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Uptake of the recently introduced vaccines among children aged 12–23 months in Ethiopia: a multilevel analysis of the 2019 Ethiopia Mini Demographic and Health Survey

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ABSTRACT

Objective Though vaccination coverage in Ethiopia has shown steady progress over the years, there are districts with below targeted vaccination coverage. This study assessed the magnitude and determinants of recently introduced vaccines uptake among children aged 12–23 months in Ethiopia.

Design National cross-sectional study.

Setting Ethiopia.

Participants Mothers with children aged between 12 and 23 months.

Outcome measures The outcome variable was the uptake of recently introduced vaccines (rotavirus vaccine (RV) and pneumococcal conjugate vaccine (PCV)) among children aged 12–23.

Results Our analysis revealed that 45.7%, 53.4% and 43.5% of the children completed vaccination with PCV, RV and both PCV and RV, respectively. Being in the age group of 20–34 (adjusted OR (AOR)=2.03, 95% CI: 1.37 to 3.02) and 35–49 (AOR=2.44, 95% CI: 1.52 to 3.91), having at least four antenatal care contacts (AOR=2.73, 95% CI: 2.06 to 3.62), having postnatal care (AOR=1.84, 95% CI: 1.42 to 2.37), delivery in the health facility (AOR=1.45, 95% CI: 1.17 to 1.79) and having exposure to media (AOR=1.24, 95% CI: 1.09 to 1.56) and any of the wealth quintile categories higher than poorest category were positively associated with the uptake of newly introduced vaccines. Rural residency was found to be negatively associated with the uptake of newly introduced vaccines.

Conclusion The overall full uptakes of newly introduced vaccines among children aged 12–23 months were significantly lower. Hence, this study emphasises the need to strengthen maternal and child healthcare services, particularly to the younger age mother and those with lower socioeconomic status.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study's strength was its use of national data and a large, representative sample reflecting the country's socioeconomic, geographic and infrastructural diversity.
⇒ Multilevel analysis was used to identify an accurate representation of the variability in the data.
⇒ Recall bias risk exists because mothers' self-reports were used when vaccination cards or health records were not available.
⇒ Due to the lack of vaccine supply data in the Ethiopia Mini Demographic and Health Survey, our investigation focused mainly on demand-side determinants.

INTRODUCTION

Vaccination is one of the most effective and efficient preventive public health interventions worldwide.[1 2] It is one of modern medicine's greatest success stories,[3 4] and it averts between 2 and 3 million deaths every year.[2] The impact of vaccination on achieving the Sustainable Development Goals (SDGs) cannot be overstated, as it plays a crucial role in 14 out of the 17 goals (excluding goals 12, 14 and 15).[2 4 5] Not only does vaccination prevent illnesses and deaths from infectious diseases, but it also contributes to improvements in education and economic development.[2] Particularly in disadvantaged communities and developing countries, vaccination has been proven to significantly reduce mortality and morbidity rates.[2] However, over 1.5 million lives are still lost each year due to vaccine-preventable diseases, largely due to inadequate coverage.[6] With a global effort to improve vaccination coverage, these deaths could be avoided.

Sub-Saharan Africa is characterised by a high burden of vaccine-preventable diseases and a significant number of vaccine-preventable deaths among children.[7] However, vaccine coverage remains suboptimal in many countries, particularly in sub-Saharan Africa, where children are at a higher risk of vaccine-preventable diseases

Table 1 National immunisation schedules for infants in Ethiopia

Type of vaccine	Age (when to give)
BCG, OPV0	At birth
(DPT-HepB-Hib)1, OPV1, PCV1, Rota 1	6 weeks
(DPT-HepB-Hib)2, OPV2, PCV, Rota2	10 weeks
(DPT-HepB-Hib)3, OPV3, PCV3	14 weeks
Measles	9 months

BCG, Bacillus Calmette-Guérin; DPT-HepB-Hib, diphtheria, pertussis, tetanus, hepatitis B, Haemophilus influenza type B; OPV, oral polio vaccine; PCV, pneumococcal conjugate vaccine; Rota, rotavirus vaccine.

due to various socioeconomic and healthcare system-related challenges.[8]

A total of 116 low-income and middle-income countries have introduced vaccines that they did not use previously between 2010 and 2017,[9] including those against major killers such as pneumococcal pneumonia, diarrhoea, cervical cancer, typhoid, cholera and meningitis. Sub-Saharan Africa is characterised by a high burden of vaccine-preventable diseases and a significant number of vaccine-preventable deaths among children.[8 10] Ethiopia's vaccination efforts demonstrate a strong commitment to public health, ensuring all children receive essential immunisations to protect their health and well-being. Since 1980, the Expanded Program on Immunization (EPI) has gradually introduced vaccines to address the nation's wide range of health issues with the goal of preventing numerous vaccine-preventable diseases. Initially, the routine immunisation programme for under-five children included only six vaccine-preventable diseases: tuberculosis, poliomyelitis, tetanus, diphtheria, pertussis and measles. Yet, the current routine immunisation service includes 10 vaccines preventable diseases: measles, diphtheria, Haemophilus influenza type B, tetanus, pertussis, hepatitis B, pneumococcal disease, poliomyelitis, rotavirus infections and tuberculosis[11 12] (table 1).

The introduction of new vaccines offers an opportunity to address burden and improve child health outcomes.[13] Even though pneumococcal conjugate vaccine (PCV) was available starting from 2009,[14] the government of Ethiopia introduced the PCV and monovalent human rotavirus vaccine (RV1) into the national infant immunisation programme in 2011 and 2013, respectively.[6 15 16] At this time, there was a high dropout rate, low vaccine coverage and a very low level of full immunisation coverage compared with the 66% national target. On the other hand, the Comprehensive Multi-Year Plan (cMYP) 2011–2015 was endorsed by the Ethiopian Federal Ministry of Health with the aim to bolster the nation's immunisation programme. The cMYP is typically revised every 5 years and serves as the medium-term strategic framework for national EPI, aligning with the health sector's 5-year strategic plan.[11 17 18]

Ethiopia, as one of the most populous countries in sub-Saharan Africa, faces unique challenges in achieving high vaccine coverage due to its diverse population, geographical disparities and limited healthcare resources.[19] The pooled estimate of vaccination coverage among children aged 12–23 months in Ethiopia was estimated to be 65%.[20] However, other studies found that among children aged 12 to 23 months (according to a vaccination card or the mother's recall) only 44% had received all basic vaccines, 40% were vaccinated before their first birthday, and 19% had not been vaccinated at all.[21]

According to previous studies, institutional delivery, travel to the vaccination site for <2 hours, received at least one antenatal care (ANC) visit, good maternal knowledge of immunisation, being informed on the immunisation schedule, living in urban areas and a household visit by healthcare providers during the postnatal period were identified to be factors associated with full vaccination among children aged 12–23 months.[20 21]

Understanding the factors associated with vaccine uptake among children aged 12–23 months is crucial for designing targeted interventions to address barriers and improve immunisation coverage in Ethiopia. By conducting a multilevel analysis using data from the 2019 Ethiopia Mini Demographic and Health Survey (EMDHS), this study aims to provide insights into the uptake of recently introduced vaccines among children aged 12–23 months in Ethiopia. The findings will contribute to the existing evidence base on vaccine utilisation in the country and inform policymakers, programme implementers, and healthcare providers about the magnitude and factors influencing vaccine uptake.

METHODS

Study design

Secondary data analysis was performed using the 2019 EMDHS extracted from the DHS Program with permission.[22] The EMDHS is a cross-sectional study conducted by the Central Statistical Agency and Ethiopian Public Health Institute under the auspices of the Federal Minister of Health with technical assistance from ICF International through its Measure Demographic and Health Survey (DHS) project. The survey was representative of both the national and regional levels. The Ethiopia Demographic and Health Survey (EDHS) was undertaken in nine Ethiopian regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and Peoples, which currently includes Sidama and Southwestern Ethiopia regions, Gambela and Harari) and two chartered city administrations (Addis Ababa and Dire Dawa) from 21 March 2019 to 28 June 2019. The detailed study design was described in the EMDHS 2019.[7]

Sampling technique and study population

To recruit study participants for the 2019 EDHS, a two-stage stratified sample technique was used. There were 21 sampling strata in each region, which were divided into urban and rural areas. In the first stage, a total of 305 clusters were chosen with a sample probability proportionate to population size, out of which 212 clusters were from rural areas. Then, for each of the chosen clusters, households were listed and used as a sampling frame for selecting households. In the second stage, equal probability systematic sampling was used to select a fixed number of 30 households in each cluster, resulting in a selection of 8794 occupied households. All women between the ages of 15 and 49 who were either permanent residents of the selected houses or guests who stayed in the household the night before the survey were eligible to participate in EMDHS. As a result, 9012 eligible mothers with their 5753 children were identified; among which 2833 of them had children of age between 12 and 23 months and all were successfully interviewed.[23]

Data collection

Immunisation cards or health cards were used as a reliable source of information to directly copy the information during the survey. In the absence of either of those documents, mothers were asked and probed to recall vaccines and doses received by the child. In cases where a child had visited health facilities, the mother's recall information is complemented by looking for any relevant vaccination records from the health facility.

Study variables

The outcome variable was the uptake of recently introduced vaccine among children aged 12–23 months. At this age, children are expected to have taken all the relevant childhood vaccinations including RV and PCV. Vaccination status was taken into account by considering both vaccines in (three) different scenarios (analysed combined as one variable—PCV and RV or as two separate variables—PCV, RV). In scenario 1, a child who received two doses of RV and three doses of PCV was considered 'completely vaccinated', whereas a child who did not receive at least one dose of the vaccines was classified as 'not fully vaccinated'. In scenario 2, a child who received two doses of RV was considered 'completely vaccinated with RV'; otherwise, the child was classified as 'not fully vaccinated'. In scenario 3, a child who received three doses of PCV was considered 'completely vaccinated with PCV'; otherwise, the child was classified as 'not fully vaccinated'.

The independent variables in the study were: child characteristics including sex and birth order; mother's characteristics such as age at childbirth, level of education, marital status, religion, region, place of residence, exposure to media (ie, access to newspaper, radio and television; those who had access to any of these three outlets at least once a week were considered exposed to media, while others were not), use of ANC (four ANC contacts were considered adequate, whereas one to three contacts were considered inadequate), place of delivery, postnatal care (PNC) and the household wealth index, which is calculated using asset ownership, other attributes such as a source of drinking water, bathroom facilities, cooking fuel, materials used in housing construction, land ownership and other assets were used to estimate household's economic status.

Statistical analysis

STATA (V.14.0) was used to analyse the data analysis. Sample weights were used to account for the impact of the underlying complex sampling design on logistic regression parameters for unequal probability sampling and non-response. The two-level structure multilevel logistic regression with a child as level 1 and regions as level 2 was used. Children from the same region are assumed to share more similar characters than randomly from different regions. For this study, two-level models, that is, models accounting for children-level and regional-level effects, were used. Three multilevel logistic regression models, an empty model with random intercept, random intercept with the fixed effects model and random coefficient with a random intercept model, have been fitted. In the first step, the heterogeneity of proportions between regions in a multilevel analysis was tested using the likelihood ratio test and deviance test. Finally, the adjusted OR (AOR) with a 95% CI was reported, and p values less than 0.05 were considered to be statistically significant. The specifications of the models were based on variables that showed significant associations in the bivariate analysis (p values ≤0.2, using the backward elimination fitting approach.

Let π_{ij} denote the probability that the response variable equals 1, $\pi_{ij} = P(y_{ij} = 1/x_{ij})$ the probability of i^{th} children fully vaccinated with PCV or RV in the j^{th} region. The two-level logistic regression model is given by:

$$logit(\pi_{ij}) = log\left[\frac{\pi_{ij}}{1-\pi_{ij}}\right] = \beta_0 + \beta_1 X_{ij} + U_{oj}$$

where U_{oj} is a random quantity and follows a normal distribution with mean zero and variance σ_u^2. This model can be split into two models; one for level 1 (individuals or children) and the other for level 2 (region),

$logit(\pi_{ij}) = log\left[\frac{\pi_{ij}}{1-\pi_{ij}}\right] = \beta_{oj} + \beta_1 X_{ij}$ level 1, (random intercept model),

$\beta_{oj} = \beta_o + U_{oj}$ level 2, (empty model).

$$\text{where } \pi_{ij} = \frac{e^{\beta_o + \sum_{h=1}^{k} \beta_h X_{hij} + U_{oj}}}{1 + e^{\beta_o + \sum_{h=1}^{k} \beta_h X_{hij} + U_{oj}}}$$

Thus, in the random intercept multilevel logistic regression model,

$$\text{Logit}(\pi_{ij}) = \log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_o + \sum_{h=1}^{k} \beta_h x_{ij} + U_{oj} \sum_{h=1}^{k} U_{hj} x_{ij}$$

The first part, $\beta_o + \sum_{h=1}^{k} \beta_h x_{ij}$, is the fixed part and the second part, $U_{oj} + \sum_{h=1}^{k} U_{hj} x_{ij}$, is the random part. The random variables or effects, $U_{0j}, U_{1j}, \ldots, U_{kj}$, are

assumed to be independent between groups but may be correlated within groups. Then the intraclass correlation (ICC) at level 2 (the regions) is given by:[24]

$$ICC = \frac{\sigma_{\mu}^2}{\sigma_{\mu}^2+\sigma_{e}^2}$$

where σ_{μ}^2 is the between-group variance and σ_{e}^2 is the within-group variance.

Further, the median OR (MOR) was computed to measure unexplained cluster heterogeneity.[25]

Patient and public involvement

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

RESULTS

Maternal and sociodemographic characteristics of the sample population

Table 2 shows the characteristics of 2833 mothers and children pairs involved in this study. There was a significant difference between residential places, but the regional variation was almost consistent (7% in the Somali and Afar regions and 12% in the Oromia region). The average age of these mothers was 27.51±9.06 SD years old. By age cohort, three-fourths (75.2%) of these mothers were 20–34 years old and about one-in-six (17.6%) were over 34 years old. Regarding education level, nearly half (50.3%) of the participants had no education and one-third (34.2%) had attended primary education. The male children to females ratio was 1:1.05. The percentage of mothers who had media access was 35.6%. About 51% of mothers had delivered at health facilities, and concerning ANC during pregnancy, 32.4% of mothers had at least four contacts from skilled providers during pregnancy.

Prevalence of uptake of currently introduced vaccination

By percentage, 62.9% of children received PCV1 and only 45.7% of the children received all the three doses of PCV. The proportions of children who had received RV2 were 53.4%. The percentage of children fully vaccinated with three doses of PCV and two doses of RV was 43.5% (figure 1).

Table 2 presents the uptake of recently introduced vaccines among children 12–23 months old by mother's characteristics. Nearly 93% and 88% of the total children in Addis Ababa received all the two doses of RV and three doses of PCV, respectively. The proportion of children fully vaccinated with currently introduced childhood vaccines also highly varied by place of residence. Among children born in urban areas, 75% were fully vaccinated with RV and 68% were fully vaccinated with PCV, whereas only 46% and 38% of children from rural counterparts had fully vaccinated with RV and PCV, respectively. Regarding the mothers' age at birth, the proportion of full vaccination with RV (38%) and PCV (27%) was lower among children born to mothers less than 20 years old.

By place of delivery, 68% and 60% of children born at health facilities were fully vaccinated with RV and PCV, respectively. In contrast, only 35% and 27% of children born at home were fully vaccinated with RV and PCV, respectively. The proportion of children fully vaccinated with RV and PCV increases with the number of mothers' ANC contacts during pregnancy.

Table 2 also shows, among children from mothers with access to media, 69% and 62% were fully vaccinated with RV and PCV, respectively. The proportion of children fully vaccinated with currently introduced childhood vaccines increased with the mother's level of education. For instance, 82% and 73% of children from a mother who had completed higher education were fully vaccinated with RV and PCV, respectively, whereas only 45% and 37% of children from a mother with no education were fully vaccinated with RV and PCV, respectively. At last, regarding household wealth quintile, 65% and 53% of children from the richest households were fully vaccinated with RV and PCV, while from the poorest wealth quintile, only 31% and 24% were fully vaccinated with RV and PCV, respectively.

Factors associated with the uptake of newly introduced childhood vaccines

The result of the multilevel logistic regression model was presented in online supplemental table 1. Initially, we started with all the candidate predictors included in the bivariate analysis with p values ≤0.2 and then applied backward elimination techniques to arrive at the final model. In the random effects, the results of the null model indicated that there was statistically significant variability in the odds of full vaccination, with a region variance of 25%. The ICC value was 8.6% (95% CI: 3.5% to 19.6%), indicating that 8.6% of the total variability of full vaccination status was attributed to differences between clusters (regions), while the rest were unexplained. Moreover, the MOR was estimated at 1.32 (95% CI: 1.19 to 1.52), revealing that if a child moved to another community with a higher probability of full vaccination, the median increase in the odds of being fully vaccinated would be 1.32, with an ICC of 8.6%. Furthermore, model comparison based on deviance ((−2) log-likelihood ratio (−2 LLR)) revealed that the full model was the best-fitted model for the data, since it has the lowest deviance value.

The most consistent predictors of full childhood vaccination with PCV and RV were maternal age, place of residence, household wealth quintile, ANC contacts, PNC, place of delivery and exposure to media. Similar factors have been found to be statistically significantly associated with all the three scenarios (PCV; RV; both PCV and RV combined); with similar strength of measure of association across scenarios (online supplemental table 1). We found that children belonging to mothers who were 20–34 (AOR=2.03; 95% CI (1.37 to 3.02)) and above 34 years old (AOR=2.44; 95% CI (1.52 to 3.91)) were two times more likely to be fully vaccinated with both PCV and RV when compared with those who were born to younger mothers.

Table 2 Prevalence of PCV and RV vaccination across characteristics of mothers and children, 2019 EMDHS (n=2833)

Variables	Children (n) N (%)	Fully vaccinated with PCV N (%)	Fully vaccinated with RV N (%)	Fully vaccinated with PCV and RV
Woman age at birth (years)				
<20	203 (7.2)	54 (26.6)	77 (37.9)	51 (25.2)
20–34	2130 (75.2)	1009 (47.4)	1157 (54.4)	947 (44.8)
35–49	500 (17.6)	231 (46.2)	276 (55.1)	226 (45.5)
Geographical region				
Tigray	241 (8.5)	151 (62.7)	166 (68.9)	143 (59.6)
Afar	301 (10.6)	49 (16.3)	75 (25.0)	46 (15.4)
Amhara	276 (9.7)	172 (62.3)	190 (68.3)	167 (60.5)
Oromia	352 (12.4)	150 (42.6)	188 (53.6)	146 (41.8)
Somali	253 (8.9)	42 (16.6)	72 (28.2)	40 (15.9)
Benishangul-Gumuz	261 (9.2)	142 (54.4)	158 (61.2)	131 (51.0)
SNNPR	321 (11.3)	115 (35.8)	137 (43.4)	99 (31.5)
Gambela	235 (8.3)	106 (45.1)	120 (51.5)	102 (43.8)
Harari	215 (7.6)	99 (46.0)	102 (46.6)	89 (41.6)
Addis Ababa	170 (6.0)	149 (87.6)	158 (92.9)	148 (87.1)
Dire Dawa	208 (7.3)	119 (57.2)	144 (69.2)	113 (54.6)
Type of place of residence				
Urban	700 (24.7)	475 (67.9)	524 (74.8)	459 (65.9)
Rural	2133 (75.3)	819 (38.4)	986 (46.3)	765 (36.2)
Woman highest educational level				
No education	1424 (50.3)	529 (37.1)	645 (45.2)	496 (35.1)
Primary	970 (34.2)	478 (49.3)	546 (56.6)	450 (46.9)
Secondary	271 (9.6)	164 (60.50)	182 (67.2)	156 (57.6)
Higher	168 (5.9)	123 (73.2)	137 (81.5)	122 (72.6
Household wealth quintile				
Poorest	878 (31.0)	211 (24.0)	270 (30.8)	192 (22.1)
Poorer	487 (17.2)	211 (43.3)	261 (53.4)	200 (41.2)
Middle	407 (14.4)	189 (46.4)	217 (53.7)	178 (44.2)
Richer	368 (13.0)	195 (53.0)	238 (65.0)	181 (49.6)
Richest	693 (24.5)	488 (70.4)	524 (75.6)	473 (68.8)
Sex of child				
Male	1449 (51.1)	674 (46.5)	775 (53.8)	636 (44.4)
Female	1384 (48.9)	620 (44.8)	735 (53.0)	588 (42.6)
Woman religion				
Orthodox	866 (30.6)	534 (61.7)	594 (68.7)	514 (59.6)
Muslim	1371 (48.4)	513 (37.4)	624 (45.4)	478 (35.1)
Protestant	544 (19.2)	228 (41.9)	274 (50.7)	216 (40.1)
Others	52 (1.8)	19 (36.5)	18 (35.3)	16 (31.4)
Childbirth order				
First	617 (21.8)	322 (52.2)	374 (60.5)	305 (49.7)
2–3	975 (34.4)	476 (48.8)	535 (54.9)	449 (46.4)
4–5	638 (22.5)	280 (43.9)	326 (51.4)	263 (41.6)
6+	603 (21.3)	216 (35.8)	275 (45.6)	207 (34.7)

Continued

Table 2 Continued

Variables	Children (n) N (%)	Fully vaccinated with PCV N (%)	Fully vaccinated with RV N (%)	Fully vaccinated with PCV and RV
Antenatal care contacts				
No visit	724 (25.6)	128 (17.7)	181 (25.0)	122 (17.0)
1–3	1184 (41.9)	746 (63.0)	840 (71.1)	710 (60.2)
4+	915 (32.4)	414 (45.2)	483 (52.8)	386 (42.7)
Place of delivery				
Home	1250 (44.1)	342 (27.4)	438 (35.1)	320 (25.9)
Health facility	1583 (55.9)	952 (60.1)	1072 (67.8)	904 (57.4)
Number of under-five children				
3 or less	2780 (98.1)	1280 (46.0)	1492 (53.7)	1210 (43.9)
4 or more	53 (1.9)	14 (26.4)	18 (34.6)	14 (26.9)
Woman marital status				
Never in union	23 (0.8)	8 (34.8)	11 (47.8)	8 (34.8)
Married/living with partner	2665 (94.1)	1229 (46.1)	1430 (53.7)	1162 (43.9)
Others	145 (5.1)	57 (39.3)	69 (47.9)	54 (37.5)
Media exposure				
Not exposed	1789 (63.1)	660 (36.9)	802 (44.9)	618 (34.8)
Exposed	1008 (35.6)	620 (61.5)	690 (68.7)	594 (59.5)
Postnatal care				
No	2454 (86.6)	1043 (42.5)	1234 (50.3)	985 (40.4)
Yes	374 (13.2))	247 (66.0)	273 (73.2)	236 (63.8)

EMDHS, Ethiopia Mini Demographic and Health Survey; PCV, pneumococcal conjugates vaccine; RV, rotavirus vaccine; SNNPR, South Nations Nationalities and Peoples region.

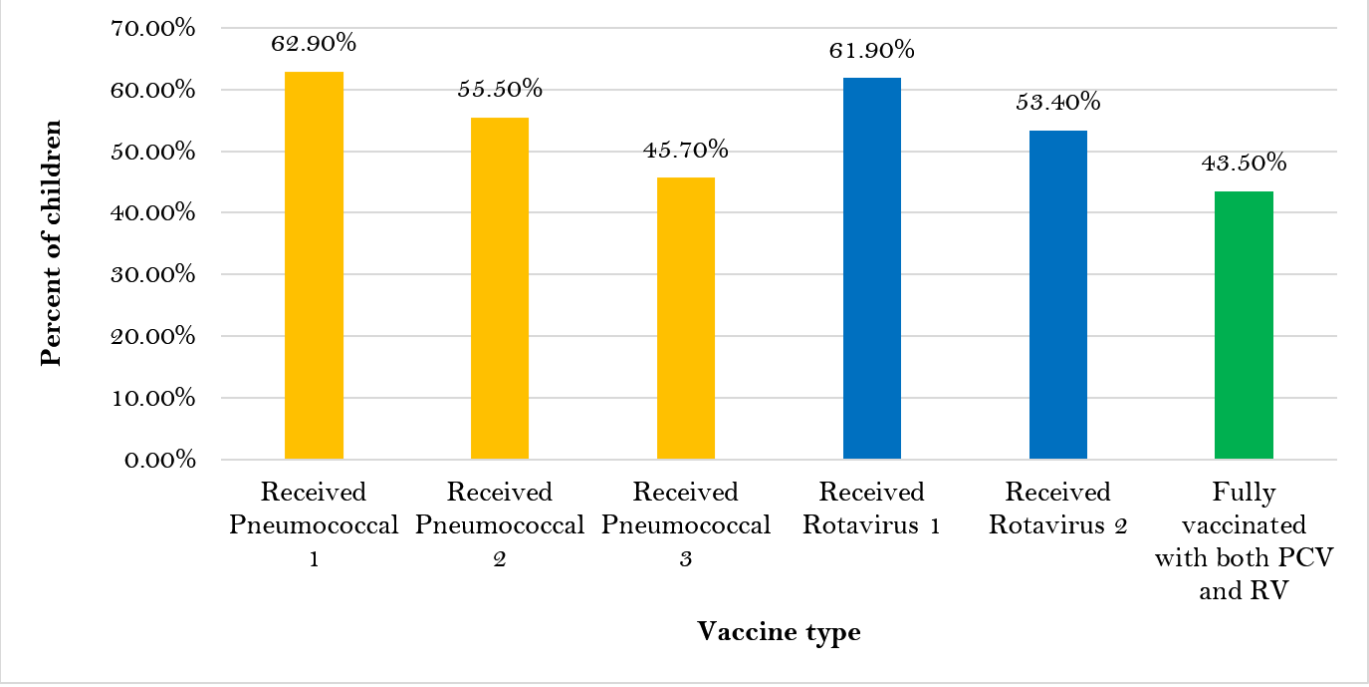

Figure 1 Proportions of children who received newly introduced childhood vaccines in Ethiopia, Ethiopia Mini Demographic and Health Survey 2019 (n=2833). PCV, pneumococcal conjugate vaccine; RV, rotavirus vaccine.

On the other hand, the lower odds of full vaccination with newly introduced childhood vaccines were observed in the rural areas. Compared with the urban counterpart, children from the rural area were 26% (AOR=0.74, 95% CI 0.55 to 0.99) less likely to be fully vaccinated with PCV and RV. The study also found that the odds of full vaccination with newly introduced childhood vaccines were strictly increased with the household wealth quintile. Children born to mothers from a higher wealth quintile were 2.24 (AOR=2.24; 95% CI (1.49 to 3.36)) times more likely to be fully vaccinated with both PCV and RV compared with the poorest household.

ANC during pregnancy was found to be the most important predictor of full vaccination with newly introduced childhood vaccines. At least four ANC contacts from a skilled provider were associated with 2.73 (AOR=2.73; 95% CI (2.06 to 3.62)), odds of full vaccination with both PCV and RV, compared with no ANC contacts. Whereas, children who had attended PNC were 84% (AOR=1.84; 95% CI (1.42 to 2.37) more likely to be fully vaccinated with both PCV and RV, compared with those children who had not attended PNC.

Our analyses found that delivery at health facilities was significantly associated with increased odds of full vaccination with newly introduced childhood vaccines. Children born at health facilities were 45% (AOR=1.45; 95% CI (1.17 to 1.79)) more likely to be fully vaccinated with both PCV and RV compared with who were born at home. The media exposure of mothers was another significant predictor of newly introduced childhood vaccines in Ethiopia. A woman who has media access was 24% (AOR=1.24; 95% CI (1.09 to 1.56)) more likely to have their child fully vaccinated with both PCV and RV compared with those who had no media exposure.

DISCUSSION

The SDG envisions ensuring healthy lives and promoting well-being for all at all ages.[26] Immunisation is among the most cost-effective ways to support a healthier and safer world.[27] Therefore, the Ethiopian Health Sector Transformation Plan (HSTP) planned to achieve coverage of 75% full immunisation for the prevention-led health policy in the country.[28] Our analysis focused on the newly introduced vaccines, PCV administered for the prevention of pneumonia infection; and RV used for the prevention of childhood diarrhoea in the list of the country's vaccination service; with the aim of identifying individual and community-level factors associated with the uptake of newly introduced childhood vaccines among children aged 12–23 months in Ethiopia using the 2019 EMDHS.

Our analysis revealed that nearly 4 in 9 (45.7%), 5 in 10 (53.4%) and 4 in 10 (43.5%) of the children completed vaccination with PCV, RV and both PCV and RV, respectively. The slight difference in vaccine coverage between PCV and RV could be attributed to the difference in the dose schedules, three doses for PCV versus two doses for RV, where there could be an increased chance of dropout for the three-dose vaccine than the two-dose vaccine.[29] The overall uptake of the two vaccines indicates that more than half of children are not protected from pneumococcal and rotavirus infections, which are the common killer diseases among children.[30 31] This impacts both the country's and the global strive to reduce child mortality. The finding was slightly lower than the study by Wondimu *et al*, which reported 56% for RV and 49.1% for PCV,[32] but slightly higher than the full immunisation coverage of 38.3%[33] found in the reanalysis of the EDHS 2016. The observed coverage of the two vaccines in Ethiopia is far below the Ethiopian National EPI and the Global Vaccine Action Plan set coverage goals of 90% at the national level and 80% at the district level by 2020.[34] It is also below the country's claim of 61% coverage in all pentavalent vaccines in the year 2019 and the plan to increase it to 85% by the end (2025) of the HSTP.[28] To maximise the benefits of vaccination programmes, it is also critical to work towards high universal coverage. As a result, authorities must keep a close eye on vaccination coverage and pursue evidence-based strategies to increase vaccine uptake and eliminate coverage disparities across different groups of people.

Various factors can influence immunisation coverage in children. Our investigation revealed age, place of residence, household wealth quintile, ANC contacts, PNC, place of delivery and exposure to media as factors significantly associated with PCV and RV uptake of the complete schedule.

With regard to the age of mothers, the odds of uptake of newly introduced vaccines (PCV or RV or PCV and RV together) among children from mothers in the age category of 20–34 and over 34 years old were higher than children from mothers of less than 20 years. It could be from the fact that mothers with better exposure to education and maternal and child healthcare experience could have better awareness to vaccinate their children.[33] In this regard, it is less likely that mothers of age less than 20, particularly the teenagers, could get a better education or better health-seeking behaviour as a result of attribution to taboos of teenage pregnancy or awareness about where and when to see medical attention to their children.

On the other hand, the lower odds of full vaccination with newly introduced childhood vaccines were observed in rural areas. Children from rural areas had less odds of vaccination than their urban counterparts in all three scenarios (PCV; RV; both PCV and RV). This could be related to the accessibility to health and vaccination-related information, as well as to health facilities, which is limited in a rural setup. A similar finding was reported by Tamirat and Sisay, where children of rural resident mothers had lower odds of being fully vaccinated in Ethiopia.[33]

The study also found that the odds of full vaccination with newly introduced childhood vaccines strictly increased with the household wealth quintile. Compared with children from households with lowest wealth quintiles, the odds of vaccination uptake among children from

the households with any of the four upper wealth quintile categories (poorer, middle, richer and richest) were higher in all the three vaccination scenarios considered (PCV; RV; PCV and RV). Despite the fact that childhood vaccination is free in Ethiopia, there is still a significant financial burden connected with it due to travel costs and lost revenue due to income loss during travel time while seeking immunisation service for the children. This finding is consistent with findings from earlier investigations.[30 32 35]

ANC during pregnancy was found to be the most important predictor of full vaccination with newly introduced childhood vaccines. The odds of children of mothers who had at least four ANC contacts from a skilled provider were about three times more fully vaccinated with PCV and RV compared with those children of mothers with no ANC contacts. This result is consistent with the findings of many other studies elsewhere.[36 37] Based on the Demographic and Health Surveys of 12 East African countries, Tesema *et al* found that having one to three ANC visits and four and above ANC visits were significantly associated with complete childhood vaccination.[36] Residing in communities possessing higher maternal ANC services utilisation was positively associated with childhood full immunisation.[32 38] This is due to mothers' education during ANC, and their knowledge may be increased and attitude may be influenced as they get more information on vaccination during ANC consultation. ANC attendance was significantly associated with having good knowledge of the routine immunisation programme. Moreover, the chances of not being fully immunised reduced for children whose mothers attended antenatal clinics.[39 40] As a result, expanding ANC and increasing the frequencies of ANC consultation is beneficial for the mothers to fully immunise their children, as four or more ANC visits are associated with complete vaccination status.[41 42]

Whereas, children of mothers who attended PNC were 85% and 82% more likely to be fully vaccinated with PCV and RV, respectively, compared with those children of mothers who did not attend PNC. Evidence showed that having a PNC visit was found to be strongly linked with complete childhood immunisation.[36] This is also supported by the finding of another study conducted in Malawi,[43] which showed when compared with children who had a PNC check within 2 months, those who did not have a PNC check had a higher chance of being undervaccinated.

Our research discovered that maternal delivery in a health facility was also linked to full vaccination with recently introduced child vaccines. When compared with children born at home, those born in health facilities were 49% more likely to be fully vaccinated in both PCV and RV. Another study found that facility delivery was also linked to full childhood vaccination.[36] Similar research works also indicated consistent results.[37 40 44–46] Children whose mothers struggled to reach health facilities and who resided in socioeconomically challenged communities and states were more likely to be vaccinated insufficiently.[40] These findings suggest that maternal healthcare utilisation and mothers' knowledge of the age at which their children begin and finish vaccination are the most important determinants in achieving complete immunisation coverage. To enhance community knowledge of the need for immunisation, prenatal care and institutional delivery, local activities must be strengthened.

Another important predictor of newly introduced children vaccination in Ethiopia was maternal media exposure. When compared with those who were not exposed to media, women who had access to the media were 25% and 21% more likely to fully vaccinate their children against PCV and RV, respectively. Similarly, media exposure was substantially associated with full childhood vaccination, according to the Demographic and Health Surveys of 12 East African nations.[36] According to the study, bad vaccine news accounts for a significant amount of online news and had the potential to affect public vaccine sentiment and attitude.[47] A substantial link was found between media exposure and vaccine uptake in another investigation as well.[48] Furthermore, similar findings were found in other research conducted worldwide.[38 49] This is because when people are exposed to more media, they will get more information.

The study used national representative data, reflecting diverse socioeconomic, geographic and infrastructural variations. Multilevel analysis was applied to accurately identify sources of data variability. However, limitations exist that may impact the findings. Due to the secondary nature of the data, a limited number of variables were included in this analysis. For instance, due to the absence of vaccine supply-related data, we primarily focused on demand-side determinants in our study. Future studies need to consider vaccine supply factors, which could undeniably have a considerable impact on immunisation coverage. Due to the cross-sectional nature of the data, a cause–effect relationship could not be established. Recall bias could be introduced. Yet, the survey included health facility recorded data on children's vaccinations to confirm mothers' reports whose children have no vaccination cards to avoid recall bias.

CONCLUSION

The overall coverage of the newly introduced vaccine (PCV; RV; both PCV and RV) was considerably low and is below the national target in Ethiopia. Age of the mother, place of residence, household wealth quintile, ANC contacts, PNC, place of delivery and exposure to media were significant predictors of uptake of newly introduced vaccines. Vaccination uptake has shown a direct relationship with the increasing order of household wealth quintile.

Hence, this study emphasises the need to strengthen our maternal and child healthcare services. In addition, interventions aimed at increasing immunisation uptake

need to target mothers in the younger age categories and those with lower socioeconomic status along the wealth quintile. Findings also suggest that messages via media outlets could have an impact on improving the vaccination uptake as it can cover a large audience at once and create a possibility for peer dialogue in a local setup.

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