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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 recently introduced vaccines uptake among children aged 12–23 months in Ethiopia.

**Methods**: Secondary data analysis was done using the 2019 Ethiopia Mini Demographic and Health Survey (EMDHS). The EMDHS was a cross-sectional study conducted from March 21, 2019, to June 28, 2019. A multilevel logistic regression analysis was employed, and the adjusted odds ratio (AOR) with 95% confidence interval (CI) was reported. The statistical significance was declared at p-value < 0.05. The intra-class correlation coefficient, median odds ratio, proportional change in Variance, and deviance (-2LL) were used for model comparison and checking model fitness.

**Results**: Our analysis revealed that 45.7%, 53.4%, and 43.5% of the children completed vaccination for Pneumococcal Conjugate vaccine (PCV), Rotavirus vaccine (RV), and both PCV and RV respectively. Being in the age group of 20-34 (AOR = 2.03, 95% CI: 1.37, 3.02) and 35-49 (AOR = 2.44, 95% CI: 1.52, 3.91), having at least 4 antenatal care contacts (AOR = 2.73, 95% CI: 2.06, 3.62), having postnatal care (AOR = 1.84, 95% CI:1.42, 2.37), delivery in the health facility (AOR = 1.45, 95% CI: 1.17, 1.79), and having exposure to media (AOR = 1.24, 95% CI:1.09, 1.56), and any of the wealth quintile categories higher than poorest category were positively associated with uptake of newly introduced vaccines. Rural residency was found to be negatively related with the uptake of newly introduced vaccines.

**Conclusion**: The overall full uptakes of newly introduced vaccines among children 12-23 months were significantly lower. Hence, this study emphasizes the need to strengthen maternal

and child healthcare services particularly, to the younger age mother and those with lower socio-economic status.

**Keywords:** Childhood immunization; Newly introduced vaccine; Children 12–23 months; Multilevel analysis; Ethiopia

## Strength and Limitation of the study

- The strength of this study is that it is based on national data, a large sample size representative of the entire socio-economic, geographic and infrastructural variations in the country.
- Also we used multilevel analysis to identify an accurate representation of the source of variability in the data.
- There is a risk of recall bias because mothers' self-report is employed as a source of information for the child's vaccination status whenever vaccination card or health sector record of the child could not be available.
- Because of the absence of vaccine supply-related data in EMDHS, we focused primarily on the demand side of the determinants in our investigation. Vaccine supplies undeniably could have a considerable impact on immunization coverage.

## 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 fourteen out of the seventeen 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 characterized 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 due to various socio-economic and healthcare system-related challenges(8).

A total of 116 low-and middle-income countries have introduced vaccines that they did not use previously between 2010 and 2017 (9), including those against major killers like pneumococcal pneumonia, diarrhea, cervical cancer, typhoid, cholera and meningitis. Sub-Saharan Africa is characterized by a high burden of vaccine-preventable diseases and a significant number of vaccine-preventable deaths among children (8,10). The introduction of new vaccines, such as the Rota virus, pneumococcal conjugate vaccine (PCV), and MR vaccine, offers an opportunity to address this burden and improve child health outcomes (11).

Even though PCV was available starting from 2009 (12), the government of Ethiopia introduced the pneumococcal conjugate vaccine (PCV) and monovalent human rotavirus vaccine (RV1) into the national infant immunization program in 2011 and 2012, respectively (6,13,14). However, the successful implementation of these vaccines relies on the timely and widespread uptake among the target population.

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 (15). The pooled estimate of vaccination coverage among children aged 12-23 months in Ethiopia was estimated to be 65% (16). However, other studies revealed that vaccination coverage among children aged 12 to 23 months who received specific vaccines at any time prior to the survey (according to a vaccination card or the mother's recall) was only 4 out of 10 children (44%) had received all basic vaccinations at some point, with 40% receiving these vaccinations before their first birthday, and nearly 2 out of 10 children (19%) in this age group having received no vaccinations at all (17).

According to previous studies, institutional delivery, travel to vaccination site for <2 hours , received at least one antenatal (ANC) visit, good maternal knowledge of immunization, being informed on immunization schedule, living in urban areas, and a household visit by health-care providers during the postnatal period were identified to be factors associated with full vaccination among children age 12-23 (16,17).

Understanding the factors associated with vaccine uptake among children aged 12-23 months is crucial for designing targeted interventions to address barriers and improve immunization coverage in Ethiopia. By conducting a multilevel analysis using data from the 2019 Ethiopia mini DHS, 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 utilization in the country and inform policymakers, program 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 http://www.DHSprogram.com with permission. The EMDHS is a cross-sectional study and conducted by the Central Statistical Agency (CSA) and Ethiopian Public Health Institute (EPHI) under the auspices of Federal Minister of Health (FMoH) with technical assistance from ICF International through its MEASURE DHS project. The survey was representative of both the national and regional levels. The Ethiopian Demographic and Health Survey (EDHS) was undertaken in nine Ethiopian regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul Gumuz, Southern Nations Nationalities and Peoples (SNNP) which currently includes Sidama and Southwestern Ethiopia regions, Gambella, and Harari) and two chartered city administrations (Addis Ababa and Dire Dawa) from March 21, 2019, to June 28, 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 8,794 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, 9,012 eligible mothers with their 5,753 children were identified; among which 2,833 of them had children of age between 12-23 month and all were successfully interviewed (18).

**Data collection**

Immunization 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 uptake of recently introduced vaccine among 12-23 months children. 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 (analyzed combined as one variable-PCV and RV or as two separate variables- PCV, RV). Therefore, scenario one is a child who received two doses of RV and three doses of PCV was regarded "completely vaccinated," whereas a child who did not receive at least one dose of the vaccines was termed "not fully vaccinated". Scenario two, on the other hand is a child who received two doses of RV is considered "completely vaccinated for

RV" otherwise "not fully vaccinated"; and third, a child who received three doses of PCV was regarded "completely vaccinated for PCV" otherwise "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 (i.e., 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 was considered adequate whereas one–three contacts were considered inadequate), place of delivery, post-natal care, 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 (version 14.0) was used to analyze 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, i.e., 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 has been fitted. In the first step, the heterogeneity of proportions between regions in a multilevel analysis was tested using the likelihood ratio test (LRT) and Deviance test. Finally, the adjusted odds ratio (AOR) with a 95% confidence interval

(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 $\leq 0.2$), using the backward elimination fitting approach.

Let $\pi_{ij}$ denote the probability that the response variables equals 1, $\pi_{ij} = P(y_{ij} = 1/x_{ij})$ the probability of i[th] children fully vaccinated 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 $U_{oj}$ a random quantity and follows a normal distribution with mean zero and variance $\sigma_u^2$. 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)

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 (19)

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

Where $\sigma_{\mu}^{2}$ is the between group variance and $\sigma_{e}^{2}$ is the within group variance.

Further, the Median Odds Ratio (MOR) was computed to measure unexplained cluster heterogeneity (20).

**Patient and public involvement**

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

## Results

**Maternal and socio-demographic characteristics of the sample population**

Table 1 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 standard deviation (SD) years old. By age cohort, three-fourth (75.2%) of these mothers was 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 rate of male children to females 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 antenatal care during pregnancy, and 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 was 53.4%. The percentage of fully vaccinated of three doses of PCV and two doses of RV was 43.5% (Figure 1). Table 1 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 of currently introduced childhood vaccination also highly varied by place of residence. Among children born in urban areas 75% fully vaccinated RV, 68% fully vaccinated PCV, whereas only 46% and 38% of children from rural counterparts had fully vaccinated RV and PCV, respectively. Regarding the mothers age at birth, the proportion of full vaccination of 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 fully vaccinated RRV and PCV, respectively. In contrast only 35% and 27% of children born at home fully vaccinated RV and PCV, respectively. The proportion of children fully vaccinated RV and PCV increases with the number of mothers' antenatal care contacts during pregnancy. Table 1 also shows, among children from mothers with access to media, 69% and 62% were fully vaccinated RV and PCV, respectively. By mothers' level of education, the proportion fully vaccination of currently introduced childhood vaccines was increased as mother education level increases. For instance, 82% and 73% of children from a mother who had completed higher education were fully vaccinated RV and PCV, respectively, whereas only 45% and 37% of children from a mother with no education were fully vaccinated RV and PCV, respectively. Lastly, regarding household wealth quintile, 65% and 53% of children among the richest household had fully vaccinated RV and PCV, while from poorest wealth quintile, only 31% and 24%, full vaccinated 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 Table 2. 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 fully vaccination, with a region variance of 25%. The ICC value was 8.6% (95% CI: 3.5%, 19.6%) 8.6% of the total variability of fully 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, 1.52), revealing that if a child moved to another community with a higher probability of full vaccination , the median increase in its odds of fully vaccinated would be 1.32, with an ICC of 8.6%. Furthermore, model comparison based on deviance (-2LLR) 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 childhood fully PCV and RV vaccination were maternal age, place of residence, household wealth quintile, antenatal care (ANC) contacts, postnatal care (PNC), place of delivery, and exposure to media. Similar factors have been found statistically significantly associated with all the three scenarios (PCV; RV; both PCV and RV together); with similar strength of measure of association across scenarios (Table 2).

We found that children belonging to mothers who were 20-34 (AOR = 2.03; 95% CI (1.37, 3.02)) and above 34 years old (AOR= 2.44; 95% CI (1.52, 3.91)) were 2 times more likely to be fully vaccinated both PCV and RV when compared with those who were born to younger mothers.

On the other hand, the lower odds of fully vaccination of newly introduced childhood vaccine were observed in the rural areas. Compared to the urban counterpart, children from the rural area were 26% (AOR= .74, 95% CI .55, .99) less likely to fully vaccinated PCV and RV. The study also found that the odds of fully vaccination of newly introduced childhood vaccination 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, 3.36)), times more likely to be fully vaccinated for both PCV and RV compared to the poorest household.

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

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

## Discussion

The Sustainable Development Goal envisions ensuring healthy lives and promoting well-being for all at all ages (21). Immunization is among the most cost-effective ways to support a healthier and safer world (22). Therefore the Ethiopian Health sector transformation plan planned to achieve coverage of 75% full immunization for the prevention led health policy in the country (23). Our analysis focused on the newly introduced vaccines, pneumococcal conjugate vaccine (PCV) administered for the prevention of pneumonia infection; and Rotavirus vaccine (RV) used for the prevention of childhood diarrhea in the list of country's vaccination service; with the aim of identifying individual and community-level factors associated with the uptake of newly introduced childhood vaccination among children 12–23 months of age in Ethiopia using the 2019 Mini Ethiopia Demographic and Health Survey.

Our analysis revealed that nearly four in nine (45.7%), five in ten (53.4%) and four in ten (43.5%) of the children completed vaccination for 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 2 doses for RV, where there could be an increased chance of drop out for the three dose vaccine than the two dose vaccine (24). The overall uptake of the two vaccines indicates that more than half of children are not protected from the pneumococcal and Rotavirus infections which are the common killer disease among children(25,26). This impacts the county's as well as the global strive to reduce child mortality. The finding was slightly lower than study by Wondimu A et al., 56% RV and 49.1% PCV (27) and is slightly higher than the full immunization coverage 38.3% (28) of the re-analysis of the EDHS 2016. The observed coverage of the two vaccines in Ethiopia is far below the Ethiopian National Expanded Program on Immunization (EPI) and the Global Vaccine Action Plan (GVAP) set coverage goals of 90% at the national level and 80% at the district level by 2020 (29). It is as well, 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 Health Sector Transformation Plan (HSTP) (23). To maximize the benefits of vaccination programs, it is also critical to work toward 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 immunization coverage in children. Our investigation, revealed age, place of residence, household wealth quintile, antenatal care (ANC) contacts, postnatal care (PNC), place of delivery, and exposure to media as factors significantly associated with PCV and RV uptake of the complete schedule.

322 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 health care experience could have better awareness to vaccinate their children(28). In this regard, it is less likely that mothers of age less than 20, particularly the teen, could get a better education or better health-seeking behavior 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 of 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 is limited in rural setup. A similar finding was reported by Sisay Koku et al. where children of rural resident mothers had lower odds of having competed for vaccination in Ethiopia (28).

The study also found that the odds of fully vaccination of newly introduced childhood vaccination strictly increased with the household wealth quintile. Compared to 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 immunization service for the children. This finding is consistent with findings from earlier investigations(25,27,30).

Antenatal care during pregnancy was found to be the most important predictor of full vaccination of newly introduced childhood vaccinations. The odds of children of mothers who had at least four ANC contact from a skilled provider were about three times more fully vaccinated of PCV and RV compared to those children of mothers with no ANC contacts. This result is consistent with the findings of many other studies elsewhere (31,32). Based on the Demographic and Health Surveys of 12 East African countries, Tesema et al., found having 1–3 ANC visits and four and above ANC visits were significantly associated with complete childhood vaccination (31). Residing in communities possessing higher maternal antenatal care services utilization was positively associated with childhood full immunization (27,33). 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. Antenatal care attendance was significantly associated with having good knowledge of the routine immunization program. Moreover, the chances of not being fully immunized reduced for children whose mothers attended antenatal clinics (34,35). As a result, expanding ANC and increasing the frequencies of ANC consultation is beneficial for the mothers to fully immunize their children as four or more ANC visits are associated with complete vaccination status (36,37).

Whereas, children of mothers who attended postnatal care were 85% and 82% more likely to be fully vaccinated of PCV and RV, respectively, compared to those children of mothers who did not attend postnatal care. Evidence showed that having a PNC visit was found to be strongly linked with complete childhood immunization (31). This is also supported by the finding of another study conducted in Malawi (38), which showed when compared to children who had a PNC check within two months, those who did not had a PNC check had a higher chance of being under-vaccinated.

Our research discovered that maternal delivery in a health facility was also linked to full vaccination of recently introduced child vaccines. When compared to children born at home, those born in health facilities were 49 percent more likely to be fully vaccinated in both PCV and RV. Another study found that facility delivery was also linked to full childhood vaccination (31). Similar research works also indicated consistent results (32,35,39–41). Children whose mothers struggled to reach to health facilities and who resided in socioeconomically challenged communities and states were more likely to be vaccinated insufficiently (35). These findings suggest that maternal health-care utilization and mothers' knowledge of the age at which their children begin and finish vaccination are the most important determinants in achieving complete immunization coverage. To enhance community knowledge of the need of immunization, 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 to 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 (31). 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 (42). A substantial link was found between media exposure and vaccine uptake in another investigation as well (43). Furthermore, similar findings were found in other research conducted worldwide (33,44). This is because when people are exposed to more media, they will get more information.

## 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, antenatal care (ANC) contacts, postnatal care (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 emphasizes the need to strengthen our maternal and child healthcare services. In addition, interventions aimed at increasing immunization uptake need to target mothers in the younger age categories and those with lower socio-economic status along the wealth quintile. Findings suggest also 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.

**Ethics and dissemination**

The study used data from the 2019 EMDHS obtained from Measure DHS data archive http://www.DHSprogram.com, with the appropriate request and permission. The DHS program owns data that are collected following all the necessary ethical procedures in accordance with the relevant guidelines and regulations. Therefore, for the data used in this analysis, all methods were carried out in accordance with relevant guidelines and regulations. The DHS Program is authorized to distribute, at no cost, unrestricted survey data files for legitimate academic research. Registration is required for access to data.

**Availability of data and materials**

The raw data used in this study can be accessed from the DHS website: http://www.DHSprogram.com.

## Competing interests

The authors declare that they have no conflict of interest.

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## Author Contributions

GTG and SH conceived the study, BTW, TGD, SH, TDB and FH carried out the statistical analysis, GTG, TGD, TDB, SH and BTW conducted the literature review. SH, GTG, BTW and TGD wrote draft manuscript while FH and TDB reviewed and commented the draft manuscript. All authors read and approved the final version of the manuscript.

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550 Table 1: Prevalence of PCV and RV vaccination across characteristics of mothers and children,

551 2019 EMDHS (n = 2833).

| Variables | | Number of children | Fully vaccinated PCV | Fully vaccinated RV | Fully vaccinated PCV and RV |
|---|---|---|---|---|---|
| | | n(%) | n (%) | n (%) | |
| Woman age at birth | <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 (60.5)0 | 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) |

| | | | | | |
|---|---|---|---|---|---|
| Child birth 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) |
| 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) |

552 PCV Pneumococcal conjugates vaccine, RV Rotavirus vaccine, EMDHS Ethiopian Mini
553 Demographic and Health Survey, SNNPR south Nations Nationalities and Peoples
554 region

555 Table 2: Factors associated with uptake of the PCV and RV in children aged 12–23 months in Ethiopia, bivariate and multivariate
556 multilevel logistic regression analysis (n = 2833).

| | PCV | | RV | | Fully vaccination of both PCV and RV | |
|---|---|---|---|---|---|---|
| Variables | COR (95% C. I) | AOR (95% C. I) | COR (95% C. I) | AOR (95% C. I) | COR (95% C. I) | AOR (95% C. I) |
| Mother age | | | | | | |
| < 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 20-34 | 2.39 (1.70, 3.35) | 1.73 (1.19, 2.50) | 1.83 (1.34, 2.50) | 2.16 (1.46, 3.19) | 2.2[illegible] (1.62, 3.22) | 2.03 (1.37, 3.02) |
| 35-49 | 2.14 (1.47, 3.12) | 1.96 (1.26, 3.10) | 1.79 (1.28, 2.55) | 2.38 (1.48, 3.80) | 2.24 (1.[illegible]3, 3.28) | 2.44 (1.52, 3.91) |
| Residence | | | | | | |
| Urban | 1 | 1 | 1 | 1 | 1 | 1 |
| Rural | .349 (.28, .43) | .64 (.48, .87) | .34 (.27, .43) | .69 (.51, .93) | .35 (.28, .43) | .74 (.55, .99) |
| Mother education | | | | | | |
| No education | 1 | 1 | 1 | 1 | 1 | 1 |
| Primary | 1.35 (1.13, 1.62) | .95 (.76, 1.18) | 1.34 (1.12, 1.61) | .96 (.77, 1.19) | 1.35 (1.[illegible]2, 1.62) | .99 (.80, 1.24) |
| Secondary | 1.86 (1.39, 2.49) | .86 (.60, 1.22) | 1.83 (1.36, 2.46) | .89 (.63, 1.26) | 1.79 (1.35, 2.40) | .89 (.64, 1.26) |
| Higher | 2.63 (1.78, 3.87) | 1.25 (.77, 2.03) | 3.25 (2.11, 5.01) | .99 (.64, 1.54) | 2.83 (1.[illegible]2, 4.17) | 1.15 (.74, 1.78) |
| Wealth quintile | | | | | | |
| Poorest | 1 | 1 | 1 | 1 | 1 | 1 |
| Poorer | 1.66 (1.28, 2.15) | 1.61 (1.23, 2.09) | 1.98 (1.54, 2.54) | 1.36 (1.03, 1.78) | 1.73 (1.[illegible]3, 2.25) | 1.44 (1.09, 1.91) |
| Middle | 1.86 (1.42, 2.44) | 1.49 (1.12, 1.99) | 1.99 (1.53, 2.61) | 1.42 (1.05, 1.90) | 1.93 (1.47, 2.55) | 1.53 (1.13, 2.06) |
| Richer | 2.72 (2.05, 3.59) | 1.82 (1.21, 2.73) | 3.68 (2.77, 4.89) | 1.66 (1.20, 2.28) | 2.72 (2.[illegible]5, 3.62) | 1.72 (1.25, 2.37) |
| Richest | 5.23 (3.98, 6.87) | 2.19 (1.59, 3.02 | 5.29 (4.03, 6.97) | 2.02 (1.34, 3.02) | 5.5[illegible] (4.23, 7.36) | 2.24 (1.49, 3.36) |
| Child sex | | | | | | |
| Male | 1 | 1 | 1 | 1 | 1 | 1 |
| Female | .88 (.75, 1.03) | .94 (.78, 1.10) | .93 (.79, 1.09) | .87 (.73, 1.03) | .89 (.75, 1.04) | .88 (.74, 1.04) |
| Religion | | | | | | |
| Orthodox | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Muslim | .81 (.63, 1.04) | .85 (.63, 1.14) | .74 (.57, .97) | .92 (.69, 1.22) | .77 (.59, .99) | .88 (.66, 1.16) |
| Protestant | .78 (.58, 1.05) | .90 (0.65, 1.25) | .78 (.58, 1.05) | .91 (.66, 1.25) | .79(.59, 1.07) | .89 (.65, 1.22) |
| Others | .61 (.33, 1.12) | .70 (.36, 1.38) | .39 (.21, .75) | 1.12 (.58, 2.19) | .52 (.27, .99) | .85 (.42, 1.69) |
| Birth order | | | | | | |
| First birth | 1 | 1 | 1 | 1 | 1 | 1 |
| 2-3 | 1.04 (.83, 1.29) | .87 (.67, 1.13) | .92 (.74, 1.14) | .948 (.73, 1.22) | 1.04 ([illegible], 1.30) | .96 (.75, 1.25) |
| 4-5 | .91 (.72, 1.16) | .94 (.69, 1.28) | .86 (.67, 1.09) | .95 (.69, 1.28) | .93 ([illegible], 1.18) | .99 (.73, 1.34) |
| 6+ | .73 (.57, .94) | .88 (.62, 1.23) | .76 (.59, .97) | .81 (.58, 1.14) | .78 (.61, 1.01) | .88 (.63, 1.24) |
| ANC | | | | | | |
| No ANC | 1 | 1 | 1 | 1 | 1 | 1 |
| 1- 3 | 3.03 (2.37, 3.87) | 2.04 (1.59, 2.61) | 2.91 (2.32, 3.65) | 2.13 (1.63, 2.77) | 2.86 (2.[illegible]3, 3.67) | 2.09 (1.60, 2.74) |
| 4+ | 5.14 (4.03, 6.55) | 2.86 (2.19, 3.73) | 5.23 (4.14, 6.57) | 2.80 (2.12, 3.71) | 4.74 (3.[illegible]0, 6.07) | 2.73 (2.06, 3.62) |
| Place of delivery | | | | | | |
| Home | 1 | 1 | 1 | 1 | 1 | 1 |
| Health facility | 2.86 (2.41, 3.41) | 1.49 (1.21, 1.85) | 2.96 (2.49, 3.51) | 1.49 (1.20, 1.85) | 2.78 (2.[illegible]3, 3.31) | 1.45 (1.17, 1.79) |
| Number of under five children | | | | | | |
| 3 or less | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 or more | .80 (.42, 1.54) | .92 (.48, 1.76) | .81 (.44, 1.48) | .91 (.46, 1.81) | .93 (.48, 1.78) | 1.06 (.53, 2.13) |
| Marital status | | | | | | |
| Single | 1 | 1 | 1 | 1 | 1 | 1 |
| Married/living with partner | 2.25 (.90, 5.58) | 1.01 (.38, 2.63) | 1.67 (.71, 3.97) | 1.35 (.49, 3.71) | 2.05 (.83, 5.11) | 1.34(.48, 3.73) |
| Others | 1.48 (.56, 3.89) | .77 (.28, 2.14) | 1.17 (.46, 2.97) | .99 (.34, 2.91) | 1.36 (.52, 3.61) | .89 (.30, 2.59) |
| Postnatal care | | | | | | |
| No | 1 | 1 | 1 | 1 | 1 | 1 |
| Yes | 2.20 (1.73, 2.81) | 1.85 (1.41, 2.43) | 2.29 (1.77, 2.95) | 1.82 (1.41, 2.35) | 2.20 (1.[illegible]3, 2.80) | 1.84 (1.42, 2.37) |
| Media exposure | | | | | | |
| Not exposed | 1 | 1 | 1 | 1 | 1 | 1 |
| Exposed | 2.21 (1.84, 2.65) | 1.25 (1.07,1.57) | 2.25 (1.87, 2.72) | 1.21 (1.05, 1.52) | 2.26 (1.[illegible]7, 2.71) | 1.24 (1.09, 1.56) |
| Random-effects parameters | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Region | | | | | | |
| var(_cons) | | .25 (.09, .67) | | .28 (.11, .74) | | .31 (.12, .80) |
| LRT | $\chi^2$ = 59.27, p-value = 0.0001 | | $\chi^2$ = 59.55 , p-value = 0.0001 | | $\chi^2$ = 68.75, p-value = 0.0001 | |
| ICC | 0.07 (0.027, 0.170) | | 0.08 (0.031, 0.183) | | | 0.086 (0.035, 0.196) |
| MOR | 1.61 (1.33, 2.18) | | 1.65 (1.36, 2.26) | | | 1.32 (1.19, 1.52) |
| Deviance (-2LLR) | 3522.69 | 3157.30 | 3570.56 | 3183.67 | 3472.[illegible]8 | 3120.52 |

PCV Pneumococcal conjugates vaccine, RV Rotavirus vaccine, EMDHS Ethiopian Mini Demographic and Health Survey, SNNPR south Nations Nationalities and Peoples region

Figure

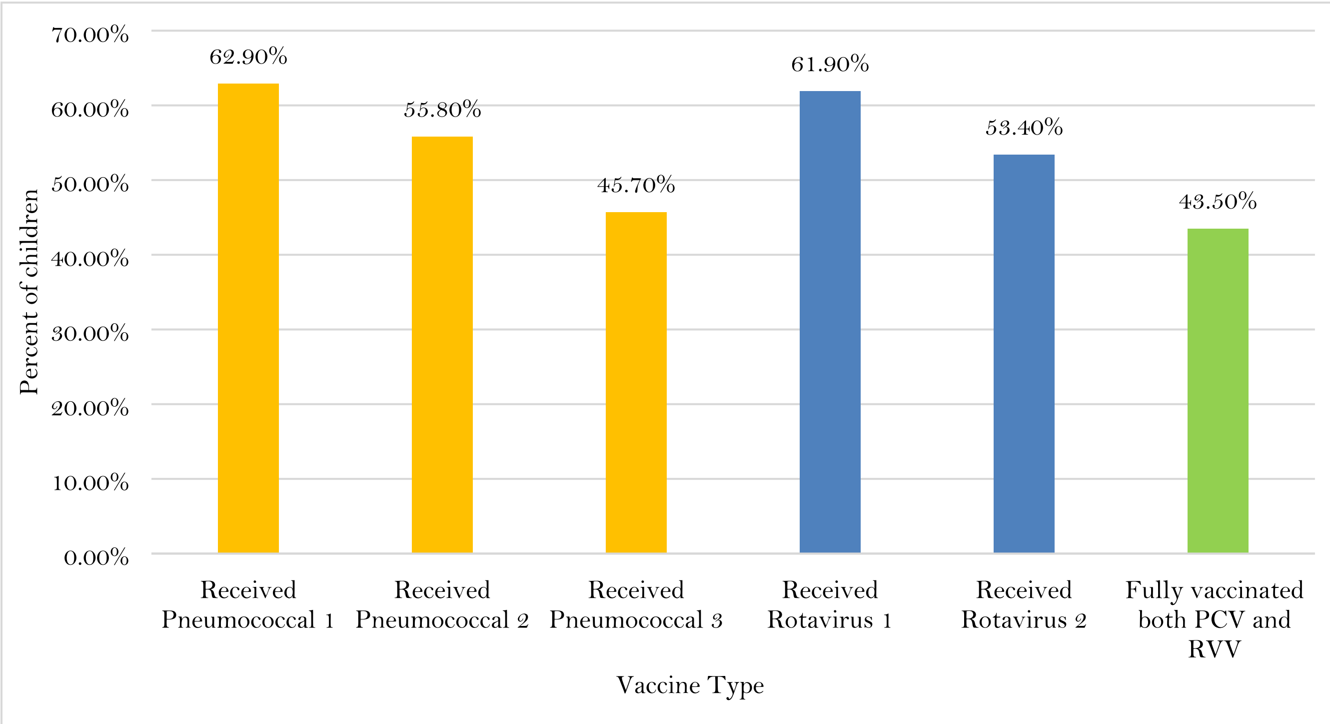


Figure 1: Proportions of children who received newly introduced childhood vaccination in Ethiopia, EMDHS 2019 (n=2833).

# 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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# 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 recently introduced vaccines uptake among children aged 12–23 months in Ethiopia.

**Results**: Our analysis revealed that 45.7%, 53.4%, and 43.5% of the children completed vaccination for Pneumococcal Conjugate vaccine (PCV), Rotavirus vaccine (RV), and both PCV and RV respectively. Being in the age group of 20-34 (AOR = 2.03, 95% CI: 1.37 - 3.02) and 35-49 (AOR = 2.44, 95% CI: 1.52 - 3.91), having at least 4 antenatal care contacts (AOR = 2.73, 95% CI: 2.06 - 3.62), having postnatal care (AOR = 1.84, 95% CI: 1.42 - 2.37), delivery in the health facility (AOR = 1.45, 95% CI: 1.17 - 1.79), and having exposure to media (AOR = 1.24, 95% CI: 1.09 - 1.56), and any of the wealth quintile categories higher than poorest category were positively associated with uptake of newly introduced vaccines. Rural residency was found to be negatively related with the uptake of newly introduced vaccines.

**Conclusion**: The overall full uptakes of newly introduced vaccines among children 12-23 months were significantly lower. Hence, this study emphasizes the need to strengthen maternal and child healthcare services particularly, to the younger age mother and those with lower socio-economic status.


**Keywords:** Childhood immunization; Newly introduced vaccine; Children 12–23 months; Multilevel analysis; Ethiopia

**Strength and Limitation of the study**

- The study's strength was its use of national data and a large, representative sample reflecting the country's socio-economic, 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 lack of vaccine supply data in Ethiopia Mini Demographic and Health Survey (EMDHS), 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 fourteen out of the seventeen 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 characterized 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 due to various socio-economic and healthcare system-related challenges[8].

A total of 116 low-and middle-income countries have introduced vaccines that they did not use previously between 2010 and 2017 [9], including those against major killers like pneumococcal pneumonia, diarrhea, cervical cancer, typhoid, cholera and meningitis. Sub-Saharan Africa is characterized 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 immunizations 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 immunization program for under-five children included only six vaccine-preventable diseases; tuberculosis, poliomyelitis, tetanus, diphtheria, pertussis, and measles. Yet, the currently routine immunization service includes ten 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 PCV was available starting from 2009 [14], the government of Ethiopia introduced the PCV and monovalent human rotavirus vaccine (RV1) into the national infant immunization program 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 immunization coverage compared to the 66% national target. On theother hand, the Comprehensive Multi-Year Plan (cMYP) 2011-2015 was endorsed by Ethiopian Federal Ministry of Health with the aim to bolster the nation immunization program. The cMYP typically revised every five years and serves as the medium-term strategic framework for national EPI, aligning with the health sector's five-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 revealed that vaccination coverage among children aged 12 to 23 months who received specific vaccines at any time prior to the survey (according to a vaccination card or the mother's recall) was only 4 out of 10 children (44%) had received all basic vaccinations at some point, with 40% receiving these vaccinations before their first birthday, and nearly 2 out of 10 children (19%) in this age group having received no vaccinations at all [21].

According to previous studies, institutional delivery, travel to vaccination site for <2 hours , received at least one antenatal (ANC) visit, good maternal knowledge of immunization, being informed on immunization schedule, living in urban areas, and a household visit by health-care providers during the postnatal period were identified to be factors associated with full vaccination among children age 12-23 [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 immunization coverage in Ethiopia. By conducting a multilevel analysis using data from the 2019 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 utilization in the country and inform policymakers, program 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 and conducted by the Central Statistical Agency (CSA) and Ethiopian Public Health Institute (EPHI) under the auspices of Federal Minister of Health (FMoH) with technical assistance from ICF International through its MEASURE DHS project. The survey was representative of both the national and regional levels. The Ethiopian Demographic and Health Survey (EDHS) was undertaken in nine

Ethiopian regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul Gumuz, Southern Nations Nationalities and Peoples (SNNP) which currently includes Sidama and Southwestern Ethiopia regions, Gambella, and Harari) and two chartered city administrations (Addis Ababa and Dire Dawa) from March 21, 2019, to June 28, 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 8,794 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, 9,012 eligible mothers with their 5,753 children were identified; among which 2,833 of them had children of age between 12-23 month and all were successfully interviewed [23].

**Data collection**

Immunization 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 uptake of recently introduced vaccine among 12-23 months children. 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 (analyzed combined as one variable-PCV and RV or as two separate variables-PCV, RV). Therefore, scenario one is a child who received two doses of RV and three doses of PCV was regarded "completely vaccinated," whereas a child who did not receive at least one dose of the vaccines was termed "not fully vaccinated". Scenario two, on the other hand is a child who received two doses of RV is considered “completely vaccinated for RV” otherwise “not fully vaccinated”; and third, a child who received three doses of PCV was regarded "completely vaccinated for PCV" otherwise “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 (i.e., 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 was considered adequate whereas one–three contacts were considered inadequate), place of delivery, post-natal care, 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 (version 14.0) was used to analyze 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, i.e., 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 has been fitted. In the first step, the heterogeneity of proportions between regions in a multilevel analysis was tested using the likelihood ratio test (LRT) and Deviance test. Finally, the adjusted odds ratio (AOR) with a 95% confidence interval (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 $\leq 0.2$), using the backward elimination fitting approach.

Let $\pi_{ij}$ denote the probability that the response variables equals 1, $\pi_{ij} = P(y_{ij} = 1/x_{ij})$ the probability of i[th] children fully vaccinated 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 $U_{oj}$ a random quantity and follows a normal distribution with mean zero and variance $\sigma_u^2$. 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)

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,

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

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 $U_{0j}, U_{1j}, \dots, U_{kj}$ 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 $\sigma_\mu^2$ is the between group variance and $\sigma_e^2$ is the within group variance.

Further, the Median Odds Ratio (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 socio-demographic 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 standard deviation (SD) years old. By age cohort, three-fourth (75.2%) of these mothers was 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 rate of male children to females 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 antenatal care during pregnancy, and 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 was 53.4%. The percentage of fully vaccinated of 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 of currently introduced childhood vaccination also highly varied by place of residence. Among children born in urban areas 75% fully vaccinated RV, 68% fully vaccinated PCV, whereas only 46% and 38% of children from rural counterparts had fully vaccinated RV and PCV, respectively. Regarding the mothers age at birth, the proportion of full vaccination of 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 fully vaccinated RV and PCV, respectively. In contrast only 35% and 27% of children born at home fully vaccinated RV and PCV, respectively. The proportion of children fully vaccinated RV and PCV increases with the number of mothers' antenatal care contacts during pregnancy.

Table 2 also shows, among children from mothers with access to media, 69% and 62% were fully vaccinated RV and PCV, respectively. By mothers' level of education, the proportion fully vaccination of currently introduced childhood vaccines was increased as mother education level increases. For instance, 82% and 73% of children from a mother who had completed higher education were fully vaccinated RV and PCV, respectively, whereas only 45% and 37% of children from a mother with no education were fully vaccinated RV and PCV, respectively. Lastly, regarding household wealth quintile, 65% and 53% of children among the richest household had fully vaccinated RV and PCV, while from poorest wealth quintile, only 31% and 24%, full vaccinated 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 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 fully vaccination, with a region variance of 25%. The ICC value was 8.6% (95% CI: 3.5%-19.6%) 8.6% of the total variability of fully vaccination status was attributed to differences between clusters (regions), while the rest were unexplained. Moreover, the MOR was estimated at 1.32 (95% CI: 1.19-1.52), revealing that if a child moved to another community with a higher probability of full vaccination , the median increase in its odds of fully vaccinated would be 1.32, with an ICC of 8.6%. Furthermore, model comparison based on deviance (-2LLR) 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 childhood fully PCV and RV vaccination were maternal age, place of residence, household wealth quintile, antenatal care (ANC) contacts, postnatal care (PNC), place of delivery, and exposure to media. Similar factors have been found statistically significantly associated with all the three scenarios (PCV; RV; both PCV and RV together); with similar strength of measure of association across scenarios (Supplemental Table 1). We found that children belonging to mothers who were 20-34 (AOR = 2.03; 95% CI (1.37 - 3.02)) and above 34 years old (AOR= 2.44; 95% CI (1.52 - 3.91)) were 2 times more likely to be fully vaccinated both PCV and RV when compared with those who were born to younger mothers.

On the other hand, the lower odds of fully vaccination of newly introduced childhood vaccine were observed in the rural areas. Compared to the urban counterpart, children from the rural area were 26% (AOR= 0.74, 95% CI 0.55 – 0.99) less likely to fully vaccinated PCV and RV. The study also found that the odds of fully vaccination of newly introduced childhood vaccination 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 – 3.36)), times more likely to be fully vaccinated for both PCV and RV compared to the poorest household.

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

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

## Discussion

The Sustainable Development Goal envisions ensuring healthy lives and promoting well-being for all at all ages [26]. Immunization is among the most cost-effective ways to support a healthier and safer world [27]. Therefore the Ethiopian Health sector transformation plan planned to achieve coverage of 75% full immunization for the prevention led health policy in the country [28]. Our analysis focused on the newly introduced vaccines, pneumococcal conjugate vaccine (PCV) administered for the prevention of pneumonia infection; and Rotavirus vaccine (RV) used for the prevention of childhood diarrhea in the list of country's vaccination service; with the aim of identifying individual and community-level factors associated with the uptake of newly introduced childhood vaccination among children 12–23 months of age in Ethiopia using the 2019 Mini Ethiopia Demographic and Health Survey.

Our analysis revealed that nearly four in nine (45.7%), five in ten (53.4%) and four in ten (43.5%) of the children completed vaccination for 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 2 doses for RV, where there could be an increased chance of drop out 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 the pneumococcal and Rotavirus infections which are the common killer disease among children[30,31]. This impacts the county's as well as the global strive to reduce child mortality. The finding was slightly lower than study by Wondimu A et al., 56% RV and 49.1% PCV [32] and is slightly higher than the full immunization coverage 38.3% [33] of the re-analysis of the EDHS 2016. The observed coverage of the two vaccines in Ethiopia is far below the Ethiopian National Expanded Program on Immunization (EPI) and the Global Vaccine Action Plan (GVAP) set coverage goals of 90% at the national level and 80% at the district level by 2020 [34]. It is as well, 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 Health Sector Transformation Plan (HSTP) [28]. To maximize the benefits of vaccination programs, it is also critical to work toward 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 immunization coverage in children. Our investigation, revealed age, place of residence, household wealth quintile, antenatal care (ANC) contacts, postnatal care (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 health care 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 teen, could get a better education or better health-seeking behavior 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 of 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 is limited in rural setup. A similar finding was reported by Sisay Koku et al. where children of rural resident mothers had lower odds of having competed for vaccination in Ethiopia [33].

The study also found that the odds of fully vaccination of newly introduced childhood vaccination strictly increased with the household wealth quintile. Compared to 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

338 higher in all the three vaccination scenarios considered (PCV; RV; PCV and RV). Despite the fact
339 that childhood vaccination is free in Ethiopia, there is still a significant financial burden connected
340 with it due to travel costs and lost revenue due to income loss during travel time while seeking
341 immunization service for the children. This finding is consistent with findings from earlier
342 investigations[30,32,35].

343 Antenatal care during pregnancy was found to be the most important predictor of full vaccination
344 of newly introduced childhood vaccinations. The odds of children of mothers who had at least
345 four ANC contact from a skilled provider were about three times more fully vaccinated of PCV
346 and RV compared to those children of mothers with no ANC contacts. This result is consistent
347 with the findings of many other studies elsewhere [36,37]. Based on the Demographic and Health
348 Surveys of 12 East African countries, Tesema et al., found having 1–3 ANC visits and four and
349 above ANC visits were significantly associated with complete childhood vaccination [36]. Residing
350 in communities possessing higher maternal antenatal care services utilization was positively
351 associated with childhood full immunization [32,38]. This is due to mothers' education during ANC
352 and their knowledge may be increased and attitude may be influenced as they get more
353 information on vaccination during ANC consultation. Antenatal care attendance was
354 significantly associated with having good knowledge of the routine immunization program.
355 Moreover, the chances of not being fully immunized reduced for children whose mothers
356 attended antenatal clinics [39,40]. As a result, expanding ANC and increasing the frequencies of
357 ANC consultation is beneficial for the mothers to fully immunize their children as four or more
358 ANC visits are associated with complete vaccination status [41,42].

359 Whereas, children of mothers who attended postnatal care were 85% and 82% more likely to be
360 fully vaccinated of PCV and RV, respectively, compared to those children of mothers who did not
361 attend postnatal care. Evidence showed that having a PNC visit was found to be strongly linked

with complete childhood immunization [36]. This is also supported by the finding of another study conducted in Malawi [43], which showed when compared to children who had a PNC check within two months, those who did not had a PNC check had a higher chance of being under-vaccinated. Our research discovered that maternal delivery in a health facility was also linked to full vaccination of recently introduced child vaccines. When compared to children born at home, those born in health facilities were 49 percent 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 to health facilities and who resided in socioeconomically challenged communities and states were more likely to be vaccinated insufficiently [40]. These findings suggest that maternal health-care utilization and mothers' knowledge of the age at which their children begin and finish vaccination are the most important determinants in achieving complete immunization coverage. To enhance community knowledge of the need of immunization, 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 to 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 utilized national representative data, reflecting diverse socio-economic, 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 the demand side of the determinants in our study. Future studies need to consider vaccine supplies factors which is undeniably could have a considerable impact on immunization coverage. Due to the crosssectional nature of the data, a cause-effect relationship could not be established. There could be recall bias could be introduced. Yet , the survey included a health facility recorded data on children's vaccinations to confirm mother's report 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, antenatal care (ANC) contacts, postnatal care (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 emphasizes the need to strengthen our maternal and child healthcare services. In addition, interventions aimed at increasing immunization uptake need to target mothers in the younger age categories and those with lower socio-economic status along the wealth quintile. Findings suggest also 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.

410 **Ethics and dissemination**

411 The study used data from the 2019 EMDHS obtained from Measure DHS data archive
412 (https://www.dhsprogram.com/) with the appropriate request and permission. The DHS program
413 collects data in compliance with all necessary ethical procedures, guidelines, and regulations.
414 Moreover, informed consent was obtained from participants at the start of each interview.
415 Ethical approval was not required for this study as it utilized publicly available data. However,
416 permission to use the data was granted by the Demographic Health Survey program.

417 **Availability of data and materials**

418 The data used in this study can be accessed from the DHS website:
419 http://www.DHSprogram.com.

420 **Competing interests**

421 The authors declare that they have no conflict of interest.

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427 **Author Contributions**

428 GTG and SH conceived the study, BTW, TGD, SH, TDB and FH carried out the statistical
429 analysis, GTG, TGD, TDB, SH and BTW conducted the literature review. SH, GTG, BTW and
430 TGD wrote draft manuscript while SH, FH and TDB reviewed and commented the draft
431 manuscript. All authors read and approved the final version of the manuscript. SH acted as
432 guarantor.

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Table 1: National immunization 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-Guerin; OPV-Oral Polio Vaccine; DPT-HepB-Hib: Diphtheria, Pertussis, Tetanus, Hepatitis B, Haemophilus Influenza Type B; PCV: Pneumococcal Conjugate Vaccine; Rota: Rotavirus Vaccine.

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

| Variables | | Number of children | Fully vaccinated PCV | Fully vaccinated RV | Fully vaccinated PCV and RV |
|---|---|---|---|---|---|
| | | n(%) | n (%) | n (%) | |
| Woman age at birth | <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 (60.5)0 | 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) |

| | | | | | |
|---|---|---|---|---|---|
| Child birth 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) |
| 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) |

PCV Pneumococcal conjugates vaccine, RV Rotavirus vaccine, EMDHS Ethiopian Mini Demographic and Health Survey, SNNPR south Nations Nationalities and Peoples region

**Figure lengend**

Figure 1: Proportions of children who received newly introduced childhood vaccination in Ethiopia, EMDHS 2019 (n=2833)

Figure

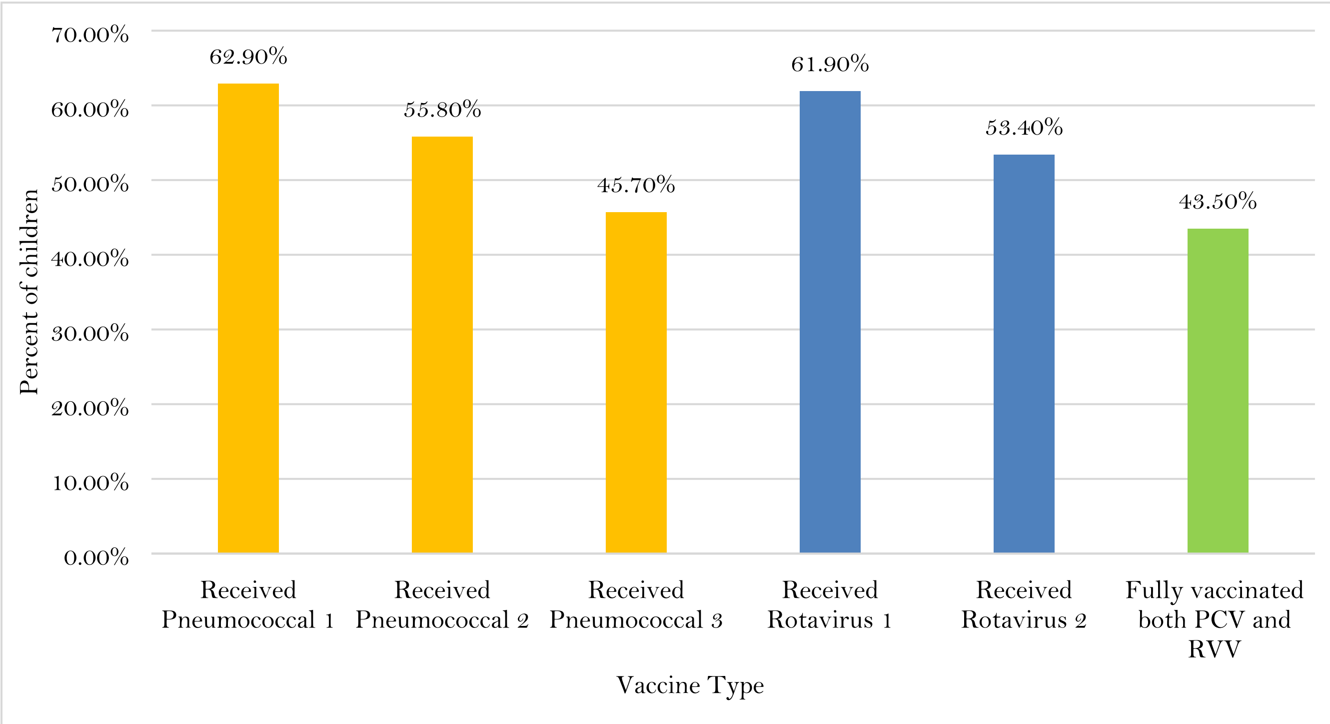


Figure 1: Proportions of children who received newly introduced childhood vaccination in Ethiopia, EMDHS 2019 (n=2833).

Supplemental Table 1: Factors associated with uptake of the PCV and RV in children aged 12–23 months in Ethiopia, bivariate and multivariate multilevel logistic regression analysis (n = 2833).

| | PCV | | RV | | Fully vaccination of both PCV and RV | |
|---|---|---|---|---|---|---|
| Variables | COR (95% C. I) | AOR (95% C. I) | COR (95% C. I) | AOR (95% C. I) | COR (95% C. I) | AOR (95% C. I) |
| Mother age | | | | | | |
| < 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 20-34 | 2.39 (1.70, 3.35) | 1.73 (1.19, 2.50) | 1.83 (1.34, 2.50) | 2.16 (1.46, 3.19) | 2.28 (1.62, 3.22) | 2.03 (1.37, 3.02) |
| 35-49 | 2.14 (1.47, 3.12) | 1.96 (1.26, 3.10) | 1.79 (1.28, 2.55) | 2.38 (1.48, 3.80) | 2.24 (1.53, 3.28) | 2.44 (1.52, 3.91) |
| Residence | | | | | | |
| Urban | 1 | 1 | 1 | 1 | 1 | 1 |
| Rural | .349 (.28, .43) | .64 (.48, .87) | .34 (.27, .43) | .69 (.51, .93) | .35 (.28, .43) | .74 (.55, .99) |
| Mother education | | | | | | |
| No education | 1 | 1 | 1 | 1 | 1 | 1 |
| Primary | 1.35 (1.13, 1.62) | .95 (.76, 1.18) | 1.34 (1.12, 1.61) | .96 (.77, 1.19) | 1.35 (1.12, 1.62) | .99 (.80, 1.24) |
| Secondary | 1.86 (1.39, 2.49) | .86 (.60, 1.22) | 1.83 (1.36, 2.46) | .89 (.63, 1.26) | 1.79 (1.35, 2.40) | .89 (.64, 1.26) |
| Higher | 2.63 (1.78, 3.87) | 1.25 (.77, 2.03) | 3.25 (2.11, 5.01) | .99 (.64, 1.54) | 2.83 (1.92, 4.17) | 1.15 (.74, 1.78) |
| Wealth quintile | | | | | | |
| Poorest | 1 | 1 | 1 | 1 | 1 | 1 |
| Poorer | 1.66 (1.28, 2.15) | 1.61 (1.23, 2.09) | 1.98 (1.54, 2.54) | 1.36 (1.03, 1.78) | 1.73 (1.33, 2.25) | 1.44 (1.09, 1.91) |
| Middle | 1.86 (1.42, 2.44) | 1.49 (1.12, 1.99) | 1.99 (1.53, 2.61) | 1.42 (1.05, 1.90) | 1.93 (1.47, 2.55) | 1.53 (1.13, 2.06) |
| Richer | 2.72 (2.05, 3.59) | 1.82 (1.21, 2.73) | 3.68 (2.77, 4.89) | 1.66 (1.20, 2.28) | 2.72 (2.05, 3.62) | 1.72 (1.25, 2.37) |
| Richest | 5.23 (3.98, 6.87) | 2.19 (1.59, 3.02 | 5.29 (4.03, 6.97) | 2.02 (1.34, 3.02) | 5.58 (4.23, 7.36) | 2.24 (1.49, 3.36) |
| Child sex | | | | | | |
| Male | 1 | 1 | 1 | 1 | 1 | 1 |
| Female | .88 (.75, 1.03) | .94 (.78, 1.10) | .93 (.79, 1.09) | .87 (.73, 1.03) | .89 (.75, 1.04) | .88 (.74, 1.04) |
| Religion | | | | | | |
| Orthodox | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Muslim | .81 (.63, 1.04) | .85 (.63, 1.14) | .74 (.57, .97) | .92 (.69, 1.22) | .77 (.5[illegible], .99) | .88 (.66, 1.16) |
| Protestant | .78 (.58, 1.05) | .90 (0.65, 1.25) | .78 (.58, 1.05) | .91 (.66, 1.25) | .79 (.59, 1.07) | .89 (.65, 1.22) |
| Others | .61 (.33, 1.12) | .70 (.36, 1.38) | .39 (.21, .75) | 1.12 (.58, 2.19) | .52 (.2[illegible], .99) | .85 (.42, 1.69) |
| Birth order | | | | | | |
| First birth | 1 | 1 | 1 | 1 | 1 | 1 |
| 2-3 | 1.04 (.83, 1.29) | .87 (.67, 1.13) | .92 (.74, 1.14) | .948 (.73, 1.22) | 1.04 (.84, 1.30) | .96 (.75, 1.25) |
| 4-5 | .91 (.72, 1.16) | .94 (.69, 1.28) | .86 (.67, 1.09) | .95 (.69, 1.28) | .93 (.7[illegible], 1.18) | .99 (.73, 1.34) |
| 6+ | .73 (.57, .94) | .88 (.62, 1.23) | .76 (.59, .97) | .81 (.58, 1.14) | .78 (.6[illegible], 1.01) | .88 (.63, 1.24) |
| ANC | | | | | | |
| No ANC | 1 | 1 | 1 | 1 | 1 | 1 |
| 1- 3 | 3.03 (2.37, 3.87) | 2.04 (1.59, 2.61) | 2.91 (2.32, 3.65) | 2.13 (1.63, 2.77) | 2.86 (2.23, 3.67) | 2.09 (1.60, 2.74) |
| 4+ | 5.14 (4.03, 6.55) | 2.86 (2.19, 3.73) | 5.23 (4.14, 6.57) | 2.80 (2.12, 3.71) | 4.7[illegible] (3.70, 6.07) | 2.73 (2.06, 3.62) |
| Place of delivery | | | | | | |
| Home | 1 | 1 | 1 | 1 | 1 | 1 |
| Health facility | 2.86 (2.41, 3.41) | 1.49 (1.21, 1.85) | 2.96 (2.49, 3.51) | 1.49 (1.20, 1.85) | 2.78 (2.33, 3.31) | 1.45 (1.17, 1.79) |
| Number of under five children | | | | | | |
| 3 or less | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 or more | .80 (.42, 1.54) | .92 (.48, 1.76) | .81 (.44, 1.48) | .91 (.46, 1.81) | .93 (.48, 1.78) | 1.06 (.53, 2.13) |
| Marital status | | | | | | |
| Single | 1 | 1 | 1 | 1 | 1 | 1 |
| Married/living with partner | 2.25 (.90, 5.58) | 1.01 (.38, 2.63) | 1.67 (.71, 3.97) | 1.35 (.49, 3.71) | 2.[illegible]5 (.83, 5.11) | 1.34(.48, 3.73) |
| Others | 1.48 (.56, 3.89) | .77 (.28, 2.14) | 1.17 (.46, 2.97) | .99 (.34, 2.91) | 1.36 (.52, 3.61) | .89 (.30, 2.59) |
| Postnatal care | | | | | | |
| No | 1 | 1 | 1 | 1 | 1 | 1 |
| Yes | 2.20 (1.73, 2.81) | 1.85 (1.41, 2.43) | 2.29 (1.77, 2.95) | 1.82 (1.41, 2.35) | 2.20 (1.73, 2.80) | 1.84 (1.42, 2.37) |
| Media exposure | | | | | | |
| Not exposed | 1 | 1 | 1 | 1 | 1 | 1 |
| Exposed | 2.21 (1.84, 2.65) | 1.25 (1.07,1.57) | 2.25 (1.87, 2.72) | 1.21 (1.05, 1.52) | 2.26 (1.87, 2.71) | 1.24 (1.09, 1.56) |
| Random-effects parameters | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Region | | | | | | |
| var(_cons) | | .25 (.09, .67) | | .28 (.11, .74) | | .31 (.12, .80) |
| LRT | $\chi^2$ = 59.27, p-value = 0.0001 | | $\chi^2$ = 59.55 , p-value = 0.0001 | | $\chi^2$ = 68.75, p-value = 0.0001 | |
| ICC | 0.07 (0.027, 0.170) | | 0.08 (0.031, 0.183) | | | 0.086 (0.035, 0.196) |
| MOR | 1.61 (1.33, 2.18) | | 1.65 (1.36, 2.26) | | | 1.32 (1.19, 1.52) |
| Deviance (-2LLR) | 3522.69 | 3157.30 | 3570.56 | 3183.67 | 3472.88 | 3120.52 |

PCV Pneumococcal conjugates vaccine, RV Rotavirus vaccine, EMDHS Ethiopian Mini Demographic and Health Survey, SNNPR south Nations Nationalities and Peoples region

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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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# 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 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 12-23 months.

**Outcome measures**: The outcome variable was uptake of recently introduced vaccine (RV and PCV) among 12-23 months children.

**Results**: Our analysis revealed that 45.7%, 53.4%, and 43.5% of the children completed vaccination for Pneumococcal Conjugate vaccine (PCV), Rotavirus vaccine (RV), and both PCV and RV respectively. Being in the age group of 20-34 (AOR = 2.03, 95% CI: 1.37 - 3.02) and 35-49 (AOR = 2.44, 95% CI: 1.52 - 3.91), having at least 4 antenatal care contacts (AOR = 2.73, 95% CI: 2.06 - 3.62), having postnatal care (AOR = 1.84, 95% CI: 1.42 - 2.37), delivery in the health facility (AOR = 1.45, 95% CI: 1.17 - 1.79), and having exposure to media (AOR = 1.24, 95% CI: 1.09 - 1.56), and any of the wealth quintile categories higher than poorest category were positively associated with uptake of newly introduced vaccines. Rural residency was found to be negatively related with the uptake of newly introduced vaccines.

**Conclusion**: The overall full uptakes of newly introduced vaccines among children 12-23 months were significantly lower. Hence, this study emphasizes the need to strengthen maternal and child healthcare services particularly, to the younger age mother and those with lower socio-economic status.

**Keywords:** Childhood immunization; Newly introduced vaccine; Children 12–23 months; Multilevel analysis; Ethiopia

## Strength and Limitation of the study

- The study's strength was its use of national data and a large, representative sample reflecting the country's socio-economic, 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 lack of vaccine supply data in Ethiopia Mini Demographic and Health Survey (EMDHS), 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 fourteen out of the seventeen 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 characterized 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 due to various socio-economic and healthcare system-related challenges[8].

A total of 116 low-and middle-income countries have introduced vaccines that they did not use previously between 2010 and 2017 [9], including those against major killers like pneumococcal pneumonia, diarrhea, cervical cancer, typhoid, cholera and meningitis. Sub-Saharan Africa is characterized 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 immunizations 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 immunization program for under-five children included only six vaccine-preventable diseases; tuberculosis, poliomyelitis, tetanus, diphtheria, pertussis, and measles. Yet, the currently routine immunization service includes ten 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 PCV was available starting from 2009 [14], the government of Ethiopia introduced the PCV and monovalent human rotavirus vaccine (RV1) into the national infant immunization program 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 immunization coverage compared to the 66% national target. On theother hand, the Comprehensive Multi-Year Plan (cMYP) 2011-2015 was endorsed by Ethiopian Federal Ministry of Health with the aim to bolster the nation immunization program. The cMYP typically revised every five years and serves as the medium-term strategic framework for national EPI, aligning with the health sector's five-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 revealed that vaccination coverage among children aged 12 to 23 months who received specific vaccines at any time prior to the survey (according to a vaccination card or the mother's recall) was only 4 out of 10 children (44%) had received all basic vaccinations at some point, with 40% receiving these vaccinations before their first birthday, and nearly 2 out of 10 children (19%) in this age group having received no vaccinations at all [21].

According to previous studies, institutional delivery, travel to vaccination site for <2 hours , received at least one antenatal (ANC) visit, good maternal knowledge of immunization, being informed on immunization schedule, living in urban areas, and a household visit by health-care providers during the postnatal period were identified to be factors associated with full vaccination among children age 12-23 [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 immunization coverage in Ethiopia. By conducting a multilevel analysis using data from the 2019 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 utilization in the country and inform policymakers, program 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 and conducted by the Central Statistical Agency (CSA) and Ethiopian Public Health Institute (EPHI) under the auspices of Federal Minister of Health (FMoH) with technical assistance from ICF International through its MEASURE DHS project. The survey was representative of both the national and regional levels. The Ethiopian Demographic and Health Survey (EDHS) was undertaken in nine

Ethiopian regions (Tigray, Afar, Amhara, Oromia, Somali, Benishangul Gumuz, Southern Nations Nationalities and Peoples (SNNP) which currently includes Sidama and Southwestern Ethiopia regions, Gambella, and Harari) and two chartered city administrations (Addis Ababa and Dire Dawa) from March 21, 2019, to June 28, 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 8,794 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, 9,012 eligible mothers with their 5,753 children were identified; among which 2,833 of them had children of age between 12-23 month and all were successfully interviewed [23].

**Data collection**

Immunization 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 uptake of recently introduced vaccine among 12-23 months children. 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 (analyzed combined as one variable-PCV and RV or as two separate variables-PCV, RV). Therefore, scenario one is a child who received two doses of RV and three doses of PCV was regarded "completely vaccinated," whereas a child who did not receive at least one dose of the vaccines was termed "not fully vaccinated". Scenario two, on the other hand is a child who received two doses of RV is considered “completely vaccinated for RV” otherwise “not fully vaccinated”; and third, a child who received three doses of PCV was regarded "completely vaccinated for PCV" otherwise “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 (i.e., 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 was considered adequate whereas one–three contacts were considered inadequate), place of delivery, post-natal care, 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 (version 14.0) was used to analyze 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, i.e., 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 has been fitted. In the first step, the heterogeneity of proportions between regions in a multilevel analysis was tested using the likelihood ratio test (LRT) and Deviance test. Finally, the adjusted odds ratio (AOR) with a 95% confidence interval (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 $\leq 0.2$), using the backward elimination fitting approach.

Let $\pi_{ij}$ denote the probability that the response variables equals 1, $\pi_{ij} = P(y_{ij} = 1/x_{ij})$ the probability of i^th children fully vaccinated 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 $U_{oj}$ a random quantity and follows a normal distribution with mean zero and variance $\sigma_u^2$. 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)

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

200 Thus, in the random intercept multilevel logistic regression model,

201 $$\text{Logit}(\pi_{ij}) = \log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_o + \sum_{h=1}^{k} \beta_h x_{ij} + U_{oj} + \sum_{h=1}^{k} U_{hj} x_{ij}$$

202 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]

206 $$ICC = \frac{\sigma_\mu^2}{\sigma_\mu^2 + \sigma_e^2}$$

207 Where $\sigma_\mu^2$ is the between group variance and $\sigma_e^2$ is the within group variance.

208 Further, the Median Odds Ratio (MOR) was computed to measure unexplained cluster heterogeneity [25].

210 **Patient and public involvement**

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

## 213 Results

214 **Maternal and socio-demographic characteristics of the sample population**

215 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 standard deviation (SD) years old. By age cohort, three-fourth (75.2%) of these mothers was 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 rate of male children to females was 1:1.05. The percentage of mothers who had media access was 35.6%. About 51% of

223 mothers had delivered at health facilities and concerning antenatal care during pregnancy, and 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 was 53.4%. The percentage of fully vaccinated of 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 of currently introduced childhood vaccination also highly varied by place of residence. Among children born in urban areas 75% fully vaccinated RV, 68% fully vaccinated PCV, whereas only 46% and 38% of children from rural counterparts had fully vaccinated RV and PCV, respectively. Regarding the mothers age at birth, the proportion of full vaccination of 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 fully vaccinated RV and PCV, respectively. In contrast only 35% and 27% of children born at home fully vaccinated RV and PCV, respectively. The proportion of children fully vaccinated RV and PCV increases with the number of mothers' antenatal care contacts during pregnancy.

Table 2 also shows, among children from mothers with access to media, 69% and 62% were fully vaccinated RV and PCV, respectively. By mothers' level of education, the proportion fully vaccination of currently introduced childhood vaccines was increased as mother education level increases. For instance, 82% and 73% of children from a mother who had completed higher education were fully vaccinated RV and PCV, respectively, whereas only 45% and 37% of children from a mother with no education were fully vaccinated RV and PCV, respectively. Lastly, regarding household wealth quintile, 65% and 53% of children among the richest household had fully vaccinated RV and PCV, while from poorest wealth quintile, only 31% and 24%, full vaccinated 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 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 fully vaccination, with a region variance of 25%. The ICC value was 8.6% (95% CI: 3.5%-19.6%) 8.6% of the total variability of fully vaccination status was attributed to differences between clusters (regions), while the rest were unexplained. Moreover, the MOR was estimated at 1.32 (95% CI: 1.19-1.52), revealing that if a child moved to another community with a higher probability of full vaccination , the median increase in its odds of fully vaccinated would be 1.32, with an ICC of 8.6%. Furthermore, model comparison based on deviance (-2LLR) 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 childhood fully PCV and RV vaccination were maternal age, place of residence, household wealth quintile, antenatal care (ANC) contacts, postnatal care (PNC), place of delivery, and exposure to media. Similar factors have been found statistically significantly associated with all the three scenarios (PCV; RV; both PCV and RV together); with similar strength of measure of association across scenarios (Supplemental Table 1). We found that children belonging to mothers who were 20-34 (AOR = 2.03; 95% CI (1.37 - 3.02)) and above 34 years old (AOR= 2.44; 95% CI (1.52 - 3.91)) were 2 times more likely to be fully vaccinated both PCV and RV when compared with those who were born to younger mothers.

On the other hand, the lower odds of fully vaccination of newly introduced childhood vaccine were observed in the rural areas. Compared to the urban counterpart, children from the rural area were 26% (AOR= 0.74, 95% CI 0.55 – 0.99) less likely to fully vaccinated PCV and RV. The study also found that the odds of fully vaccination of newly introduced childhood vaccination 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 – 3.36)), times more likely to be fully vaccinated for both PCV and RV compared to the poorest household.

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

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

## Discussion

The Sustainable Development Goal envisions ensuring healthy lives and promoting well-being for all at all ages [26]. Immunization is among the most cost-effective ways to support a healthier and safer world [27]. Therefore the Ethiopian Health sector transformation plan planned to achieve coverage of 75% full immunization for the prevention led health policy in the country [28]. Our analysis focused on the newly introduced vaccines, pneumococcal conjugate vaccine (PCV) administered for the prevention of pneumonia infection; and Rotavirus vaccine (RV) used for the prevention of childhood diarrhea in the list of country's vaccination service; with the aim of identifying individual and community-level factors associated with the uptake of newly introduced childhood vaccination among children 12–23 months of age in Ethiopia using the 2019 Mini Ethiopia Demographic and Health Survey.

Our analysis revealed that nearly four in nine (45.7%), five in ten (53.4%) and four in ten (43.5%) of the children completed vaccination for 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 2 doses for RV, where there could be an increased chance of drop out 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 the pneumococcal and Rotavirus infections which are the common killer disease among children[30,31]. This impacts the county's as well as the global strive to reduce child mortality. The finding was slightly lower than study by Wondimu A et al., 56% RV and 49.1% PCV [32] and is slightly higher than the full immunization coverage 38.3% [33] of the re-analysis of the EDHS 2016. The observed coverage of the two vaccines in Ethiopia is far below the Ethiopian National Expanded Program on Immunization (EPI) and the Global Vaccine Action Plan (GVAP) set coverage goals of 90% at the national level and 80% at the district level by 2020 [34]. It is as well, 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 Health Sector Transformation Plan (HSTP) [28]. To maximize the benefits of vaccination programs, it is also critical to work toward 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 immunization coverage in children. Our investigation, revealed age, place of residence, household wealth quintile, antenatal care (ANC) contacts, postnatal care (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 health care 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 teen, could get a better education or better health-seeking behavior 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 of 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 is limited in rural setup. A similar finding was reported by Sisay Koku et al. where children of rural resident mothers had lower odds of having competed for vaccination in Ethiopia [33].

The study also found that the odds of fully vaccination of newly introduced childhood vaccination strictly increased with the household wealth quintile. Compared to 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

343 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 immunization service for the children. This finding is consistent with findings from earlier investigations[30,32,35].

348 Antenatal care during pregnancy was found to be the most important predictor of full vaccination of newly introduced childhood vaccinations. The odds of children of mothers who had at least four ANC contact from a skilled provider were about three times more fully vaccinated of PCV and RV compared to 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 having 1–3 ANC visits and four and above ANC visits were significantly associated with complete childhood vaccination [36]. Residing in communities possessing higher maternal antenatal care services utilization was positively associated with childhood full immunization [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. Antenatal care attendance was significantly associated with having good knowledge of the routine immunization program. Moreover, the chances of not being fully immunized 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 immunize their children as four or more ANC visits are associated with complete vaccination status [41,42].

364 Whereas, children of mothers who attended postnatal care were 85% and 82% more likely to be fully vaccinated of PCV and RV, respectively, compared to those children of mothers who did not attend postnatal care. Evidence showed that having a PNC visit was found to be strongly linked

with complete childhood immunization [36]. This is also supported by the finding of another study conducted in Malawi [43], which showed when compared to children who had a PNC check within two months, those who did not had a PNC check had a higher chance of being under-vaccinated. Our research discovered that maternal delivery in a health facility was also linked to full vaccination of recently introduced child vaccines. When compared to children born at home, those born in health facilities were 49 percent 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 to health facilities and who resided in socioeconomically challenged communities and states were more likely to be vaccinated insufficiently [40]. These findings suggest that maternal health-care utilization and mothers' knowledge of the age at which their children begin and finish vaccination are the most important determinants in achieving complete immunization coverage. To enhance community knowledge of the need of immunization, 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 to 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 utilized national representative data, reflecting diverse socio-economic, 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 the demand side of the determinants in our study. Future studies need to consider vaccine supplies factors which is undeniably could have a considerable impact on immunization coverage. Due to the crosssectional nature of the data, a cause-effect relationship could not be established. There could be recall bias could be introduced. Yet , the survey included a health facility recorded data on children's vaccinations to confirm mother's report 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, antenatal care (ANC) contacts, postnatal care (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 emphasizes the need to strengthen our maternal and child healthcare services. In addition, interventions aimed at increasing immunization uptake need to target mothers in the younger age categories and those with lower socio-economic status along the wealth quintile. Findings suggest also 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.

## Ethics and dissemination

The study used data from the 2019 EMDHS obtained from Measure DHS data archive (https://www.dhsprogram.com/) with the appropriate request and permission. The DHS program collects data in compliance with all necessary ethical procedures, guidelines, and regulations. Moreover, informed consent was obtained from participants at the start of each interview. Ethical approval was not required for this study as it utilized publicly available data. However, permission to use the data was granted by the Demographic Health Survey program.

## Availability of data and materials

The data used in this study can be accessed from the DHS website: http://www.DHSprogram.com.

## Competing interests

The authors declare that they have no conflict of interest.

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## Author Contributions

GTG and SH conceived the study, BTW, TGD, SH, TDB and FH carried out the statistical analysis, GTG, TGD, TDB, SH and BTW conducted the literature review. SH, GTG, BTW and TGD wrote draft manuscript while SH, FH and TDB reviewed and commented the draft manuscript. All authors read and approved the final version of the manuscript. SH acted as guarantor.

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578 Table 1: National immunization 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 |

579 BCG: Bacillus Calmette-Guerin; OPV-Oral Polio Vaccine; DPT-HepB-Hib: Diphtheria,
580 Pertussis, Tetanus, Hepatitis B, Haemophilus Influenza Type B; PCV: Pneumococcal Conjugate
581 Vaccine; Rota: Rotavirus Vaccine.
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584
585

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

| Variables | | Number of children | Fully vaccinated PCV | Fully vaccinated RV | Fully vaccinated PCV and RV |
|---|---|---|---|---|---|
| | | n(%) | n (%) | n (%) | |
| Woman age at birth | <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 (60.5)0 | 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) |

| | | | | | |
|---|---|---|---|---|---|
| Child birth 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) |
| 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) |

588 PCV Pneumococcal conjugates vaccine, RV Rotavirus vaccine, EMDHS Ethiopian Mini
589 Demographic and Health Survey, SNNPR south Nations Nationalities and Peoples region
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593 **Figure lengend**
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595 Figure 1: Proportions of children who received newly introduced childhood vaccination in
596 Ethiopia, EMDHS 2019 (n=2833)

Figure

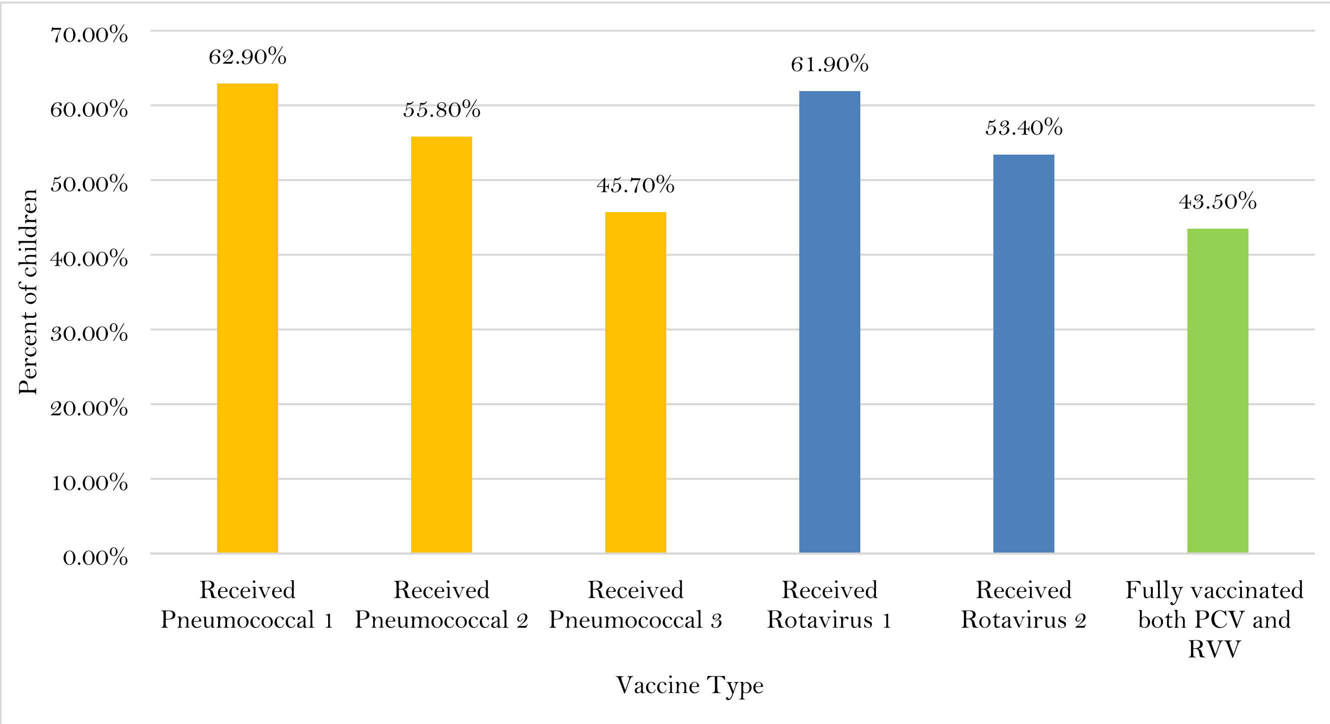


Figure 1: Proportions of children who received newly introduced childhood vaccination in Ethiopia, EMDHS 2019 (n=2833).

Supplemental Table 1: Factors associated with uptake of the PCV and RV in children aged 12–23 months in Ethiopia, bivariate and multivariate multilevel logistic regression analysis (n = 2833).

| | PCV | | RV | | Fully vaccination of both PCV and RV | |
|---|---|---|---|---|---|---|
| Variables | COR (95% C. I) | AOR (95% C. I) | COR (95% C. I) | AOR (95% C. I) | COR (95% C. I) | AOR (95% C. I) |
| Mother age | | | | | | |
| < 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 20-34 | 2.39 (1.70, 3.35) | 1.73 (1.19, 2.50) | 1.83 (1.34, 2.50) | 2.16 (1.46, 3.19) | 2.28 (1.62, 3.22) | 2.03 (1.37, 3.02) |
| 35-49 | 2.14 (1.47, 3.12) | 1.96 (1.26, 3.10) | 1.79 (1.28, 2.55) | 2.38 (1.48, 3.80) | 2.24 (1.53, 3.28) | 2.44 (1.52, 3.91) |
| Residence | | | | | | |
| Urban | 1 | 1 | 1 | 1 | 1 | 1 |
| Rural | .349 (.28, .43) | .64 (.48, .87) | .34 (.27, .43) | .69 (.51, .93) | .35 (.28, .43) | .74 (.55, .99) |
| Mother education | | | | | | |
| No education | 1 | 1 | 1 | 1 | 1 | 1 |
| Primary | 1.35 (1.13, 1.62) | .95 (.76, 1.18) | 1.34 (1.12, 1.61) | .96 (.77, 1.19) | 1.35 (1.12, 1.62) | .99 (.80, 1.24) |
| Secondary | 1.86 (1.39, 2.49) | .86 (.60, 1.22) | 1.83 (1.36, 2.46) | .89 (.63, 1.26) | 1.79 (1.35, 2.40) | .89 (.64, 1.26) |
| Higher | 2.63 (1.78, 3.87) | 1.25 (.77, 2.03) | 3.25 (2.11, 5.01) | .99 (.64, 1.54) | 2.83 (1.92, 4.17) | 1.15 (.74, 1.78) |
| Wealth quintile | | | | | | |
| Poorest | 1 | 1 | 1 | 1 | 1 | 1 |
| Poorer | 1.66 (1.28, 2.15) | 1.61 (1.23, 2.09) | 1.98 (1.54, 2.54) | 1.36 (1.03, 1.78) | 1.73 (1.33, 2.25) | 1.44 (1.09, 1.91) |
| Middle | 1.86 (1.42, 2.44) | 1.49 (1.12, 1.99) | 1.99 (1.53, 2.61) | 1.42 (1.05, 1.90) | 1.93 (1.47, 2.55) | 1.53 (1.13, 2.06) |
| Richer | 2.72 (2.05, 3.59) | 1.82 (1.21, 2.73) | 3.68 (2.77, 4.89) | 1.66 (1.20, 2.28) | 2.72 (2.05, 3.62) | 1.72 (1.25, 2.37) |
| Richest | 5.23 (3.98, 6.87) | 2.19 (1.59, 3.02 | 5.29 (4.03, 6.97) | 2.02 (1.34, 3.02) | 5.58 (4.23, 7.36) | 2.24 (1.49, 3.36) |
| Child sex | | | | | | |
| Male | 1 | 1 | 1 | 1 | 1 | 1 |
| Female | .88 (.75, 1.03) | .94 (.78, 1.10) | .93 (.79, 1.09) | .87 (.73, 1.03) | .89 (.75, 1.04) | .88 (.74, 1.04) |
| Religion | | | | | | |
| Orthodox | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Muslim | .81 (.63, 1.04) | .85 (.63, 1.14) | .74 (.57, .97) | .92 (.69, 1.22) | .77 (.59, .99) | .88 (.66, 1.16) |
| Protestant | .78 (.58, 1.05) | .90 (0.65, 1.25) | .78 (.58, 1.05) | .91 (.66, 1.25) | .79 (.59, 1.07) | .89 (.65, 1.22) |
| Others | .61 (.33, 1.12) | .70 (.36, 1.38) | .39 (.21, .75) | 1.12 (.58, 2.19) | .52 (.27, .99) | .85 (.42, 1.69) |
| Birth order | | | | | | |
| First birth | 1 | 1 | 1 | 1 | 1 | 1 |
| 2-3 | 1.04 (.83, 1.29) | .87 (.67, 1.13) | .92 (.74, 1.14) | .948 (.73, 1.22) | 1.04 (.84, 1.30) | .96 (.75, 1.25) |
| 4-5 | .91 (.72, 1.16) | .94 (.69, 1.28) | .86 (.67, 1.09) | .95 (.69, 1.28) | .93 (.73, 1.18) | .99 (.73, 1.34) |
| 6+ | .73 (.57, .94) | .88 (.62, 1.23) | .76 (.59, .97) | .81 (.58, 1.14) | .78 (.6[illegible], 1.01) | .88 (.63, 1.24) |
| ANC | | | | | | |
| No ANC | 1 | 1 | 1 | 1 | 1 | 1 |
| 1- 3 | 3.03 (2.37, 3.87) | 2.04 (1.59, 2.61) | 2.91 (2.32, 3.65) | 2.13 (1.63, 2.77) | 2.86 (2.23, 3.67) | 2.09 (1.60, 2.74) |
| 4+ | 5.14 (4.03, 6.55) | 2.86 (2.19, 3.73) | 5.23 (4.14, 6.57) | 2.80 (2.12, 3.71) | 4.74 (3.70, 6.07) | 2.73 (2.06, 3.62) |
| Place of delivery | | | | | | |
| Home | 1 | 1 | 1 | 1 | 1 | 1 |
| Health facility | 2.86 (2.41, 3.41) | 1.49 (1.21, 1.85) | 2.96 (2.49, 3.51) | 1.49 (1.20, 1.85) | 2.78 (2.33, 3.31) | 1.45 (1.17, 1.79) |
| Number of under five children | | | | | | |
| 3 or less | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 or more | .80 (.42, 1.54) | .92 (.48, 1.76) | .81 (.44, 1.48) | .91 (.46, 1.81) | .93 (.48, 1.78) | 1.06 (.53, 2.13) |
| Marital status | | | | | | |
| Single | 1 | 1 | 1 | 1 | 1 | 1 |
| Married/living with partner | 2.25 (.90, 5.58) | 1.01 (.38, 2.63) | 1.67 (.71, 3.97) | 1.35 (.49, 3.71) | 2.05 (.83, 5.11) | 1.34(.48, 3.73) |
| Others | 1.48 (.56, 3.89) | .77 (.28, 2.14) | 1.17 (.46, 2.97) | .99 (.34, 2.91) | 1.36 (.52, 3.61) | .89 (.30, 2.59) |
| Postnatal care | | | | | | |
| No | 1 | 1 | 1 | 1 | 1 | 1 |
| Yes | 2.20 (1.73, 2.81) | 1.85 (1.41, 2.43) | 2.29 (1.77, 2.95) | 1.82 (1.41, 2.35) | 2.20 (1.73, 2.80) | 1.84 (1.42, 2.37) |
| Media exposure | | | | | | |
| Not exposed | 1 | 1 | 1 | 1 | 1 | 1 |
| Exposed | 2.21 (1.84, 2.65) | 1.25 (1.07,1.57) | 2.25 (1.87, 2.72) | 1.21 (1.05, 1.52) | 2.26 (1.87, 2.71) | 1.24 (1.09, 1.56) |
| Random-effects parameters | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Region | | | | | | |
| var(_cons) | | .25 (.09, .67) | | .28 (.11, .74) | | .31 (.12, .80) |
| LRT | $\chi^2$ = 59.27, p-value = 0.0001 | | $\chi^2$ = 59.55 , p-value = 0.0001 | | $\chi^2$ = 68.75, p-value = 0.0001 | |
| ICC | 0.07 (0.027, 0.170) | | 0.08 (0.031, 0.183) | | | 0.086 (0.035, 0.196) |
| MOR | 1.61 (1.33, 2.18) | | 1.65 (1.36, 2.26) | | | 1.32 (1.19, 1.52) |
| Deviance (-2LLR) | 3522.69 | 3157.30 | 3570.56 | 3183.67 | 3472.88 | 3120.52 |

PCV Pneumococcal conjugates vaccine, RV Rotavirus vaccine, EMDHS Ethiopian Mini Demographic and Health Survey, SNNPR south Nations Nationalities and Peoples region