9)	766 (46.0)	286 (17.2)	29 (1.7)	370 (22.2)	77.8

[a] Vaccinations are considered in time if applied within 3 days prior to and 28 days after the recommended age.
[b] Penta1 given before BCG or Penta3 given after Measles.
[c] Missing if not received until age 365 days.
[d] Includes all children except those with missing vaccinations.

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Table 2
Vaccination failures according to the specified vaccination schedule in 1665 children with a health card seen from Nouna Health and Demographic Surveillance System, 2008/09.

Variable	Category	Adherence[a] *n* (%)	Failure[b] *n* (%)	Missing[c] *n* (%)	Total
Respondent	Mother	303 (18.7)	899 (55.5)	419 (25.8)	1621
	Other	4 (9.1)	28 (63.6)	12 (27.3)	44
Sex	Male	156 (18.8)	462 (55.8)	210 (25.4)	828
	Female	151 (18.0)	465 (55.6)	221 (26.4)	837
Year of birth	2007/2008	282 (19.1)	820 (55.6)	374 (25.3)	1476
	2006	25 (13.2)	107 (56.6)	57 (30.2)	189
Season of birth	Rainy	159 (21.7)	401 (54.7)	173 (23.6)	733
	Dry	148 (15.9)	526 (56.4)	258 (27.7)	932
Religion	Christian	102 (21.6)	255 (54.0)	115 (24.4)	472
	Muslim	186 (16.9)	616 (56.1)	297 (27.0)	1099
	Animist/other	19 (20.2)	56 (59.6)	19 (20.2)	94
Ethnicity	Indigenous	230 (19.2)	674 (56.3)	294 (24.5)	1198
	Migrant	77 (16.5)	253 (54.2)	137 (29.3)	467
Household size	1–10 members	166 (19.3)	480 (55.8)	214 (24.9)	860
	11–20 members	103 (16.9)	337 (55.4)	168 (27.6)	608
	More than 20	38 (19.3)	110 (55.8)	49 (24.9)	197
Education	Any	57 (24.8)	118 (51.3)	55 (23.9)	230
	None	250 (17.4)	809 (56.4)	376 (26.2)	1435
Wealth quintile	Q5 (highest)	84 (21.6)	219 (56.4)	85 (21.9)	388
	Q4	54 (16.5)	197 (60.1)	77 (23.5)	328
	Q3	44 (14.7)	159 (53.2)	96 (32.1)	299
	Q2	50 (20.9)	128 (53.6)	61 (25.5)	239
	Q1 (lowest)	41 (20.5)	110 (55.0)	49 (24.5)	200
	Unknown	34 (16.1)	114 (54.0)	63 (29.9)	211
Area of residence	Urban	52 (14.8)	188 (53.6)	111 (31.6)	351
	Rural ≤ 5 km	124 (25.4)	260 (53.2)	105 (21.5)	489
	Rural > 5 km	131 (15.9)	479 (58.1)	215 (26.1)	825
Number of siblings	0	60 (17.9)	185 (55.1)	91 (27.1)	336
	1–3	139 (18.5)	401 (53.5)	210 (28.0)	750
	4+	87 (19.0)	271 (59.0)	101 (22.0)	459
	Unknown	21 (17.5)	70 (58.3)	29 (24.2)	120
Age of mother at birth	20–35	204 (18.3)	624 (55.9)	289 (25.9)	1117
	<20	37 (18.5)	103 (51.5)	60 (30.0)	200
	36+	43 (21.2)	117 (57.6)	43 (21.2)	203
	Unknown	23 (15.9)	83 (57.2)	39 (26.9)	145
Total		307 (18.4)	927 (55.7)	431 (25.9)	1665

[a] Received all recommended vaccinations within 3 days prior to and 28 days after recommended time.
[b] Received vaccinations earlier than 3 days prior to or later than 28 days after recommendation.
[c] Missing vaccinations (at age 365 days).

4. Discussion

The present study shows that only a minority of children received timely vaccination according to the recommended schedule in Burkina Faso. This result is in line with others studies conducted in SSA and elsewhere [12,16,31]. Two studies on the effect of distance to the closest health facility on vaccination timeliness were conducted in Kenya and Tanzania. In Kenya, the authors did not observe any association between distance to the closest vaccination site and delay of vaccination [32]. In the Tanzanian study, children living farther than 5 km from the closest health facility were significantly more likely to receive late vaccination with BCG, while there was no significant association with the other vaccinations [25]. In the present study, area of residence had a strong effect on timely BCG vaccination, where children born in the urban area were significantly more likely to be vaccinated on time. This is most likely explained by the fact that many children in the urban setting were born in health facilities and therefore were vaccinated with BCG immediately after birth. In the present study an opposite effect of area of residence is seen for Penta3 and measles vaccination. This can be attributed to Burkina Faso's outreach activities with one monthly visit of a vaccination team to each village. Although the urban area has a better health infrastructure compared to the surrounding villages, caregivers need to take their children to the health facilities by their own initiative, while rural villages are visited by a vaccination team each month. When looking at the effect of distance on complete vaccination coverage, the present results contrast with common findings, which relate increasing distance to a health facility to a higher probability of incomplete vaccination coverage [33,34].

Education was a strong factor influencing timely adherence to the complete vaccination schedule. Some reading ability may facilitate understanding of the recommended vaccination schedule, which is especially important to mothers in the urban area who have to bring their children to the vaccination sites by their own initiative. Several studies support the finding of higher education being related to better adherence to the vaccination schedule [9,10,35,36]. However, comparisons are made on higher educational levels such as secondary versus primary school, while there is less research on literacy [37].

The effect of SES on overall timely vaccination and vaccination with Penta3 was much higher in the urban area as compared to the

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Table 3
Factors associated with failure of full timely vaccination in 1665 children from Nouna Health and Demographic Surveillance System, 2008/09.

Variable	Category	*N*	OR[a]	95%CI[b]	*P*-value[c]
Sex	Boys[d]	828			0.37
	Girls	837	1.09	0.90–1.31	
Year of birth	2007/08[d]	1476			0.25
	2006	189	1.19	0.88–1.61	
Season of birth	Rainy[d]	733			0.006
	Dry	932	1.31	1.08–1.59	
Religion	Christian[d]	472			0.57
	Muslim	1099	1.04	0.82–1.31	
	Animist/other	94	0.82	0.53–1.28	
Ethnicity	Indigenous[d]	1198			0.33
	Migrant	467	1.12	0.89–1.40	
Household size	1–10[d]	860			0.64
	11–20	608	1.09	0.88–1.36	
	21+	197	0.97	0.69–1.35	
Education	Any[d]	230			0.02
	None	1435	1.42	1.06–1.89	
Wealth quintile	Q5 (highest)[d]	388			0.02
	Q4	328	1.25	0.93–1.68	
	Q3	299	1.72	1.26–2.34	
	Q2	239	1.24	0.88–1.74	
	Q1 (lowest)	200	1.25	0.87–1.81	
	Unknown	211	1.51	1.08–2.12	
Area of residence	Urban[d]	351			0.0007
	Rural ≤5 km	489	0.58	0.43–0.77	
	Rural >5 km	825	0.79	0.61–1.03	
Number of siblings	0[d]	336			0.61
	1–3	750	1.11	0.83–1.49	
	4+	459	0.97	0.69–1.36	
	Unknown	120	0.90	0.52–1.55	
Age of mother at birth	20–35[d]	1117			0.43
	<20	200	1.13	0.80–1.60	
	36+	203	0.82	0.60–1.13	
	Unknown	145	1.24	0.78–1.98	

[a] Odds ratio based on multivariable ordered logistic regression analysis.
[b] 95% confidence interval.
[c] *P*-value from Wald test.
[d] Reference category.

rural areas, with odds ratios between 2.3 and 5.6 for comparison of quintiles 1–4 with the least deprived quintile (data not shown). Other studies support the finding of the least deprived children having the highest timely adherence to the complete vaccination schedule [11,12,23].

Family characteristics such as household size, number of siblings, and age of the mother were shown to influence adherence to the vaccination schedule in the literature [9,10,23]. However, these effects were not shown in the present analysis, the only exception being an increase of vaccination failure of Penta3 with increasing number of older siblings.

Later year of birth was associated with better timely vaccination. This observation attests a positive trend of vaccination program performance in the study area over the years.

Nouna HDSS comprises rural villages as well as the urban area of Nouna town, so the present study was able to look into rural–urban differences. The majority of children failed to adhere to the complete vaccination schedule in a timely manner but only one quarter failed severely. These differences in severity were exploited by the ordered logistic regression used. Other studies mainly used standard logistic regression or Cox regression [23,32,36,38,39], which both have disadvantages. While in standard logistic regression every failure of timely vaccination is weighted equally, Cox regression inherently assumes that earlier failures in time are more severe than later failures. Both hypotheses might not be true when looking at failure of timely vaccination, especially concerning early vaccinations.

It is a major issue for all studies looking at timely vaccinations that thresholds are rather arbitrary and cannot be compared between countries due to the different vaccination schedules. We assume, however, that we chose thresholds which are appropriate for our study setting, where vaccination teams visit each village monthly. We assumed vaccination three days prior to and 28 days after the recommended schedule as suitable, so every child had the chance to be visited by a vaccination team within this time frame at least once. Comparable time frames have also been used in previous research from Burkina Faso and other African countries [11,23,40]. In a sensitivity analysis using less stringent thresholds for timely vaccination, we detected the same effects as in the present analyses.

We assume that vaccination timeliness and coverage differ between the children with and without health cards. In spite of this likely being true for some of the influential variables as well, we believe that associations shown in analysis are true associations not confounded by the availability of the health cards. In a sensitivity analysis, where children without health cards were assigned missing vaccination for the complete schedule and failure for the vaccination-specific analyses, the main findings were largely comparable, especially for our main findings on mothers' education and area of residence.

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Table 4
Factors associated with failure of timely fulfillment of vaccination with BCG, Penta3, and Measles in 1665 children from Nouna Health and Demographic Surveillance System, 2008/09.

Variable	Category	*N*	BCG			Penta3			Measles		
			OR[a]	95%CI[b]	*P*-value[c]	OR[a]	95%CI[b]	*P*-value[c]	OR[a]	95%CI[b]	*P*-value[c]
Sex	Boys[d]	828			0.05			0.75			0.11
	Girls	837	1.24	1.00–1.54		1.03	0.85–1.26		1.18	0.97–1.43	
Year of birth	2007/08[d]	1476			0.10			0.002			0.43
	2006	189	1.32	0.94–1.84		1.69	1.21–2.35		1.14	0.83–1.56	
Season of birth	Rainy[d]	733			0.83			0.20			0.0003
	Dry	932	1.02	0.82–1.28		0.87	0.71–1.07		1.46	1.19–1.78	
Religion	Christian[d]	472			0.02			0.87			0.46
	Muslim	1099	1.47	1.12–1.94		0.98	0.77–1.26		0.95	0.74–1.21	
	Animist/other	94	1.04	0.63–1.73		0.88	0.56–1.40		0.75	0.47–1.18	
Ethnicity	Indigenous[d]	1198			0.66			0.01			0.05
	Migrant	467	1.06	0.82–1.36		1.36	1.07–1.73		1.26	1.00–1.59	
Household size	1–10[d]	860			0.87			0.52			0.92
	11–20	608	0.94	0.73–1.20		1.12	0.89–1.42		0.96	0.76–1.21	
	21+	197	0.96	0.66–1.40		1.18	0.83–1.69		1.01	0.71–1.43	
Education	Any[d]	230			0.72			0.0005			0.03
	None	1435	1.07	0.75–1.51		1.73	1.27–2.36		1.41	1.04–1.90	
Wealth quintile	Q5 (highest)[d]	388			0.34			0.01			0.09
	Q4	328	1.12	0.80–1.58		1.49	1.09–2.04		1.09	0.80–1.49	
	Q3	299	1.38	0.97–1.96		1.88	1.35–2.62		1.54	1.11–2.14	
	Q2	239	1.02	0.69–1.52		1.51	1.06–2.17		1.31	0.92–1.87	
	Q1 (lowest)	200	1.08	0.70–1.66		1.39	0.94–2.05		1.17	0.80–1.71	
	Unknown	211	0.90	0.61–1.33		1.56	1.09–2.23		1.47	1.03–2.10	
Area of residence	Urban[d]	351			<.0001			<.0001			0.005
	Rural ≤5 km	489	1.79	1.24–2.58		0.40	0.29–0.55		0.60	0.44–0.82	
	Rural >5 km	825	3.02	2.18–4.19		0.61	0.46–0.81		0.72	0.54–0.95	
Number of siblings	0[d]	336			0.49			0.05			0.77
	1–3	750	1.01	0.72–1.41		1.41	1.03–1.92		0.99	0.73–1.35	
	4+	459	0.81	0.54–1.20		1.66	1.15–2.39		0.96	0.67–1.37	
	Unknown	120	1.07	0.57–2.00		1.09	0.61–1.96		0.75	0.42–1.33	
Age of mother at birth	20–35[d]	1117			0.69			0.34			0.27
	<20	200	1.23	0.83–1.81		1.15	0.79–1.66		0.90	0.63–1.30	
	36+	203	1.14	0.78–1.65		0.96	0.68–1.35		0.83	0.59–1.16	
	Unknown	145	1.08	0.63–1.84		1.56	0.94–2.59		1.45	0.88–2.40	

[a] Odds ratio from multivariable logistic regression.
[b] 95% confidence interval.
[c] *P*-value from Wald test.
[d] Reference category.

Due to a restricted sample size, we were not able to examine higher education of the mother in detail. However, mothers' education has been shown to significantly influence timely adherence to the vaccination schedule for all vaccinations except BCG despite the grouping of all educational levels. In sensitivity analyses with different groupings of mothers' education, odds ratios generally maintained their original direction and magnitude.

In conclusion, area of residence was the strongest factor influencing timely vaccination with specific vaccines and overall. Urban children and children having a health facility within 5 km of reach had least failures of BCG vaccination. If this is in fact attributable to the higher proportion of women giving birth in a health facility, additional health facilities and encouragement of women to give birth in these facilities could not only reduce complications at birth but also improve timely vaccination with BCG. As was shown for Penta3, measles, and overall timely adherence, rural children had an advantage over the urban children, which is probably attributable to the outreach vaccination teams amongst other factors. As urban children rely on their mothers' own initiative to get vaccinated, urban mothers should be encouraged more strongly to get their children vaccinated in time. As literacy is a strong factor contributing to timely vaccination, the proportion of children not timely vaccinated should decrease by provision of better education and literacy.

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