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

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Assefa Desalew, MSc¹, Agumasie Semahegn, PhD¹, Simon Birhanu, MPH¹, and Gezahegn Tesfaye, PhD¹

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% Cl: 25-35). Maternal illiteracy (OR = 1.96; 95% Cl: 1.40, 2.74) and home delivery (OR = 2.78; 95% Cl: 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% Cl: 0.30, 0.52), and tetanus toxoid vaccine (3+) (OR = 0.42; 95% Cl: 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.¹⁻³ 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

Corresponding Author:

Assefa Desalew, MSc, College of Health and Medical Sciences, Haramaya University, 1000, harar, Harar, P. Box 235, Ethiopia. Email: assefad 100@gmail.com

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¹College of Health and Medical Sciences, Haramaya University, Harar, Ethiopia

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.^{8,9} For instance, more than 17 million cases and 83 439 deaths attributable to measles occurred worldwide in 2017.^{10,11} The impact of vaccines extends beyond public health, which affects children's educational achievements and national economic growth.¹ 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.^{2,12}

Globally, 86% of infants (116.3 million) received the recommended 3 doses of diphtheria-tetanus-pertussis (DTP) vaccine in 2018.^{13,14} 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 affected 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.^{14,19} 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 health-care 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.^{3,19,28,29} 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,

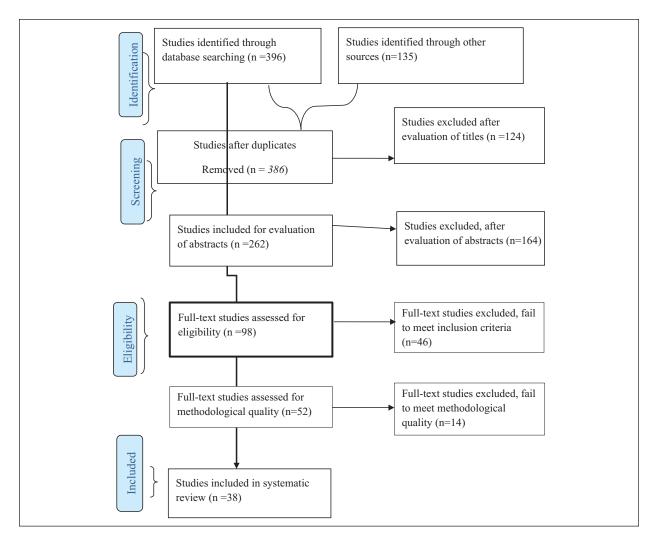


Figure I. PRISMA flow diagram depicting the selection process of studies for systematic review and meta-analysis.

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 Calmette-Guerin (BCG); (b) 3 doses of oral polio were compute vaccine DPT, hepatitis B vaccines, Hib and (c) 1 dose of measles vaccine, all before attaining 1 year.^{2–4} However, the Cochran C

measles vaccine, all before attaining 1 year.^{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 rigorousness 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 I² statistics, where substantial heterogeneity was assumed if the I² 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

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

included studies.

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^{17,21,22,24,26,27,33–64} were included in this systematic review and meta-analysis.

Characteristics of the Included Studies

From the 38 included studies in the systematic review and meta-analysis, 33 studies were community-based cross-sectional studies, some were nationwide surveys, and 5 were case-control studies. A total of 30646 children and 9581 cases with incomplete vaccination were included in the analysis. The smallest (n=107) and largest (n=2941) sample sizes were reported in studies conducted in the Southern Nations, Nationalities, and People's Region (SNNPR) and nationwide survey.^{21,39} The details of the included studies' characteristics and descriptions are presented using a table (Table 1).

Table I. Det	scribe the Charac	Table I. Describe the Characteristics of Included Studies for Outcome Variables in the Systematic Review and Meta-Analysis	e Variables in the	Systematic Re	eview and I	Meta-Analysis.	
Author	Study setting	Objective	Target population	Study design	Sample size	Outcome N(%)	Associated factors
Ali et al ³⁴	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 al ³⁵	Arba Minch, SNNPR	To measured immunization coverage and identified the predictors	l 2–23 months	Cross- sectional	630	128 (20.3%)	Mother education, 'perception of, mothers' knowledge, and place of deliverv
Aregawi et al ³⁶	Laelay Adiabo, Tigray	To identify the determinants of defaulting from child immunization completion	9–23 months	Case- control	270	I	>30 minutes to reach the vaccination site, poor participation in women's developmental groups; no postnatal care. and poor knowledge
Asfaw et al ³⁷	Sodo Zurea, SNNPR	To identify determinants of default to full completion of immunization	l 2–23 months	Case- control	344	I	Maternal education, no postnatal care follow up, maternal knowledge, and maternal favorable attitude
CSA ³⁸	Nationwide	Data on vaccination coverage	12–23 months	Survey	2004	902 (45%)	1
-NACJ	Nationwide	Data on vaccination coverage	I 2–23 months	Survey	8701	388 (37.7%)	1
Debie and Lakew ²⁷	Emerging regions of Ethiopia	To identify the factors associated with the access and continuum of childhood vaccination	l 2–23 months	Survey	642	214 (33.4%)	Mothers' formal education, ANC, health facility-based delivery, and rich wealth
Deressa et al ²¹	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
Ebot ³⁹	Nationwide	To assess women's household autonomy and immunization	12–30 months	Survey	2941	1588 (61%)	Women's socioeconomic status and household autonomy
Etana and Deressa ⁴⁰	Ambo, Oromia	To assess complete immunization coverage and its associated factors	l 2–23 months	Cross- sectional	536	218 (40.7%)	Antenatal care follow-up, born in the health facility, mothers' knowledge
G/Mariam et al ⁴¹	Bench Maji, SNNPR	To identify determinants of incomplete vaccination	12–23 months	Case- control	312	I	No ANC, home delivery, having no postnatal care visit, the inconvenient appointment time
Girmay and Dadi ⁴²	Sekota Zuria, Amhara	Aimed at bringing data about immunization service coverage and its associated factors	12–23 months	Cross- sectional	620	96 (15.5%)	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
Gualu and Dilie ⁴³	Debre Markos, Amhara	To determine vaccination coverage and associated factors	12–23 months	Cross- sectional	288	19 (6.6%)	Male birth, wanted pregnancy, ANC follow-ups, a short distance from the vaccination site
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Table I.	

Associated factors	Older mothers' age, ANC, tetanus- toxoid vaccination, mothers knowing the age and being a female	Mothers knowledge, tetanus toxoid immunization and Urban residence	Residence and mother's education	Children from pastoral areas mothers/ caregivers aged 30 or above	Delivered at home, no ANC visit, misperception on vaccine contraindication, and no Postnatal care visit	Mother's education, husband employment, mother's religion, ANC visit, presence of vaccination document, region	Information from vaccination card, received postnatal check-up, women's awareness, and rich wealth index	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	Being unmarried, traveling time greater than 2 hours on foot	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	Primary caregivers knowledge, ANC attendance and place of delivery
Outcome N(%)	333 (29.8%)	163 (21.66%)	53 (23.9%)	256 (42.7%)	I	I	I	128 (21.7%)	I 05 (I8.5%)	I 59 (49.4%)	113 (26.2%)	96 (20.0%)
Sample size	6111	751	220	600	308	1929	1927	591	566	322	436	473
Study design	Cross sectional	Cross- sectional	Cross- sectional	Cross- sectional	Case- control	Survey	Survey	Cross- sectional	Cross- sectional	Cross- sectional	Cross- sectional	Cross- sectional
Target population	6–36 months	I 2–23 months	2– 3 months	l 2–23 months	12–23 months	12–23 months	12–23 months	I 2–23 months	I 2–23 months	I 2–23 months	I 2–23 months	12–23 months
Objective	To evaluate immunization coverage and identify factors of incomplete vaccination	To assess immunization coverage and associated factors	To identify factors influencing urban and rural immunization	To identify factors associated with the timeliness of vaccine doses	To identify factors associated with incomplete childhood vaccinations	To assess individual and community level factors associated with full immunization	Identify factors associated with full immunization coverage	To assess complete immunization coverage and its associated factors	To assess the immunization coverage and its factors	To assess immunization and factors associated	To assess immunization and associated factors	To assess incomplete vaccination and associated factors
Study setting	Wonago SNNPR	Lay- Armachiho Amhara	Tselemti, Tigray	Nationwide	East Gojjam, Amhara	Nationwide	Nationwide	Bale Zone, Oromia	Minjar- shenkora, Amhara	Mizan Aman, SNNPR	Oromia	Yirgalem, SNNPR
Author	Hailu et al ²⁴	Kassahun et al ⁴⁴	Kidane and Tekie ⁴⁵	Kidanne et al ⁴⁶	Kindie Yenit ⁴⁷	Kinfe et al ⁶³	Lakew et al ⁶⁴	Legesse and Dechasa ⁴⁸	Mekonnen et al ⁴⁹	Meleko et al ⁵⁰	Negero et al ⁵¹	Mesfin ⁵²

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Table	

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Author	Study setting	Objective	Target population	Study design	Sample size	Outcome N(%)	Associated factors
Mohammed and Atomsa ²²	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 ⁵³	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 ⁵⁴	Sidama, SNNPR	To identify determinant factors of incomplete childhood immunization	12–23 months	Case- control	548	I	Young mothers, a mother's knowledge about immunization benefits, mother's negative, perception of vaccine side effects
Okwaraji et al ⁵⁵	Dabat, Amhara	To assess vaccine coverage and factors associated	12–59 months	Cross- sectional	775	36 (4.6%)	Travel time
Porth et al ⁵⁶	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 ⁵⁷	Nationwide	To assess full immunization coverage and its determinants among children	I2–23 months	Cross- sectional	6061	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 ⁵⁸	Worabe, SNNPR	To assess factors associated with full immunization	12–23 months	Cross- sectional	484	187 (39%)	Fewer ANC visits
Tesfaye et al ⁵⁹	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
Tessema et al ⁶⁰	Pastoral zones in Ethiopia	To assess vaccination coverage, estimate dropout rates, and identify associated factors	I 2–23 months	Cross- sectional	600	121 (21.0%)	Residence, age and education, and maternal occupation
Tolera ⁶¹	Addis Ababa	To determine full immunization coverage and the predictors that influence the complete	I 2–23 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 ⁶²	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 ²⁶	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 ³³	Jimma, Oromia	To assess reason for incomplete vaccination and associated factors	l 2–23 months	Cross- sectional	267	126 (45.5%)	Educational status, marital status, and monthly income

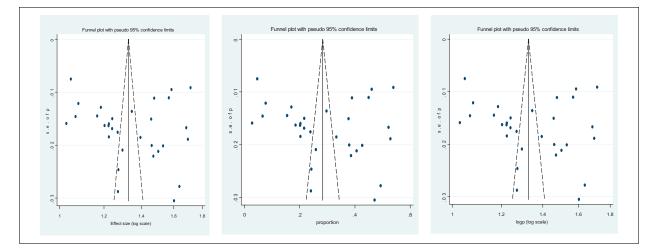


Figure 2. Funnel plot to visualize reporting bias (n=31 studies).

Reporting Bias

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 25008 and 8878 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 randomeffects model was implemented when there was heterogeneity among the included studies with a consideration of I² 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 I² 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 I² statistics indicated the presence of heterogeneity (91%), (93%), and (94%) respectively.

Study ID			ES (95% CI)	% Weigh
Ali et al., 2019	*	1	0.08 (0.05, 0.10)	3.15
Animaw et al., 2014			0.20 (0.17, 0.23)	
CSA ,2016		-	0.45 (0.43, 0.47)	
CSA ,2019			0.38 (0.35, 0.41)	
Debie & Lakew, 2020		-	0.33 (0.30, 0.37)	
Deressa et al., 2020	-	1	0.03 (-0.00, 0.06)	
Ebot, 2015	-	1	 ◆ 0.54 (0.52, 0.56) 	
Etana & Deressa, 2012		· · · ·	0.41 (0.37, 0.45)	
Girmay & Dadi, 2019	-	- !	0.15 (0.13, 0.18)	
Gualu & Dilie, 2017	+	i i	0.07 (0.04, 0.09)	
Hailu et al., 2019		+	0.30 (0.27, 0.32)	
Kassahun et al., 2015			0.22 (0.19, 0.25)	
Kidane & Tekie. 2003		-	0.24 (0.18, 0.30)	
Kidanne et al., 2019		· · · · · · · · · · · · · · · · · · ·	0.43 (0.39, 0.47)	
Legesse & Dechasa, 2015		-	0.22 (0.18, 0.25)	
Mekonnen et al., 2019		➡	0.19 (0.15, 0.22)	
Meleko et al., 2017		- i -	★ 0.49 (0.44, 0.55)	
Melese Girmaye Negero, 2019			0.26 (0.22, 0.30)	
Mesfin, 2015			0.20 (0.17, 0.24)	
Mohammed & Atomsa, 2013		1		
Mohamud et al., 2014			0.38 (0.34, 0.42)	3.11
Okwaraji et al., 2012		1	0.05 (0.03, 0.06)	3.16
Porth et al., 2020)			0.46 (0.44, 0.48)	3.16
Tamirat & Sisay, 2019		+	0.39 (0.37, 0.41)	3.15
Tefera et al., 2018		i —	0.39 (0.34, 0.43)	3.10
Tesfaye et al., 2018		-	0.17 (0.14, 0.20)	3.15
Tessema et al., 2019			0.20 (0.17, 0.23)	3.13
Tolera, 2014			0.24 (0.20, 0.27)	3.13
Wado et al., 2014		1	• 0.52 (0.49, 0.55)	3.13
Workina et al., 2019		-	► 0.47 (0.41, 0.53)	3.04
Yismaw et al., 2019			0.24 (0.19, 0.29)	3.08
		۲	0.36 (0.35, 0.36)	3.17
Overall (I-squared = 99.3%, p = 0.000)		\Leftrightarrow	0.30 (0.25, 0.35)	100.00
NOTE: Weights are from random effects analysis				
566	0		.566	

Figure 3. Pooled prevalence of incomplete vaccination in Ethiopia (n=31 studies).

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-knowl-edgeable women. The random-effect model was assumed for the analysis because the I^2 value was 87% (Figure 6).

Maternal Autonomy

This analysis result revealed that women's decisionmaking 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

Study ID		ES (95% CI)	% Weight
		E3 (33 % CI)	weight
Addis Ababa			
Tolera, 2014		0.24 (0.20, 0.27)	3.23
Subtotal (I-squared = .%, p = .)		0.24 (0.20, 0.27)	3.23
	I. I.		
Amhara			
Gualu & Dilie, 2017	*	0.07 (0.04, 0.09)	3.24
Kassahun et al., 2015	-	0.22 (0.19, 0.25)	3.24
Mekonnen et al., 2019		0.19 (0.15, 0.22)	3.23
Yismaw et al., 2019		0.24 (0.19, 0.29)	3.20
Ali et al., 2019	÷	0.08 (0.05, 0.10)	3.24
Girmay & Dadi, 2019		0.15 (0.13, 0.18)	3.24
Okwaraji et al., 2012	•	0.05 (0.03, 0.06)	3.25
Tesfaye et al., 2018	*	0.17 (0.14, 0.20)	3.24
Subtotal (I-squared = 96.8%, p = 0.000)	\sim \sim	0.14 (0.09, 0.20)	25.88
	1		
Emerging regions of Ethiopia		0 00 /0 00 0 <i>c</i> =	
Debie & Lakew, 2020		0.33 (0.30, 0.37)	3.22
Mohamud et al., 2014		0.38 (0.34, 0.42)	3.22
Tessema et al., 2019		0.20 (0.17, 0.23)	3.23 9.67
Subtotal (I-squared = 96.3%, p = 0.000)		0.30 (0.20, 0.41)	9.67
Nationwide			
Ebot, 2015		• 0.54 (0.52, 0.56)	3.25
CSA ,2016		0.45 (0.43, 0.47)	3.25
CSA ,2019		0.38 (0.35, 0.41)	3.25
Kidanne et al., 2019		0.43 (0.39, 0.47)	3.24
Porth et al., 2020)		0.46 (0.44, 0.48)	3.22
Tamirat & Sisay, 2019		0.39 (0.37, 0.41)	3.25
Subtotal (I-squared = 96.6%, p = 0.000)		> 0.44 (0.39, 0.49)	19.45
Subiotal (FSqualed = 50.0%, p = 0.000)		0.44 (0.35, 0.45)	19.45
Oromia	1		
Legesse & Dechasa, 2015		0.22 (0.18, 0.25)	3.23
Melese Girmaye Negero, 2019	-	0.26 (0.22, 0.30)	3.21
Workina et al., 2019		0.47 (0.41, 0.53)	3.16
Mohammed & Atomsa, 2013	1	0.53 (0.49, 0.57)	3.22
Etana & Deressa, 2012	· · · · · · · · · · · · · · · · · · ·	0.41 (0.37, 0.45)	3.21
Subtotal (I-squared = 97.9%, p = 0.000)		0.38 (0.25, 0.50)	16.04
SNNPR			
Animaw et al., 2014		0.20 (0.17, 0.23)	3.23
Deressa et al., 2020	• I	0.03 (-0.00, 0.06)	3.23
Hailu et al., 2019		0.30 (0.27, 0.32)	3.24
Meleko et al., 2017		0.49 (0.44, 0.55)	3.18
Mesfin, 2015		0.20 (0.17, 0.24)	3.22
Tefera et al., 2018		0.39 (0.34, 0.43)	3.21
Wado et al., 2014	L		3.23
Subtotal (I-squared = 99.0%, p = 0.000)		0.30 (0.18, 0.43)	22.55
Tigray	-		
Kidane & Tekie, 2003		0.24 (0.18, 0.30)	3.17
Subtotal (I-squared = .%, p = .)	\sim	0.24 (0.18, 0.30)	3.17
•			
Overall (I-squared = 99.3%, p = 0.000)	\sim	0.30 (0.24, 0.36)	100.00
NOTE: Weights are from random effects analysis			
566 0		.566	

Figure 4. Forest plot for the subgroup analysis of incomplete vaccination among children in Ethiopia (n=31 studies).

random-effect model was used for the analysis, as the I^2 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 I^2 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

	Illiterate m		Educated m			Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events			M-H, Random, 95% CI	M-H, Random, 95% CI
Ali et al., 2019	15	131	15	349	3.2%	2.88 [1.37, 6.07]	
Animaw et al., 2014	112	262	57	368	3.7%	4.07 [2.80, 5.92]	
Aregawi et al., 2017	66	178	24	92	3.5%	1.67 [0.96, 2.91]	
Asfaw et al., 2016	118	201	54	143	3.6%	2.34 [1.51, 3.64]	
Debie & Lakew, 2020	280	458	61	184	3.7%	3.17 [2.21, 4.55]	
Ebot, 2015	1230	2040	832	901	3.8%	0.13 [0.10, 0.16]	
Etana & Deressa, 2012	196	257	149	279	3.7%	2.80 [1.93, 4.06]	
G/Mariam et al., 2018	86	213	18	99	3.5%	3.05 [1.71, 5.44]	
Girmay & Dadi, 2019	85	309	55	311	3.7%	1.77 [1.20, 2.59]	
Hailu et al., 2019	407	817	124	299	3.8%	1.40 [1.07, 1.83]	
Kassahun et al., 2015	114	402	66	259	3.7%	1.16 [0.81, 1.65]	
Kidane & Tekie, 2003	26	92	1	18	1.6%	6.70 [0.85, 52.92]	
Kinfe et al., 2019	838	1210	347	719	3.8%	2.41 [2.00, 2.92]	-
Lakew et al., 2015	1044	1307	356	624	3.8%	2.99 [2.43, 3.68]	-
Meleko et al., 2017	120	171	66	151	3.6%	3.03 [1.91, 4.80]	
Melese Girmaye Negero, 2019	60	151	53	280	3.6%	2.82 [1.81, 4.39]	
Mesfin, 2015	62	179	44	294	3.6%	3.01 [1.93, 4.70]	
Mohammed & Atomsa, 2013	376	458	159	236	3.7%	2.22 [1.55, 3.19]	
Mohamud et al., 2014	196	510	26	72	3.5%	1.10 [0.66, 1.84]	
Negussie et al., 2016	129	378	53	166	3.7%	1.10 [0.75, 1.63]	
Tamirat & Sisay, 2019	833	1064	385	845	3.8%	4.31 [3.53, 5.26]	+
Tefera et al., 2018	72	176	115	308	3.7%	1.16 [0.80, 1.70]	- -
Tesfaye et al., 2018	251	626	94	204	3.7%	0.78 [0.57, 1.08]	
Tessema et al., 2019	80	126	41	149	3.5%	4.58 [2.75, 7.63]	
Tolera, 2014	41	122	121	463	3.6%	1.43 [0.93, 2.20]	
Wado et al., 2014	276	674	88	215	3.7%	1.00 [0.73, 1.37]	+
Workina et al., 2019	89	129	73	141	3.6%	2.07 [1.26, 3.41]	
Yismaw et al., 2019	38	82	35	219	3.5%	4.54 [2.58, 7.99]	
Total (95% CI)		12723		8388	100.0%	1.96 [1.40, 2.74]	◆
Total events	7240		3512				
Heterogeneity: Tau ² = 0.76; Chi ²	= 665.34, df =	27 (P < 1	0.00001); I ² =	96%			
Test for overall effect: Z = 3.91 (P							0.01 0.1 1 10 10 Favours Illiterate Favours Educated

Figure 5. The influence of maternal education on incomplete vaccination in Ethiopia (n=28 studies).

	Goo	d	Poo	r		Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% Cl	M-H, Random, 95% Cl
Aregawi et al., 2017	23	150	67	120	8.9%	0.14 [0.08, 0.25]	
Asfaw et al., 2016	36	109	134	233	9.4%	0.36 [0.23, 0.59]	
Ebot, 2015	250	426	95	110	8.9%	0.22 [0.13, 0.40]	
G/Mariam et al., 2018	88	290	16	22	6.8%	0.16 (0.06, 0.43)	
Girmay & Dadi, 2019	101	476	39	144	9.6%	0.73 [0.47, 1.11]	
Kassahun et al., 2015	42	203	132	344	9.7%	0.42 [0.28, 0.63]	
Kindie Yenit, 2015	78	175	72	128	9.5%	0.63 (0.40, 0.99)	
Legesse & Dechasa, 2015	79	421	58	189	9.8%	0.52 [0.35, 0.77]	
Meleko et al., 2017	89	210	97	112	8.7%	0.11 [0.06, 0.21]	
Mohammed & Atomsa, 2013	264	408	271	286	9.0%	0.10 [0.06, 0.18]	
Tolera, 2014	118	464	44	131	9.7%	0.67 [0.44, 1.02]	
Total (95% CI)		3332		1819	100.0%	0.31 [0.20, 0.47]	•
Total events	1168		1025				
Heterogeneity: Tau ² = 0.43; Chi	² = 77.98	df = 10) (P < 0.0	0001);	l² = 87%		
Test for overall effect: Z = 5.51	(P < 0.000	001)					0.01 0.1 1 10 10 Favours Good Favours Poor

Figure 6. The influence of maternal knowledge on incomplete vaccination in Ethiopia (n = 11 studies).

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 I² 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:

	Yes	5	No			Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI	M-H, Random, 95% CI
Aregawi et al., 2017	14	103	76	167	16.4%	0.19 [0.10, 0.36]	
Ebot, 2015	185	1793	269	1109	21.8%	0.36 [0.29, 0.44]	-
Mekonnen et al., 2019	91	252	47	114	19.0%	0.81 [0.51, 1.27]	
Tamirat & Sisay, 2019	136	412	608	1497	21.6%	0.72 [0.57, 0.91]	-
Wado et al., 2014	200	489	164	400	21.2%	1.00 [0.76, 1.30]	+
Total (95% CI)		3049		3287	100.0%	0.54 [0.33, 0.89]	◆
Total events	626		1164				
Heterogeneity: Tau ² = 0.	28; Chi ² =	53.77,	df = 4 (P	< 0.00	001); I ² = 9	3%	
Test for overall effect: Z =	= 2.41 (P =	= 0.02)					0.01 0.1 1 10 100 Favours Yes Favours No

Figure 7. The influence of maternal decision-making power on incomplete vaccination in Ethiopia (n=5 studies).

	Urba	n	Rura	al		Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI	M-H, Random, 95% Cl
Animaw et al., 2014	27	178	142	452	8.0%	0.39 (0.25, 0.62)	
Aregawi et al., 2017	6	34	84	236	5.6%	0.39 (0.15, 0.97)	
Debie & Lakew, 2020	32	108	309	534	8.1%	0.31 [0.20, 0.48]	
Ebot, 2015	67	147	278	389	8.3%	0.33 [0.23, 0.49]	
G/Mariam et al., 2018	13	40	91	272	6.7%	0.96 [0.47, 1.94]	
Kassahun et al., 2015	32	170	148	581	8.2%	0.68 [0.44, 1.04]	
Kidane & Tekie, 2003	13	40	14	70	5.8%	1.93 [0.80, 4.66]	+
Melese Girmaye Negero, 2019	11	39	102	392	6.6%	1.12 [0.54, 2.32]	
Mohamud et al., 2014	102	290	120	292	8.6%	0.78 [0.56, 1.09]	
Negussie et al., 2016	22	64	169	480	7.6%	0.96 [0.56, 1.67]	
Tamirat & Sisay, 2019	133	398	1032	1511	9.0%	0.23 [0.18, 0.29]	≁
Tesfaye et al., 2018	159	441	186	389	8.8%	0.62 [0.47, 0.81]	
Wado et al., 2014	89	214	277	675	8.7%	1.02 [0.75, 1.40]	+
Total (95% CI)		2163		6273	100.0%	0.61 [0.43, 0.86]	•
Total events	706		2952				
Heterogeneity: Tau ² = 0.33; Chi ² :	= 103.82,	df = 12	(P < 0.00	0001); I	²= 88%		
Test for overall effect: Z = 2.84 (P	= 0.005)						0.01 0.1 1 10 100 Favours Urban Favours Rural

Figure 8. The influence of place of residence on incomplete vaccination in Ethiopia (n = 13 studies).

0.30, 0.52) compared to those who did not have utilized postnatal care. We analyzed a random effect model because the I² 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 I² 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 I² value was 97%.

Husband Employment. The results of the review indicated that husband employment was significantly associated with childhood vaccination status. Infants

	Yes		No			Odds Ratio	Odds Ratio
Study or Subgroup	Events					M-H, Random, 95% CI	M-H, Random, 95% Cl
Ali et al., 2019	33	465	4	15	2.5%	0.21 [0.06, 0.70]	
Animaw et al., 2014	145	569	24	61	4.2%	0.53 [0.31, 0.91]	
Aregawi et al., 2017	76	246	14	24	3.3%	0.32 [0.14, 0.75]	
Asfaw et al., 2016	124	271	48	73	4.3%	0.44 [0.26, 0.75]	
Debie & Lakew, 2020	143	369	207	273	4.8%	0.20 [0.14, 0.29]	
Deressa et al, 2020	18	91	8	16	2.7%	0.25 [0.08, 0.75]	
Ebot, 2015	172	337	173	199	4.5%	0.16 [0.10, 0.25]	
3/Mariam et al., 2018	75	280	29	32	2.4%	0.04 [0.01, 0.13]	
∋irmay & Dadi, 2019	87	464	53	156	4.6%	0.45 [0.30, 0.67]	
Sualu & Dilie, 2017	18	260	6	28	2.9%	0.27 [0.10, 0.76]	
Hailu et al., 2019	146	250	386	767	4.9%	1.39 [1.04, 1.85]	
Kassahun et al., 2015	129	582	51	169	4.7%	0.66 [0.45, 0.97]	
kindie Yenit, 2015	52	163	98	139	4.4%	0.20 [0.12, 0.32]	
<infe 2019<="" al.,="" et="" td=""><td>568</td><td>1140</td><td>557</td><td>685</td><td>5.0%</td><td>0.23 [0.18, 0.29]</td><td>-</td></infe>	568	1140	557	685	5.0%	0.23 [0.18, 0.29]	-
akew et al., 2015	169	349	1200	1507	5.0%	0.24 [0.19, 0.31]	
egesse & Dechasa, 2015	76	435	61	156	4.6%	0.33 [0.22, 0.49]	
deleko et al., 2017	80	185	106	137	4.4%	0.22 [0.14, 0.37]	
Aesfin, 2015	66	394	40	79	4.3%	0.20 [0.12, 0.33]	
Aohammed & Atomsa, 2013	268	380	262	314	4.7%	0.47 [0.33, 0.69]	
Famirat & Sisay, 2019	603	1227	562	682	5.0%	0.21 [0.16, 0.26]	-
Fefera et al., 2018	165	458	22	26	2.7%	0.10 [0.03, 0.30]	
Fesfaye et al., 2018	279	736	66	94	4.5%	0.26 [0.16, 0.41]	
Tolera, 2014	114	450	48	135	4.6%	0.61 [0.41, 0.93]	
Vado et al., 2014	154	376	310	513	4.9%	0.45 [0.35, 0.60]	
Total (95% CI)		10477		6280	100.0%	0.30 [0.23, 0.39]	•
otal events	3760		4335				
leterogeneity: Tau ² = 0.34; Ch	i ² = 211.65	, df = 23	3 (P < 0.0	0001):	I ² = 89%		ter de la c
est for overall effect: Z = 8.99							0.01 0.1 i 10 10 Favours Yes, Favours No

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

	Hom		Health fac			Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events			M-H, Random, 95% CI	M-H, Random, 95% CI
Ali et al., 2019	13	44	24	436	2.9%	7.20 [3.34, 15.51]	
Animaw et al., 2014	145	446	24	184	4.1%	3.21 [2.00, 5.15]	
Aregawi et al., 2017	54	124	36	146	3.9%	2.36 [1.41, 3.95]	
Asfaw et al., 2016	165	229	7	15	2.1%	2.95 [1.03, 8.46]	
Debie & Lakew, 2020	288	465	53	177	4.5%	3.81 [2.62, 5.52]	
Deressa et al, 2020	10	24	16	83	2.3%	2.99 [1.13, 7.95]	
Ebot, 2015	1588	2495	300	832	5.1%	3.10 [2.64, 3.66]	-
Etana & Deressa, 2012	263	344	82	192	4.4%	4.36 [2.98, 6.36]	
3/Mariam et al., 2018	16	25	88	287	2.6%	4.02 [1.71, 9.45]	
Sirmay & Dadi, 2019	95	275	45	345	4.4%	3.52 [2.36, 5.25]	
Gualu & Dilie, 2017	6	34	18	254	2.2%	2.81 [1.03, 7.66]	
Hailu et al., 2019	399	799	132	317	4.9%	1.40 [1.07, 1.82]	
<assahun 2015<="" al.,="" et="" td=""><td>137</td><td>510</td><td>43</td><td>241</td><td>4.4%</td><td>1.69 [1.15, 2.48]</td><td></td></assahun>	137	510	43	241	4.4%	1.69 [1.15, 2.48]	
kindie Yenit, 2015	97	129	53	172	3.9%	6.81 [4.07, 11.38]	
akew et al., 2015	1348	1694	112	236	4.8%	4.31 [3.26, 5.72]	
_egesse & Dechasa, 2015	94	401	43	190	4.3%	1.05 [0.69, 1.58]	+
veleko et al., 2017	102	149	89	173	4.1%	2.05 [1.30, 3.23]	
lelese Girmaye Negero, 2019	60	163	53	268	4.2%	2.36 [1.53, 3.66]	
lesfin, 2015	59	122	47	352	4.1%	6.08 [3.80, 9.72]	
Aohammed & Atomsa, 2013	463	577	72	117	4.3%	2.54 [1.66, 3.88]	
Iohamud et al., 2014	173	425	49	157	4.4%	1.51 [1.03, 2.23]	
Famirat & Sisay, 2019	800	1064	385	845	5.1%	3.62 [2.98, 4.40]	+
Fesfaye et al., 2018	131	209	214	621	4.7%	3.19 [2.31, 4.42]	
Folera, 2014	35	81	127	505	4.0%	2.26 [1.40, 3.67]	
Nado et al., 2014	323	788	41	101	4.3%	1.02 [0.67, 1.55]	+
Total (95% CI)		11616		7246	100.0%	2.78 [2.28, 3.38]	•
Total events	6864		2153				
leterogeneity: Tau ² = 0.19; Chi ²	= 146.96.	df = 24 (P < 0.00001); l ² = 84	4%		
fest for overall effect: Z = 10.25 (,					0.01 0.1 1 10 1 Favours Home Favours Health facilities

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

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).

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

	Yes	5	No			Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI	M-H, Random, 95% CI
Asfaw et al., 2016	55	151	117	193	10.2%	0.37 [0.24, 0.58]	
Debie & Lakew, 2020	14	52	327	590	8.1%	0.30 (0.16, 0.56)	
G/Mariam et al., 2018	59	251	45	61	8.0%	0.11 [0.06, 0.21]	
Girmay & Dadi, 2019	45	243	95	377	10.7%	0.67 (0.45, 1.00)	
Kassahun et al., 2015	42	218	138	533	10.8%	0.68 [0.46, 1.01]	
Kindie Yenit, 2015	20	71	130	231	8.7%	0.30 [0.17, 0.54]	<u> </u>
Lakew et al., 2015	98	190	1304	1663	11.6%	0.29 [0.22, 0.40]	-
Legesse & Dechasa, 2015	55	305	82	286	10.8%	0.55 [0.37, 0.81]	
Meleko et al., 2017	76	158	110	164	10.1%	0.45 [0.29, 0.71]	
Tolera, 2014	82	370	80	215	11.0%	0.48 [0.33, 0.70]	
Total (95% CI)		2009		4313	100.0%	0.39 [0.30, 0.52]	◆
Total events	546		2428				
Heterogeneity: Tau ² = 0.16; C	hi ² = 38.7	2, df = !	9 (P < 0.0	0001); F		0.01 0.1 1 10 100	
Test for overall effect: Z = 6.38	8 (P < 0.0)	0001)				0.01 0.1 1 10 100 Favours Yes Favours No	

Figure 11. The influence of maternal postnatal care on incomplete vaccination in Ethiopia (n = 10 studies).

	Yes		No			Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI	M-H, Random, 95% CI
Ali et al., 2019	31	445	6	35	9.3%	0.36 [0.14, 0.94]	
Etana & Deressa, 2012	187	350	158	186	12.7%	0.20 [0.13, 0.32]	
Hailu et al., 2019	294	966	237	350	13.7%	0.21 [0.16, 0.27]	-
Kassahun et al., 2015	72	358	108	393	13.3%	0.66 [0.47, 0.93]	
Kindie Yenit, 2015	47	123	103	179	12.6%	0.46 [0.29, 0.73]	
Meleko et al., 2017	77	179	109	143	12.5%	0.24 [0.14, 0.38]	
Mohamud et al., 2014	80	242	122	340	13.3%	0.88 [0.62, 1.25]	
Tolera, 2014	67	273	35	138	12.6%	0.96 [0.60, 1.53]	
Total (95% CI)		2936		1764	100.0%	0.42 [0.26, 0.69]	◆
Total events	855		878				
Heterogeneity: Tau ² = 0.44	4; Chi ² = 7	8.63, d	%	0.01 0.1 1 10 100			
Test for overall effect: Z = 3	3.45 (P =	0.0006		0.01 0.1 1 10 100 Favours Yes Favours No			

Figure 12. The influence of TT3 on incomplete vaccination in Ethiopia (n = 8 studies).

	Employ	yed	Unemployed			Odds Ratio	Odds Ratio	
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Fixed, 95% CI	M-H, Fixed, 95% CI	
Aregawi et al., 2017	8	40	82	230	16.4%	0.45 [0.20, 1.02]		
Kinfe et al., 2019	985	1660	126	166	78.7%	0.46 [0.32, 0.67]		
Tolera, 2014	4	15	140	516	4.9%	0.98 [0.31, 3.12]		
Total (95% CI)		1715		912	100.0%	0.49 [0.35, 0.67]	•	
Total events	997		348					
Heterogeneity: Chi ² = 1	1.48, df =	2 (P = 1	0.48); I ² =					
Test for overall effect:	Z = 4.37 (P < 0.0	001)	0.01 0.1 1 10 100 Favours Employed Favours Unemployed				

Figure 13. The influence of husband employment status on incomplete vaccination in Ethiopia (n=3 studies).

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 I² 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)

	Less than 3	30 min	30 min and	more		Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI	M-H, Random, 95% Cl
Aregawi et al., 2017	57	215	33	55	6.6%	0.24 [0.13, 0.45]	.
Asfaw et al., 2016	88	164	84	180	7.1%	1.32 [0.87, 2.02]	+
Girmay & Dadi, 2019	50	328	90	292	7.2%	0.40 [0.27, 0.60]	
Gualu & Dilie, 2017	16	247	8	41	5.7%	0.29 [0.11, 0.72]	
Kindie Yenit, 2015	100	197	14	34	6.3%	1.47 [0.70, 3.08]	
Kinfe et al., 2019	105	773	435	1156	7.5%	0.26 [0.21, 0.33]	
_egesse & Dechasa, 2015	116	462	21	129	6.9%	1.72 [1.03, 2.88]	
dekonnen et al., 2019	55	291	83	275	7.2%	0.54 [0.36, 0.80]	
delese Girmaye Negero, 2019	87	349	26	82	6.9%	0.72 [0.42, 1.21]	
Mesfin, 2015	99	430	7	41	5.9%	1.45 [0.62, 3.38]	
Okwaraji et al., 2012	7	241	32	476	6.0%	0.42 [0.18, 0.95]	
Tefera et al., 2018	64	157	123	327	7.2%	1.14 [0.77, 1.68]	
Fesfaye et al., 2018	213	451	132	379	7.4%	1.67 [1.26, 2.22]	
Tolera, 2014	154	545	8	40	6.1%	1.58 [0.71, 3.50]	
rismaw et al., 2019	61	278	12	23	5.9%	0.26 [0.11, 0.61]	
Total (95% CI)		5128		3530	100.0%	0.70 [0.46, 1.08]	•
Total events	1272		1108				
Heterogeneity: Tau ² = 0.63; Chi ² :	= 171.27, df =	14 (P < I	0.00001); I² =	: 92%			
Test for overall effect: Z = 1.60 (P	= 0.11)						Favours Less than 30 min Favours 30 min and more

Figure 14. The influence of time to reach vaccination centers on incomplete vaccination in Ethiopia (n = 15 studies).

	Male	e	Fema	le		Odds Ratio	Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI	M-H, Random, 95% CI
Animaw et al., 2014	91	325	78	290	7.0%	1.06 [0.74, 1.51]	+
Asfaw et al., 2016	97	191	75	153	6.5%	1.07 [0.70, 1.64]	+
Debie & Lakew, 2020	195	357	146	285	7.4%	1.15 [0.84, 1.57]	+-
Etana & Deressa, 2012	181	274	164	262	7.1%	1.16 [0.82, 1.66]	
G/Mariam et al., 2018	55	172	49	140	6.1%	0.87 [0.54, 1.40]	
Gualu & Dilie, 2017	6	34	18	254	2.9%	2.81 [1.03, 7.66]	
Hailu et al., 2019	280	556	251	571	8.0%	1.29 [1.02, 1.64]	-
Kassahun et al., 2015	74	384	106	367	7.2%	0.59 [0.42, 0.83]	
Lakew et al., 2015	777	1010	684	920	8.2%	1.15 [0.93, 1.42]	-
Legesse & Dechasa, 2015	60	139	77	352	6.5%	2.71 [1.78, 4.13]	
Mesfin, 2015	44	246	62	227	6.4%	0.58 [0.37, 0.90]	
Negussie et al., 2016	107	308	75	136	6.6%	0.43 [0.29, 0.65]	
Tefera et al., 2018	95	243	92	241	7.0%	1.04 [0.72, 1.50]	+
Tessema et al., 2019	57	176	64	199	6.4%	1.01 [0.65, 1.56]	-
Tolera, 2014	70	288	92	297	7.0%	0.72 [0.50, 1.03]	
Total (95% CI)		4703		4694	100.0%	1.00 [0.81, 1.23]	•
Total events	2189		2033				
Heterogeneity: Tau ² = 0.13; Cl	hi² = 68.3	9, df =	14 (P < 0	.00001); I ² = 809	6	0.01 0.1 1 10 100
Test for overall effect: Z = 0.00	(P = 1.00		0.01 0.1 1 10 100 Favours Male Favours Female				

Figure 15. The influence of child sex on incomplete vaccination in Ethiopia (n = 15 studies).

and incomplete vaccination (OR=1.00; 95% CI: 0.81, 1.23). The random-effect model was assumed for the analysis because the I^2 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.^{17,38} The country is unable to achieve the WHO target of vaccination coverage of 90% by 2020.⁵ This likely translates to insufficient herd immunity against many VPDs.⁶⁵ This systematic review and metaanalysis 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 decisionmaking 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 prenatally. Women's participation in health care decisionmaking 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,⁷⁵ 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 serviceseeking 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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ORCID iD

Assefa Desalew (D) https://orcid.org/0000-0001-6065-0708

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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