Incomplete Vaccination and Its Predictors among Children in Ethiopia: A Systematic Review and Meta-Analysis

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Abstract

Background. Vaccination is an effective public health intervention that has contributed to a substantial reduction in the burden of vaccine-preventable diseases. Abridged evidence on incomplete vaccination is not well established in Ethiopia. Therefore, this meta-analysis aimed to estimate the pooled prevalence of incomplete vaccination and its predictors among children aged 12 to 23 months. Methods. Primary studies conducted in Ethiopia were searched. The methodological quality of the included studies was assessed using the Joanna Briggs Institute (JBI) checklist. The analysis was conducted using STATA 14 and RevMan. The presence of statistical heterogeneity was checked using the Cochran Q test, and its level was quantified using I2 statistics. Pooled prevalence and odds ratio (OR) were computed at a 95% confidence interval (CI). Results. The pooled prevalence of incomplete vaccination was 30% (95% CI: 25-35). Maternal illiteracy (OR = 1.96; 95% CI: 1.40, 2.74) and home delivery (OR = 2.78; 95% CI: 2.28, 3.38) were associated factors that increased incomplete vaccination. However, maternal autonomy (OR = 0.54; 95% CI: 0.33, 0.89), maternal knowledge (OR = 0.31; 95% CI: 0.20, 0.47), husband employment (OR = 0.49; 95% CI: 0.35, 0.67), urban residence (OR = 0.61; 95% CI: 0.43, 0.86), ANC visits (OR = 0.30; 95% CI: 0.23, 0.39), postnatal care (OR = 0.39; 95% CI: 0.30, 0.52), and tetanus toxoid vaccine (3+) (OR = 0.42; 95% CI: 0.26, 0.69) were factors that reduced incomplete vaccination. Conclusion. In Ethiopia, 3 out of 10 children have incomplete vaccination. Policies should focus on strengthening and improving women’s education, maternal health knowledge, empowering women, and the utilization of prenatal care can overcome some of the barriers.

Keywords
vaccination, immunization, systematic review, meta-analysis, children, Ethiopia

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Background

Vaccination is an effective public health intervention that has contributed to the substantial reduction in the burden of vaccine-preventable diseases (VPDs) worldwide.1,2,3 Approximately 23 million deaths are averted with the measles vaccine between 2010 and 2018.4 More than half of early childhood deaths are caused by diseases that could be easily prevented or treated with easily affordable interventions, such as administering vaccines.5 The Expanded Program of Immunization (EPI) was launched by the World Health Organization (WHO) in 1974, and Ethiopia has launched in 1980 to vaccinate all children.6,7

The global immunization target is to reach 90% national coverage for all vaccines by 2020.5 The Sustainable Development Goals (SDGs) aimed to ensure maintaining the hard-won gains on vaccination to achieve more, leaving no one behind in all the countries by 2030.2 Vaccination attributes a 24% reduction in...
mortality rates in under 5 children between 2010 and 2017.² Despite the significant reductions in the incidence of VPDs, a considerable number of children have incomplete vaccination, which causes marked variation in vaccination coverage worldwide.³,⁴ For instance, more than 17 million cases and 83,439 deaths attributable to measles occurred worldwide in 2017.⁵,⁶ The impact of vaccines extends beyond public health, which affects children’s educational achievements and national economic growth.⁷ Moreover, children suffer from vaccine-preventable disabilities, impaired growth, and cognitive development. An estimated 24 million people will fall under poverty by 2030, linked with VPDs.²,⁸

Globally, 86% of infants (116.3 million) received the recommended 3 doses of diphtheria-tetanus-pertussis (DTP) vaccine in 2018.⁹,¹⁰ The WHO and United Nations Children’s Fund (UNICEF) reported that more than 20 million children have not received a full course of basic vaccines worldwide.²,⁴,⁵ Of these, more than 60% of unvaccinated and undervaccinated children live in 10 low- and middle-income countries (LMICs), including Ethiopia, which may disproportionately affect by infectious disease, which has been exacerbated due to the fragile nature of the health care system or conflict in regions.⁵,¹⁴ Similarly, approximately 10 million children remain unvaccinated or partially vaccinated in Africa.¹⁵,¹⁶

As a result of implementing vaccination programs through EPI, a vaccination campaign, and community health expansion programs, under-five mortality reduced to 55 deaths per 1000 live births in Ethiopia in 2019.¹⁷ Ethiopia scheduled, single-dose for BCG, 3 doses of diphtheria, tetanus, pertussis, hepatitis B, Haemophilus influenza type B, 2 doses of Rota, 3 doses of the pneumococcal conjugate, 3 doses of polio and one measles vaccine have been given at birth, 6, 10, 14 weeks, and 9 months for measles vaccine for infants.¹⁸ Nevertheless, vaccination coverage remains suboptimal, and sporadic outbreaks of VPDs, such as measles, occur in the country.¹⁴ Only 39% of children had fully vaccinated for the recommended vaccine in 2016.¹⁸,²⁰ Likewise, incomplete vaccination of children ranged from 2.9% to 52.9% in Ethiopia.²¹,²²

Existing literature has shown that maternal education, occupation, and residence, fear of side effects, household wealth, place of delivery, and maternal knowledge were the factors associated with incomplete vaccination in children.⁹,²⁰,²²-²⁵ Moreover, it may be related to healthcare services, including access or distance factors, missed opportunities, inadequate supply, and access to prenatal care.²⁶,²⁷ Vaccine hesitancy is defined as a lack of confidence in the safety and effectiveness of vaccines.²⁸ Other contextual factors, such as sociocultural beliefs influencing the behavior of stakeholders, also affect the completion of vaccination.³,²⁵,³⁰,³¹ However, inconsistency exists between studies concerning the abovementioned factors, and hence, pooled measures of the factors are required to feature the broad picture.

Determining which group of children are less likely to be vaccinated in terms of geographical, cultural, social, and strengthening in-country evidence-based decision-making is important to inform the development of appropriate intervention programs.³ Abridged evidence on incomplete vaccination and its associated factors are not well established in Ethiopia. Therefore, this systematic review and meta-analysis aimed to estimate the pooled prevalence of incomplete vaccination and its associated factors among children in Ethiopia.

Materials and Methods

Protocol Design

This systematic review and meta-analysis methodology was developed according to the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) 2015 recommendations.³² The necessary items of the PRISMA checklist have been addressed, and the details are found in the additional file (see Additional file 1). Likewise, the protocol of this systematic review and meta-analysis was registered by the International Prospective Register of Systematic Reviews and Meta-Analysis (PROSPERO) and identified with the registration number (CRD42020148729).

Studies Search and Identification

All published and unpublished studies were systematically searched through main electronic databases, including PubMed, African Journal Online, WHO databases (HINARI), and Google Scholar Searches. The search strings emerged from the following keywords (vaccination, immunization, an expanded program of immunization and associated factors, predictors, risk factors, determinants, children, Ethiopia). The search string was prepared according to the requirements of the specified database to identify relevant studies (see Additional file 2).

Eligibility Criteria for the Studies

Studies were included in the systematic review using the following eligibility criteria: studies written in the English language conducted in Ethiopia from 1974 to 2020, published and unpublished available studies, conducted either community or facility settings,
observational studies, and survey findings on incompletely vaccinated children aged 12 to 23 months. Nevertheless, fact sheet reports, commentaries, editorial reports, and case reports were not included. Articles not accessed after a minimum of 2 email contacts (every 2 weeks) of the primary authors were excluded.

**Selection of the Studies**

All observational studies, such as cross-sectional, cohort, and case-control studies, were included. AD and GT identified the relevant studies using the search string and applied the filters in the selected main databases. The identified studies were exported into the citation manager (EndNote) to remove duplicates. The 2 authors (AD and AS) independently screened studies based on titles and abstracts. The studies were put into 3 categories, included, excluded, and undecided categories. The 2 authors (AD and AS) again independently assessed the full texts of the included and undecided categories of the studies against the eligibility criteria to decide on their inclusion in the systematic review and meta-analysis. The studies were judged based on the eligibility criteria set forth above. Studies that did not fulfill the eligibility criteria were excluded. In case of any disagreement among reviewers, the third author (SB) consulted for understanding. The selection process was guided by the PRISMA flow diagram (Figure 1).

**Outcome Variable**

Incomplete vaccination was the primary outcome measure in this study. According to WHO, a child is considered incompletely vaccinated if he/she receives at least one of the following, but not all, (a) 1 dose of Bacille

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**Figure 1.** PRISMA flow diagram depicting the selection process of studies for systematic review and meta-analysis.
Calmette-Guerin (BCG); (b) 3 doses of oral polio vaccine DPT, hepatitis B vaccines, Hib and (c) 1 dose of measles vaccine, all before attaining 1 year.\textsuperscript{2–4} However, we found that studies including other vaccines, such as rotavirus and pneumococcal conjugate, have carefully checked the agreement with the abovementioned case definition and were included in the analysis.

**Quality Appraisal**

Studies were critically evaluated for their methodological rigor and validity of the findings. We used the Joanna Briggs Institute (JBI) critical appraisal checklist for the methodological rigor of observational studies. Studies with a positive response score of 5 or more were included. Particular attention was given to a clear statement of the objective of the study, identification of the study subjects, and precise measurement of outcomes of interest and exposure variables as well as documentation of sources of bias or confounding. The 2 authors (AD and AS) independently checked the scientific quality of the studies using the quality assessment tools mentioned above. In the case of uncertainties, we resolved by a joint discussion and consulting the third (SB) and fourth authors (GT) (see Additional file 3).

**Data Abstraction**

Raw data (frequency) were extracted using a structured data extraction form, which was designed using Microsoft Excel. The 2 authors (AD and SB) abstracted the data systematically. In addition, studies’ characteristics that mainly focused on the author, year, study area, design, objective, sampling, and key findings were summarized in the Microsoft Word Table (Table 1). The first author (AD) contacted the authors of the article and requested details through email in case of missing data, incomplete reports, or any uncertainties.

**Data Synthesis and Statistical Analyses**

The data were first presented using a narrative synthesis of the included studies. A summary table was prepared to describe the characteristics of the included studies. For those studies that were suitable for quantitative synthesis, a meta-analysis was carried out. The pooled estimate of the outcome variable was conducted using Stata 14 window Version and RevMan v5.3 software for meta-analysis. Subgroup analysis was conducted by the Regional States in the Federal Democratic Republic of Ethiopia. The 2 authors (AS and GT) conducted the meta-analysis. Pooled prevalence and odds ratio (OR) were computed at a 95% confidence interval (CI). The presence of statistical heterogeneity was checked using the Cochran Q test at a $P$-value of .05, and its level was quantified using the $I^2$ statistics, where substantial heterogeneity was assumed if the $I^2$ value was $>60\%$. The random-effects model was used to analyze the data, as there was considerable heterogeneity between the included studies. Eggers and Begg’s test was computed to examine the existence of publication bias among the included studies.

**Ethical Approval and Informed Consent**

This is a systematic review and meta-analysis of the original articles conducted in different parts of the country. Ethical approval and informed consent did not apply to this study since the data were generated from computed pooled analysis. In Ethiopia, most of the research institutions have institutional review boards and therefore the respective studies had prior approval before the actual data collection period.

**Results**

**Search Results**

As shown in Figure 1, the online database search identified 531 studies, of which 145 studies were duplicates. The remaining studies were screened for titles and abstracts, which excluded 288 studies from further screening. The full texts of 98 studies were evaluated to ensure the presence of at least one of the primary outcomes, and 46 studies were excluded. The remaining 52 studies underwent a critical appraisal, and 14 studies were excluded from the synthesis due to the relatively poor methodological quality, data inconsistency, and unavailability or incompleteness of the data. The remaining 38 studies\textsuperscript{17,21,22,24,26,27,33–64} were included in this systematic review and meta-analysis.
Table 1. Describe the Characteristics of Included Studies for Outcome Variables in the Systematic Review and Meta-Analysis.

| Author          | Study setting                | Objective                                                                 | Target population | Study design | Sample size | Outcome N(%) | Associated factors                                                                                                                                 |
|-----------------|------------------------------|---------------------------------------------------------------------------|-------------------|--------------|--------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Ali et al34     | South Wollo, Amhara          | To identify those factors associated with incomplete vaccination          | 12–23 months     | Cross-sectional | 480          | 37 (7.7%)   | Home delivery, no history of TT vaccination, living near the health post, being young maternal, parents with no education and ANC follow-ups         |
| Animaw et al35  | Arba Minch, SNNPR            | To measured immunization coverage and identified the predictors            | 12–23 months     | Cross-sectional | 630          | 128 (20.3%) | Mother education, ‘perception of, mothers’ knowledge, and place of delivery                                                                      |
| Aregawi et al36 | Laday Adiabo, Tigray         | To identify the determinants of defaulting from child immunization completion | 9–23 months      | Case-control  | 270          | –            | >30 minutes to reach the vaccination site, poor participation in women’s developmental groups; no postnatal care, and poor knowledge               |
| Asfaw et al37   | Sodo Zurea, SNNPR            | To identify determinants of default to full completion of immunization    | 12–23 months     | Case-control  | 344          | –            | Maternal education, no postnatal care follow up, maternal knowledge, and maternal favorable attitude                                                |
| CSA38           | Nationwide                   | Data on vaccination coverage                                              | 12–23 months     | Survey       | 2004         | 902 (45%)  | –                                                                                                                                               |
| CSA41           | Nationwide                   | Data on vaccination coverage                                              | 12–23 months     | Survey       | 1028         | 388 (37.7%) | –                                                                                                                                               |
| Debie and Lakew27 | Emerging regions of Ethiopia | To identify the factors associated with the access and continuum of childhood vaccination | 12–23 months     | Survey       | 642          | 214 (33.4%) | Mothers’ formal education, ANC, health facility-based delivery, and rich wealth                                                                |
| Deressa et al42 | Sidama, SNNPR                | To assess the vaccination status and its associated factors               | 9–24 months      | Cross-sectional | 107          | 3 (2.9%)    | Mothers age and birth at home                                                                                                                    |
| Etana and Deressa40 | Ambo, Oromia               | To assess women’s household autonomy and immunization                      | 12–30 months     | Survey       | 2941         | 1588 (61%) | Women’s socioeconomic status and household autonomy                                                                                             |
| G/Mariam et al41 | Bench Maji, SNNPR         | To assess complete immunization coverage and its associated factors       | 12–23 months     | Cross-sectional | 536          | 218 (40.7%) | Antenatal care follow-up, born in the health facility, mothers’ knowledge                                                                       |
| Gualu and Dille43 | Sekota Zuria, Amhara       | Aimed at bringing data about immunization service coverage and its associated factors | 12–23 months     | Cross-sectional | 620          | 96 (15.5%)  | No ANC, home delivery, having no postnatal care visit, the inconvenient appointment time                                                          |
| Gualu and Dille43 | Debre Markos, Amhara       | To determine vaccination coverage and associated factors                   | 12–23 months     | Cross-sectional | 288          | 19 (6.6%)   | Having ANC visit, higher maternal education, mothers’ good knowledge, short distance to the health facility, and born in health facility, 5 and more family size |

(continued)
| Author                | Study setting          | Objective                                                                 | Target population | Study design | Sample size | Outcome N(%) | Associated factors                                                                 |
|----------------------|------------------------|---------------------------------------------------------------------------|-------------------|--------------|-------------|--------------|-----------------------------------------------------------------------------------|
| Hailu et al.         | Wonago SNNPR           | To evaluate immunization coverage and identify factors of incomplete vaccination | 6–36 months       | Cross-sectional | 1119        | 333 (29.8%) | Older mothers’ age, ANC, tetanus toxoid vaccination, mothers knowing the age and being a female |
| Kassahun et al.      | Lay-Armachiho Amhara   | To assess immunization coverage and associated factors                    | 12–23 months      | Cross-sectional | 751         | 163 (21.66%) | Mothers knowledge, tetanus toxoid immunization and Urban residence                 |
| Kidane and Tekie     | Tselemti, Tigray       | To identify factors influencing urban and rural immunization               | 12–13 months      | Cross-sectional | 220         | 53 (23.9%)   | Residence and mother’s education                                                   |
| Kidanne et al.       | Nationwide             | To identify factors associated with the timeliness of vaccine doses        | 12–23 months      | Cross-sectional | 600         | 256 (42.7%)  | Children from pastoral areas mothers/ caregivers aged 30 or above                  |
| Kindie Yenit         | East Gojjam, Amhara    | To identify factors associated with incomplete childhood vaccinations       | 12–23 months      | Case-control   | 308         | –            | Delivered at home, no ANC visit, misperception on vaccine contraindication, and no Postnatal care visit |
| Kinfe et al.         | Nationwide             | To assess individual and community level factors associated with full immunization | 12–23 months      | Survey         | 1929        | –            | Mother’s education, husband employment, mother’s religion, ANC visit, presence of vaccination document, region |
| Lakew et al.         | Nationwide             | Identify factors associated with full immunization coverage               | 12–23 months      | Survey         | 1927        | –            | Information from vaccination card, received postnatal check-up, women’s awareness, and rich wealth index |
| Legesse and Dechasa  | Bale Zone, Oromia      | To assess complete immunization coverage and its associated factors       | 12–23 months      | Cross-sectional | 591         | 128 (21.7%)  | ANC follow up, being a farmer, the level having a household family income, walking time from home to health facilities, health extension workers, mothers’ knowledge |
| Mekonnen et al.      | Minjar-shenkora, Amhara| To assess the immunization coverage and its factors                       | 12–23 months      | Cross-sectional | 566         | 105 (18.5%) | Being unmarried, traveling time greater than 2 hours on foot                      |
| Meleko et al.        | Mizan Aman, SNNPR      | To assess immunization and factors associated                             | 12–23 months      | Cross-sectional | 322         | 159 (49.4%)  | Educational level, place of delivery, maternal health care utilization, knowledge about vaccine delivered at home, illiterate mother, poor satisfaction of services, side effects, no ANC |
| Negero et al.        | Oromia                 | To assess immunization and associated factors                             | 12–23 months      | Cross-sectional | 436         | 113 (26.2%)  | Primary caregivers knowledge, ANC attendance and place of delivery                |
| Mesfin               | Yirgalem, SNNPR        | To assess incomplete vaccination and associated factors                    | 12–23 months      | Cross-sectional | 473         | 96 (20.0%)   |                                                                                 |
| Author                  | Study setting               | Objective                                                                 | Target population | Study design | Sample size | Outcome N(%) | Associated factors                                                                                                                                 |
|-------------------------|-----------------------------|---------------------------------------------------------------------------|-------------------|--------------|-------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Mohammed and Atomsa      | Eastern, Oromia             | To assess the immunization coverage and its determinants                   | 12–23 months      | Cross-sectional | 694         | 367 (52.9%) | Unaware of the need for immunization, fear of the side reaction, time of immunization wrong perception about the time of immunization                  |
| Mohamud et al            | Jigjiga, Somali             | To measure the immunization coverage and associated factors                | 12–23 months      | Cross-sectional | 582         | 221 (38%)   | Maternal literacy, tetanus toxoid vaccine, place of delivery and place of residence                                                                      |
| Negussie et al           | Sidama, SNNPR              | To identify determinant factors of incomplete childhood immunization      | 12–23 months      | Case-control  | 548         | –            | Young mothers, a mother’s knowledge about immunization benefits, mother’s negative, perception of vaccine side effects                             |
| Okwaraji et al           | Dabat, Amhara               | To assess vaccine coverage and factors associated                          | 12–59 months      | Cross-sectional | 775         | 36 (4.6%)   | Travel time                                                                                                                                         |
| Porth et al              | Nationwide                  | To explores healthcare services utilization or receiving a vaccine        | 12–23 months      | Survey        | 2722        | 1255 (46.1%) | Residence and possession of a vaccination card                                                                                                                                 |
| Tamirat and Sisay        | Nationwide                  | To assess full immunization coverage and its determinants among children  | 12–23 months      | Cross-sectional | 1909        | 744 (39%)   | Rural residence, employed, female household head, wealth index [middle and richness primary school, maternal education, ANC follow-ups and delivery at health facilities |
| Tefera et al             | Worabe, SNNPR              | To assess factors associated with full immunization                        | 12–23 months      | Cross-sectional | 484         | 187 (39%)   | Fewer ANC visits                                                                                                                                 |
| Tesfaye et al            | East Gojam, Amhara          | To assess vaccination coverage and its predicting factors                  | 12–23 months      | Cross-sectional | 846         | 144 (17%)   | Urban residence, having ANC visit, place of delivery, and vaccination site at health institutions                                                       |
| Tseessa et al            | Pastoral zones in Ethiopia  | To assess vaccination coverage, estimate dropout rates, and identify associated factors | 12–23 months      | Cross-sectional | 600         | 121 (21.0%) | Residence, age and education, and maternal occupation                                                                                                                                 |
| Tolera                   | Addis Ababa                 | To determine full immunization coverage and the predictors that influence the complete | 12–23 months      | Cross-sectional | 585         | 140 (24%)   | Maternal occupation, postnatal care follow up, knowledge about the objective of vaccination and place of delivery                                                                                   |
| Wado et al               | SNNPR                       | To examine the influences of women’s autonomy on the vaccination           | 12–24 months      | Cross-sectional | 889         | 464 (41%)   | Women’s autonomy, mother’s education, use of ANC services, and proximity to a health facility                                                                 |
| Yismaw et al             | Gondar, Amhara              | To determine incomplete vaccination and associated factors                 | 12–23 months      | Cross-sectional | 301         | 73 (24.3%)  | Knowledge of vaccination age of the child, time to reach a health facility                                                                                                                                 |
| Workina et al            | Jimma, Oromia               | To assess reason for incomplete vaccination and associated factors         | 12–23 months      | Cross-sectional | 267         | 126 (45.5%) | Educational status, marital status, and monthly income                                                                                                                                 |

Table 1. (continued)
A random-effect model was used to analyze the data to moderate the variability between and within studies. Reporting bias was assessed using both funnel plot illustration (Figure 2). Publication bias was not noticed in the included studies, as evidenced by Egger’s test ($P = .362$) and Begg’s test continuity corrected ($P = .339$).

**Pooled Prevalence of Incomplete Vaccination**

In 31 studies with a sample size of 25,008 and 8,878 cases of incomplete vaccination, the pooled prevalence of incomplete vaccination was 30% (95% CI: 25-35) (Figure 3).

Subgroup analysis of the pooled prevalence of incomplete vaccination for 31 studies was carried out based on regions and nationwide studies in Ethiopia. Only 1 study was included in the capital city, Addis Ababa, which showed a pooled prevalence of 24%. In 6 nationwide studies, the prevalence of incomplete vaccination was 44% (95% CI: 39-49). Likewise, in 5 studies included from Oromia and 8 studies from Amhara Regional State, incomplete vaccination was 38% (95% CI: 25-50) and 14% (95% CI: 9-20), respectively (Figure 4).

**Factors Associated with Incomplete Vaccination**

In this meta-analysis, maternal education, maternal knowledge, maternal decision making, urban residence, husband employment, place of delivery, antenatal care (ANC) (at least one visit), postnatal care, and tetanus toxoid vaccine (3+) were statistically associated with incomplete vaccination. However, maternal age, marital status, maternal occupation, distance to vaccination centers, wealth status, maternal attitude, and fear of side effects were not statistically associated with incomplete vaccination. To calculate the effect sizes, the random-effects model was implemented when there was heterogeneity among the included studies with a consideration of $I^2$ of more than 60%.

**Maternal Education**

The overall adjusted odds ratio (OR = 1.96; 95% CI: 1.40, 2.74) indicated that children from illiterate women were nearly 2 times more likely to have incomplete vaccination compared with children of educated mothers. Despite the heterogeneity of the studies, the findings showed a statistically significant association. We used a random-effect model for the analysis because the $I^2$ value was 96% (Figure 5).

**Maternal Age, Occupation, and Marital Status**

This systematic review revealed that no significant association between maternal age (OR = 1.23; 95% CI: 0.88, 1.72) and marital status (OR = 0.71; 95% CI: 0.34, 1.51) with incomplete vaccination. Similarly, maternal occupation showed no statistical association with incomplete vaccination (OR = 0.93; 95% CI: 0.66, 1.31). We assumed a random effect model for the analysis because the $I^2$ statistics indicated the presence of heterogeneity (91%), (93%), and (94%) respectively.
Maternal Knowledge

The overall analysis of studies showed that maternal knowledge of vaccination is associated with incomplete vaccination. Knowledgeable women about vaccination were less likely to incompletely vaccinate their infants (OR = 0.31; 95% CI: 0.20, 0.47) compared to non-knowledgeable women. The random-effect model was assumed for the analysis because the I² value was 87% (Figure 6).

Maternal Autonomy

This analysis result revealed that women’s decision-making power had an association with incomplete vaccination, where autonomous women were less likely to have incompletely immunized children (OR = 0.54; 95% CI: 0.33, 0.89) compared to non-autonomous women. The random-effect model was used for the analysis, as the I² test result was 93% (Figure 7).

Place Residence

As per the factor analysis of the included studies, the place of residence was significantly associated with incomplete vaccination. We found that urban dwellings were less likely to be incompletely immunized (OR = 0.61; 95% CI: 0.43, 0.86) compared to rural children. The
random-effect model was used for the analysis, as the I² test result was 88% (Figure 8).

**Perinatal Care-Related Factors**

**Antenatal Care.** From this review, ANC (at least one visit) utilization has a negative association with incomplete vaccination. Women who attended ANC were less likely to have incompletely immunized children (OR = 0.30; 95% CI: 0.23, 0.39) compared to those who did not initiate ANC follow-up. We analyzed a random effect model because the I² value was 89% (Figure 9).

**Place of Delivery.** According to this systematic review and meta-analysis, women who gave birth at home were nearly 3 times more likely to have incompletely...
immunized children (OR = 2.78; 95% CI: 2.28, 3.38) than women who delivered at health facilities. We applied a random effect model for the meta-analysis because the $I^2$ value was 84% (Figure 10).

**Postnatal Care.** Postnatal care utilization showed a negative association with incomplete vaccination. Women who attended postnatal care were less likely to have incompletely immunized infants (OR = 0.39; 95% CI: 0.29, 0.52).
0.30, 0.52) compared to those who did not have utilized postnatal care. We analyzed a random effect model because the $I^2$ value was 77% (Figure 11).

**Tetanus Toxoid Vaccine.** There was a significant association between tetanus toxoid vaccination of mothers and incomplete child vaccination. Women who took the tetanus toxoid vaccine were less likely to have incompletely vaccinated children (OR = 0.42; 95% CI: 0.26, 0.69) compared with women who did not take the vaccine. As a result of significant heterogeneity, a random effect model was used because the $I^2$ value was 91% (Figure 12).

**Wealth Status.** Monthly average family wealth status was not significantly associated with childhood vaccination. It was demonstrated that monthly average family low wealth status was not associated with incomplete vaccination (OR = 1.78; 95% CI: 0.99, 3.20) compared to women whose average family wealth was medium and high. The random-effect model was assumed for the analysis because the $I^2$ value was 97%.

**Husband Employment.** The results of the review indicated that husband employment was significantly associated with childhood vaccination status. Infants
from employed fathers were less likely to be incompletely vaccinated (OR = 0.49; 95% CI: 0.35, 0.67) compared with children from an unemployed father (Figure 13).

Figure 9. The influence of antenatal care follow-up on incomplete vaccination in Ethiopia (n = 24 studies).

Figure 10. The influence of place of delivery on incomplete vaccination in Ethiopia (n = 25 studies).

Time Taken to Reach Vaccination Centers. According to this meta-analysis, the time taken to reach vaccination centers was not significantly associated with incomplete vaccination (OR = 0.70; 95% CI: 0.46, 1.08). The
random-effect model was assumed for the analysis because the $I^2$ value was 92\% (Figure 14).

**Mother's Attitude.** As evidenced in this meta-analysis, maternal attitude was not associated with incomplete vaccination (OR = 0.82; 95\% CI: 0.37, 1.83). Moreover, there was no association between fear of side effects and incomplete vaccination (OR = 1.36; 95\% CI: 0.57, 3.22).

We assumed a random effect model for the analysis because the $F$ statistics indicated the presence of heterogeneity (91\%) and (90\%), respectively.

**Child Sex.** According to this meta-analysis, there is no association between child sex (being male or female)
and incomplete vaccination (OR = 1.00; 95% CI: 0.81, 1.23). The random-effect model was assumed for the analysis because the I² value was 80% (Figure 15).

**Discussion**

In Ethiopia, an evidence-based understanding of the barriers to incomplete vaccination and addressing the root causes is critical to improving childhood immunization, which subsequently reduces child mortality. Hence, designing and implementing tailored interventions are essential to ensure that children are vaccinated fully and are safe from VPDs. Without such a systematic approach, millions of children will continue to die from VPDs. For instance, only 39% to 43.3% of children 12 to 23 months are fully vaccinated in Ethiopia with all recommended vaccine doses.\(^\text{17,38}\) The country is unable to achieve the WHO target of vaccination coverage of 90% by 2020.\(^\text{5}\) This likely translates to insufficient herd immunity against many VPDs.\(^\text{65}\) This systematic review and meta-analysis estimated the pooled prevalence of incomplete vaccination and identified its key barriers in Ethiopia.
The overall pooled magnitude of incomplete vaccination among children in Ethiopia was 30% (95% CI: 25-35). This finding is similar to the findings of studies carried out in Australia (35%),66 India (32%),67 and global routine vaccination coverage in 2017 (30%).68 However, the present finding is lower than studies in Pakistan (46%),69 Aurangabad (37.76%),70 and the 2016 and 2019 EDHS (45%),38 (37.7%)17 in Ethiopia. The variations highlight the gradient of vaccination system performance across Ethiopia, given diverse religious, sociocultural, or health service coverage and performance differences.71 Moreover, it might be related to variations in access to preventive care services and perceptions of the importance of vaccination between populations of different countries.

In this meta-analysis, maternal education, maternal knowledge, maternal autonomy, urban residence, husband employment, place of delivery, ANC follow-up, postnatal care, and tetanus toxoid vaccine (3 +) were found to be significantly associated with incomplete vaccination. The importance of maternal education and knowledge in children’s health is universally recognized.72 Accordingly, children of less-educated mothers are more likely to be incompletely vaccinated. Knowledgeable women about vaccination are less likely to incompletely vaccinate their infants. This finding is supported by studies conducted in Togo,73 India,67 Indonesia,74 Pakistan,69,75 northern Ethiopia,26 Sub-Saharan Africa,76 and a systematic review of LMICs and across the world.77–80 This could be because women with a better educational background are more likely to be knowledgeable about the benefits of full vaccine doses. It is also possible that better-educated mothers are more flexible, receptive to new ideas, and make confident decisions about their families’ health, including vaccination.

This review further revealed that women’s decision-making power has an association with incomplete vaccination, where autonomous women were less likely to have incompletely immunized children. This finding is in line with several other studies.62,39,81,82 concluded that childhood vaccine decision-making begins perinatally. Women’s participation in health care decision-making enables women to decide independently, and in particular, it helps to reduce the vaccine dropout rate.36,81

The husband’s employment status was significantly associated with childhood vaccination. Infants from employed fathers were less likely to be incompletely vaccinated. This might be because employed husbands could have better knowledge and exposure to vaccination-related information from their workplace. It may also be related to the husband’s earnings that eases transport or indirect expenses related to vaccination.64

As per this analysis, place of residence was significantly associated with incomplete vaccination. Mothers who lived in urban areas were less likely to have incomplete vaccination of their children. This finding was supported by studies performed in the emerging regions of Ethiopia.27 This might be explained by urban resident mothers who might have better information and recognize the importance of vaccination. However, this finding is contrary to studies in Sub-Saharan Africa and India, which reported that children from urban areas were more likely to be partially immunized than those from rural areas.67,76 This might be the presence of underserved children living in urban slums with limited access to vaccination services.

Furthermore, ANC follow-up, place of delivery, postnatal care, and tetanus toxoid vaccine (3 +) were associated with incomplete vaccination. Accordingly, women who attended and received at least one ANC visit, postnatal care, and tetanus toxoid vaccine are less likely to have incomplete vaccination of their children. However, women who gave birth at home were nearly 3 times more likely to have partially immunized children. Similar findings were reported in other studies in India,67 Pakistan,72 Senegal,71 Philippines,83 Tigray, northern Ethiopia,36 a systematic review across the globe77 and in LMICs.84 The positive impacts of ANC visits and postnatal care on the completion of infants’ vaccination can be explained by the fact that mothers have more opportunities to receive messages on the benefits of childhood vaccination that encourage them to fully vaccinate their children. Prenatal care visits establish communication and build trust between healthcare providers and mothers, which may affect mothers’ immunity-related service-seeking behaviors.84–86

This systematic review had some limitations. First, the majority of the included studies were cross-sectional and prone to confounding. Second, we included data obtained using maternal recall, and vaccination record cards may introduce recall biases. Thirdly, the fact that the current meta-analysis is carried-out despite the presence of heterogeneity across the included studies might have influenced the effect estimates of the study. Finally, many of the data were concentrated in Amhara, Oromia, and Southern nation, national, and people regional states. The review also has strengths. The review considered pertinent and comprehensive databases for the literature search. Subgroup analysis was also conducted to appreciate the regional variations in the overall burden of incomplete vaccination. The review also considered both published and unpublished literature.
Conclusion

In this review and meta-analysis, 3 in every 10 children had incomplete vaccination, which is a public health concern in the country. Maternal education, knowledge, decision-making power, urban residence, husband employment, ANC visits, home delivery, postnatal care, and tetanus toxoid vaccine were identified as factors associated with incomplete vaccination. Increasing women's education and improving maternal health knowledge and empowering women in decision making would provide an approach to reduce partial immunization. Regular vaccination outreach campaigns and integration of immunization with other services may improve childhood vaccination. Strengthening the interaction between healthcare workers and mothers and improving the quality of prenatal and postnatal care services reduce the rate of incomplete vaccination.

Authors' Contributions

AD* and AS initiated and formulated this meta-analysis. AD conducts activities from initiation to finalization of the manuscript. AD, GT, SB, and AS build-up the search strategies, meta-analysis, and interpretation of the findings. All authors read thoroughly and approved the manuscript.

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Availability of data and materials

All data generated or analyzed during this review are included in this manuscript and its supplementary information files.

Supplemental Material

Supplemental material for this article is available online.

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