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Research Article

Partial Proportional Odds of Child Polio Vaccination Status Among Children Aged 12–23 Months in Ethiopia

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Background: The poliovirus is mostly transmitted by the fecal–oral route and can cause viremia after replication in the gastrointestinal tract. The current global coverage of polio immunization is 85%, against the 90% target, while the total coverage of inactivated polio vaccine (IPV) coverage in sub-Saharan Africa is 73%. Only 30% of the children living in rural areas of Ethiopia were fully vaccinated at the appropriate ages in 2016 EDHS (Ethiopian Demographic and Health Survey) data. This study evaluated the prevalence and factors associated with the vaccination status of children aged 12 and 23 months in Ethiopia.
Methods: The Ethiopian Mini Demographic and Health Survey 2019 (Mini EDHS, 2019) was used for this study. The partial proportional ordinal logistic regression model was used to determine the risk factors associated with the polio vaccination status of children aged 12 and 23 months using SAS version 9.40 statistical software at a 5% level of significance.
Results: The prevalence of polio vaccination status of children showed that about 33.00% of children never received vaccination, 21.20% were partially vaccinated, and 45.70% were fully vaccinated. The age of mother (AOR [adjusted odds ratio] = 1.06, 95% CI: 1.025, 1.094), age of mother at the first birth (AOR = 0.94, 95% CI: 0.909, 0.976), rural residence (AOR = 0.66; 95% CI: 0.499, 0.867), higher education (AOR = 1.25; 95% CI: 1.241, 1.730), at least four and more ANC (AOR = 2.34; 95% CI: 1.845, 2.968), and ANC visits in health facilities (AOR = 2.33, 95% CI: 1.902, 2.864) had a significant effect on child polio vaccination.
Conclusion: The coverage of full polio vaccination in Ethiopia was below 50%, which is below the global and regional percentage. Policies and programs must be formulated and implemented with a strong focus on women who have not used ANC visits, residents in rural areas, and uneducated women in child vaccination must be considered in Ethiopia.

Keywords: childhood; partial proportional odds model; polio vaccination; polio virus

1. Background of the Study

Poliovirus (PV) is the most infectious and incurable viral disease caused by a live vaccine-derived virus that remains endemic [1]. Poliomyelitis, an acute viral disease of the central nervous system of humans, can be effectively controlled and eliminated through the use of the inactivated polio vaccine (IPV) or the live attenuated oral polio vaccine (OPV) [2]. The PV can be divided into three different serotypes, such as PV1, PV2, and PV3, and can cause poliomyelitis and other neurological disorders, which could be found a serious infectious disease and can cause permanent residual paralysis [1].

Approximately, 1.5 million children die each year due to diseases that can be avoided by vaccination [3]. Children everywhere are susceptible to polio illnesses as long as they are infected. If polio is not controlled in these final strongholds, there could be up to 200,000 new cases for 10 years worldwide annually [4].

Vaccination policies in posteradication era discussions are still being discussed, with stalled progress toward the

radication of PV circulation in most regions and countries worldwide [5, 6]. After the global eradication of PVs, the potential persistence and circulation of vaccine-derived PVs is a risk that cannot be underestimated when advancing strategies to stop PV vaccination [6]. The current global coverage of polio immunization accounts for 85%, against the 90% target, while the total coverage of IPV coverage in sub-Saharan Africa is 73% [7]. According to the World Health Organization's (WHO) guidelines, children are considered fully vaccinated against polio when they have received all recommended vaccination doses during the age of 12–23 months [8–10].

The Ethiopian Demographic and Health Survey (EDHS) indicates that the percentage of children aged 12–23 months who are fully vaccinated increased by 15%, from 24% in 2011 to 39% in 2016 [11]. The EDHS (2016) showed that only 30% of children living in rural areas were fully vaccinated at the appropriate ages. Furthermore, only 53% of children in rural areas had received the three full recommended doses of OPV (OPV 3) [12]. Unvaccinated travelers, especially children, pregnant women, and those with weakened immune systems who travel to areas with outbreaks of polio are at risk [13]. However, countries that have been cleared from wild PV, but with low vaccination rates and weak PV surveillance systems, continue to be at risk of reintroduction of the virus due to imported cases [14]. Again, surveillance evolves according to epidemiological changes, and indications of the performance of the surveillance system given by the WHO may be susceptible to the integration of additional analysis systems [15].

Polio constitutes a major cause of death among years of age under-five children and shows that most studies conducted on childhood vaccination focused on basic childhood vaccines together to determine whether a child was fully vaccinated or not. This method makes it challenging to comprehend the circumstances around particular immunizations, such as the polio vaccine. Different studies try to investigate the prevalence of vaccination status and factors associated among children aged 12–23 months in Ethiopia using the BCG, polio, and pentavalent vaccine (DTP-hepB-Hib), pneumococcal conjugate vaccine (PCV), measles [16–18] jointly. The other study [19] shows the predictors of incomplete polio vaccination among children aged 12–23 months in Ethiopia separately, but the study categorizes the outcome variable of the vaccination status dichotomies variable in fully vaccinated and incomplete vaccination. Due to inadequate information on childhood vaccination against polio in Ethiopia, the severity and descriptions of it are quite scarce. Therefore, this study aimed to examine the prevalence and factors associated with different vaccination statuses against polio among children aged between 12 and 23 months using ordinal logistic regression in Ethiopia.

2. Materials and Methods

2.1. Source of Data. The Mini EDHS, 2019, on the polio vaccination status of children aged 12–23 months was used for this current investigation. The survey was conducted between March 21, 2019 and June 28, 2019, based on a nationally representative sample that provided national and regional estimates for urban and rural areas [20]. The outcome variable of the study was vaccination status, which classified into three categories, such as, not vaccinated, partially (incompletely) vaccinated, and fully vaccinated (received all three doses of oral polio vaccine (OPV). Considering the WHO protocol not vaccinated doesn't receive any vaccine, three doses of oral polio vaccine [21, 22]; Incomplete vaccination is for children who missed at least one dose of the three vaccines between 12 and 23 months, [23, 24] and fully vaccinated also defined a child aged 12–23 months old who receives all three doses of oral polio vaccine. Therefore, polio vaccination was captured as an ordinal variable and coded 0 if a child had no polio vaccination, 1 if a child had missed at least one dose from three doses of polio vaccine and 2 if a child had complete three doses of polio vaccine [25, 26].

2.2. Variables of the Study

2.2.1. Outcome Variable. The vaccination status was the outcome variable of the study and was classified into three categories, such as, not vaccinated, partially (incompletely) vaccinated, and fully vaccinated. Considering the WHO protocol not vaccinated is defined as a child aged 12–23 months who did not receive any vaccine [21, 22]. Incomplete vaccination is children who missed at least one dose of the four vaccines between 12 and 23 months [23, 24] and fully vaccinated also defined a child aged 12–23 months old who receives all doses of vaccine. Therefore, polio vaccination was captured as an ordinal variable and coded 0 if a child aged between 12 and 23 months had no polio vaccination, 1 if a child between 12 and 23 months had missed at least one dose of the four basic doses of OPV (polio 0 at birth, polio 1 at 6 weeks polio 2 at 10 weeks, and polio 3 at 14 weeks) and 2 if a child aged between 12 and 23 months had complete polio vaccination [25, 26].

2.3. Statistical Analysis. The SAS version 9.4 statistical software was used to analyze the data. Frequencies and percentages were used to describe the categorical variables of the study. The response variables for polio vaccination status were ordered in nature. Models for ordinal outcome variables are important in many areas of research, as respondents are often classified on an ordinal or graded scale. All variables with p-values < 0.05 have been considered statistically significant.

2.4. Ordinal Regression Model. The ordinal proportional odds model (OPOM) was used to identify the factors associated with childhood polio vaccination status grouped into nonvaccinated, partially vaccinated, and partially vaccinated [27]. The general form of the ordinal regression model may be written as follows:

$$f\left(Y_j(x)\right) = \log\left(\frac{f\left(Y_j(x)\right)}{1 - f\left(Y_j(x)\right)}\right) = \log\left(\frac{pr(y \le j|\boldsymbol{x})}{pr(y > j|x)}\right) = \alpha_j + \beta x, j = 1, \ldots, J-1,$$

$$Y_j(x) = \frac{\mathrm{Exp}\left(\alpha_j + \beta x\right)}{1 + \mathrm{Exp}\left(\alpha_j + \beta x\right)}.$$

There are several ordinal logistic regression models, such as the proportional odds model (POM), the partial proportional

odds model (PPOM) without restrictions and with restrictions, the continuous ratio model, and the stereotype model. This study used POM and PPOM.

2.5. The POM. The POM is used as a tool to model the ordinal nature of a dependent variable by defining cumulative probabilities instead of considering the probability of an individual event [28]. The POM assumes that cumulative logits can be represented as parallel linear functions of independent variables [28].

Let Y be the response variable with ordered categories:

$$\text{Odds}\,(pr(Y \le j)) = \left(\frac{pr(Y \le j))}{1 - pr(Y \le j))}\right) = \frac{\pi_j}{1 - \pi_j},$$
$$\text{where } j = 1, 2 \ldots k - 1.$$

The proportional odds of the cumulative probability model are the logarithmic odds of the first k –1 cumulative probability as follows:

$$\text{Logit}\,(pr(Y \le j)) = \log\left(\frac{pr(Y \le j))}{1 - pr(Y \le j))}\right) = \log\left(\frac{\pi_j}{1 - \pi_j}\right),$$
$$\text{where } j = 1, 2 \ldots k - 1.$$

Then, the logit or log-odds of having $pr(Y \le j) = \pi_j$ is modeled as a linear function of the explanatory variables as follows:

$$\text{Logit}\,(pr(Y \le j)) = \log\left(\frac{pr(Y \le j))}{1 - pr(Y \le j))}\right) = \log\left(\frac{\pi_j}{1 - \pi_j}\right) = \alpha_j + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p,$$

where $0 \le \pi_j \le 1$ and $j = 1, 2 \ldots k–1$.

2.6. Testing of Parallel Lines. For the proportional odds ordinal regression model, the assumption of parallel lines of all levels of categorical data is satisfied [29]. Thus, the assumption of parallel lines must be tested. The proportionality assumptions for POM were checked using χ^2 parallel line tests [30].

2.7. PPOM. The PPOM formulated by the study [31] imposes constraints on parallel lines only where they are needed. The POM equation is now extended to accommodate the unconstrained parameters that violated the assumption. The model has the following form [31]:

$$\lambda_j(\mathrm{x}) = \log\left(\frac{pr\ (Y = 1/x) + \ldots Y = j/x)}{pr(Y = j + 1/x) + \ldots Y = k/x)}\right) = \frac{\sum_1^j pr(Y = j/x)}{\sum_{j+1}^k pr(Y = j + 1/x)},$$

$$\lambda_j(\mathrm{x}) = \alpha_j + \left\{\left[\beta_1 + \gamma_{j1}\right]x_1 + \ldots + \left[\beta_q + \gamma_{jq}\right]x_q + \left[\beta_{q+1}x_{q+1}\ldots + \left[\beta_p x_p\right\}, \text{where } j = 1, 2 \ldots k - 1.\right.\right.$$

If there is then a set of restrictions γ_{k1} may be included in the model to clarify this linearity. When these restrictions are included, this model is called the restricted PPOM. The τ_j parameters are fixed scale parameters that take the form of restrictions allocated to the parameters. In this case, for a given coverable, α_p does not depend on the cut-off points but is multiplied by τ_j for each jth logit. The model becomes [31]:

$$\lambda_j(\mathrm{x}) = \log\left(\frac{pr\ (Y = 1/x) + \ldots Y = j/x)}{pr(Y = j + 1/x) + \ldots Y = k/x)}\right) = \frac{\sum_1^j pr(Y = j/x)}{\sum_{j+1}^k pr(Y = j + 1/x)},$$

$$\lambda_j(\mathrm{x}) = \alpha_j + \left\{\tau_j\left(\left[\beta_1 + \gamma_{j1}\right]x_1 + \ldots + \left[\beta_q + \gamma_{jq}\right]x_q + \left[\beta_{q+1}x_{q+1}\right] + \ldots + \left[\beta_p x_p\right\}, \text{where } j = 1, 2 \ldots k - 1.\right.\right.$$

2.8. Ethical Consideration. This study used a secondary source of data, which is publicly available survey data from the EDHS programs, ethical approval, and participant consent were taken when the data were collected, but were not necessary for this study. We requested the DHS program and permission was granted to download and use the data for this study from http://www.dhsprogram.com/data/availabledatasets.cfm. There are no names of individuals or household addresses in the data files. Therefore, ethical approval was not necessary for this study.

3. Result and Discussion

3.1. Coverage of Polio Vaccination in Ethiopia. From the total children sampled in Ethiopia, 1060 (33.00%) were not vaccinated, 681 (21.20%) were partially vaccinated, and 1467 (45.70%) had received all recommended polio vaccinations (Figure 1). Therefore, fewer than half of children (45.70%) have received all recommended polio vaccinations in Ethiopia.

3.2. Sociodemographic and Economic Characteristics of Parents and Children. Most of the study's participants were rural residents (76.12%), of these 38.53%, 22.15%, and 39.31% were not vaccinated, partially vaccinated, and fully vaccinated, respectively. Most mothers of children (51.37%) were not educated, but a small number of mothers (5.74%) had higher education. About more than half of respondents (65.77%) had no source of information about polio vaccination. Similarly, almost all respondents in the households (94.98%) had no transportation system to a health facility. More than a fourth of the respondents (79.83%) were male household heads. About 49.69%, 14.00%, and 36.32% of the households had a poor, middle, and rich wealth status. About 94.30% of the women were married, 2.24% were living alone (single), and 3.46% were divorced and widowed. Most of the children in this study (97.85%) were single births, and the other (2.15%) were twins. A low number of mothers of children (9.85%) were currently pregnant. About 33.79%, 29.05%, and 37.16% of mothers had no ANCV visits one to three ANCV visits and more than three ANCV visits, respectively. Finally, ~46.54%, 47.97%, and 5.49% of mothers flowed their ANCV visit at a home,

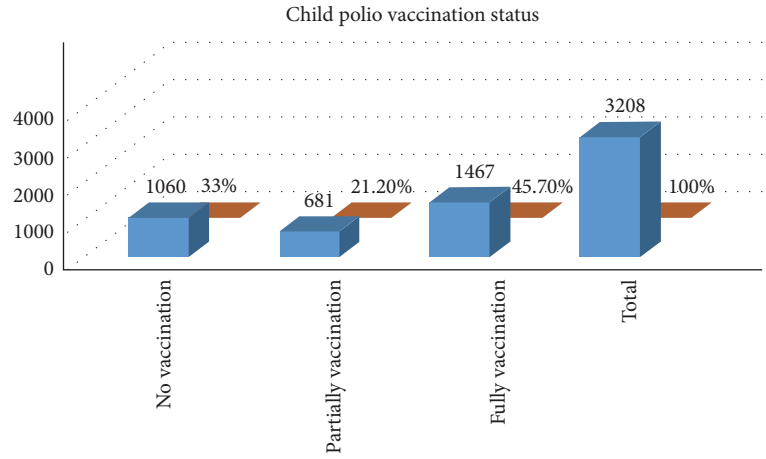

FIGURE 1: Prevalence of children's status of polio vaccination between 12 and 23 months in Ethiopia.

government health sector, and private health sector, respectively (Table 1).

3.3. Determinants of Polio Vaccination Coverage Among Children Aged 12–23 Months

3.3.1. Test of Proportional Odds Assumption. The proportional odds assumption indicates that the estimated average logits for all categories in the distinct variable are almost parallel in shape, except for the variable region and the educational level of the mother. The average logarithms of different categories for the region (p-value = 0.024) and the educational level of the mother (p-value < 0.001) did not support the parallel line assumption of POM. Furthermore, the general score test of proportional odds assumption (p-value = 0.023) violated the assumption of a parallel line of POM (Table 2). Since this variable violated the assumption of proportional odds, this interpretation may be invalid. Therefore, this study used a PPOM.

3.3.2. Partial Proportional Odds Ordinal Logistic Regression Analysis. The final selected PPOM showed that age of the mother, age of mother at first birth, number of children under 5 years of age in the household, birth order, region, residence, mother's educational level, religion, duration of breastfeeding, number of ANC and place of ANC visit were factors significantly associated with childhood polio vaccination status in Ethiopia. The age of the mother was 1.06 (AOR [adjusted odds ratio] = 1.06, 95% CI: 1.025, 1.094) times more likely to have been partially or fully vaccinated for polio vaccination when the age of the mother increased by 1 year.

The age of the mother at the first birth was 0.94 (AOR = 0.94, 95% CI: 0.909, 0.976) times less likely to have been partially or fully vaccinated against polio when the age of the mother increased by a year. The number of years of age under-five children was 0.81 (AOR = 0.81, 95% CI: 0.710, 0.923) times less likely to be partially or fully vaccinated with child polio vaccination when the age of the mother increases by 1 year. Birth orders were 0.90 (AOR = 0.90, 95% CI: 0.819, 0.980) times less likely to be partially or fully vaccinated for child polio vaccination when the age of the mother increases by a year. The odds of fully vaccinating children with polio in the Afar region were 0.55 times compared to the Tigray region (AOR = 0.55; 95% CI: 0.324, 0.948). The odds of partial or full polio vaccination of children compared to those without vaccination who lived in rural areas were 0.66 times compared to the urban area (AOR = 0.66; 95% CI: 0.499, 0.867). The odds of fully vaccinated children compared to those without vaccination with mothers who had attended primary and higher education were 1.15 (AOR = 1.15; 95% CI: 1.020, 1.568) and 1.25 (AOR = 1.25; 95% CI: 1.241, 1.730) times compared to those without education, respectively. Children in the Protestant religion households compared to Orthodox had 0.63 (AOR = 0.63; 95% CI: 0.449, 0.882) times less likely to be partially or fully vaccinated of children. Children whose mothers made one to three and at least four or more visits to ANC during pregnancy were 1.74 (AOR = 1.74; 95% CI: 1.398, 2.160) and 2.34 (AOR = 2.34; 95% CI: 1.845, 2.968) times more likely to be partially or fully vaccinated than children whose mothers did not have any antenatal follow up. Children who never breastfed or have ever breastfed but are not currently breastfeeding were 0.65 (AOR = 0.65; 95% CI: 0.419, 0.993) and 0.70 (AOR = 0.70; 95% CI: 0.575, 0.842) times less likely to be partially or fully vaccinated than children who are still breastfed.

Finally, the place of ANC visit to health facilities was 2.33 (AOR = 2.33, 95% CI: 1.902, 2.864) times more likely to be partially or fully vaccinated than the mother's place of visit to ANC at home (Table 3).

4. Discussion

This study aimed to investigate the determinant factors of polio vaccination coverage among children aged 12–23 months in Ethiopia using the EDHS-2019 dataset. In Ethiopia, the prevalence of polio vaccination coverage was 33.0% no vaccination, 21.2% partially vaccinated, and 45.7% fully vaccinated. According to preliminary data from the 2000 EDHS, 35% of childhood were expected to be covered by OPV3 vaccination [32]. The 2016 EDHS report, indicated that about 16% of children aged 12–23 months had not received any polio vaccine, 81% had received their first dose of the polio vaccine, and 56% had

Table 1: Sociodemographic and economic characteristics of parents and children aged 12–23 months.

Children's polio vaccination status by categorical variables cross-tabulation						
Variables	**Categories of the variable**	**Children's polio vaccination status**				χ^2 **test**
		No vaccination	**Partially vaccination**	**Fully vaccination**	**Total**	
Region	Tigray	32 (12.26%)	44 (16.86%)	185 (70.88%)	261 (8.14%)	560.99 (<0.0001)
	Afar	230 (61.99%)	80 (21.56%)	61 (16.44%)	371 (11.56%)	
	Amhara	70 (23.81%)	44 (14.97%)	180 (61.22%)	294 (9.16%)	
	Oromia	134 (33.67%)	95 (23.87%)	169 (42.46%)	398 (12.41%)	
	Somali	184 (57.32%)	79 (24.61%)	58 (18.07%)	321 (10.00%)	
	Benishangul	67 (23.18%)	61 (21.11%)	161 (55.71%)	289 (9.01%)	
	SNNP	150 (41.67%)	82 (22.78%)	128 (35.56%)	360 (11.22%)	
	Gambela	77 (31.17%)	57 (23.08%)	113 (45.75%)	247 (7.70%)	
	Harari	72 (28.69%)	61 (24.30%)	118 (47.01%)	251 (7.82%)	
	Addis Ababa	13 (7.22%)	17 (9.44%)	150 (83.33%)	180 (5.61%)	
	Dire Dawa	31 (13.14%)	61 (25.85%)	144 (61.02%)	236 (7.36%)	
Residence	Urban	119 (15.54%)	140 (18.28%)	507 (66.19%)	766 (23.88)	189.59 (<0.0001)
	Rural	941 (38.53%)	541 (22.15%)	960 (39.31%)	2442 (76.12%)	
Educational level	No education	689 (41.81%)	349 (21.18%)	610 (37.01%)	1648 (51.37%)	174.53 (<0.0001)
	Primary	304 (28.15%)	221 (20.46%)	555 (51.39%)	1080 (33.67%)	
	Secondary	49 (16.55%)	76 (25.68%)	171 (57.77%)	296 (9.23%)	
	Higher	18 (9.78%)	35 (19.02%)	131 (71.20%)	184 (5.74%)	
Have a source of information	Yes	221 (20.13%)	204 (18.58%)	673 (61.29%)	1098 (34.23%)	178.22 (<0.0001)
	No	839 (39.76%)	477 (22.61%)	794 (37.63%)	2110 (65.77%)	
Having own transport system	Yes	17 (10.56%)	33 (20.50%)	111 (68.94%)	161 (5.02%)	45.95 (<0.0001)
	No	1043 (34.23%)	648 (21.27%)	1356 (44.5%)	3047 (94.98%)	
Religion	Orthodox	179 (19.27%)	162 (17.44%)	588 (63.29%)	929 (28.96%)	182.16 (<0.0001)
	Protestant	203 (34.52%)	138 (23.47%)	247 (42.01%)	588 (18.33%)	
	Muslim	648 (39.68%)	370 (22.66%)	615 (37.66%)	1633 (50.9%)	
	Other	30 (51.72%)	11 (18.97%)	17 (29.31%)	58 (1.81%)	
Sex of household head	Male	834 (32.57%)	538 (21.01%)	1189 (46.43%)	2561 (79.83%)	2.52 (0.2840)
	Female	226 (34.93%)	143 (22.10%)	278 (42.97%)	647 (20.17%)	
Wealth index	Poor	732 (45.92%)	351 (22.02%)	511 (32.06%)	1594 (49.69%)	327.68 (<0.0001)
	Middle	138 (30.73%)	96 (21.38%)	215 (47.88%)	449 (14.00%)	
	Rich	190 (16.31%)	234 (20.09%)	741 (63.61%)	1165 (36.32%)	
Currently pregnant	Yes	109 (34.49%)	65 (20.57%)	142 (44.94%)	316 (9.85%)	0.34 (0.8423)
	No	951 (32.88%)	616 (21.30%)	1325 (45.82%)	2892 (90.15%)	
Contraceptive use	No	867 (41.19%)	474 (22.52%)	764 (36.29%)	2105 (65.62%)	246.9 (<0.0001)
	Yes	193 (17.50%)	207 (18.77%)	703 (63.74%)	1103 (34.38%)	
Contraceptive use and intention	Not intend to use	867 (41.19%)	474 (22.52%)	764 (36.29%)	2105 (65.62%)	248.10 (<0.0001)
	Modern method	189 (17.55%)	204 (18.94%)	684 (63.51%)	1077 (33.57%)	
	Traditional method	4 (15.38%)	3 (11.54%)	19 (73.08%)	26 (0.81%)	

Table 1: Continued.

Children's polio vaccination status by categorical variables cross-tabulation						
Variables	**Categories of the variable**	**Children's polio vaccination status**				**χ^2 test**
		No vaccination	**Partially vaccination**	**Fully vaccination**	**Total**	
Currently breastfeeding	No	279 (33.53%)	172 (20.67%)	381 (45.79%)	832 (25.94%)	0.25 (0.8842)
	Yes	781 (32.87%)	509 (21.42%)	1086 (45.71%)	2376 (74.06%)	
Marital status	Single	20 (27.78%)	18 (25.00%)	34 (47.22%)	72 (2.24%)	8.66 (0.1939)
	Married	999 (33.02%)	636 (21.17%)	1390 (45.95%)	3025 (94.30%)	
	Widowed/divorced	41 (36.94%)	27 (24.32%)	43 (38.74%)	111 (3.46%)	
The child is a twin	Single birth	1038(33.07%)	661 (21.06%)	1440 (45.87%)	3139 (97.85%)	2.70 (0.2594)
	Multiple	22 (31.88%)	20 (28.99%)	27 (39.13%)	69 (2.15%)	
Sex of child	Male	531 (32.66%)	338 (20.79%)	757 (46.56%)	1626 (50.69%)	0.94 (0.6241)
	Female	529 (33.44%)	343 (21.68%)	710 (44.88%)	1582 (49.31%)	
The child lives with whom	Respondent	1040 (32.81%)	673 (21.23%)	1457 (45.96%)	3170 (98.81%)	7.64 (0.0220)
	Lives elsewhere	20 (52.63%)	8 (21.05%)	10 (26.32%)	38 (1.18%)	
Duration of breastfeeding	Ever breastfed	318 (32.65%)	193 (19.82%)	463 (47.54%)	974 (29.52%)	33.95 (<0.0001)
	Never breastfed	65 (55.56%)	25 (21.37%)	27 (23.08%)	117 (3.65%)	
	Still breastfeeding	677 (31.98%)	463 (21.87%)	977 (46.15%)	2117 (65.99%)	
ANCA	No ANCV visits	586 (54.06%)	221 (20.39%)	277 (25.55%)	1084 (33.79%)	430.24 (<0.0001)
	1–3 ANCV visit	272 (29.18%)	229 (24.57%)	431 (46.24%)	932 (29.05%)	
	≥ 3 ANCV	202 (16.95%)	231 (19.38%)	759 (63.67%)	1192 (37.16%)	
Place of ANCV delivery	Home	738 (49.43%)	337 (22.57%)	418 (28.00%)	1493 (46.54%)	424.96 (<0.0001)
	Government sector	288 (18.71%)	300 (19.49%)	951 (61.79%)	1539 (47.97%)	
	Private sector	34 (19.32%)	44 (25.00%)	98 (55.68%)	176 (5.49%)	

Table 2: Parallel line test for proportional odds assumption.

Categorical variable	−2 log likelihood	χ^2	Sig
Region	123.07	20.57	0.024
Residence	28.87	1.93	0.165
Educational level	50.35	16.03	<0.001
Source of information	29.50	0.09	0.978
Own transport system	25.94	1.47	0.219
Religion	49.91	0.79	0.852
Wealth	41.357	4.920	0.085
Sex of household head	41.36	4.92	0.085
Marital status	40.324	6.475	0.091
Contraceptive use	29.41	0.84	0.359
Contraceptive use intention	35.319	1.277	0.528
Duration of breastfeeding	39.13	1.94	0.379
Child is twin	25.180	2.198	0.138
ANCV	41.15	0.04	0.993
Place of ANCV	39.80	2.02	0.364
Overall	4591.635	52.346	0.023

received three doses of the polio vaccine [33]. The study of the timeliness of vaccination among newborns and infants in Ethiopia showed that 51.1% of OPV 0 were given after 1 month. Infant vaccine doses were also typically delayed with 63.8% of DTP dose 1, and 63.1% of Polio dose 1. Vaccination coverage ranged from 15.3% for polio dose 0%–76.7% for polio dose 1 [34]. A study conducted in Jigjiga woreda, Somali Region, reported coverage of OPV 0 and OPV 3, according to card and history, of 14.6% and 44.1% [10], and the 2011 EDHS reported coverage of OPV 3 of 44.3% [35]. This study showed an increase in complete vaccination with polio in the child. This can be attributed to the implementation of the health extension program implementation that increased maternal understanding of the value of child vaccination. This vaccination coverage is less than 79% in Kenya [36], 54% in Uganda [37], 86.4% in Malaysia [38], and 51% in Malawi [39]. Variations in vaccination coverage may be due to differences in the data generation processes and nature of the survey, and the country's health services of the vaccination program.

Concerning maternal age, it was found that the odds of partial or full vaccination against polio increase with increasing age. This finding is consistent with the findings of studies carried out in Ethiopia [19, 40, 41] and other middle-income countries support the finding [42, 43] which found that young maternal age is a risk factor for incomplete childhood immunization.

The number of children in the household is negatively related to the partial or full vaccination of children. This shows that increasing the number of children under 5 years of age in the household leads to no vaccination of children. It was consistent studies done in Ethiopia [44] and Nigeria [21], it could be due to mothers who gave an average size child at birth being more interested in keeping their child healthy and visiting child health care services such as immunization programs than women who gave large size child at birth [45, 46].

The study showed that increasing household size decreases the status of polio vaccination status. This is similar to or supported by another study conducted in Pakistan [47] showing that household size had a negative association with infant immunization.

This study observed an inverse relationship between birth order and the status of polio vaccination. Birth order is also a determining factor for a lower coverage of polio vaccination coverage. A study reported that children of higher birth order had a lower risk of receiving partial or full polio vaccination. Similar findings have also been indicated by studies conducted in Bangladesh [48] and Brazil [49].

The level of maternal education positively associated with child vaccination, children born to educated mothers were more likely to be vaccinated as compared with children born to non-educated mothers. This study was supported by previous findings that showed that a higher level of parental education was associated with higher odds of child vaccination status [19, 50–54].

The potential reason for this could be the fact that educated parents are aware of vaccination and child protection and may benefit from full vaccination for their children. Furthermore, most educated parents lived in an urban area and had better follow-up of ANC than educated parents; which increases knowledge of vaccination.

The result also showed that children of the protestant Cristiana religion were less likely to be fully immunized compared to orthodox religious groups and this result is consistent with the reviewed literature and the contribution of different studies on religion [53, 54], showed that the orthodox Cristiana religion was more fully immunized compared to other religion. The attribute of this result needs further investigation. The increase in the number of prenatal visits during pregnancy increases the child's polio vaccination immunization status of polio vaccination; this study was also confirmed by previous research [50, 52–55]. A woman

Table 3: Partial proportional ordinal logistic regression on child polio vaccination status in Ethiopia.

Odds ratio estimates and confidence intervals			
Covariates of the study	**Category of variables**	$p\ (Y_i \leq j/x_i)$ **AOR (95% CI)**	$p\ (Y_i \leq j/x_i)$ **AOR (95% CI)**
Intercept	—	2.11 (3.472, 9.558)	0.68 (0.298, 1.527)
Age	Continuous	1.06 (1.025, 1.094)	1.06 (1.025, 1.094)
Age of mother at first birth	Continuous	0.94 (0.909, 0.976)	0.94 (0.909, 0.976)
Number of household members	Continuous	1.03 (0.975, 1.077)	1.03 (0.975, 1.077)
Number of under-five children	Continuous	0.81 (0.710, 0.923)	0.81 (0.710, 0.923)
Birth order	Continuous	0.90 (0.819, 0.980)	0.90 (0.819, 0.980)
Preceding birth interval	Continuous	0.99 (0.993, 1.010)	0.99 (0.993, 1.010)
Region (ref = Tigray)	Addis Ababa	0.98 (0.401, 2.401)	1.30 (0.679, 2.485)
	Afar	0.67 (0.374, 1.181)	0.55 (0.324, 0.948)
	Amhara	0.96 (0.566, 1.635)	1.33 (0.866, 2.043)
	Benishangul	1.24 (0.701, 2.203)	1.35 (0.842, 2.156)
	Dire Dawa	1.46 (0.750, 2.833)	1.08 (0.628, 1.842)
	Gambela	1.07 (0.584, 1.963)	0.93 (0.550, 1.568)
	Harari	1.07 (0.574, 1.992)	0.82 (0.479, 1.406)
	Oromia	1.11 (0.637, 1.925)	0.86 (0.537, 1.374)
	SNNR	0.64 (0.370, 1.095)	0.70 (0.440, 1.121)
	Somali	1.05 (0.585, 1.878)	0.76 (0.436, 1.311)
Residence (ref = urban)	Rural	0.66 (0.499, 0.867)	0.66 (0.499, 0.867)
Educational level (ref = no education)	Primary	1.04 (0.827, 1.318)	1.15 (1.020, 1.568)
	Secondary	1.26 (0.786, 2.019)	0.77 (0.515, 1.143)
	Higher	1.19 (0.612, 2.311)	1.35 (1.241, 1.730)
Source of information (ref = no)	Yes	1.18 (0.951, 1.469)	1.18 (0.951, 1.469)
Religion (ref = orthodox)	Muslim	0.80 (0.582, 1.106)	0.80 (0.582, 1.106)
	Protestant	0.63 (0.449, 0.882)	0.63 (0.449, 0.882)
	Other	0.88 (0.470, 1.647)	0.88 (0.470, 1.647)
Wealth (ref = poor)	Middle	1.25 (0.976, 1.609)	1.25 (0.976, 1.609)
	Rich	1.21 (0.928, 1.576)	1.21 (0.928, 1.576)
Contraceptive use (ref = no)	Yes	1.36 (0.497, 3.732)	1.36 (0.497, 3.732)
Contraceptive intention to use (ref = does not intend to use)	Modern method	1.26 (0.459, 3.454)	1.26 (0.459, 3.454)
Duration of breastfeeding (ref = still breastfeeding)	Never breastfed	0.65 (0.419, 0.993)	0.65 (0.419, 0.993)
	Ever breastfed, currently not breastfeeding	0.70 (0.575, 0.842)	0.70 (0.575, 0.842)
ANC visit (ref = no antenatal visits)	1–3 ANCV	1.74 (1.398, 2.160)	1.74 (1.398, 2.160)
	More than 3 ANCV	2.34 (1.845, 2.968)	2.34 (1.845, 2.968)
Place ANC visit (ref = home)	Government sector	2.33 (1.902, 2.864)	2.33 (1.902, 2.864)
	Private sector and others	1.18 (0.787, 1.764)	1.18 (0.787, 1.764)

provides not only professional care but also advice and education on how to use postnatal care and vaccination services during institutional delivery [52].

Children living in rural areas have been reported to have lower vaccination status compared to urban areas. This finding supports studies in Ethiopia [19, 50] and Afghanistan [56], total vaccination level in urban residents was always higher than in rural residents. This could be because urban areas have better access to healthcare facilities and healthcare professionals than rural areas. Furthermore, geographic regions were statistically associated with childhood vaccination. Children who lived in Afar were less likely to be vaccinated compared to children who lived in Tigray. The result is consistent with a previous study done in Ethiopia [54]. The potential explanation for this regional variation is that there is a discrepancy between regions in the coverage of health services, including the vaccination program.

This study showed that the attendance of ANC women in the public health sector is a significant factor in the coverage of polio vaccination coverage. This study was supported by another study [19]. Women who deliver in health facilities are likely to receive adequate training from health professionals

on the importance of childhood vaccinations, which builds their confidence in preventive health services [57]. The duration of breastfeeding is one of the important factors of childhood vaccination status. Children who feed the mother's breast are more vaccinated than the child who is still breastfed. This is also supported by the study [58], which showed a positive effect on child vaccination.

5. Conclusion

The study investigated the factors associated with the status of polio vaccination in children aged between 12 and 23 months in Ethiopia. Based on this study, the prevalence of child polio vaccination status in Ethiopia was 33.000% without vaccination, 21.20% partially vaccinated, and 45.70% fully vaccinated. Maternal age, age of mother at the first birth, number of children under 5 years of age, birth order, region, residence, educational level, religion, duration of breastfeeding, place of delivery, and number of ANC visits were factors significantly associated with childhood polio vaccination coverage. Therefore, it is necessary to increase child polio vaccination by promoting institutional delivery and prenatal care visits, as well as maternal ANC visits. Additionally, public initiatives are needed to improve child vaccination coverage and women's education. Furthermore, policies and programs aimed at addressing rural areas and noneducated women in child vaccination need to be formulated, and their implementation must be strongly pursued. Thus, stakeholders must consider all significant predictors revealed in the results of this study.

6. Limitations of the Study

The study used a secondary source of data from EDHS. However, the data have missing values in the variable, and some variables are not measured in 2019 Min EDHS than those of previous EDHS data in Ethiopia, which are missing from the analysis. Therefore, missing data were the main limitation of the study.

Nomenclature

ANCV: Antenatal care visit
AOR: Adjusted odds ratio
EDHS: Ethiopia Demographic and Health Survey
IPV: Inactivated polio vaccine
OPOM: Ordinal proportional odds model
OPV: Oral polio vaccine
POM: Proportional odds model
PV: Polio vaccine
SNNP: South nation and nationality of Ethiopia
WHO: World Health Organization.

Data Availability Statement

The data were accessible online at www.dhsprogram.com without requiring participant identification. Furthermore, the data used to support the findings of this study are available from the corresponding author upon request.

Ethics Statement

This study used a secondary source of data, which is publicly available survey data from the EDHS programmer, ethical approval, and participant consent were taken when the data were collected but were not necessary for this study. We requested the DHS program, and permission was granted to download it at http://www.dhsprogram.com/data/availabledatasets.cfm. There are no names of individuals or household addresses in the data files. Therefore, ethical approval was not necessary for this study.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

A.T.B. was involved in the study design, performed data extraction, analyzed the data, and produced the manuscript. D.B.B. was involved in the study design, counseled at each stage, and read the paper. A.T.B., S.A.Y., and Y.A.M. contributed to the manuscript's development. The final paper was critically evaluated and approved by all authors. A.T.B., D.B.B., S.A.Y., and Y.A.M. approved the final manuscript and agreed with the submission.

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