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Determinants of childhood vaccination among children aged 12–23 months in Ethiopia: A multilevel analysis using 2019 Ethiopia mini demographic and health survey

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Abstract

Objective: vaccination is a highly cost-effective critical element than any other healthcare service in reaching larger population globally. Due to different reasons, we are facing new emergence and resurgence of vaccine preventable diseases currently. Thus, study was aimed at identifying current prevalence and associated factors in Ethiopia.

Design: Community based cross-sectional study

Setting: We used data from 2019 Ethiopia Mini Demographic and Health Survey (EMDHS). The survey included all the nine regional states and two city administrations of Ethiopia.

Participants: A weighted sample of 1,008 children 12-23 months of age was included in the analysis.

Main outcome measures: Multilevel proportional odds model was fitted to identify determinants of childhood vaccination status. In the final model, variables with p-value of less than 5% and an adjusted odds ratio with a 95% CI reported.

Result: The full childhood vaccination coverage of Ethiopia was 39.09% (95% CI: 36.06%, 42.28). Maternal education, being in union, keeping vaccination cards, children received Vitamin A_1, living in Afar, Somali, Gambela, Harari, Dire Dawa regions, and rural residents were factors significantly associated with childhood vaccination.

Conclusion: The coverage of full childhood vaccination in Ethiopia was low remained unchanged since 2016. The study identified both the individual- and community-level factors affected the vaccination status. Accordingly, public health intervention targeted to these identified factors can increase childhood full vaccination status.

Keywords: full vaccination; multilevel; ordinal, 12-23 months children; Ethiopia

Strengths and limitations of this study

- This study used most recent nationwide secondary data that shows proportion of EPI coverage among children aged 12–23 months in Ethiopia.
- Data of 1,008 children was extracted from the 2019 Ethiopia mini demographic and health survey (EMDHS) dataset for this analysis.
- We used multilevel proportional odds model to overcome the hierarchical nature of EMDHS data and to identify both individual and community-level factors of EPI.
- Recall bias is the most relevant limitation of the study.

Introduction

According to the United Nations Children Fund (UNICEF), vaccination is a dynamic constituent of frontline health care to access larger population compared to any health or social activities by reducing global annual death by significant proportion(1–4). It save lives and protects peoples' health, improves countries' productivity and resilience, and helps to ensure a safer and healthier world(5,6). Vaccine preventable diseases become the big burden in war affected parts of the world and underdeveloped countries like Ethiopia(7); despite the existence of highly cost-effective vaccines on global markets(8). The global inequality health care distribution forced many low and middle income countries to live under the bundle of pestilent cumulative old health problems(9). Regardless of advancement and attainments of immunization, new emergence and resurgence of vaccine preventable diseases become very common. There are still people who deprived of accessing immunization in some countries which are becoming the reason for of vaccine preventable diseases at large-scale as the disparities honestly admitted by World Health Organization (WHO) and other studies 2018(10–12). This fact is also true in Ethiopia where studies described that educated and rich people get their children vaccinated by nearly 30% to 31% in the country(13). Due to this fact, globally, an estimated 6.6 million children still die every single year and half of the deaths would have been prevented by vaccination(14).

As Africa is of the regions severely affected by global imbalanced immunization resources, the overview of the proportion of the fully immunization become the apparent reflection of the fact (1,15). Some evidences indicated that global vaccine coverage is decreasing in some countries and at global level(16). The study summarized the Demographic Health Surveys (DHS) of Sub-Saharan countries showed that the coverage was limited to 59.40% in 2021(17). In Mogadishu full immunization coverage was 45.2% and (41.4%) in 2020 and 2021 respectively(18,19). In Togo

the full immunization coverage was 69.3% in Lome district in 2019(20). In Ethiopia a study in Southeast Ethiopia showed that full immunization coverage was 76.8%(21); however, the most recent pooled prevalence of vaccination amongst 12–23 month old children in the country was 47% in 2020(22). EDHS 2016 demonstrated that coverage of full vaccination was 38.3%(23). The magnitude of full vaccination increased from 14.3% in 2000 to 38.5% in 2016 from other study(24). All evidence indicates the most recent coverage of full vaccination is not adequate as per early increase referenced.

There are a number of factors that are superimposed the argument that resources disparities might be the only cause of poor coverage. A systematic review conducted in Sub-Saharan countries showed lack of knowledge of immunization, distance to access point, financial deprivation, lack of partners support, and distrust in vaccines and immunization programs were the barrier to utilization(25). The absence of immunization card, respondents' sex, level of education, marital status, and organization of health system has been mentioned in another study(20). A study included larger sub Saharan countries showed maternal education, health facility delivery, fathers secondary education and above, ANC visits, PNC visit, wealth index, media exposure, and distance to health facility affected full vaccination coverage(17). In Ethiopia, from previous four EDHS, postnatal check-up, awareness, regional difference, educational status, residence, and women wealth index influenced full vaccination(13,22,26). From other study antenatal care visit, higher level of maternal education, mothers' good knowledge on immunization, short distance to health facility, and being born in health institutions determined complete immunization of a child(27).

In summary, evidences of poor complete immunization varied from vaccination resource limitation to the individual and community constraining factors. The initial hope of eradicating

vaccine preventable diseases become just a hope and the current reports showed coverage dwindling again. Despite those mentioned factors, researching for new events leading to decreased coverage which become an issue because of emerging and remerging vaccine preventable outbreaks deserve further country level analysis. Therefore, this study aimed discovering further prevalence and associated factors to assist in policy improvements.

Methods

Study design

This study used the 2019 cross-sectional data of Ethiopian mini demographic and health survey (EMDHS). The survey dataset used in this analysis was obtained from demographic and health survey website (http://dhsprogram.com/data/) after getting permission to access the data. The mini survey was conducted in March 2019 to June 2019 for the second time in Ethiopia. The Ethiopian Public Health Institute (EPHI) in collaboration with Central Statistical Agency (CSA) and Federal Ministry of Health (FMOH) implemented a nationally representative household survey.

Participants

The 2019 EMDHS used the sampling frame created for the upcoming Ethiopia population and housing census list of 149,093 enumeration areas (EA). Participants of the study were selected through a stratified two-stage cluster sampling technique. Initially, each region of the country was stratified into urban and rural areas. Probability proportional to EA size was used to select 305 EAs (93 in urban and 212 in rural areas). In the second stage, lists of households were used as a sampling frame to select 30 households per cluster by equal probability systematic selection technique. Eligible women for the interview were all women aged 15-49 and residents of the selected households. Accordingly, 8,885 women were interviewed out of 9,012 eligible women

identified for interviews, giving a response rate of 98.6%. All living children age 12–23 months at the time of the survey were the source population of the study. The details of the survey methods and procedures are available in the 2019 Ethiopia Mini Demographic and Health Survey report (28).

Eligibility criteria

All children born in the 2 years preceding the survey were included in the analysis. However, children who were not alive at the time of the survey were excluded from this study. Accordingly, data of 1,008 children who had born in the last 2 years and surviving were extracted from the 2019 EMDHS datasets for this analysis.

Study setting

The EMDHS survey included all the nine regions and two city administrations of the country. Ethiopia is the second most populous country from Africa and located in the horn of Africa.

Measurements of variables of the Study

Dependent variable

Child vaccination status was the outcome variable of the study. The outcome variable was ordered into three categories: not vaccinated, partially vaccinated and fully vaccinated.

Fully vaccinated: is a child that has received one dose of Bacille Calmette-Guerin (BCG), three doses of pentavalent, three doses of polio, two doses of Rota, three doses of pneumococcal conjugate vaccine (PCV), and one dose of measles (MCV1).

Partially vaccinated: is a child who had missed at least one or more of the thirteen vaccines/doses.

Not vaccinated: is a child that has not received any vaccine at all.

The interviewers of the 2019 EMDHS obtained information on vaccination coverage from written vaccination cards (infant immunization card and other health cards), from mothers' verbal reports, and from health facility records. They request mothers who born child in the three preceding years of the survey to show the infant immunization card or health card. Subsequently, they copy the dates of each vaccination given in the corresponding questionnaire. Similarly, they ask mother who did not kept the cards to recall whether the child received that specific vaccination and the number of doses that the child received. In addition, to complement these data (information collected based on the mother's recall) the field supervisor collect complementary vaccination records from health facility for a child who visited a health facility and missed vaccination data.

Independent variables

In this study, we considered both individual and community-level independent variables. The individual-level variables included were maternal age, maternal educational level, religion, marital status, relationship to household head, sex of household head, wealth index, number of antenatal care (ANC) visits, place of delivery, utilized postnatal care, presence of vaccination document, birth order number, preceding birth interval, sex of child, received vitamin A1, total children ever born, and number of under five children in household. While region, type of place of residence, community women education, community poverty, and community ANC utilization were community-level factors of the study. Region is a grouping of the first administrative level of Ethiopia. During the survey period, there were 9 regions and 2 city administrations in the country namely, Tigray, Amhara, Afar, Oromia, Somali, Benishangul-Gumuz, South nations nationalities and people's region (SNNPR), Gambela, Harari, and two city administrations (Addis Ababa and Dire Dawa). Moreover, community women education, community poverty and community ANC utilization were community-level variables derived by aggregating individual-level factors. They

were categorized as "low" or "high" based on the median value since the EMDHS were not normally distributed.

Data processing and statistical analysis

The data were cleaned, re-coded and analyzed using STATA/SE version 14.0. Descriptive statistics were used to summarize both the individual- and community-level variables. Sample weight was applied to manage for sampling errors and non-responses. The hierarchical nature of the DHS data (or sampling methods DHS apply) violates the assumption of independence or lack of correlation of the residuals. In the DHS survey, observations are interdependent as participants nested in the same cluster are more likely to function in the same way than participants nested in different clusters in terms of the outcome of interest. As a result, we used a two-level multilevel proportional odds model since a single-level traditional statistical model might not be adequate to control for the clustering effect. Moreover, we used multilevel proportional odds model to consider the natural ordering of the response variable (not vaccinated, partially vaccinated and fully vaccinated). Accordingly, four consecutive models were built to identify determinants of child vaccination in Ethiopia. We first fitted the null model or the intercept only model. Then, model 1 was fitted with the individual-level variables only that were initially significant at p-value of < 0.25. Similarly, model 2 (with only community-level factors) was constructed. Finally, model 3 or the mixed-effects model was fitted with both individual- and community-level factors. The intra-class correlation coefficient (ICC) was used to determine the clustering effect or community variation and it was calculated using the following formula.

$$\text{ICC} = \frac{V_A}{V_A + \frac{\pi^2}{3}}$$

Where: V_A is community level variance and $\frac{\pi^2}{3}$ is individual level variance, which is equal to 3.29. On the other hand, Proportional Change in Variance (PCV), Median Odds Ratio (MOR), and Deviance were checked by using the following formulas to determine the fitness of the model. PCV $=\frac{V_0 - V_i}{V_0}$. Where: V_0 is variance in the null model and V_i is variance in the consecutive models. MOR $= e^{0.95V_i}$ where: V_i indicates that cluster variance. The model with the lowest deviance (Model III) was selected as the best-fitted model. Furthermore, the proportional odds assumption that states the effect of each factor is assumed to be equal across the outcome categories was examined by score test. Variance Inflation Factor (VIF) was tested to assess the presence of multicollinearity among the independent variables and the mean VIF was found to be 1.60, indicating absence of multicollinearity (min 1.03 and max 2.76). In bivariable analysis, variables with p-value less than 0.25 were considered as candidate variables for the multivariable multilevel proportional odds analysis. Finally, in the multivariable analysis variables with p-value less than 5% and adjusted proportional odds ratio (APOR) with the 95% confidence interval were reported as statistically significant variables with child vaccination in Ethiopia.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Result

Individual and community-level characteristics of mothers and children

The current study included 1,008 mothers who have children aged 12-23 months. Out of the total respondents, more than half (52.78%) were in the range of 25-34, nearly half (48.91%) did not attended education, and almost one-third (32.14%) were Orthodox religion followers. In this study,

four out of ten mothers (39.98%) were from high income households and the majorities (94.05%) were currently in union. Among the participants, less than half (44.15%) were practiced home delivery, nearly a quarter (24.31%) had no ANC visit, and almost one-tenth (13.99%) received PNC service. Majority of the mothers (71.73%) kept immunization document and 88.1% of the interviewed mothers have less than or equal to 2 under five children in their households. From the total number of children, half (50.30%) were males, 22.72% were first-born, and 59.33% were received the most recent vitamin A1. Three-fourth of respondents (73.51%) was from rural areas and 12.6% were from Oromia region of the country (Table 1).

Table 1: Individual and community-level characteristics of mothers of children aged 12-23 months in Ethiopia, 2019

Variables	Frequency (n)	Percentage (%)
Maternal age		
15-24	298	29.56
25-34	532	52.78
35-49	178	17.66
Maternal education		
No education	493	48.91
Primary	342	33.93
Secondary	99	9.82
Higher	74	7.34
Marital status		
Not in union	60	5.95

In union	948	94.05
Religion		
Orthodox	324	32.14
Protestant	177	17.56
Muslim	481	47.72
Others	26	2.58
Relationship to household head		
Household head	167	16.57
Wife or husband	730	72.42
Others	111	11.01
Sex of household head		
Male	797	79.07
Female	211	20.93
Wealth index		
Poor	469	46.53
Middle	136	13.49
Rich	403	39.98
Number of ANC visits		
None	245	24.31
1-3 times	313	31.05
4 and above	450	44.64
Place of delivery		
Home	445	44.15

Health facility	563	55.85
PNC service		
No	836	86.01
Yes	136	13.99
Sex of child		
Male	507	50.30
Female	501	49.70
Birth order number		
1st born	229	22.72
2nd to 3rd	372	36.90
4th to 5th	204	20.24
6th and above	203	20.14
Presence of vaccination document		
No	285	28.27
Yes	723	71.73
Preceding birth order		
< 24 months	186	18.45
24-48	357	35.42
48 and above	465	46.13
Received Vitamin A1		
No	410	40.67
Yes	598	59.33
Total children ever born		

1-3 children	598	59.33
4-6 children	278	27.58
7 and above	132	13.10
Number of <5 children in household		
≤ 2	888	88.10
> 2	120	11.90
Region		
Tigray	93	9.23
Amhara	111	11.01
Afar	99	9.82
Oromia	127	12.60
Somali	85	8.43
Benishabgul	83	8.23
SNNPR	116	11.51
Gambela	77	7.64
Harari	73	7.24
Addis Ababa	64	6.35
Dire Dawa	80	7.94
Type of place of residence		
Urban	267	26.49
Rural	741	73.51
Community women education		
Low	468	46.43

High	540	53.57
Community poverty		
Low	495	49.11
High	513	50.89
Community ANC utilization		
Low	468	46.43
High	540	53.57

Childhood vaccination status in Ethiopia

The full vaccination coverage among children aged 12-23 months in Ethiopia was 39.09% (95% CI: 36.06%, 42.28) (Fig. 1). On the other hand, two in ten children (22.32%) of 12-23 months have not received any vaccination during three years before the 2019 survey period. Among the total children of 12-23 months included in the study, 70.24% received BCG, 57.84% received the third dose of pentavalent, 55.75% received the third dose of polio, 60.62% received the second dose of rotavirus vaccine, 55.16% received the third dose of PCV, and 57.04% received the first dose of measles vaccination (Fig. 2).

Factors affecting child vaccination in Ethiopia

The fixed effect analysis result

The multivariable analysis showed that maternal educational level, maternal age, marital status, presence of vaccination document, received Vitamin A_1, region, place of residence, and community women education were significantly associated variables with childhood vaccination. Children who were born from mothers who attended primary, secondary, and higher schools were 2.2 [AOR=2.16; 95% CI: 1.43-3.26], 2 [AOR=2.02; 95% CI: 1.07-3.79], and 2.7 [AOR=2.67; 95%

CI: 1.25-5.71] respectively times more likely to be partially or fully vaccinated as compared to children whose mothers have no education. The odds to be partially or fully vaccinated was 1.8 [AOR=1.79; 95% CI: 1.08-2.99] times higher among children whose mothers were in the age range of 35-49 as compared to those children whose mothers were in the age range of 15-19. Children whose mothers were currently in union were 2.2 [AOR=2.21; 95% CI: 1.06-4.58] times more likely to be partially or fully vaccinated than their counterparts. Children whose mothers kept vaccination cards were 26 [AOR=26.18; 95% CI: 15.75-43.53] times more likely to be partially or fully vaccinated as compared to those children whose mothers did not kept vaccination cards. Compared with children who have not received Vitamin A_1 (the most recent), the likelihood to be partially or fully vaccinated was 4 [AOR=4.14; 95% CI: 2.9-5.9] times higher for children who received Vitamin A_1. Children from Afar [AOR=0.14; 95% CI: 0.04-0.45], Somali [AOR=0.19; 95% CI: 0.06-0.60], Gambela [AOR=0.22; 95% CI: 0.06-0.77], Harari [AOR=0.14; 95% CI: 0.04-0.52], and Dire Dawa [AOR=0.23; 95% CI: 0.06-0.79] regions were less likely to be partially or fully vaccinated as compared to those children from Tigray region. Children living in rural areas were 47% [AOR=0.53; 95% CI: 0.30-0.93] less likely to be partially or fully vaccinated than children living in urban areas of the country. Children in the community with high level of maternal education had 47% [AOR=0.53; 95% CI: 0.29-0.97] lower odds of partially or fully vaccinated as compared to children in the community with low maternal education (Table 2).

Table 2: Multivariable multilevel ordinal logistic regression analysis of individual and community-level determinants of child vaccination in Ethiopia, 2019

Variables	Null Mode1	Mode1 I AOR (95% CI)	Mode1 II AOR (95% CI)	Mode1 III AOR (95% CI)

Maternal educational level			
	No education	1	1
	Primary	1.97 (1.33, 2.93)**	2.16 (1.43, 3.26)***
	Secondary	1.80 (0.97, 3.33)	2.02 (1.07, 3.79)*
	Higher	2.85 (1.35, 6.02)	2.67 (1.25, 5.71)*
Maternal age			
	15-24	1	1
	25-34	1.13 (0.78, 1.63)	1.15 (0.79, 1.66)
	35-49	1.81 (1.09, 3.02)*	1.79 (1.08, 2.99)*
Religion			
	Orthodox	1	1
	Protestant	0.46 (0.27, 0.77)**	0.69 (0.36, 1.30)
	Muslim	0.71 (0.47, 1.09)	1.28 (0.73, 2.24)
	Other	0.39 (0.14, 1.22)	0.56 (0.18, 1.68)
Marital status			
	Not in union	1	1
	In union	1.84 (0.89, 3.80)	2.21 (1.06, 4.58)*
Relationship to HH head			
	Household head	1	1
	Wife or husband	0.79 (0.50, 1.23)	0.72 (0.46, 1.14)
	Others	0.67 (0.36, 1.27)	0.62 (0.33, 1.17)
Household wealth index			
	Poor	1	1

Middle	0.83 (0.51, 1.35)	0.77 (0.47, 1.29)
Rich	1.28 (0.83, 1.97)	1.05 (0.63, 1.74)
Number of ANC visits		
None	1	1
1-3	0.97 (0.61, 1.53)	0.99 (0.63, 1.58)
4 and above	1.40 (0.86, 2.29)	1.27 (0.77, 2.09)
Place of delivery		
Home	1	1
Health facility	1.22 (0.82, 1.83)	1.11 (0.74, 1.66)
PNC utilized		
No	1	1
Yes	1.04 (0.67, 1.63)	1.05 (0.67, 1.65)
Immunization document		
Available	1	1
Not available	27.32 (16.44,45.41)***	26.18(15.75,43.53)***
Preceding birth interval		
< 24 months	1	1
24-48 months	1.07 (0.69, 1.65)	1.04 (0.67, 1.62)
48 and above	1.05 (0.67, 1.65)	1.06 (0.67, 1.67)
Received Vitamin A_1		
No	1	1
Yes	4.32 (3.04, 6.15)***	4.14 (2.9, 5.9)***
Number of < 5 children		

≤ 2 children	1		1
>2 children	0.62 (0.36, 1.07)		0.68 (0.39, 1.16)
Region			
Tigray		1	1
Afar		0.08 (0.03, 0.23)***	0.14 (0.04, 0.45)**
Amhara		0.59 (0.24, 1.48)	0.5 (0.22, 1.13)
Oromia		0.21 (0.09, 0.48)***	0.45 (0.18, 1.09)
Somali		0.08 (0.03, 0.22)***	0.19 (0.06, 0.60)**
Benishangul		1.13 (0.37, 3.40)	0.74 (0.25, 2.22)
SNNPR		0.19 (0.08, 0.45)***	0.48 (0.19, 1.17)
Gambella		0.38 (0.12, 1.22)	0.22 (0.06, 0.77)*
Harari		0.43 (0.12, 1.48)	0.14 (0.04, 0.52)**
Addis Ababa		1.27 (0.39, 4.14)	1.14 (0.37, 3.47)
Dire Dawa		0.78 (0.23, 2.62)	0.23 (0.06. 0.79)*
Type of place of residence			
Urban		1	1
Rural		0.25 (0.14, 0.44)***	0.53 (0.30, 0.93)*
Community women education			
Low		1	1
High		1.04 (0.56, 1.94)	0.53 (0.29, 0.97)*
Community poverty			
Low		1	1
High		0.98 (0.55, 1.77)	1.11 (0.62, 2.00)

Community ANC utilization			
	Low	1	1
	High	1.81 (0.83, 3.96)	0.87 (0.41, 1.83)

Key * = p < 0.05, * = p < 0.01, * = p < 0.001

The random effect analysis result

Table 3 presents the random effect analysis result of childhood vaccination status in Ethiopia. The appropriateness of application of multilevel analysis and the presence of significant variations of childhood vaccination status between clusters (the clustering effect) was justified by the ICC of Null model (48.19%). The value of ICC decreased from 48.19% in the null model to 14.55% in the final model showing the effect of clustering was more or less controlled. In addition, as depicted in the table below the largest PCV of final model (81.70%) indicates the goodness of model fitness. In another words, the final model (Model 3) has the highest capacity than model I or model II alone to explain the variations in childhood vaccination status. On top of that, Model III was the best explanatory model able to explain the variation in childhood vaccination status between the clusters since the value of deviance observed in the final model was smallest than the remaining models (Table 3).

Table 3: Random effects analysis and model fit statistics of child vaccination in Ethiopia, 2019

Parameters	Null Model	Model I	Model II	Model III
Community level Variance (SE)	3.06	0.76	1.21	0.56
PCV (%)	Reference	75.16%	60.46%	81.70%
ICC (%)	48.19%	18.77%	26.89%	14.55%

MOR	5.31	2.29	2.84	2.03
Log-likelihood	-988.74	-684.36	-919.88	-667.78
Deviance	1,977.48	1,368.72	1,839.76	1,335.56
AIC	1983.49	1418.72	1873.77	1413.56
BIC	1998.24	1540.70	1957.34	1603.86

Discussion

From this analysis, complete immunization in Ethiopia was 39.08%. Compared to other studies in the country, it is less than76.8% in South East (21), 47% pooled prevalence(22), and 67% in 2016 from other study(29). It is also less than 59.40% summarized Sub-Saharan coverage(17), 69.21% in East Africa(29), 45.2% in Mogadishu (18), and 69.3% in Togo in 2019(20). It is 38.3% from 2016 EDHS which is in the confidence interval. This indicates that the current prevalence of full immunization unchanged over time. The reasons might be political instabilities in the country in the last five years, while it might also be due to the increased inequalities health service access regardless of increased population in these years because of less resource development. Un-education (48.91%) of mothers is also decades old persistent problem; however, it was still improved from 67% in 2015(26). It is also better than regional recent figure (Sub-Saharan countries)(17). Although there are some improvements from previous, there is an ample of gaps from expected standard which might indicate efforts short of effectiveness. Poverty, which is another old problem, is also persisted as only 39.98% mothers were from high income families. From other study, 36.6% mothers were from wealthy families(26). Despite the issue with full vaccination, other socioeconomic factors showed some improvements over the last few years; however, their effect might be insignificant to influence vaccination due to the unstable market inflation that might be cancelling its development.

The evidence from the current study also showed, maternal education had positive association with higher level complete immunization category which is also similar from other studies(17,24,26). The consistence might indicate that education is an independent predictor of complete immunization which needs undivided attention. Education is evidenced by individually and community level influences. Increased maternal age puts mothers in the higher level of full immunization category. Other studies also showed higher age has association with full immunization(3,17). This might indicate maturity is an important factor in caring for own child, which might also indicate early marriage, child bearing at younger age, and age at first birth needs adequate consideration in birth planning. Children whose mothers remained in union had higher tendency to be in higher category of full immunization. From previous studies, there are consistent findings(17,18). This might be an indication that disrupted family might be tight in self-survival activities than looking after their children and so that staying in union should be encouraged. Mothers who keep evidence of vaccination tend to be in higher category of immunization coverage. This is also true for some studies(18,19,26). This means, women who keeps children evidence of vaccination might have indeed great regards for full immunization while carelessness might start from poor evidence keeping. Children who received Vitamin A_1 had higher chance of completing full vaccination. The fact that vitamin A supplied towards the end of most vaccine might raise to this association (12). This might be another persist issue we never eased in previous efforts as per evidence from this study and could be set as an objective to attain other sub-objectives. Ethiopia further classified in city administrations, agrarian, and pastoralist regions. Pastoralists regions like Afar and Somali in relation with agrarian but semi pastoralist regions like Gambela, Benishangul Gumuz and Harari had higher tendency of failing to low category of full immunization. All other country level data analysis indicated similar facts(26). This is also

confirmed by other studies that compared developed and underdeveloped regions(24,26). The issue here is very apparent that attention deprived regions should be the next intervention areas. This problem is relatively similar between the rural and urban place of residence. Other studies also laud that inequalities between rural and urban residence need careful considerations(13). This might be apparently due to access, awareness, and availability. This study provided fabulous information for the scientific community; however, it should advisable to use it in recalling secondary data, disproportional nature of the data, and cross sectional nature of the data. Authors followed standards of data handling as per guidelines of DHS, weighted data, and performed explicit analysis described under method section to relax possible limitations.

Conclusion

Although full immunization increased from EDHS 2000 to 2016, the current analysis of EMDHS result showed it was indeed remained unchanged. The analysis identified many factors that might be contributed for the no changed. Maternal educational level, maternal age, marital status, presence of vaccination document, received Vitamin A_1, region, place of residence, and community women education were some of the contributors. Analyzing associated factors showed some of the factors are old enough causing the problem for decades. Even though the political situation in the country might also contributed to the persistency of these factors, it is advisable that accessibility, awareness, available coupled with maternal education and poverty especially family and maternal capacity remained critical and need all round efforts like further government commitment, dedicated international supports, and peace and security can override the problem.

Abbreviation/Acronyms: Demographic Health Survey (DHS); Ethiopian Demographic Health Survey (EDHS); Ethiopian Mini-Demographic Health Survey(EMDHS); World Health Organization (WHO); United Nations Children's Fund (UNICEF); Adjusted Odds Ratio (AOR);

Antenatal Care (ANC); Postnatal Care (PNC); Pneumococcal Conjugate Vaccine (PCV); and Measles Containing Vaccine (MCV); Bacille Calmette-Guerin (BCG); South Nations Nationalities and Peoples Region (SNNPR); Intra-class Correlation Coefficient (ICC); Median Odds Ratio (MOR), Confidence Interval (CI)

Declarations

Ethics approval and consent to participate

This study used secondary data from demographic and health survey data files. Initially, the MEASURE DHS team was formally requested to access the datasets by completing the online request form on their website (www.dhsprogram.com). Accordingly, permission to access the data and the letter of authorization was obtained from ICF international. Therefore, for this study consent to participate is not applicable. We kept all data confidential, and no effort was made to identify households or individuals. The Ethiopian Health Nutrition and Research Institute (EHNRI) Review Board and the National Research Ethics Review Committee (NRERC) at the Ministry of Science and Technology of Ethiopia, approved EMDHS 2019. The authors also confirm that all methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable

Availability of data and materials

The survey dataset used in this analysis are third party data from the demographic and health survey website (www.dhsprogram.com) and permission to access the data is granted only for registered DHS data user.

Competing interests

The authors have declared that no competing interest existed.

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Authors' contribution

SS has obtained and analyzed the EMDHS data. SS, GG, SH were equally involved in the conception of the study, interpreted the results, drafted and critically revised the manuscript. All authors have read and approved the final version of the manuscript.

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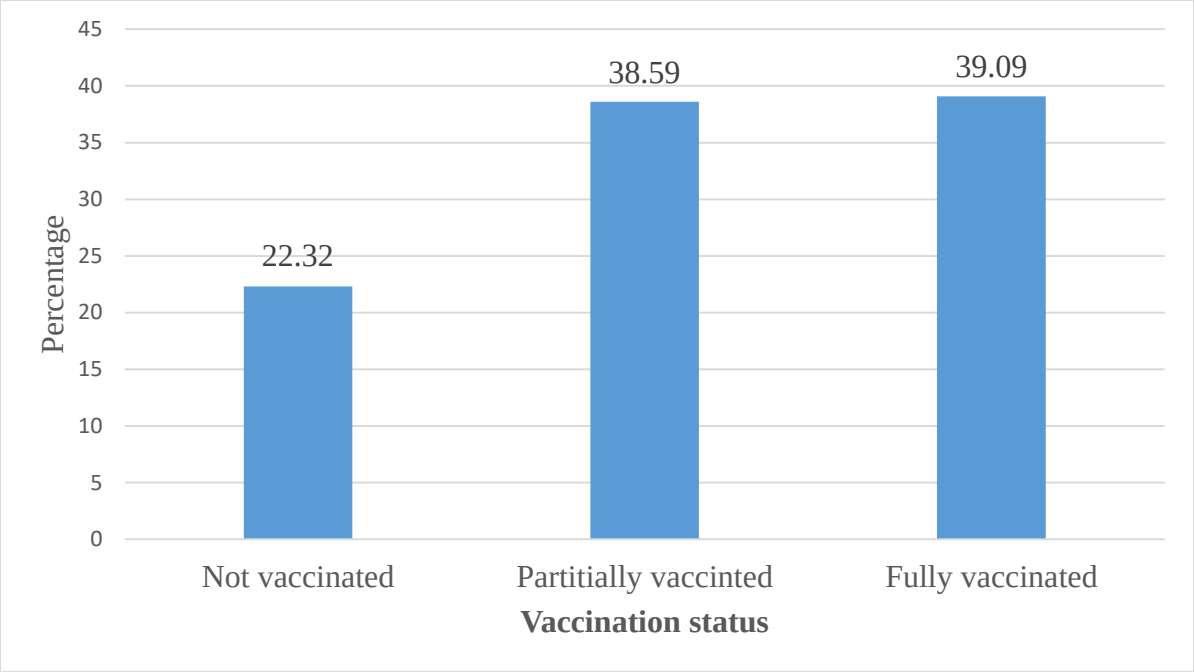

Fig. 1: Vaccination status of children aged 12-23 months in Ethiopia, 2019

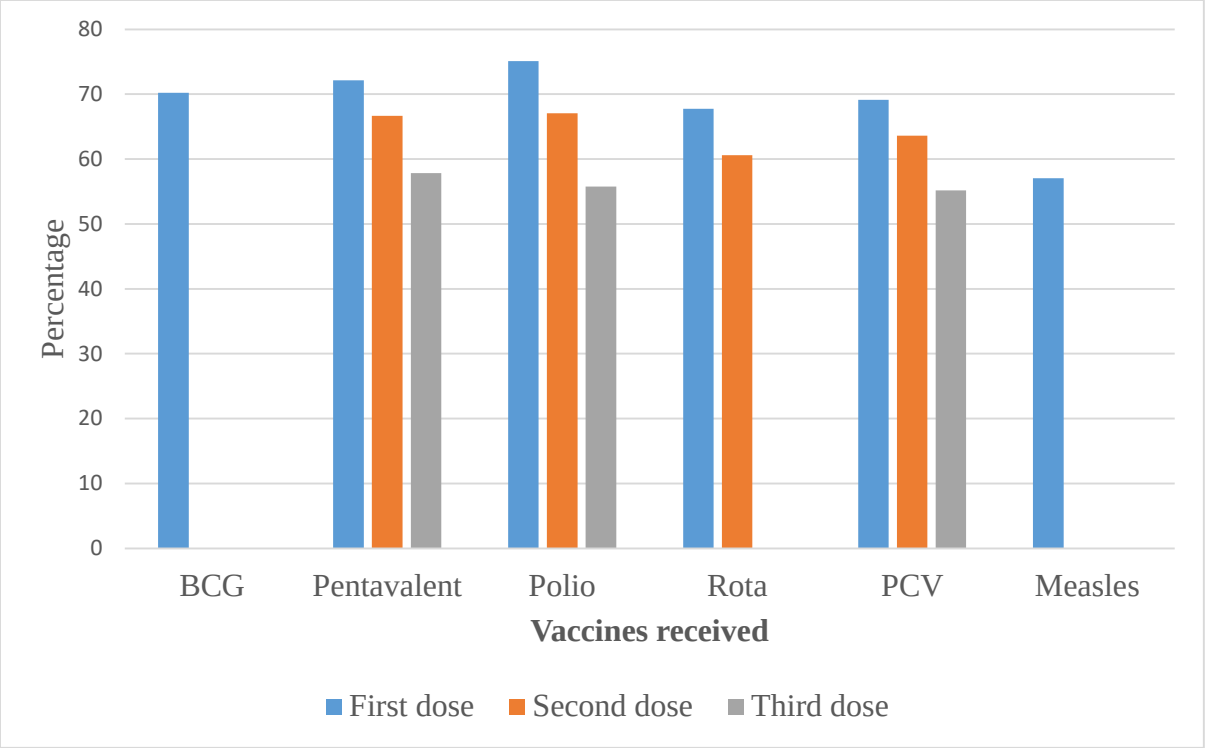

Fig. 2: Percentage of children aged 12-23 months who received a particular vaccine in Ethiopia, 2019

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Determinants of childhood vaccination among children aged 12–23 months in Ethiopia: A community-based cross-sectional study

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Abstract

Objective: Childhood vaccination is a cost-effective essential service to reach larger population globally. Due to unclear reasons, new emergence and resurgence of vaccine preventable diseases gets increase. Thus, the aim of this study is to identify prevalence and determinants of childhood vaccination in Ethiopia.

Design: Community based cross-sectional study

Setting: We used data from 2019 Ethiopia Mini Demographic and Health Survey (EMDHS). The survey included all the nine regional states and two city administrations of Ethiopia.

Participants: A weighted sample of 1,008 children 12-23 months of age was included in the analysis.

Main outcome measures: Multilevel proportional odds model was fitted to identify determinants of childhood vaccination status. In the final model, variables with p-value of less than 5% and an adjusted odds ratio with a 95% CI reported.

Result: The full childhood vaccination coverage of Ethiopia was 39.09% (95% CI: 36.06%, 42.28). Mothers attended primary [AOR=2.16; 95% CI: 1.43-3.26], secondary [AOR=2.02; 95% CI: 1.07-3.79], and higher schools [AOR=2.67; 95% CI: 1.25-5.71], being in union [AOR=2.21; 95% CI: 1.06-4.58], kept vaccination cards [AOR=26.18; 95% CI: 15.75-43.53], children received Vitamin A_1 [AOR=4.14; 95% CI: 2.9-5.9], living in Afar [AOR=0.14; 95% CI: 0.04-0.45], Somali [AOR=0.19; 95% CI: 0.06-0.60], Gambela [AOR=0.22; 95% CI: 0.06-0.77], Harari [AOR=0.14; 95% CI: 0.04-0.52], Dire Dawa [AOR=0.23; 95% CI: 0.06-0.79] regions, and rural residents [AOR=0.53; 95% CI: 0.30-0.93] were factors significantly associated with childhood vaccination.

Conclusion: The coverage of full childhood vaccination in Ethiopia was low remained unchanged since 2016. The study identified both the individual- and community-level factors affected the vaccination status. Accordingly, public health intervention targeted to these identified factors can increase childhood full vaccination status.

Keywords: full vaccination; multilevel; ordinal, 12-23 months' children; Ethiopia

Strengths and limitations of this study

- This study used most recent nationwide secondary data that shows proportion of EPI coverage among children aged 12–23 months in Ethiopia.
- Data of 1,008 children was extracted from the 2019 Ethiopia mini demographic and health survey (EMDHS) dataset for this analysis.
- We used multilevel proportional odds model to overcome the hierarchical nature of EMDHS data and to identify both individual and community-level factors of EPI.
- Establishing temporal relationship of causation between childhood vaccination and its determinants was impossible due to the nature of the study design used for the survey.
- Recall bias is the most relevant limitation of the study.

Introduction

According to the United Nations Children Fund (UNICEF), immunizations is a dynamic constituent of frontline health care to access larger populations. Compared to any other health or social activities, immunization reduces global annual death by significant proportion(1–4). It saves lives and protects people's health, improves countries' productivity and resilience, and helps to ensure a safer and healthier world(5,6).

According to the Ethiopian Ministry of Health, a child takes OPV_0 and BCG at Birth. At six weeks after birth, a child takes OPV1(oral polio vaccine), Pentavalent1(DPT+HepB+HIb), Pneumococcal1, and Rotavirus1. Then 10 weeks after birth the child takes OPV2, and Pentavalent2, Pneumococcal2, and Rota2. The child takes OPV3, Pentavalent3, Pneumococcal3, Inactivated polio vaccine (IPV) at 14^{th} weeks. Other vaccines such as Measles Containing Vaccine (MCV1) at 9^{th} month and MCV2 at 15^{th} month and human papilloma virus (HPV) at 14^{th} years for girls are given. However, this study only considers vaccines between 1 to 2 years. All vaccines are equally important(7). Currently, Ethiopia do not provide Rubella, Mumps and chickenpox vaccines to immunize children. Depending on the amount of immunity or protection after receiving a dose, a child may require more than one dose for some vaccine(8). Additionally, more than one dose is needed to build high enough immunity to prevent disease and boost immunity that fades over time(9). For vaccines that do not initiate full protection at first introduction, additional dose of vaccine usually repeated(10). However, this does not mean one vaccine is better than the other is or more important than another since it depends on the nature of the disease.

Globally, about 6.6 million children die every year and half of the deaths would have been prevented by vaccination(11). The global inequality in health care distribution force many low and middle income countries to live under the bundle of pestilent cumulative old health problems(12).

Africa is among the regions severely affected by globally imbalanced immunization resources distribution. Vaccine preventable diseases become the big burden in war affected parts of the world and underdeveloped countries like Ethiopia(13). Despite the existence of highly cost-effective vaccines on global markets, situations such as war, displacements, under vaccination, and poor access to vaccine contributes to the prevalence of vaccine preventable disease(14). The proportion of the full immunization reflects how resources distribution caused the imbalance in childhood vaccination(1,15).

Regardless of advancement and attainments of immunization, newly emerging vaccine preventable diseases become still common in Africa(16). There are people who deprived of accessing immunization in some countries and becoming the reason for the prevalence of vaccine preventable diseases as admitted by World Health Organization (WHO) and other studies(17–19). In Ethiopia a study has described that educated (30%) and rich (31%) people better vaccinate their children(20).

Some evidences indicated that global vaccine coverage is decreasing(21). A study summarized the Demographic Health Surveys (DHS) of Sub-Saharan African countries showed that the full vaccination coverage was 59.40% in 2021(22). In Mogadishu, full immunization was 45.2% and 41.4% in 2020 and 2021 respectively(22–24). In Togo, the full immunization coverage was 69.3% in Lome district in 2019(25). In Ethiopia. the full immunization coverage is 76.81% in the Southeast region(26); however, the pooled prevalence amongst 12–23 month old children in Ethiopia is 47%(27). EMDHS 2019 demonstrated that coverage of full vaccination was 44(28)%. The magnitude of full vaccination was increased from 14.3% in 2000 to 44% in 2019(29). From this, we understand that the coverage of full vaccination is not adequate.

Many factors that support the argument of resource disparities as a reason for low coverage in some countries. A systematic review conducted in Sub-Saharan African countries showed that lack of knowledge of immunization knowledge, distance to access point, financial deprivation, lack of partners support, and distrust in vaccines and immunization programs were the barrier(30). The absence of immunization card, respondents' sex, level of education, marital status, and organization of health system are mentioned in another study(25). A study included many sub Saharan African countries showed that maternal education, health facility delivery, fathers secondary education and above, ANC visits, PNC visit, wealth index, media exposure, and distance to health facility affected the vaccination coverage(22). In Ethiopia, from previous four EDHS, postnatal check-up, maternal awareness, regional difference (economic, education and life style), educational status, residence, and women wealth index have been influenced vaccination(20,27,31). From another study antenatal care visit, higher level of maternal education, good knowledge of immunization, short distance to health facility, and institutional delivery were the determinants of childhood immunization(32).

Different small scale and large scale (national level) studies have been done to identify the determinants of childhood vaccination in the country. However, majority of the studies conducted did not examined natural ordering of child's vaccination status as fully, partially, or not vaccinated at all. Hence, we used multilevel proportional odds model which overcomes the hierarchal nature of the DHS data and considers natural ordering of the outcome variable. In addition, the coverage of full vaccination still remains far behind the national health sector transformation plan II of Ethiopia (75% by 2024/25)(33), showing the need for further study. Therefore, this study aimed determining prevalence of childhood vaccination coverage and its determinants to assist in policy improvements.

Methods

Study design

This study used the 2019 cross-sectional data of Ethiopian mini demographic and health survey (EMDHS). We obtained the dataset from demographic and health survey website (http://dhsprogram.com/data/) after getting permission to access. The mini survey was conducted in March 2019 to June 2019 for the second time in Ethiopia. The Ethiopian Public Health Institute (EPHI) in collaboration with Central Statistical Agency (CSA) and Federal Ministry of Health (FMOH) implemented a nationally representative household survey.

Study setting

The EMDHS survey included all the nine regions and two city administrations of the country. Ethiopia is the second most populous country from Africa and located in the horn of Africa.

Participants

The 2019 EMDHS used the sampling frame created for the upcoming Ethiopia population and housing census list of 149,093 enumeration areas (EA). Participants of the study were selected through a stratified two-stage cluster sampling technique. Initially, they stratified each region in the country into urban and rural areas. Probability proportional to EA size was used to select 305 EAs (93 in urban and 212 in rural areas). In the second stage, lists of households were used as a sampling frame to select 30 households per cluster by equal probability systematic selection technique. Eligible participants for the interview were all women aged 15-49 years and who were the residents of the selected households. Accordingly, 8,885 women were interviewed out of 9,012 eligible women, giving a response rate of 98.6%. All living children age 12–23 months at the time

of the survey were the source population of the study. The details of the survey methods and procedures are available in the 2019 EMDHS report (29).

Eligibility criteria

All children born in the 2 years preceding the survey were included in the analysis. However, children who were not alive at the time of the survey were excluded from this study. Accordingly, data of 1,008 children who had born in the last 2 years and surviving were extracted from the 2019 EMDHS datasets for this analysis (Fig. 1).

Measurements of variables of the Study

Dependent variable

Child vaccination status was the outcome variable of the study. We categorized the outcome variable as not vaccinated, partially vaccinated and fully vaccinated.

Fully vaccinated: is a child that has received one dose of Bacille Calmette-Guerin (BCG), three doses of pentavalent, three doses of polio, two doses of Rota, three doses of pneumococcal conjugate vaccine (PCV), and one dose of measles (MCV1).

Partially vaccinated: is a child who had missed at least one or more of the thirteen vaccines/doses.

Not vaccinated: is a child that has not received any vaccine at all.

The interviewers of the 2019 EMDHS obtained information on vaccination coverage from written vaccination cards (infant immunization card and other health cards), from mothers' verbal reports, and from health facility records. They request mothers who born child in the three preceding years of the survey to show the infant immunization card or health card. Subsequently, they copy the dates of each vaccination given in the corresponding questionnaire. Similarly, they ask mother who did not kept the cards to recall whether the child received that specific vaccination and the

number of doses that the child received. In addition, to complement these data (information collected based on the mother's recall) the field supervisor collects complementary vaccination records from health facility for a child who visited a health facility and missed vaccination data. Finally, a Health Facility Questionnaire was used to record vaccination information for all children without a vaccination card seen during the mother's interview; however, we dropped records with the missing data.

Independent variables

In this study, we considered both individual and community-level variables. The individual-level variables included are maternal age, maternal educational level, religion, marital status, relationship to household head, sex of the household head, wealth index, number of antenatal care (ANC) visits, place of delivery, utilized postnatal care, presence of vaccination document, birth order number, preceding birth interval, sex of child, vitamin A1, total children ever born, and number of under five children in household. Region, type of place of residence, community women education, community poverty, and community ANC utilization are community-level factors of the study. Region is a grouping of the first administrative level of Ethiopia. During the survey period, there were 9 regions and 2 city administrations in the country namely, Tigray, Amhara, Afar, Oromia, Somali, Benishangul-Gumuz, South nations nationalities and people's region (SNNPR), Gambela, Harari, and two city administrations (Addis Ababa and Dire Dawa). Moreover, community women education, community poverty and community ANC utilization were community-level variables derived by aggregating individual-level factors. They were categorized as "low" or "high" based on the median value since the EMDHS were not normally distributed.

Information regarding the wealth index is derived from data collected in the Household Questionnaire. The questionnaire includes queries concerning the household's ownership of several consumer items such as television and car; dwelling characteristics such as flooring material; type of drinking water source; toilet facilities; and other characteristics related to wealth status. Each household asset for which information is collected is assigned a weight or factor score generated through principal components analysis (PCA). The resulting asset scores are standardized about a standard normal distribution with a mean of zero and a standard deviation of one. These standardized scores then used to create the breakpoints that define wealth quintiles as Lowest, Second, Middle, Fourth, and Highest(34). Here, we further categorized the wealth index into poor (lowest plus poor), average (middle), and rich (rich plus highest).

Data processing and statistical analysis

The data were cleaned, re-coded and analyzed using STATA/SE version 14.0. We used numbers, mean, percentage or proportions to describe both the individual- and community-level variables. We used sample weight to manage sampling errors and non-responses. The hierarchical nature of the DHS data (DHS sampling methods) violates the assumption of independence or lack of correlation of the residuals. In the DHS survey, observations are interdependent as participants nested in the same cluster may behave in the same way and differ to other clusters in terms of the outcome of interest. consequently, we used a two-level multilevel proportional odds model, as single-level traditional statistical model might not be adequate to control for the clustering effect. Moreover, we used multilevel proportional odds model to consider the natural ordering of the response variable (not vaccinated, partially vaccinated and fully vaccinated). Accordingly, we built four consecutive models to identify determinants of child vaccination in Ethiopia. We first fitted the null model or the intercept only model. Then, model 1 was fitted with the individual-level

variables. Similarly, we fitted model 2 (with community-level factors). Finally, model 3 or the mixed-effects model was fitted with both individual- and community-level factors. The intra-class correlation coefficient (ICC) was used to determine the clustering effect or community variation and it was calculated using the following formula.

$$\text{ICC} = \frac{V_A}{V_A + \frac{\pi^2}{3}}$$

Where: V_A is community level variance and $\frac{\pi^2}{3} = 3.29$ is individual level variance. On the other hand, we checked Proportional Change in Variance (PCV), Median Odds Ratio (MOR), and Deviance by using the following formulas to determine the fitness of the model. PCV $= \frac{V_0 - V_i}{V_0}$. Where: V_0 is a variance in the null model and V_i is a variance in the consecutive models. MOR = $e^{0.95V_i}$ where: V_i indicates that cluster variance. The last model showed the lowest deviance (Model III) and become the best-fitted model. Furthermore, we examined the proportional odds assumption that assume the equal effect of each factor across the outcome categories by score test. We checked Variance Inflation Factor (VIF) and found 1.60 to assess the presence of multicollinearity. The finding is in the acceptable range. In bi-variable analysis, we kept variables with p-value less than 0.25 for the multivariable multilevel proportional odds analysis. Finally, in the multivariable analysis, we reported variables with p-value less than 5%, adjusted proportional odds ratio (APOR) and 95% confidence interval.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Result

Individual and community-level characteristics of mothers and children

The current study included 1,008 mothers who have children aged 12-23 months. Out of the total respondents, more than half (52.78%) were in the age range of 25-34 years, nearly half (48.91%) have not attended education, and almost one-third (32.14%) were Orthodox religion followers. Four out of ten mothers (39.98%) were from high income households and the majorities (94.05%) were currently in union. Among the participants, less than half (44.15%) were practiced home delivery, nearly a quarter (24.31%) had no ANC visit, and almost one-tenth (13.99%) received PNC service. Majority of the mothers (71.73%) kept immunization document and 88.1% of the interviewed mothers have less than or equal to two under five children in their households. From the total number of children, half (50.30%) were males, 22.72% were first-born, and 59.33% were received the most recent vitamin A1. Three-fourth of respondents (73.51%) was from rural areas and 12.6% were from Oromia region of the country (Table 1).

Table 1: Individual and community-level characteristics of mothers of children aged 12-23 months in Ethiopia, 2019 (n=1008)

Variables	Frequency (n)	Percentage (%)
Maternal age		
15-24	298	29.56
25-34	532	52.78
35-49	178	17.66
Maternal education		
No education	493	48.91
Primary	342	33.93

Secondary	99	9.82
Higher	74	7.34
Marital status		
Not in union	60	5.95
In union	948	94.05
Religion		
Orthodox	324	32.14
Protestant	177	17.56
Muslim	481	47.72
Others	26	2.58
Relationship to household head		
Household head	167	16.57
Wife or husband	730	72.42
Others	111	11.01
Sex of household head		
Male	797	79.07
Female	211	20.93
Wealth index		
Poor	469	46.53
Middle	136	13.49
Rich	403	39.98
Number of ANC visits		
None	245	24.31

1-3 times	313	31.05
4 and above	450	44.64
Place of delivery		
Home	445	44.15
Health facility	563	55.85
PNC service		
No	836	86.01
Yes	136	13.99
Sex of child		
Male	507	50.30
Female	501	49.70
Birth order number		
1st born	229	22.72
2nd to 3rd	372	36.90
4th to 5th	204	20.24
6th and above	203	20.14
Presence of vaccination document		
No	285	28.27
Yes	723	71.73
Preceding birth order		
< 24 months	186	18.45
24-48	357	35.42
48 and above	465	46.13

Received Vitamin A1		
No	410	40.67
Yes	598	59.33
Total children ever born		
1-3 children	598	59.33
4-6 children	278	27.58
7 and above	132	13.10
Number of <5 children in household		
≤ 2	888	88.10
> 2	120	11.90
Region		
Tigray	93	9.23
Amhara	111	11.01
Afar	99	9.82
Oromia	127	12.60
Somali	85	8.43
Benishabgul	83	8.23
SNNPR	116	11.51
Gambela	77	7.64
Harari	73	7.24
Addis Ababa	64	6.35
Dire Dawa	80	7.94
Type of place of residence		

Urban	267	26.49
Rural	741	73.51
Community women education		
Low	468	46.43
High	540	53.57
Community poverty		
Low	495	49.11
High	513	50.89
Community ANC utilization		
Low	468	46.43
High	540	53.57

Childhood vaccination status in Ethiopia

The full vaccination coverage among children aged 12-23 months in Ethiopia was 39.09% (95% CI: 36.06%, 42.28) (Fig. 2). On the other hand, two in ten children (22.32%) of 12-23 months' age have not received any vaccination in three years before the 2019 survey period. Among the children of 12-23 months' age included in the study, 70.24% received BCG, 57.84% received the third dose of pentavalent, 55.75% received the third dose of polio, 60.62% received the second dose of rotavirus vaccine, 55.16% received the third dose of PCV, and 57.04% received the first dose of measles vaccination (Fig. 3).

Factors affecting child vaccination in Ethiopia

The fixed effect analysis result

The multivariable analysis showed that maternal educational level of mothers, maternal age, marital status, presence of vaccination document, received Vitamin A_1, region, and place of residence, were significantly associated with childhood vaccination. Children whose mothers attended primary, secondary, and higher education have 2.2 [AOR=2.16; 95% CI: 1.43-3.26], 2 [AOR=2.02; 95% CI: 1.07-3.79], and 2.7 [AOR=2.67; 95% CI: 1.25-5.71] times higher partial or full vaccination respectively compared to born to mothers with no education. The odds of partial or full vaccination was 1.8 [AOR=1.79; 95% CI: 1.08-2.99] times higher among children whose mothers are in the age range of 35-49 compared to 15-19 age group. Mothers who are currently in union have 2.2 [AOR=2.21; 95% CI: 1.06-4.58] times more likely to vaccinate their children either partially or fully. keeping vaccination cards was 26 [AOR=26.18; 95% CI: 15.75-43.53] times more likely associated with partial or full vaccination compared to not keeping vaccination cards. Children who have received Vitamin A_1 have higher likelihood of partial or full vaccination [AOR=4.14; 95% CI: 2.9-5.9]. Children from Afar [AOR=0.14; 95% CI: 0.04-0.45], Somali [AOR=0.19; 95% CI: 0.06-0.60], Gambela [AOR=0.22; 95% CI: 0.06-0.77], Harari [AOR=0.14; 95% CI: 0.04-0.52], and Dire Dawa [AOR=0.23; 95% CI: 0.06-0.79] regions have less partial or full vaccination compared to the Tigray region children. Children living in rural areas have 47% [AOR=0.53; 95% CI: 0.30-0.93] reduced partial or full vaccination than children living in urban areas of the country (Table 2).

Table 2: Multivariable multilevel ordinal logistic regression analysis of individual and community-level determinants of child vaccination in Ethiopia, 2019

Variables	Null Mode1	Mode1 I AOR (95% CI)	Mode1 II AOR (95% CI)	Mode1 III AOR (95% CI)

Maternal educational level			
	No education	1	1
	Primary	1.97 (1.33, 2.93)**	2.16 (1.43, 3.26)***
	Secondary	1.80 (0.97, 3.33)	2.02 (1.07, 3.79)*
	Higher	2.85 (1.35, 6.02)	2.67 (1.25, 5.71)*
Maternal age			
	15-24	1	1
	25-34	1.13 (0.78, 1.63)	1.15 (0.79, 1.66)
	35-49	1.81 (1.09, 3.02)*	1.79 (1.08, 2.99)*
Religion			
	Orthodox	1	1
	Protestant	0.46 (0.27, 0.77)**	0.69 (0.36, 1.30)
	Muslim	0.71 (0.47, 1.09)	1.28 (0.73, 2.24)
	Other	0.39 (0.14, 1.22)	0.56 (0.18, 1.68)
Marital status			
	Not in union	1	1
	In union	1.84 (0.89, 3.80)	2.21 (1.06, 4.58)*
Relationship to HH head			

Household head	1	1
Wife or husband	0.79 (0.50, 1.23)	0.72 (0.46, 1.14)
Others	0.67 (0.36, 1.27)	0.62 (0.33, 1.17)
Household wealth index		
Poor	1	1
Middle	0.83 (0.51, 1.35)	0.77 (0.47, 1.29)
Rich	1.28 (0.83, 1.97)	1.05 (0.63, 1.74)
Number of ANC visits		
None	1	1
1-3	0.97 (0.61, 1.53)	0.99 (0.63, 1.58)
4 and above	1.40 (0.86, 2.29)	1.27 (0.77, 2.09)
Place of delivery		
Home	1	1
Health facility	1.22 (0.82, 1.83)	1.11 (0.74, 1.66)
PNC utilized		
No	1	1
Yes	1.04 (0.67, 1.63)	1.05 (0.67, 1.65)
Immunization document		

Available	1	1
Not available	27.32 (16.44,45.41)***	26.18(15.75,43.53)***
Preceding birth interval		
< 24 months	1	1
24-48 months	1.07 (0.69, 1.65)	1.04 (0.67, 1.62)
48 and above	1.05 (0.67, 1.65)	1.06 (0.67, 1.67)
Received Vitamin A_1		
No	1	1
Yes	4.32 (3.04, 6.15)***	4.14 (2.9, 5.9)***
Number of < 5 children		
≤ 2 children	1	1
>2 children	0.62 (0.36, 1.07)	0.68 (0.39, 1.16)
Region		
Tigray	1	1
Afar	0.08 (0.03, 0.23)***	0.14 (0.04, 0.45)**
Amhara	0.59 (0.24, 1.48)	0.5 (0.22, 1.13)
Oromia	0.21 (0.09, 0.48)***	0.45 (0.18, 1.09)
Somali	0.08 (0.03, 0.22)***	0.19 (0.06, 0.60)**

Benishangul	1.13 (0.37, 3.40)	0.74 (0.25, 2.22)
SNNPR	0.19 (0.08, 0.45)***	0.48 (0.19, 1.17)
Gambella	0.38 (0.12, 1.22)	0.22 (0.06, 0.77)*
Harari	0.43 (0.12, 1.48)	0.14 (0.04, 0.52)**
Addis Ababa	1.27 (0.39, 4.14)	1.14 (0.37, 3.47)
Dire Dawa	0.78 (0.23, 2.62)	0.23 (0.06. 0.79)*
Type of place of residence		
Urban	1	1
Rural	0.25 (0.14, 0.44)***	0.53 (0.30, 0.93)*
Community women education		
Low	1	1
High	1.04 (0.56, 1.94)	0.75 (0.51, 1.10)*

Key * = p < 0.05, * = p < 0.01, * = p < 0.001

The random effect analysis result

Table 3 presents the random effect analysis result of childhood vaccination status in Ethiopia. The appropriateness of application of multilevel analysis and the presence of significant variations of childhood vaccination status between clusters (the clustering effect) was justified by the ICC of Null model (48.19%). The value of ICC decreased from 48.19% in the null model to 14.55% in

the final model showing how the effect of clustering changed. In addition, as depicted in the table below the largest PCV of the final model (81.70%) indicates the goodness of model fitness. The final model (Model 3) has the highest capacity than model I or model II alone to explain the variations in childhood vaccination status. On top of that, Model III is the best explanatory model to show the variation in the childhood vaccination. The deviance observed in the final model was smaller than that of other models (Table 3).

Table 3: Random effects analysis and model fit statistics of child vaccination in Ethiopia, 2019

Parameters	Null Model	Model I	Model II	Model III
Community level Variance (SE)	3.06	0.76	1.21	0.56
PCV (%)	Reference	75.16%	60.46%	81.70%
ICC (%)	48.19%	18.77%	26.89%	14.55%
MOR	5.31	2.29	2.84	2.03
Log-likelihood	-988.74	-684.36	-919.88	-667.78
Deviance	1,977.48	1,368.72	1,839.76	1,335.56
AIC	1983.49	1418.72	1873.77	1413.56
BIC	1998.24	1540.70	1957.34	1603.86

Discussion

In Ethiopia, full vaccination was 39.08%. Compared to other studies in the country, it is less than that of South East Ethiopia 76.8%(26), country-level pooled prevalence (47%)(27), and 67% in 2016 from other study(35). It is also less than 59.40% Sub-Saharan vaccination coverage(22), 69.21% East Africa(35), 45.2% Mogadishu (23), and 69.3% in Togo coverage(25). It is in the

same confidence intervals as 38.3% of 2016 EDHS. This indicates that the current prevalence of full vaccination was unchanged since 2016. The reasons might be the political instabilities in the country for the last five years. Dropout rate (18.8%) may also negatively affected childhood vaccination coverage of the country. The inequalities to access health services regardless of increased population in those years might be another reason. Lack of maternal education (48.91%) also affected vaccination coverage undesirably; however, it was 67% in 2015(31). It is also better than the Sub-Saharan African countries average(22). This shows that although there are some improvements, the deviation from standard is big. Only 39.98% of mothers were from higher income families. The finding is consistent with 36.6% coverage from other study(31).

Among the associated factors, maternal education had positive association with higher full or partial vaccination, which is also similar to findings from other studies(22,31,36). The consistence might indicate that education is an independent predictor of full or partial Ffivaccination, which needs focused attention. Increased maternal age puts mothers in the higher level of full immunization category. Other studies also showed that higher age has association with full immunization(3,22). This might indicate that maternal maturity is an important factor for higher childhood vaccination in contrast to the early marriage. This means child bearing at younger age, and age at first birth needs adequate attention. Children whose mothers remained in union had higher tendency to be in higher category of full vaccination. From previous studies, there are consistent findings(22,23). This might be an indication that disrupted families might endanger children's life and so that family union should be promoted. Mothers who keep evidence of vaccination tend to be in higher category of vaccination coverage. This is also true for some studies(23,24,31). This means, women who keeps children evidence of vaccination might have indeed great regards for full immunization while carelessness might start from poor evidence

keeping. Children who received Vitamin A_1 had higher chance of being vaccination category. The fact that vitamin A is schedule towards the end of most immunization program might raise to this association (19). This might be another persist issue we never eased in previous efforts as per evidence from this study and could be set as an objective to attain other sub-objectives. Ethiopia further classified in city administrations, agrarian, and pastoralist regions. Pastoralists regions such as Afar and Somali and semi pastoralist regions such as Gambela, Benishangul Gumuz and Harari had higher tendency of failing into low category of full immunization. This is also reported by other studies (31). This is also confirmed by other studies that compared developed and underdeveloped regions in Ethiopia(31,36). This apparently shows that attention deprived regions should be the next intervention areas. This problem is relatively similar between the rural and urban place of residences. Other studies also laud that inequalities between rural and urban residence need careful considerations(20). This might be apparently due to access, awareness, and availability of resources.

Besides the positive information, this study has also some limitations such as missing data in some records, the disproportion of sample in each region, secondary source data, and time-lapse between data collection and this analysis. When observable evidence of vaccination is not available, data collectors asked mothers orally and that may cause some recall and social desirability bias. However, a Health Facility Questionnaire was used to record vaccination information for all children without a vaccination card seen during the mother's interview(34). Moreover, we are unable to include some relevant variables like psychosocial variables of parents, vaccine hesitancy and other related variables since this study used a secondary data of a national survey. The authors followed international protocols of DHS data process and analyses, weighted data, carefully interpreted finding within the period, and included complete records.

Conclusion

Although full vaccination increased from EDHS 2000 to 2016, the current analysis of EMDHS 2019 result showed that it was remained unchanged. Our analysis identified many factors that might be contributed for the absence of changes. Maternal educational level, maternal age, marital status, presence of vaccination document, received Vitamin A_1, region, and place of residence, were some of the contributors. Analyzing associated factors showed some of the factors are old enough causing the problem for decades. Even though the political situation in the country might also contributed to the persistency of these factors, it is advisable to work on accessibility, awareness, and available are vital. Maternal education and poverty especially family and maternal capacity remained critical and need all round efforts such as further government commitment, dedicated international supports, and peace and security can override the problem.

Abbreviation/Acronyms: Demographic Health Survey (DHS); Ethiopian Demographic Health Survey (EDHS); Ethiopian Mini-Demographic Health Survey(EMDHS); World Health Organization (WHO); United Nations Children's Fund (UNICEF); Adjusted Odds Ratio (AOR); Antenatal Care (ANC); Postnatal Care (PNC); Pneumococcal Conjugate Vaccine (PCV); and Measles Containing Vaccine (MCV); Bacille Calmette-Guerin (BCG); South Nations Nationalities and Peoples Region (SNNPR); Intra-class Correlation Coefficient (ICC); Median Odds Ratio (MOR), Confidence Interval (CI)

Declarations

Ethics approval and consent to participate

This study used secondary data from demographic and health survey data files. Initially, the MEASURE DHS team was formally requested to access the datasets by completing the online

request form on their website (www.dhsprogram.com). Accordingly, permission to access the data and the letter of authorization was obtained from ICF international. Therefore, for this study consent to participate is not applicable. We kept all data confidential, and no effort was made to identify households or individuals. The Ethiopian Health Nutrition and Research Institute (EHNRI) Review Board and the National Research Ethics Review Committee (NRERC) at the Ministry of Science and Technology of Ethiopia, approved EMDHS 2019. The authors also confirm that all methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable

Availability of data and materials

The survey dataset used in this analysis are third party data from the demographic and health survey website (www.dhsprogram.com) and permission to access the data is granted only for registered DHS data user.

Competing interests

The authors have declared that no competing interest existed.

Funding

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Authors' contribution

SS has obtained and analyzed the EMDHS data. SS, GG, SH were equally involved in the conception of the study, interpreted the results, drafted and critically revised the manuscript. All authors have read and approved the final version of the manuscript.

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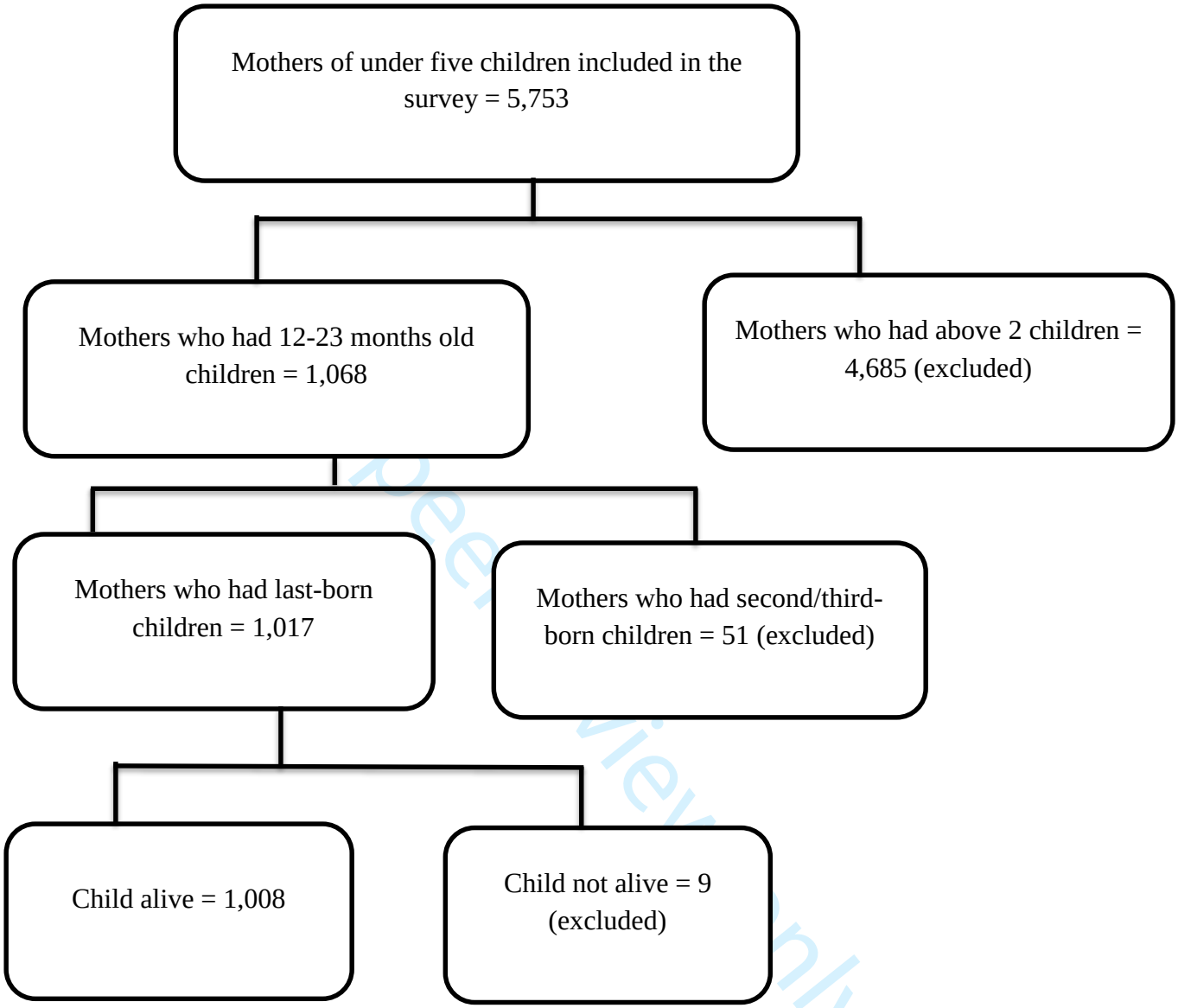

Fig. 1: Eligibility assessment for childhood vaccination coverage among children aged 12-23 month's in Ethiopia, 2019

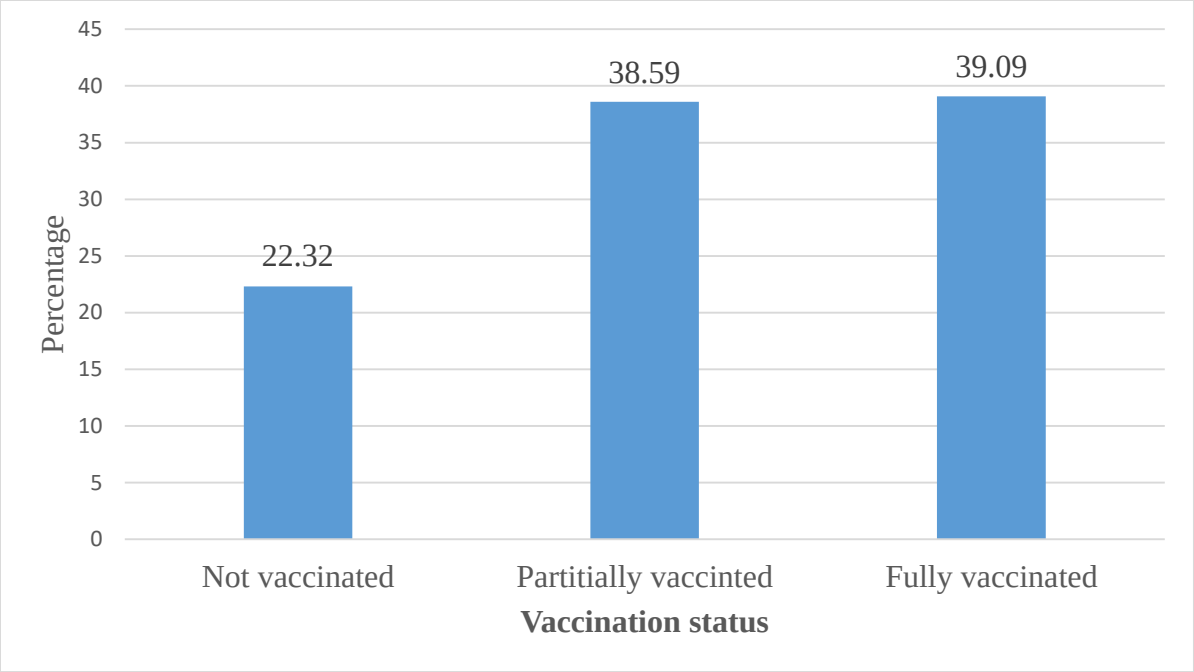

Fig. 2: Vaccination status of children aged 12-23 months in Ethiopia, 2019

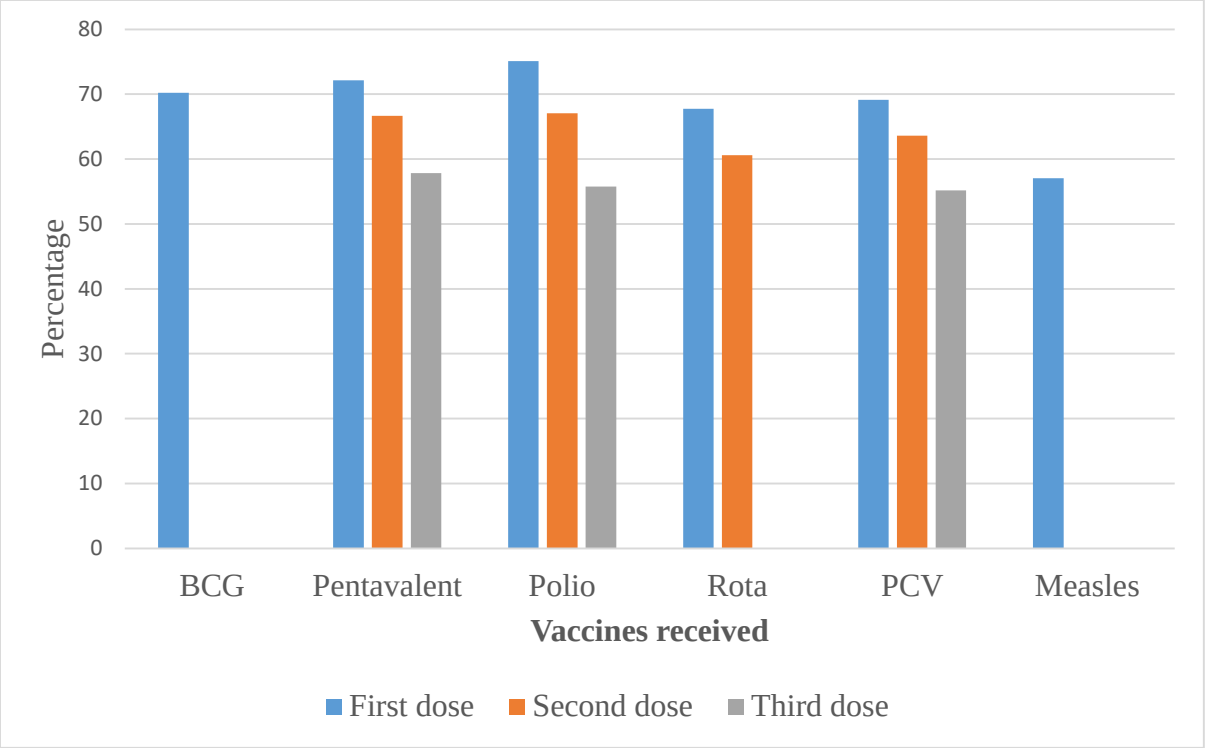

Fig. 3: Percentage of children aged 12-23 months who received a particular vaccine in Ethiopia, 2019

STROBE Statement—Checklist of items that should be included in reports of cross-sectional studies

	Item No	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*8-9*
Bias	9	Describe any efforts to address potential sources of bias	-
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10-11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	NA
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12-16
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	16
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	16-21
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and	NA

		sensitivity analyses	
Discussion			
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Determinants of childhood vaccination among children aged 12–23 months in Ethiopia: A community-based cross-sectional study

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Abstract

Objective: Childhood vaccination is a cost-effective essential service to reach larger population globally. Due to unclear reasons, new emergence and resurgence of vaccine preventable diseases gets increase. Thus, the aim of this study is to identify prevalence and determinants of childhood vaccination in Ethiopia.

Design: Community based cross-sectional study

Setting: We used data from 2019 Ethiopia Mini Demographic and Health Survey (EMDHS). The survey included all the nine regional states and two city administrations of Ethiopia.

Participants: A weighted sample of 1,008 children 12-23 months of age was included in the analysis.

Main outcome measures: Multilevel proportional odds model was fitted to identify determinants of childhood vaccination status. In the final model, variables with p-value of less than 5% and an adjusted odds ratio with a 95% CI reported.

Result: The full childhood vaccination coverage of Ethiopia was 39.09% (95% CI: 36.06%, 42.28). Mothers attended primary [AOR=2.16; 95% CI: 1.43-3.26], secondary [AOR=2.02; 95% CI: 1.07-3.79], and higher schools [AOR=2.67; 95% CI: 1.25-5.71], being in union [AOR=2.21; 95% CI: 1.06-4.58], kept vaccination cards [AOR=26.18; 95% CI: 15.75-43.53], children received Vitamin A_1 [AOR=4.14; 95% CI: 2.9-5.9], living in Afar [AOR=0.14; 95% CI: 0.04-0.45], Somali [AOR=0.19; 95% CI: 0.06-0.60], Gambela [AOR=0.22; 95% CI: 0.06-0.77], Harari [AOR=0.14; 95% CI: 0.04-0.52], Dire Dawa [AOR=0.23; 95% CI: 0.06-0.79] regions, and rural residents [AOR=0.53; 95% CI: 0.30-0.93] were factors significantly associated with childhood vaccination.

Conclusion: The coverage of full childhood vaccination in Ethiopia was low remained unchanged since 2016. The study identified both the individual- and community-level factors affected the vaccination status. Accordingly, public health intervention targeted to these identified factors can increase childhood full vaccination status.

Keywords: full vaccination; multilevel; ordinal, 12-23 months' children; Ethiopia

Strengths and limitations of this study

- This study used most recent nationwide secondary data that shows proportion of EPI coverage among children aged 12–23 months in Ethiopia.
- We used multilevel proportional odds model to overcome the hierarchical nature of EMDHS data and to identify both individual and community-level factors of EPI.
- This study did not include some important variables like psychosocial variables of parents, vaccine hesitancy and other related variables since the study used secondary data of a national survey.
- Establishing temporal relationship of causation between childhood vaccination and its determinants was impossible due to the nature of the study design used for the survey.
- Recall bias is the most relevant limitation of the study.

Introduction

According to the United Nations Children Fund (UNICEF), immunizations is a dynamic constituent of frontline health care to access larger populations. Compared to any other health or social activities, immunization reduces global annual death by significant proportion(1–4). It saves lives and protects people's health, improves countries' productivity and resilience, and helps to ensure a safer and healthier world(5,6).

According to the Ethiopian Ministry of Health, a child takes OPV_0 and BCG at Birth. At six weeks after birth, a child takes OPV1(oral polio vaccine), Pentavalent1(DPT+HepB+HIb), Pneumococcal1, and Rotavirus1. Then 10 weeks after birth the child takes OPV2, and Pentavalent2, Pneumococcal2, and Rota2. The child takes OPV3, Pentavalent3, Pneumococcal3, Inactivated polio vaccine (IPV) at 14^{th} weeks. Other vaccines such as Measles Containing Vaccine (MCV1) at 9^{th} month and MCV2 at 15^{th} month and human papilloma virus (HPV) at 14^{th} years for girls are given. However, this study only considers vaccines between 1 to 2 years. All vaccines are equally important(7). Currently, Ethiopia do not provide Rubella, Mumps and chickenpox vaccines to immunize children. Depending on the amount of immunity or protection after receiving a dose, a child may require more than one dose for some vaccine(8). Additionally, more than one dose is needed to build high enough immunity to prevent disease and boost immunity that fades over time(9). For vaccines that do not initiate full protection at first introduction, additional dose of vaccine usually repeated(10). However, this does not mean one vaccine is better than the other is or more important than another since it depends on the nature of the disease.

Globally, about 6.6 million children die every year and half of the deaths would have been prevented by vaccination(11). The global inequality in health care distribution force many low and middle income countries to live under the bundle of pestilent cumulative old health problems(12).

Africa is among the regions severely affected by globally imbalanced immunization resources distribution. Vaccine preventable diseases become the big burden in war affected parts of the world and underdeveloped countries like Ethiopia(13). Despite the existence of highly cost-effective vaccines on global markets, situations such as war, displacements, under vaccination, and poor access to vaccine contributes to the prevalence of vaccine preventable disease(14). The proportion of the full immunization reflects how resources distribution caused the imbalance in childhood vaccination(1,15).

Regardless of advancement and attainments of immunization, newly emerging vaccine preventable diseases become still common in Africa(16). There are people who deprived of accessing immunization in some countries and becoming the reason for the prevalence of vaccine preventable diseases as admitted by World Health Organization (WHO) and other studies(17–19). In Ethiopia a study has described that educated (30%) and rich (31%) people better vaccinate their children(20).

Some evidences indicated that global vaccine coverage is decreasing(21). A study summarized the Demographic Health Surveys (DHS) of Sub-Saharan African countries showed that the full vaccination coverage was 59.40% in 2021(22). In Mogadishu, full immunization was 45.2% and 41.4% in 2020 and 2021 respectively(22–24). In Togo, the full immunization coverage was 69.3% in Lome district in 2019(25). In Ethiopia. the full immunization coverage is 76.81% in the Southeast region(26); however, the pooled prevalence amongst 12–23 month old children in Ethiopia is 47%(27). EMDHS 2019 demonstrated that coverage of full vaccination was 44(28)%. The magnitude of full vaccination was increased from 14.3% in 2000 to 44% in 2019(29). From this, we understand that the coverage of full vaccination is not adequate.

Many factors that support the argument of resource disparities as a reason for low coverage in some countries. A systematic review conducted in Sub-Saharan African countries showed that lack of knowledge of immunization knowledge, distance to access point, financial deprivation, lack of partners support, and distrust in vaccines and immunization programs were the barrier(30). The absence of immunization card, respondents' sex, level of education, marital status, and organization of health system are mentioned in another study(25). A study included many sub Saharan African countries showed that maternal education, health facility delivery, fathers secondary education and above, ANC visits, PNC visit, wealth index, media exposure, and distance to health facility affected the vaccination coverage(22). In Ethiopia, from previous four EDHS, postnatal check-up, maternal awareness, regional difference (economic, education and life style), educational status, residence, and women wealth index have been influenced vaccination(20,27,31). From another study antenatal care visit, higher level of maternal education, good knowledge of immunization, short distance to health facility, and institutional delivery were the determinants of childhood immunization(32).

Different small scale and large scale (national level) studies have been done to identify the determinants of childhood vaccination in the country. However, majority of the studies conducted did not examined natural ordering of child's vaccination status as fully, partially, or not vaccinated at all. Hence, we used multilevel proportional odds model which overcomes the hierarchal nature of the DHS data and considers natural ordering of the outcome variable. In addition, the coverage of full vaccination still remains far behind the national health sector transformation plan II of Ethiopia (75% by 2024/25)(33), showing the need for further study. Therefore, this study aimed determining prevalence of childhood vaccination coverage and its determinants to assist in policy improvements.

Methods

Study design

This study used the 2019 cross-sectional data of Ethiopian mini demographic and health survey (EMDHS). We obtained the dataset from demographic and health survey website (http://dhsprogram.com/data/) after getting permission to access. The mini survey was conducted in March 2019 to June 2019 for the second time in Ethiopia. The Ethiopian Public Health Institute (EPHI) in collaboration with Central Statistical Agency (CSA) and Federal Ministry of Health (FMOH) implemented a nationally representative household survey.

Study setting

The EMDHS survey included all the nine regions and two city administrations of the country. Ethiopia is the second most populous country from Africa and located in the horn of Africa.

Participants

The 2019 EMDHS used the sampling frame created for the upcoming Ethiopia population and housing census list of 149,093 enumeration areas (EA). Participants of the study were selected through a stratified two-stage cluster sampling technique. Initially, they stratified each region in the country into urban and rural areas. Probability proportional to EA size was used to select 305 EAs (93 in urban and 212 in rural areas). In the second stage, lists of households were used as a sampling frame to select 30 households per cluster by equal probability systematic selection technique. Eligible participants for the interview were all women aged 15-49 years and who were the residents of the selected households. Accordingly, 8,885 women were interviewed out of 9,012 eligible women, giving a response rate of 98.6%. All living children age 12–23 months at the time

of the survey were the source population of the study. The details of the survey methods and procedures are available in the 2019 EMDHS report (29).

Eligibility criteria

All children born in the 2 years preceding the survey were included in the analysis. However, children who were not alive at the time of the survey were excluded from this study. Accordingly, data of 1,008 children who had born in the last 2 years and surviving were extracted from the 2019 EMDHS datasets for this analysis (Fig. 1).

Measurements of variables of the Study

Dependent variable

Child vaccination status was the outcome variable of the study. We categorized the outcome variable as not vaccinated, partially vaccinated and fully vaccinated.

Fully vaccinated: is a child that has received one dose of Bacille Calmette-Guerin (BCG), three doses of pentavalent, three doses of polio, two doses of Rota, three doses of pneumococcal conjugate vaccine (PCV), and one dose of measles (MCV1).

Partially vaccinated: is a child who had missed at least one or more of the thirteen vaccines/doses.

Not vaccinated: is a child that has not received any vaccine at all.

The interviewers of the 2019 EMDHS obtained information on vaccination coverage from written vaccination cards (infant immunization card and other health cards), from mothers' verbal reports, and from health facility records. They request mothers who born child in the three preceding years of the survey to show the infant immunization card or health card. Subsequently, they copy the dates of each vaccination given in the corresponding questionnaire. Similarly, they ask mother who did not kept the cards to recall whether the child received that specific vaccination and the

number of doses that the child received. In addition, to complement these data (information collected based on the mother's recall) the field supervisor collects complementary vaccination records from health facility for a child who visited a health facility and missed vaccination data. Finally, a Health Facility Questionnaire was used to record vaccination information for all children without a vaccination card seen during the mother's interview; however, we dropped records with the missing data.

Independent variables

In this study, we considered both individual and community-level variables. The individual-level variables included are maternal age, maternal educational level, religion, marital status, relationship to household head, sex of the household head, wealth index, number of antenatal care (ANC) visits, place of delivery, utilized postnatal care, presence of vaccination document, birth order number, preceding birth interval, sex of child, vitamin A1, total children ever born, and number of under five children in household. Region, type of place of residence, community women education, community poverty, and community ANC utilization are community-level factors of the study. Region is a grouping of the first administrative level of Ethiopia. During the survey period, there were 9 regions and 2 city administrations in the country namely, Tigray, Amhara, Afar, Oromia, Somali, Benishangul-Gumuz, South nations nationalities and people's region (SNNPR), Gambela, Harari, and two city administrations (Addis Ababa and Dire Dawa). Moreover, community women education, community poverty and community ANC utilization were community-level variables derived by aggregating individual-level factors. They were categorized as "low" or "high" based on the median value since the EMDHS were not normally distributed.

Information regarding the wealth index is derived from data collected in the Household Questionnaire. The questionnaire includes queries concerning the household's ownership of several consumer items such as television and car; dwelling characteristics such as flooring material; type of drinking water source; toilet facilities; and other characteristics related to wealth status. Each household asset for which information is collected is assigned a weight or factor score generated through principal components analysis (PCA). The resulting asset scores are standardized about a standard normal distribution with a mean of zero and a standard deviation of one. These standardized scores then used to create the breakpoints that define wealth quintiles as Lowest, Second, Middle, Fourth, and Highest(34). Here, we further categorized the wealth index into poor (lowest plus poor), average (middle), and rich (rich plus highest).

Data processing and statistical analysis

The data were cleaned, re-coded and analyzed using STATA/SE version 14.0. We used numbers, mean, percentage or proportions to describe both the individual- and community-level variables. We used sample weight to manage sampling errors and non-responses. The hierarchical nature of the DHS data (DHS sampling methods) violates the assumption of independence or lack of correlation of the residuals. In the DHS survey, observations are interdependent as participants nested in the same cluster may behave in the same way and differ to other clusters in terms of the outcome of interest. consequently, we used a two-level multilevel proportional odds model, as single-level traditional statistical model might not be adequate to control for the clustering effect. Moreover, we used multilevel proportional odds model to consider the natural ordering of the response variable (not vaccinated, partially vaccinated and fully vaccinated). Accordingly, we built four consecutive models to identify determinants of child vaccination in Ethiopia. We first fitted the null model or the intercept only model. Then, model 1 was fitted with the individual-level

variables. Similarly, we fitted model 2 (with community-level factors). Finally, model 3 or the mixed-effects model was fitted with both individual- and community-level factors. The intra-class correlation coefficient (ICC) was used to determine the clustering effect or community variation and it was calculated using the following formula.

$$\text{ICC} = \frac{V_A}{V_A + \frac{\pi^2}{3}}$$

Where: V_A is community level variance and $\frac{\pi^2}{3} = 3.29$ is individual level variance. On the other hand, we checked Proportional Change in Variance (PCV), Median Odds Ratio (MOR), and Deviance by using the following formulas to determine the fitness of the model. PCV $= \frac{V_0 - V_i}{V_0}$. Where: V_0 is a variance in the null model and V_i is a variance in the consecutive models. MOR = $e^{0.95V_i}$ where: V_i indicates that cluster variance. The last model showed the lowest deviance (Model III) and become the best-fitted model. Furthermore, we examined the proportional odds assumption that assume the equal effect of each factor across the outcome categories by score test. We checked Variance Inflation Factor (VIF) and found 1.60 to assess the presence of multicollinearity. The finding is in the acceptable range. In bi-variable analysis, we kept variables with p-value less than 0.25 for the multivariable multilevel proportional odds analysis. Finally, in the multivariable analysis, we reported variables with p-value less than 5%, adjusted proportional odds ratio (APOR) and 95% confidence interval.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Result

Socio-demographic characteristics of mothers and children

The current study included 1,008 mothers who have children aged 12-23 months. Out of the total respondents, more than half (52.78%) were in the age range of 25-34 years, nearly half (48.91%) have not attended education, and almost one-third (32.14%) were Orthodox religion followers. Four out of ten mothers (39.98%) were from high income households and the majorities (94.05%) were currently in union (Table 1).

Table 1: Socio-demographic characteristics of mothers of children aged 12-23 months in Ethiopia, 2019 (n=1008)

Variables	Frequency (n)	Percentage (%)
Maternal age		
15-24	298	29.56
25-34	532	52.78
35-49	178	17.66
Maternal education		
No education	493	48.91
Primary	342	33.93
Secondary	99	9.82
Higher	74	7.34
Marital status		
Not in union	60	5.95
In union	948	94.05
Religion		

	Orthodox	324	32.14
	Protestant	177	17.56
	Muslim	481	47.72
	Others	26	2.58
Wealth index			
	Poor	469	46.53
	Middle	136	13.49
	Rich	403	39.98
Region			
	Tigray	93	9.23
	Amhara	111	11.01
	Afar	99	9.82
	Oromia	127	12.60
	Somali	85	8.43
	Benishabgul	83	8.23
	SNNPR	116	11.51
	Gambela	77	7.64
	Harari	73	7.24
	Addis Ababa	64	6.35
	Dire Dawa	80	7.94
Type of place of residence			
	Urban	267	26.49
	Rural	741	73.51

Community women education		
Low	468	46.43
High	540	53.57
Community poverty		
Low	495	49.11
High	513	50.89
Community ANC utilization		
Low	468	46.43
High	540	53.57

Healthcare service utilization related characteristics of mothers

Among the participants, less than half (44.15%) were practiced home delivery, nearly a quarter (24.31%) had no ANC visit, and almost one-tenth (13.99%) received PNC service. Majority of the mothers (71.73%) kept immunization document and 88.1% of the interviewed mothers have less than or equal to two under five children in their households. From the total number of children, half (50.30%) were males, 22.72% were first-born, and 59.33% were received the most recent vitamin A1. Three-fourth of respondents (73.51%) was from rural areas and 12.6% were from Oromia region of the country (Table 2).

Table 2: Healthcare service utilization related characteristics of mothers with children aged 12–23 months in Ethiopia, 2019 (n=1008)

Number of ANC visits		
None	245	24.31

1-3 times	313	31.05
4 and above	450	44.64
Place of delivery		
Home	445	44.15
Health facility	563	55.85
PNC service		
No	836	86.01
Yes	136	13.99
Sex of child		
Male	507	50.30
Female	501	49.70
Birth order number		
1st born	229	22.72
2nd to 3rd	372	36.90
4th to 5th	204	20.24
6th and above	203	20.14
Presence of vaccination document		
No	285	28.27
Yes	723	71.73
Preceding birth order		
< 24 months	186	18.45
24-48	357	35.42
48 and above	465	46.13

Received Vitamin A1		
No	410	40.67
Yes	598	59.33
Total children ever born		
1-3 children	598	59.33
4-6 children	278	27.58
7 and above	132	13.10
Number of <5 children in household		
≤ 2	888	88.10
> 2	120	11.90

Childhood vaccination status in Ethiopia

The full vaccination coverage among children aged 12-23 months in Ethiopia was 39.09% (95% CI: 36.06%, 42.28) (Fig. 2). On the other hand, two in ten children (22.32%) of 12-23 months' age have not received any vaccination in three years before the 2019 survey period. Among the children of 12-23 months' age included in the study, 70.24% received BCG, 57.84% received the third dose of pentavalent, 55.75% received the third dose of polio, 60.62% received the second dose of rotavirus vaccine, 55.16% received the third dose of PCV, and 57.04% received the first dose of measles vaccination (Fig. 3).

Factors affecting child vaccination in Ethiopia

The fixed effect analysis result

The multivariable analysis showed that maternal educational level of mothers, maternal age, marital status, presence of vaccination document, received Vitamin A_1, region, and place of residence, were significantly associated with childhood vaccination. Children whose mothers attended primary, secondary, and higher education have 2.2 [AOR=2.16; 95% CI: 1.43-3.26], 2 [AOR=2.02; 95% CI: 1.07-3.79], and 2.7 [AOR=2.67; 95% CI: 1.25-5.71] times higher partial or full vaccination respectively compared to born to mothers with no education. The odds of partial or full vaccination was 1.8 [AOR=1.79; 95% CI: 1.08-2.99] times higher among children whose mothers are in the age range of 35-49 compared to 15-19 age group. Mothers who are currently in union have 2.2 [AOR=2.21; 95% CI: 1.06-4.58] times more likely to vaccinate their children either partially or fully. keeping vaccination cards was 26 [AOR=26.18; 95% CI: 15.75-43.53] times more likely associated with partial or full vaccination compared to not keeping vaccination cards. Children who have received Vitamin A_1 have higher likelihood of partial or full vaccination [AOR=4.14; 95% CI: 2.9-5.9]. Children from Afar [AOR=0.14; 95% CI: 0.04-0.45], Somali [AOR=0.19; 95% CI: 0.06-0.60], Gambela [AOR=0.22; 95% CI: 0.06-0.77], Harari [AOR=0.14; 95% CI: 0.04-0.52], and Dire Dawa [AOR=0.23; 95% CI: 0.06-0.79] regions have less partial or full vaccination compared to the Tigray region children. Children living in rural areas have 47% [AOR=0.53; 95% CI: 0.30-0.93] reduced partial or full vaccination than children living in urban areas of the country (Table 3).

Table 3: Multivariable multilevel ordinal logistic regression analysis of individual and community-level determinants of child vaccination in Ethiopia, 2019

Variables	Null Mode1	Mode1 I AOR (95% CI)	Mode1 II AOR (95% CI)	Mode1 III AOR (95% CI)

Maternal educational level			
	No education	1	1
	Primary	1.97 (1.33, 2.93)**	2.16 (1.43, 3.26)***
	Secondary	1.80 (0.97, 3.33)	2.02 (1.07, 3.79)*
	Higher	2.85 (1.35, 6.02)	2.67 (1.25, 5.71)*
Maternal age			
	15-24	1	1
	25-34	1.13 (0.78, 1.63)	1.15 (0.79, 1.66)
	35-49	1.81 (1.09, 3.02)*	1.79 (1.08, 2.99)*
Religion			
	Orthodox	1	1
	Protestant	0.46 (0.27, 0.77)**	0.69 (0.36, 1.30)
	Muslim	0.71 (0.47, 1.09)	1.28 (0.73, 2.24)
	Other	0.39 (0.14, 1.22)	0.56 (0.18, 1.68)
Marital status			
	Not in union	1	1
	In union	1.84 (0.89, 3.80)	2.21 (1.06, 4.58)*
Immunization document			
	Available	1	1
	Not available	27.32 (16.44,45.41)***	26.18(15.75,43.53)***
Received Vitamin A_1			
	No	1	1
	Yes	4.32 (3.04, 6.15)***	4.14 (2.9, 5.9)***

Region		
Tigray	1	1
Afar	0.08 (0.03, 0.23)***	0.14 (0.04, 0.45)**
Amhara	0.59 (0.24, 1.48)	0.5 (0.22, 1.13)
Oromia	0.21 (0.09, 0.48)***	0.45 (0.18, 1.09)
Somali	0.08 (0.03, 0.22)***	0.19 (0.06, 0.60)**
Benishangul	1.13 (0.37, 3.40)	0.74 (0.25, 2.22)
SNNPR	0.19 (0.08, 0.45)***	0.48 (0.19, 1.17)
Gambella	0.38 (0.12, 1.22)	0.22 (0.06, 0.77)*
Harari	0.43 (0.12, 1.48)	0.14 (0.04, 0.52)**
Addis Ababa	1.27 (0.39, 4.14)	1.14 (0.37, 3.47)
Dire Dawa	0.78 (0.23, 2.62)	0.23 (0.06. 0.79)*
Type of place of residence		
Urban	1	1
Rural	0.25 (0.14, 0.44)***	0.53 (0.30, 0.93)*
Community women education		
	1	1
Low	1.04 (0.56, 1.94)	0.75 (0.51, 1.10)*
High		

Key * = p < 0.05, * = p < 0.01, * = p < 0.001

The random effect analysis result

Table 3 presents the random effect analysis result of childhood vaccination status in Ethiopia. The appropriateness of application of multilevel analysis and the presence of significant variations of

childhood vaccination status between clusters (the clustering effect) was justified by the ICC of Null model (48.19%). The value of ICC decreased from 48.19% in the null model to 14.55% in the final model showing how the effect of clustering changed. In addition, as depicted in the table below the largest PCV of the final model (81.70%) indicates the goodness of model fitness. The final model (Model 3) has the highest capacity than model I or model II alone to explain the variations in childhood vaccination status. On top of that, Model III is the best explanatory model to show the variation in the childhood vaccination. The deviance observed in the final model was smaller than that of other models (Table 4).

Table 4: Random effects analysis and model fit statistics of child vaccination in Ethiopia, 2019

Parameters	Null Model	Model I	Model II	Model III
Community level Variance (SE)	3.06	0.76	1.21	0.56
PCV (%)	Reference	75.16%	60.46%	81.70%
ICC (%)	48.19%	18.77%	26.89%	14.55%
MOR	5.31	2.29	2.84	2.03
Log-likelihood	-988.74	-684.36	-919.88	-667.78
Deviance	1,977.48	1,368.72	1,839.76	1,335.56
AIC	1983.49	1418.72	1873.77	1413.56
BIC	1998.24	1540.70	1957.34	1603.86

Discussion

In Ethiopia, full vaccination was 39.08%. Compared to other studies in the country, it is less than that of South East Ethiopia 76.8%(26), country-level pooled prevalence (47%)(27), and 67% in

2016 from other study(35). It is also less than 59.40% Sub-Saharan vaccination coverage(22), 69.21% East Africa(35), 45.2% Mogadishu (23), and 69.3% in Togo coverage(25). It is in the same confidence intervals as 38.3% of 2016 EDHS. This indicates that the current prevalence of full vaccination was unchanged since 2016. The reasons might be the political instabilities in the country for the last five years. Dropout rate (18.8%) may also negatively affected childhood vaccination coverage of the country. The inequalities to access health services regardless of increased population in those years might be another reason. Lack of maternal education (48.91%) also affected vaccination coverage undesirably; however, it was 67% in 2015(31). It is also better than the Sub-Saharan African countries average(22). This shows that although there are some improvements, the deviation from standard is big. Only 39.98% of mothers were from higher income families. The finding is consistent with 36.6% coverage from other study(31).

Among the associated factors, maternal education had positive association with higher full or partial vaccination, which is also similar to findings from other studies(22,31,36). The consistence might indicate that education is an independent predictor of full or partial Ffivaccination, which needs focused attention. Increased maternal age puts mothers in the higher level of full immunization category. Other studies also showed that higher age has association with full immunization(3,22). This might indicate that maternal maturity is an important factor for higher childhood vaccination in contrast to the early marriage. This means child bearing at younger age, and age at first birth needs adequate attention. Children whose mothers remained in union had higher tendency to be in higher category of full vaccination. From previous studies, there are consistent findings(22,23). This might be an indication that disrupted families might endanger children's life and so that family union should be promoted. Mothers who keep evidence of vaccination tend to be in higher category of vaccination coverage. This is also true for some

studies(23,24,31). This means, women who keeps children evidence of vaccination might have indeed great regards for full immunization while carelessness might start from poor evidence keeping. Children who received Vitamin A_1 had higher chance of being vaccination category. The fact that vitamin A is schedule towards the end of most immunization program might raise to this association (19). This might be another persist issue we never eased in previous efforts as per evidence from this study and could be set as an objective to attain other sub-objectives. Ethiopia further classified in city administrations, agrarian, and pastoralist regions. Pastoralists regions such as Afar and Somali and semi pastoralist regions such as Gambela, Benishangul Gumuz and Harari had higher tendency of failing into low category of full immunization. This is also reported by other studies (31). This is also confirmed by other studies that compared developed and underdeveloped regions in Ethiopia(31,36). This apparently shows that attention deprived regions should be the next intervention areas. This problem is relatively similar between the rural and urban place of residences. Other studies also laud that inequalities between rural and urban residence need careful considerations(20). This might be apparently due to access, awareness, and availability of resources.

Besides the positive information, this study has also some limitations such as missing data in some records, the disproportion of sample in each region, secondary source data, and time-lapse between data collection and this analysis. When observable evidence of vaccination is not available, data collectors asked mothers orally and that may cause some recall and social desirability bias. However, a Health Facility Questionnaire was used to record vaccination information for all children without a vaccination card seen during the mother's interview(34). Moreover, we are unable to include some relevant variables like psychosocial variables of parents, vaccine hesitancy and other related variables since this study used a secondary data of a national survey. The authors

followed international protocols of DHS data process and analyses, weighted data, carefully interpreted finding within the period, and included complete records.

Conclusion

Although full vaccination increased from EDHS 2000 to 2016, the current analysis of EMDHS 2019 result showed that it was remained unchanged. Our analysis identified many factors that might be contributed for the absence of changes. Maternal educational level, maternal age, marital status, presence of vaccination document, received Vitamin A_1, region, and place of residence, were some of the contributors. Analyzing associated factors showed some of the factors are old enough causing the problem for decades. Even though the political situation in the country might also contributed to the persistency of these factors, it is advisable to work on accessibility, awareness, and available are vital. Maternal education and poverty especially family and maternal capacity remained critical and need all round efforts such as further government commitment, dedicated international supports, and peace and security can override the problem.

Abbreviation/Acronyms: Demographic Health Survey (DHS); Ethiopian Demographic Health Survey (EDHS); Ethiopian Mini-Demographic Health Survey(EMDHS); World Health Organization (WHO); United Nations Children's Fund (UNICEF); Adjusted Odds Ratio (AOR); Antenatal Care (ANC); Postnatal Care (PNC); Pneumococcal Conjugate Vaccine (PCV); and Measles Containing Vaccine (MCV); Bacille Calmette-Guerin (BCG); South Nations Nationalities and Peoples Region (SNNPR); Intra-class Correlation Coefficient (ICC); Median Odds Ratio (MOR), Confidence Interval (CI)

Declarations

Ethics approval and consent to participate

This study used secondary data from demographic and health survey data files. Initially, the MEASURE DHS team was formally requested to access the datasets by completing the online request form on their website (www.dhsprogram.com). Accordingly, permission to access the data and the letter of authorization was obtained from ICF international. Therefore, for this study consent to participate is not applicable. We kept all data confidential, and no effort was made to identify households or individuals. The Ethiopian Health Nutrition and Research Institute (EHNRI) Review Board and the National Research Ethics Review Committee (NRERC) at the Ministry of Science and Technology of Ethiopia, approved EMDHS 2019. The authors also confirm that all methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable

Availability of data and materials

The survey dataset used in this analysis are third party data from the demographic and health survey website (www.dhsprogram.com) and permission to access the data is granted only for registered DHS data user.

Competing interests

The authors have declared that no competing interest existed.

Funding

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Authors' contribution

SS has obtained and analyzed the EMDHS data. SS, GG, SH were equally involved in the conception of the study, interpreted the results, drafted and critically revised the manuscript. All authors have read and approved the final version of the manuscript.

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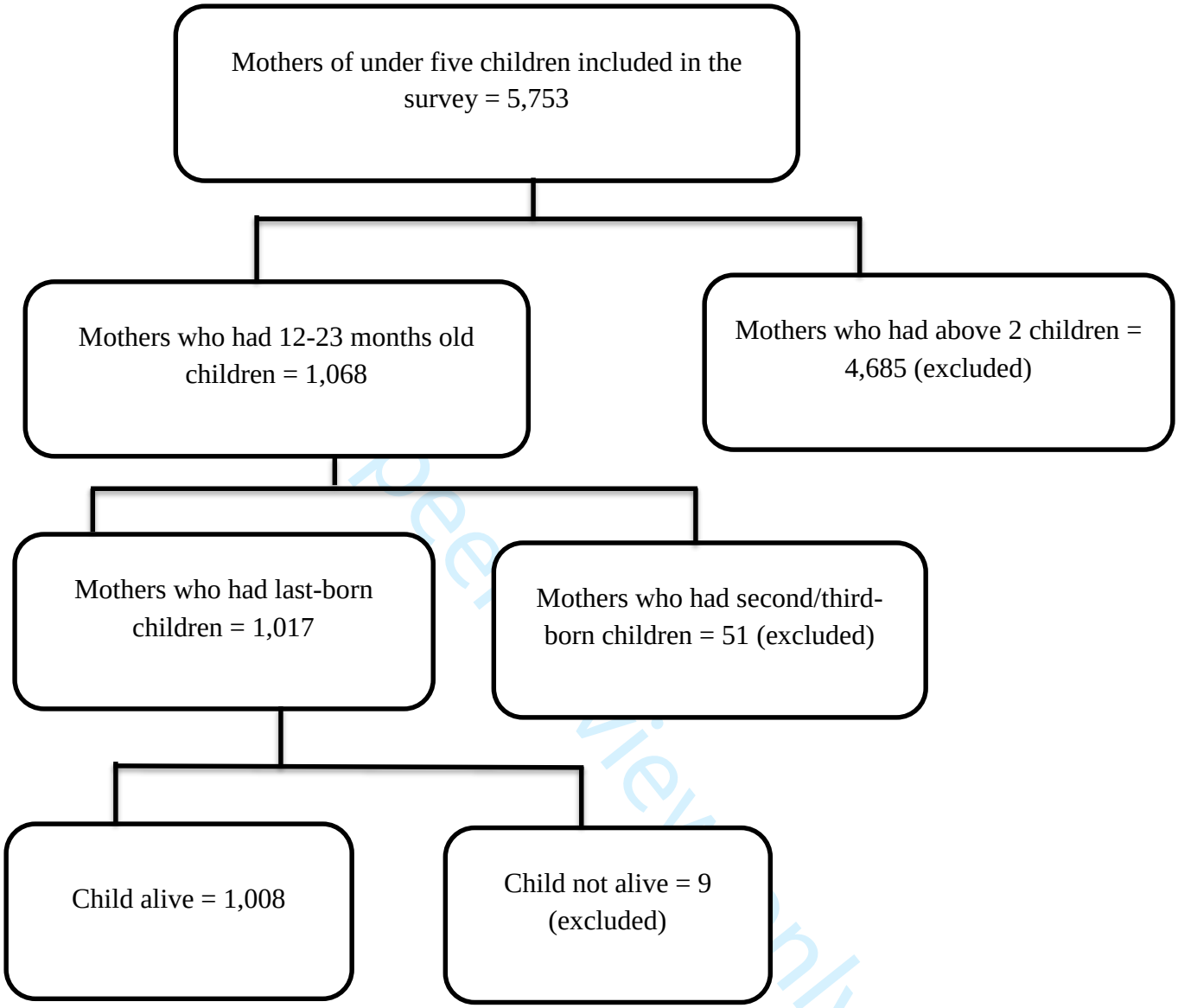

Fig. 1: Eligibility assessment for childhood vaccination coverage among children aged 12-23 month's in Ethiopia, 2019

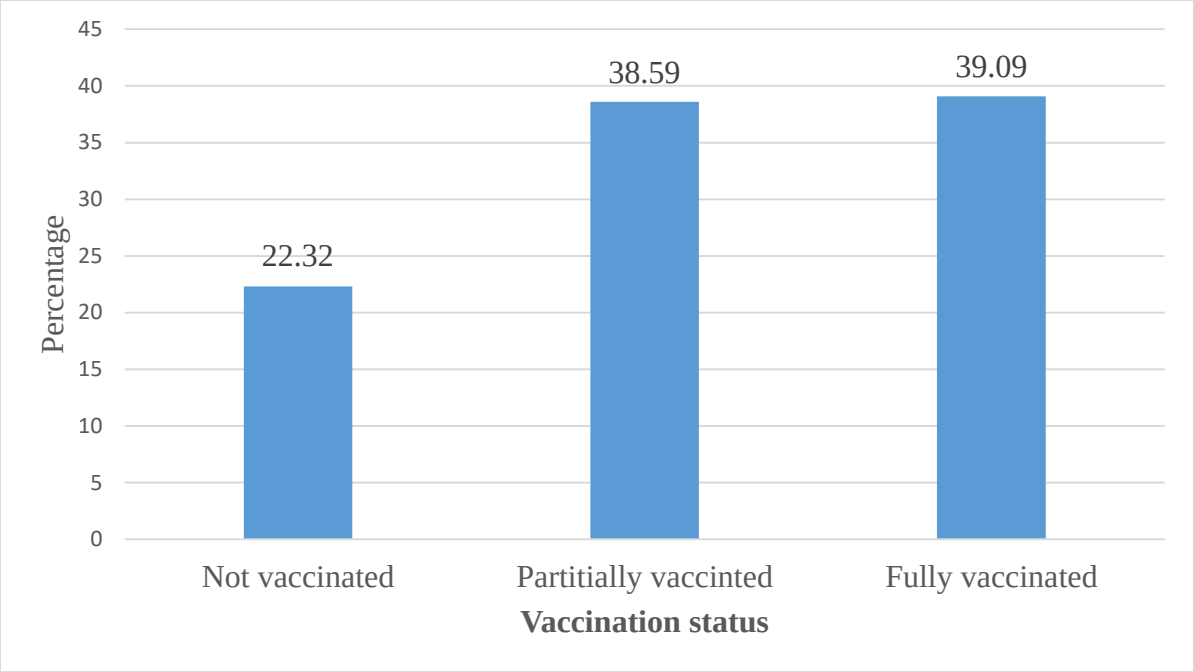

Fig. 2: Vaccination status of children aged 12-23 months in Ethiopia, 2019

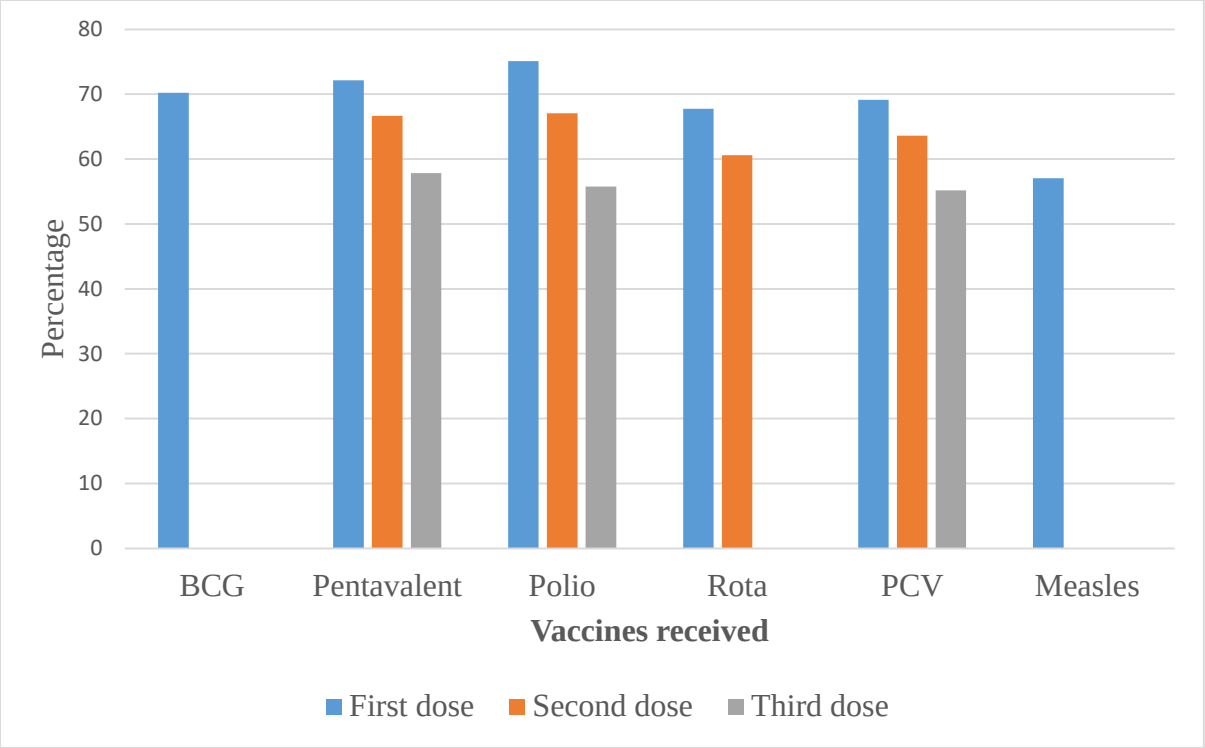

Fig. 3: Percentage of children aged 12-23 months who received a particular vaccine in Ethiopia, 2019

STROBE Statement—Checklist of items that should be included in reports of cross-sectional studies

	Item No	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*8-9*
Bias	9	Describe any efforts to address potential sources of bias	-
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10-11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	NA
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12-16
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	16
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	16-21
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and	NA

		sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	22
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	24
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	23-24
Generalisability	21	Discuss the generalisability (external validity) of the study results	22-24
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	26