HUMAN VACCINES & IMMUNOTHERAPEUTICS
2023, VOL. 19, NO. 1, 2202125
https://doi.org/10.1080/21645515.2023.2202125

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RESEARCH ARTICLE

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Incomplete immunization and its determinants among children in Africa: Systematic review and meta-analysis

Natnael Atnafu Gebeyehu[a], Kelemu Abebe Gelaw[a], Getachew Asmare Adella[b], Kirubel Dagnaw Tegegne[c], Biruk Adie Admass[d], and Molalegn Mesele Gesese[a]

[a]Department of Midwifery, College of Medicine and Health Science, Wolaita Sodo University, Sodo, Ethiopia; [b]Department of Reproductive Health, College of Medicine and Health Science, Wolaita Sodo University, Sodo, Ethiopia; [c]Department of Comprehensive Nursing, College of Medicine and Health Science, Wolaita Sodo University, Sodo, Ethiopia; [d]Department of Anesthesia, College of Medicine and Health Science, Gondar University, Gondar, Ethiopia

ABSTRACT

Immunization is one of the most cost-effective measures to prevent morbidity and mortality in children. Therefore, the purpose of this systematic review and meta-analysis was to determine the pooled prevalence of incomplete immunization among children in Africa as well as its determinants. PubMed, Google Scholar, Scopus, Science Direct, and online institutional repository homes were searched. Studies published within English language, with full text available for searching, and studies conducted in Africa were included in this meta-analysis. A pooled prevalence, Sub-group analysis, sensitivity analysis and meta-regression were conducted. Out of 1305 studies assessed, 26 met our criteria and were included in this study. The pooled prevalence of incomplete immunization was 35.5% (95% CI: 24.4, 42.7), $I^2 = 92.1\%$). Home birth (AOR=2.7; 95% CI: 1.5–4.9), rural residence (AOR = 4.6; 95% CI: 1.1–20.1), lack of antenatal care visit (AOR = 2.6; 95% CI: 1.4–5.1), lack of knowledge of immunizations (AOR=2.4; 95% CI: 1.3–4.6), and maternal illiteracy (AOR = 1.7: 95%CI: 1.3–2.0) were associated with incomplete immunization. In Africa, the prevalence of incomplete immunization is high. It is important to promote urban residency, knowledge of immunization and antenatal follow up care.

ARTICLE HISTORY
Received 6 December 2022
Revised 24 March 2023
Accepted 10 April 2023

KEYWORDS
Immunization; vaccination; children; meta-analysis; Africa

Introduction

Immunization involves the administration of a vaccine to reach immunity against an infectious agent, and especially for preventing the disease caused by the agent.[1,2] It is one of the most cost-effective public health measures to reduce child morbidity and mortality.[3] Measles vaccination has been estimated to have prevented~23 million deaths during 2010–8.[4] More than half of infant and young child deaths are related to illnesses that could be readily avoided by taking simple, inexpensive measures, such as receiving vaccines.[5] Due to inadequate and low vaccination coverage, vaccine-preventable diseases continue to cause a public health risk in South-East Asia and sub-Saharan Africa.[6]

A child is considered to have an incomplete immunization status if they failed to receive at least one of the recommended childhood vaccinations, which include BCG, three doses of the pentavalent vaccine, three doses of the PCV vaccine, two doses of the Rotavirus vaccine, and three doses of the polio and measles vaccines by the age of 12 months.[7] Globally, it has been estimated that 9 million children under the age of five die annually from vaccine-preventable diseases.[8] Infectious childhood diseases like measles, pertussis, diphtheria, tetanus, TB, meningitis, and tuberculosis in children can be prevented most effectively with vaccination.[9] Two-thirds of children under five now have a lower mortality risk because to vaccinations against infectious diseases.[10] An estimated 1–2 million under-five child deaths are prevented each year by routine childhood vaccinations (BCG, pentavalent, polio, and measles).[11,12]

The incidence of mortality among children under the age of five substantially decreased from 12.6 million in 1990 to 5.3 million in 2018[13,14] when the EPI program was introduced. Despite a significant drops in the prevalence of vaccine-preventable deaths, a significant portion of children are not fully vaccinated, which results in substantial regional and international variation in vaccination coverage.[15,16] For example, in 2017, ~83K measles-related fatalities were tabulated worldwide out of an estimated 17 million cases.[17,18] Worldwide~116 million newborns (86%) received full 3 doses of the diphtheria-tetanus-pertussis (DTP) vaccine in 2018.[19,20] According to reports from the WHO and UNICEF, more than 20 million children globally have not completed a full course of basic vaccinations.[21] In Africa, almost 10 million children are still either partially or completely unvaccinated.[22,23]

In accordance with the new Sustainable Development Goals (SDGs), all nations must work toward lowering neonatal

CONTACT Natnael Atnafu Gebeyehu jossyatnafu2020@gmail.com Department of Midwifery, College of Medicine and Health Science, Wolaita Sodo University, Sodo, Ethiopia.

Supplemental data for this article can be accessed on the publisher's website at https://doi.org/10.1080/21645515.2023.2202125.

mortality to at least 12 per 1,000 live births and under-5 mortality to at least 25 per 1,000 live births by 2030.[13] By 2030, every child should have received all recommended vaccinations, regardless of location, age, socioeconomic position, or gender-related barriers, according to the WHO's global strategy known as the Immunization Agenda 2030. As a result, the WHO launched the Expanded Program on Immunization (EPI) in 1974 to control diseases that can be prevented by vaccination.[24] Incidence of under-five deaths remained 5.3 million in 2018 after the EPI program's inception.[13,14]

Evidence suggested that a number of variables contribute to the incomplete vaccination coverage in developing countries. Incomplete vaccination has been linked to a number of factors, including birth order,[7,25] maternal age,[7,25,26] distance from a health facility,[25,27] maternal educational status,[25–29] antenatal care visit,[25,30] postnatal care (PNC) visit[30] and delivery site.[18,30,31]

The percentage of children in Africa who did not obtain all of the required vaccines ranges greatly, from Sudan (5.7%) to Nigeria (76.3%).[32,33] Despite multiple primary studies that demonstrate the prevalence of incomplete immunization across Africa, there are no pooled data at the regional level. The relevant factors that have been found differ between studies as well. Therefore, the goal of this systematic review and meta-analysis study was to identify the prevalence of incomplete immunization among children in Africa and its determinants. Clinicians and other stakeholders will be able to address gaps in immunization coverage by prioritizing and customizing immunization campaigns and operational plans based on the study's findings, which will provide them with the fundamental knowledge they need to provide every child with a life-saving vaccination.

Methods

Reporting

This systematic review and meta-analysis study was conducted to determine incomplete immunization and its determinant among children in Africa using the standard PRISMA checklist guideline[34] (**Additional 1**). It was carried out by conducting a thorough synthesis of the relevant primary studies on children's incomplete immunizations in Africa. The protocol was registered at CRD42022348643.

Search strategy

International online databases (Pub Med, Science Direct, Scopus, and Google Scholar) were used to search articles on the prevalence of incomplete immunization and determinant's in Africa. We also retrieved gray literature from Addis Ababa University, Bahir Dar University, Georgia State University, University of Ghana and University of Western Cape online research institutional repository. The search string was established using "AND" and "OR" Boolean operators. The following core search terms and phrases with Boolean operators were used to search related articles: ((((Incomplete) OR ("Incomplete" OR "partially")) AND Immunization) OR ("Immunization" OR "Vaccine" OR "Vaccination" "Immunization")) AND Children) OR ("Child" OR "Childhood" OR "Baby") AND Africa. Articles published from May 16, 2008, to May 2, 2022, were included in the search period, which ran from September 1, 2022, to October 10, 2022.

Outcome measurement

Incomplete immunization

Receiving one dose of BCG, three doses of pentavalent, three doses of polio, and one shot of measles within the first year of life indicates complete immunization, according to the World Health Organization.[35] If a child does not receive all 8 doses of these vaccines before turning 12 months old, they were considered to be only incompletely vaccinated. However, we found that studies reporting the same results in children under the age of 5 were included in the analysis.

Inclusion and exclusion criteria

Only English language papers, including peer-reviewed (scientific) literature versus non peer-reviewed (gray) literature with full text available for search, adjusted odds ratio for factors and studies that took place in Africa were included in blind screening in this meta-analysis. This systematic review and meta-analysis excluded research that used duplicated sources, qualitative studies from countries outside Africa, and articles without full text.

Quality assessment

Two authors (NAT and KDG) independently appraised the standard of the studies using the Joanna Briggs Institute (JBI) standardized quality appraisal checklist.[36] The disagreement raised during the quality assessment was resolved through a discussion led by the third author (GAA). Finally, the argument was solved and reached with an agreement. The critical analysis checklist has eight parameters with yes, no, unclear, and not applicable options (**Additional file 2).**

Risk of bias assessment

Two authors (NAG and BAA) independently assessed included studies for risk of bias through the bias assessment tool developed by Hoy et al.,[37] consisting of ten items that assess four domains of bias and internal and external validity. Any disagreement raised during the risk of bias assessment was resolved through a discussion led by the third author (KAG). Finally, the argument was solved and reached with an agreement. The first four items (items 1–4) evaluate the presence of selection bias, non-response bias, and external validity. The other six items (items 5–10) assess the presence of measuring the bias, analysis-related bias, and internal validity. Therefore, studies that received 'yes' for eight or more of the ten questions were classified as 'low risk of bias.' If studies that received 'yes' for six to seven of the ten questions were classified as 'moderate risk' whereas studies that received 'yes' for five or fewer of

the ten questions were classified as 'high risk' as reported in a supplementary file (**Additional file 3**).

Data extraction

Microsoft Excel spreadsheet (2016) and STATA version 11 software were utilized for data extraction and analysis. Two authors (NAG and KDT) independently extracted all relevant data using a standardized Joanna Briggs Institute data extraction format. Any disagreement raised during data extraction was resolved through a discussion led by the third author (BAA). Finally, the argument was solved and reached with an agreement. The name of the first author, year of publication, age of target population, study region, study setting, study design, the prevalence of incomplete immunization, sample size, and quality of each paper was extracted.

Data analysis

After extracting all relevant findings in a micro-soft excel spreadsheet, the data were exported to STATA software version 14 for analysis. The pooled prevalence of incomplete immunization was computed using a 95% confidence interval. Publication bias was checked by funnel plot and more objectively through Begg and Egger's regression tests, with $P < .05$ indicating potential publication bias. The presence of between-study heterogeneity was checked by using the Cochrane Q statistic. This heterogeneity between studies was quantified using I^2, in which a value of 0, 25, 50, and 75% represented no, low, medium, and high heterogeneity, respectively. A forest plot was used to visually assess the presence of heterogeneity, which presented at a high-level random-effect model was used for analysis to estimate the pooled estimate of incomplete immunization. Subgroup analysis was done by sample size, publication, study sub-region and age of target population. Sensitivity analysis was executed to see the effect of a single study on the overall prevalence of the meta-analysis estimate. The findings of the study were presented in the form of text, tables, and figures

Results

Search findings and study characteristics

One thousand three hundred five articles were retrieved using a search strategy about incomplete immunization in Africa through online search engines. After duplicates were removed, 930 articles remained. Then, 860 studies were excluded after reviewing for full title and abstracts from the remaining 930 studies. Therefore, 70 full-text studies were assessed for eligibility criteria, which further excluded 44 studies due to reasons. Finally, 26 articles[25,27–29,32,33,38–56] were included as criteria for this systematic review and meta-analysis study (Figure 1).

All included studies were employed by cross-sectional study design. Two of these were cross-sectional studies conducted at institutions, while the remaining 24 studies were community-based. Six studies conducted in Ethiopia,[38–43] five in Nigeria,[33,44–47] three in Togo,[27,29,48] two in Malawi,[49,50] one study in each of Uganda,[51] Gambia,[52] Cote d'ivoire,[53] Congo,[54] Mozambique,[28] Cameroon,[25] Mali,[55] Ghana,[56] South Africa[57] and Sudan.[32] The sample sizes ranged from 213 to 14,593. The prevalence of incomplete vaccination ranged from 5.6% to 76.3%. All studies were assessed by using Joanna Briggs Institute (JBI) quality appraisal checklist and yielded low risk (Table 1).

Meta-analysis

Prevalence of incomplete immunization among children in Africa

A DerSimonian and Laird random-effects model was used to determine the overall estimate of incomplete immunization. Accordingly, the regional pooled prevalence of incomplete vaccination coverage among children with a random-effects model was 35.5% (95% CI: 24.4, 42.7) with a heterogeneity index (I^2) of 92.1% ($p < .001$) (Figure 2).

Subgroup analysis

Since this meta-analysis showed a marked heterogeneity, subgroup analysis was done using sub-region where the studies were conducted, sample size, publication and age of children. Based on this, the highest (42.5%; 95% CI: 28.2, 52.8), $I^2 = 84.2\%$) and the lowest (19.8%; 95% CI: 8.4, 31.1), $I^2 = 93.9\%$) prevalence of incomplete immunization among children was observed in Western Africa region and Central Africa region, respectively The pooled prevalence for published research was (41%; 95% CI: 21.6–60.3); $I^2 = 79.3$; while for unpublished studies, it was (31.3; 95% CI: 20.5, 42.1); $I^2 = 80.9\%$.

Regarding children's ages, the highest prevalence of incomplete immunization was reported in children under the age of five (43.6; 95% CI: 23.6, 63.5); $I^2 = 68.8\%$; and the lowest prevalence was reported in children under the age of two (26.2; 95% CI: 18.5, 33.9; $I^2 = 95.7\%$). While the prevalence for samples with a sample size of less than 1000 was (24.3; 95%CI: 18.4, 30.2), $I^2 = 93.2\%$, the prevalence for samples with a sample size of more than 1000 was (45.9%; 95% CI: 31.5, 60.4), $I^2 = 91.7\%$ (Table 2).

Heterogeneity and publication bias

To adjust the reported heterogeneity of this study ($I^2 = 92.1\%$), we computed a Sub-group analysis based on the sub-region of Africa, sample size, age of target population and publication. Univar ate meta-regression was also done to identify the source of heterogeneity using sample size and age of children as a covariate. It showed that there was an effect of sample size and age of children on heterogeneity between studies (Table 3).

The presence of publication bias was assessed by funnel plot visually and by Egger's test and Begg's test objectively. The funnel plot shows asymmetrical distribution of studies by visual inspection (Figure 3). Therefore, the presence of publication bias was also assessed by Egger's regression test ($p = .4$) and Begg's rank correlation test ($p = .8$) with no evidence of publication bias.

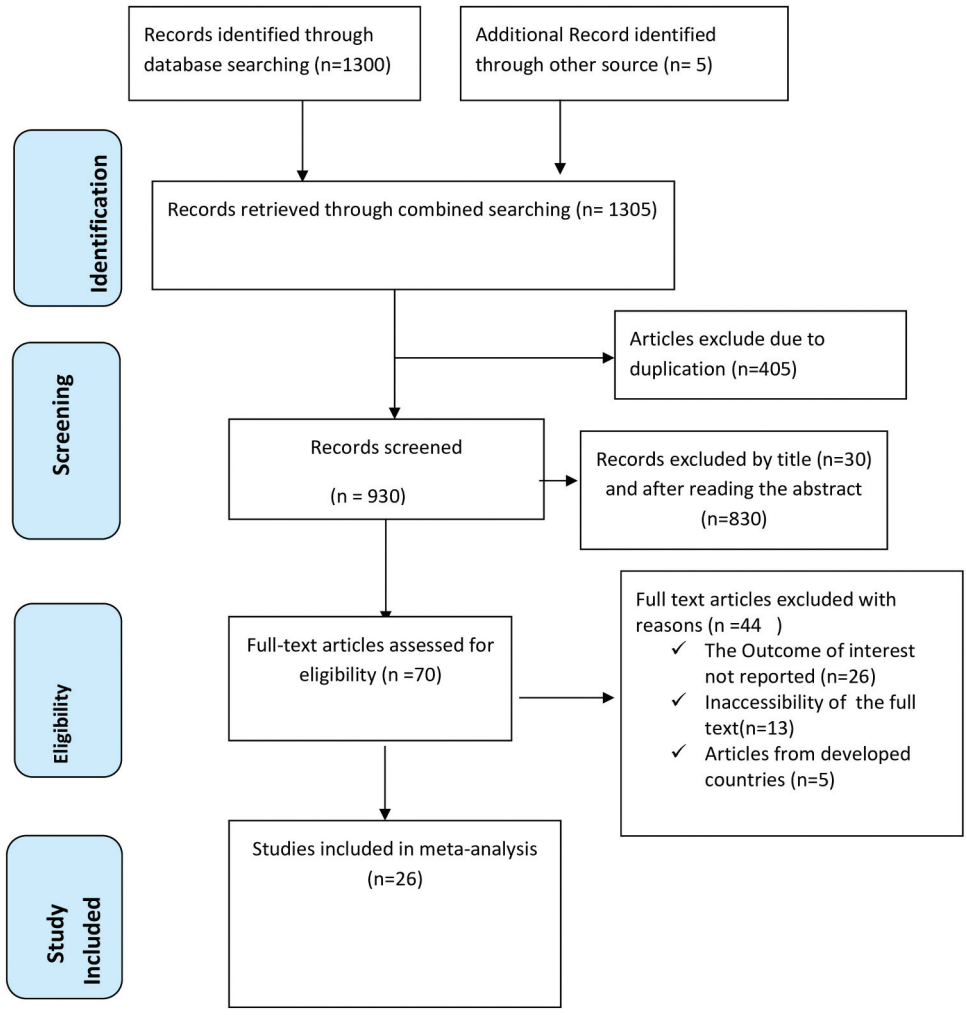

Figure 1. A Prisma diagrammatic presentation used to show the selection of studies. The inclusion criteria were variation of the title and abstracts, place of study (Africa), presence of full abstract, and reporting different results. Studies were excluded if they criteria were duplicated source, studies from other countries and qualitative studies.

Leave – one-out-sensitivity analysis

A leave-one-out sensitivity analysis was carried out to detect the effect of each study on the overall prevalence of incomplete immunization by excluding one study at a time. As a result, studies omitted at a time did not show a significant change on the overall prevalence of incomplete immunization (Table 4).

Factors associated with incomplete immunization in Africa

In this meta-analysis, lack of knowledge, place of delivery, no antenatal care visit, rural residency and maternal illiteracy were significantly associated with incomplete vaccination. However, not attending postnatal care visit was not significantly associated with incomplete immunization.

Postnatal care

As evidenced in this study, postnatal care was not significantly associated with incomplete immunization. A random effect model was used because of the presence of significant heterogeneity ($I^2 = 95.8\%$) (Figure 4).

Place of delivery

In this meta-analysis, women who gave birth at home were 2.7 times more likely to have incompletely immunized children (AOR = 2.7; 95%CI: 1.5–4.9) than women who delivered at health facility. We utilized random effect model for meta-analysis due to I^2 was 78.5% (Figure 5).

Antenatal care

According to this meta-analysis, women who had no antenatal care visit were 2.6 times more likely to have incompletely immunized children (AOR = 2.6; 95%CI: 1.4–5.1) than their counterparts. We analyzed by using random effect model because the value of I^2 was 39.3% (Figure 6).

Rural residency

There were a significant association between place of residency and incomplete immunization. The odds of having incompletely immunized children among rural women was 4.6 times higher (AOR = 4.6; 95%CI: 1.5–20.1) than urban women. In

Table 1. Characteristics of the included studies in the systematic review and meta-analysis for the prevalence of incomplete immunization in Africa.

Author/Year	country	Study setting	Study Design	Sample size	Prevalence	Age of target population	quality
Y.C Akinyemi/2020	Nigeria	community	cross-sectional	6059	56	12-23 month	Low-risk
Jillian and Kizito /2020	Uganda	Community	Cross-sectional	326	27.5	o-12 month	Low- risk
Baba Ceesay/un-pub	Gambia	Community	Cross-sectional	255	57.7	24-35 month	Low- risk
Yimam Ali et.al /2019	Ethiopia	Community	Cross-sectional	480	7.7	12-23 month	Low -risk
MohamedRT/un-pub	Ethiopia	Institutional	Cross-sectional	1889	70.9	12-23 month	Low-risk
Abduraheem et.al/2011	Nigeria	Community	Cross-sectional	685	36.4	0-11 month	Low-risk
Alfredo Douba/un-pub	Cote Divore	Community	Cross-sectional	2552	50.1	12-59 month	Low-risk
Atnafu. A/2020	Ethiopia	Community	Cross-sectional	603	23.1	12-36 month	Low-risk
Andre Mwanishayi Kabudi et.al/2015	Congo	Commuity	Cross-sectional	327	25.7	Under 5	Low-risk
Jani et.al/2008	Mozambique	Community	Cross-sectional	668	28.2	0-24 month	Low-risk
Adedokun et.al/2017	Nigeria	Community	Cross-sectional	5754	76.3	12-23 month	Low-risk
Landoh et.al/2016	Togo	Community	Cross-sectional	2067	36.2	12-59 month	Low-risk
Lucius Donsa/un-pub	Malawi	Community	Cross-sectional	14593	22	Under 5	Low-risk
Ismail et.al/2014	Sudan	Community	Cross-sectional	213	5.6	12-23 month	Low-risk
Ntenda PAM/2019	Malawi	Community	Cross-sectional	3111	26	12-23 month	Low-risk
Russo et.al/2015	Cameroon	Community	Cross-sectional	502	14.1	12-23 month	Low-risk
Sidiki Sangare et.al/2021	Mali	Community	Cross-sectional	547	18.5	12-23 month	Low – risk
Eze P et.al/2021	Nigeria	Community	Cross-sectional	1254	21.1	12-23 month	Low-risk
Wemakor et.al/2018	Ghana	Community	Cross-sectional	322	15.5	12-23 month	Low-risk
Ekouevi et.al/2018	Togo	Community	Cross-sectional	1261	27.7	12-23 month	Low-risk
D. Ndwandwe et.al/2020	South Africa	Community	Cross-sectional	708	40.8	12-23 month	Low- risk
Mesfin Mikael/un-pub	Ethiopia	Community	Cross-sectional	473	20	12-23 month	Low-risk
Ogundele OA/2022	Nigeria	Community	Cross-sectional	5384	69.6	12-23 month	Low-risk
Gebeyaw Birhan/un-pub	Ethiopia	Community	Cross-sectional	542	25.3	12-23 month	Low-risk
Zida Compaore et.al/2019	Togo	Institutional	Cross-sectional	797	20.7	12-59 month	Low-risk
Enyew EB/2022	Ethiopia	Community	Cross-sectional	1911	49	12-23 month	Low-risk

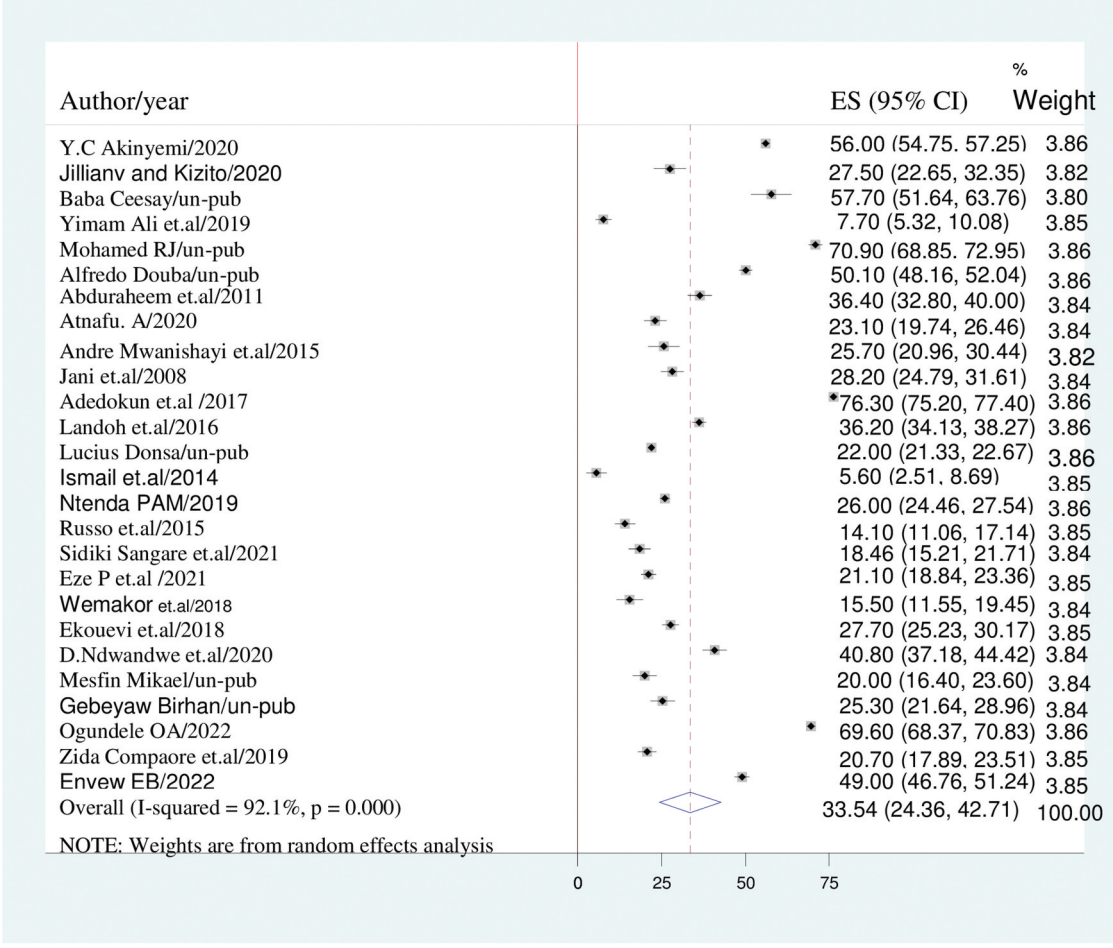

Figure 2. The forest plot of incomplete immunization with the diamond represents the summary point estimate (35.5%) and the horizontal extremity of the diamond is the confidence interval at 95% (24.4–42.7). the standard error is plotted at the y-axis and the effect size plotted at x-axis. The squares represent the effect estimate of the individual studies and the horizontal lines indicate the confidence interval; the dimension of the square reflects the weight of each study.

Table 2. The overall estimated of incomplete immunization in Africa, 95%CI and heterogeneity estimate with a p-value for sub-group analysis.

Variables	Characteristics	Pooled estimate of incomplete immunization 95%CI	I^2(*P*-value)
Sub-region	Western Africa	42.5% (28.2–52.8)	84.2 (.012)
	Eastern Africa	27.8% (17.3–38.3)	78.7% (.000)
	Central Africa	19.8% (8.4–31. 1)	93.9%(.001)
	South Africa	40.8% (37.3–44.3)	0.0%(.000)
nSample size	> 1000	45.9%(31.5–60.4)	91.7%(.006)
	< 1000	24.3%(18.4–30.2)	93.2%(.000)
Publication	Published	41% (21.6–60.3)	79.3%(.000)
	Unpublished	31.3% (20.5–42.1)	80.9%(.031)
Age of children	Under 2 year	26.2%(18.5–33.9)	95.7%(.006)
	Under 3 year	33.5%(22.2–44.8)	85.7%(.000)
	Under 5 year	43.5%(23.6–63.5)	68.8%(.000)

Table 3. Meta-regression analysis of factors affecting between-study heterogeneity.

Heterogeneity source	Coefficient's	Standard error	*p*-value
Sample size	3.6	.3	.000
Age of target population	4.1	.5	.000

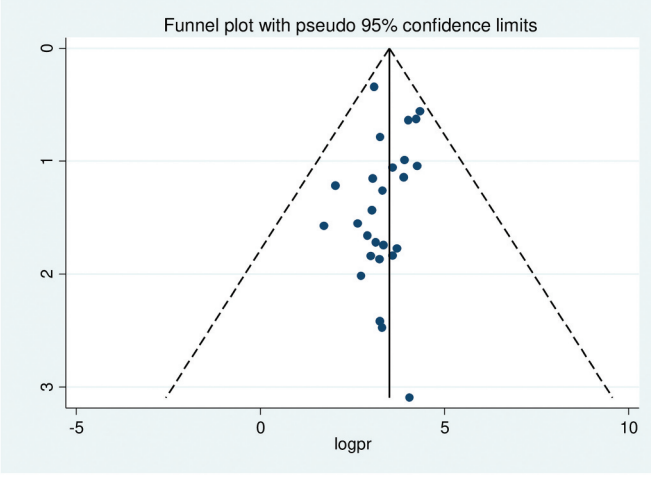

Figure 3. Funnel plot showing symmetrical distribution of studies indicating absence of publication bias. The Y-axis is the standard error and the X-axis is the study result or effect size. The dotted diagonal line of the funnel is the 95% confidence interval and the vertical. The vertical line denotes the no effect. The square represents the effect size of each study and the line across the square is confidence interval of each study.

spite of the presence of significant heterogeneity ($I^2 = 96.7\%$), We used random effect model (Figure 7).

Maternal illiteracy

In our study, maternal educational profile affects the incomplete immunization. Mothers who had no formal education were 1.6 times more likely to have incompletely immunized children (AOR = 1.7:95%CI: 1.3–2.0) compared to mothers who had high school and above education. Since there was substantial heterogeneity ($I^2 = 67.1\%$), We used the random effect model (Figure 8).

Table 4. The pooled prevalence of incomplete immunization in Africa when one study omitted from the analysis a step at a time.

Study omitted	Pooled estimate	95% Confidence interval
Y.C Akinyemi	32.6	23.0–42.3
Jillianv and Kizito	33.8	24.4–43.2
Baba Ceesay	32.6	23.2–41.9
Yimam Ali et.al	34.6	25.3–43.8
Mohamed RJ	32.0	22.8–41.3
Alfredo Douba	32.9	23.3–42.4
Abduraheem et.al	33.4	24.0–42.8
Atnafu. A	34	24.6–43.3
Andre Mwanishayi Kabudi et.al	33.9	24.5–43.2
Jani et.al	33.8	24.3–43.2
Adedokun et.al	31.8	23.7–40
Landoh et.al	33.4	23.9–43
Lucius Donsa	34.0	24.7–43.3
Ismail et.al	34.7	25.4–43.9
Ntenda PAM	33.8	24.2–43.4
Russo et.al	34.3	25.0–43.7
Sidiki Sangare et.al	34.1	24.8–43.5
Eze P et.al	34.0	24.6–43.5
Wemakor et.al	34.3	24.9–43.6
Ekouevi et.al	33.8	24.3–43.2
D.Ndwandwe et.al	33.2	23.8–42.7
Mesfin Mikael	34.1	24.7–43.5
Gebeyaw Birhan	33.9	24.5–43.3
Ogundele OA	32.1	23.1–41.0
Zida Compaore et.al	34.1	24.71–43.5
Enyew EB	32.9	23.4–42.4

Maternal knowledge

In this analysis, women who had poor knowledge of child vaccination were 2.4 times more likely to have incompletely immunized children (AOR = 2.4; 95%CI: 1.3–4.6) than their counterparts (Figure 9). We assumed a random effect model for the analysis due to the presence of heterogeneity ($I^2 = 70.5\%$).

Discussion

Incomplete immunization and its determinants among children in Africa were the targets of this systematic review and meta-analysis. The key findings were that the national pooled estimate of incomplete immunization and incomplete immunization were significantly associated with lack of knowledge, place of delivery, no antenatal care visit, rural residency and maternal illiteracy. Consequently, the pooled prevalence of incomplete immunization in this study was 35.5% (95% CI: 24.4, 42.7), which is consistent with research from India (32%),[58] Aurangabad (37%),[59] the global coverage of vaccinations in 2017 (30%),[60] and Ethiopia's meta-analysis study (30%).[61]

The pooled prevalence of incomplete immunization found in the current study is higher than those studies done in Brazil (10.9%),[62] Australia (20%)[63] and Myanmar (25.8%).[64] In contrast, the result of the current study is lower than research conducted in Indonesia (40%)[65] and Pakistan (46%).[66] The disparity may result from differences in the time gaps between the studies, infrastructure of the health system, and sociocultural factors. For example, countries with huge financial power and better health system structure have lowest rate of incomplete immunization.

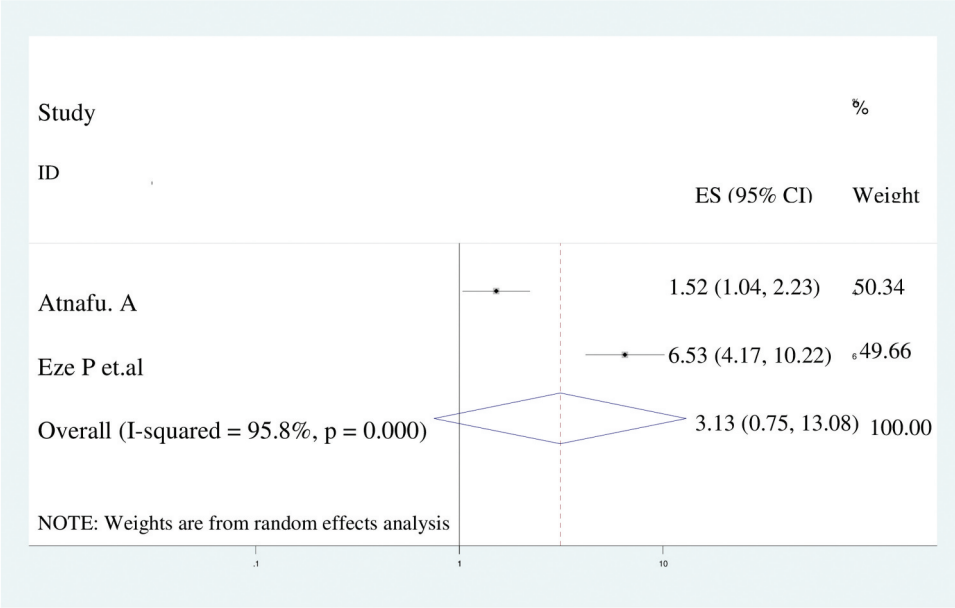

Figure 4. The forest plot of pooled odds ratios showed no association between postnatal care visit and incomplete immunization with the height of the diamond is the overall effect size (3.1) while the width is the confidence interval at 95% (0.8–13.1). The y-axis shows the standard error of each study while the x-axis the estimate of effect size of the each study. The vertical line denotes the no effect. The square represents the effect size of each study and the line across the square is confidence interval of each study.

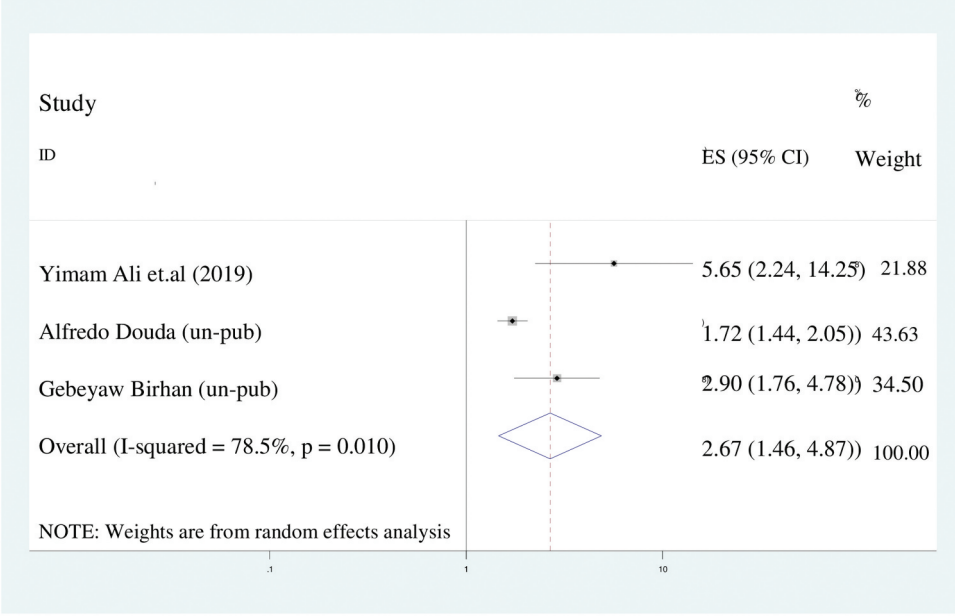

Figure 5. The forest plot of pooled odds ratios showed the association between place of delivery and incomplete immunization with the height of the diamond is the overall effect size (2.7) while the width is the confidence interval at 95% (1.5–4.9). The y-axis shows the standard error of each study while the x-axis the estimate of effect size of the each study. The vertical line denotes the no effect. The square represents the effect size of each study and the line across the square is confidence interval of each study.

The age of the target population, sample size, publication, and study sub-region were taken into account when performing sub-group analysis. As a result, West Africa and Central Africa had the highest (42.5%) and lowest (19.8%) prevalence of incomplete immunization among children, respectively. Children under the age of 5 had the highest prevalence of incomplete immunization (43.6%) while children under the age of 2 had the lowest prevalence (26.2%). The variation might be because of the difference in sample size and number of included studies in this meta-analysis. For example, twelve studies were included in West Africa whereas two studies were used in Central Africa. For published studies and unpublished studies, the prevalence of incomplete immunization was 41% and 31.3%, respectively. This might be because studies with statistically significant results aren't inflated and effect size estimates are less precise than when gray literature is included in the meta-analysis.

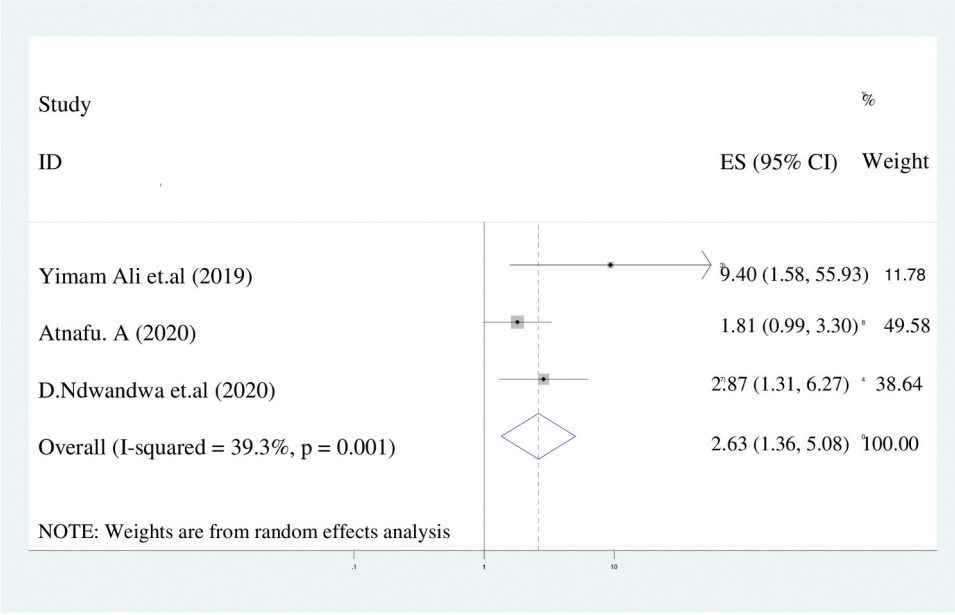

Figure 6. The forest plot of pooled odds ratios showed the association between lack of antenatal care and incomplete immunization with the height of the diamond is the overall effect size (2.6) while the width is the confidence interval at 95% (1.4–5.1). The y-axis shows the standard error of each study while the x-axis the estimate of effect size of the each study. The vertical line denotes the no effect. The square represents the effect size of each study and the line across the square is confidence interval of each study.

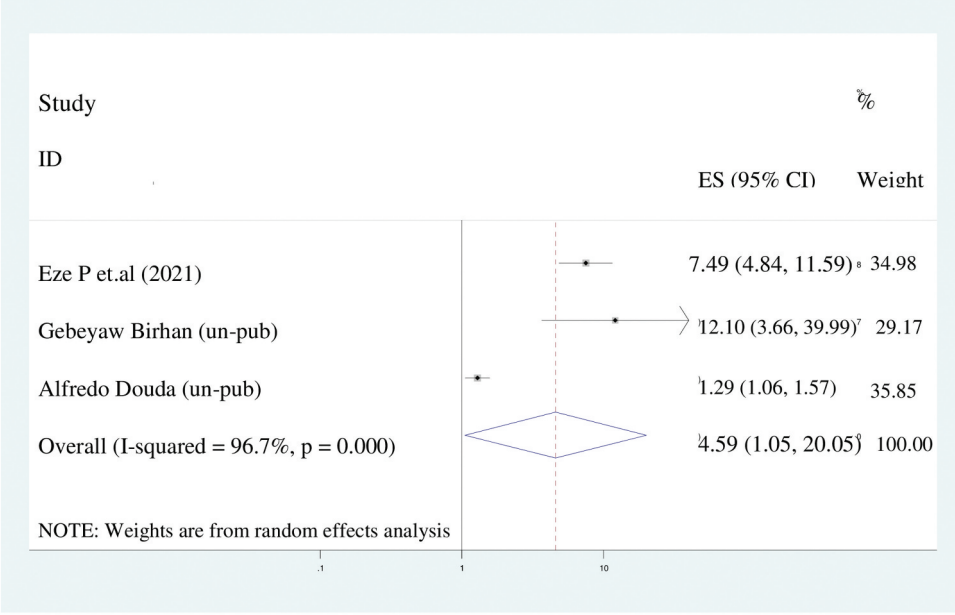

Figure 7. The forest plot of pooled odds ratios showed the association between rural residence and incomplete immunization with the height of the diamond is the overall effect size (4.6) while the width is the confidence interval at 95% (1.1–20.1). The y-axis shows the standard error of each study while the x-axis the estimate of effect size of the each study. The vertical line denotes the no effect. The square represents the effect size of each study and the line across the square is confidence interval of each study.

In this meta-analysis, place of delivery, no antenatal care visit, poor maternal knowledge of immunization, rural residency and maternal illiteracy were factors significantly associated with incomplete vaccination. Compared to mothers who gave birth in a healthcare facility, mothers who gave birth at home were 2.7 times more likely to have children who had not received all recommended vaccinations. This result is congruent with research from the Ethiopia,[61] Pakistan,[67] Philippines,[68] a global systematic review,[69] as well as studies from low- and middle-income nations.[70] The cause may be that women who gave birth at home did not receive enough child health education and counseling, which has a negative impact on the immunization travel schedule completion

The current study found a positive association between place of residency and incomplete immunization. Incomplete immunization rates were 4.6 times higher among mothers who resided in rural areas. This is in line with a study conducted in

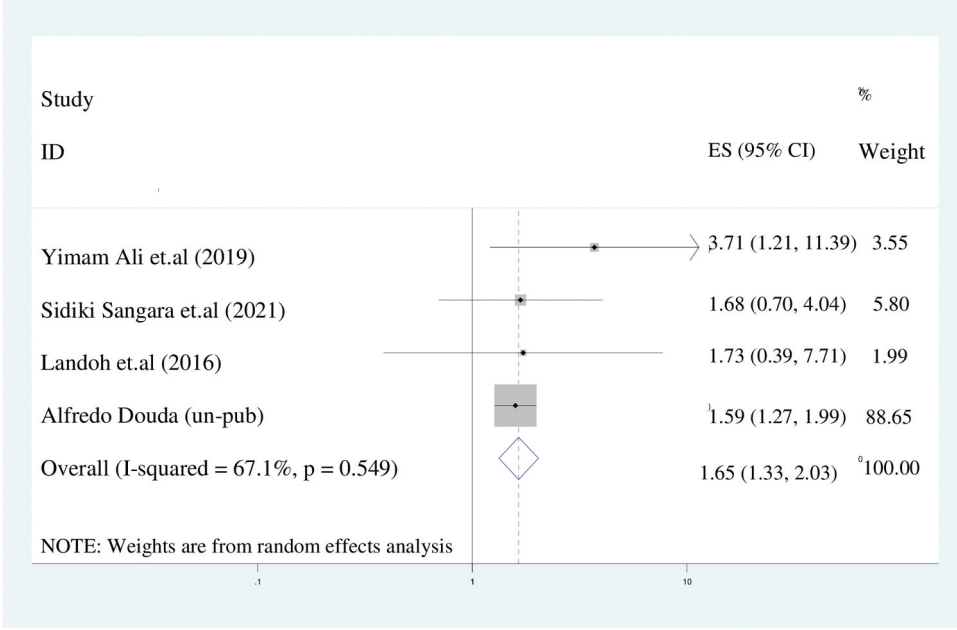

Figure 8. The forest plot of pooled odds ratios showed the association between maternal illiteracy and incomplete immunization with the height of the diamond is the overall effect size (1.7) while the width is the confidence interval at 95% (1.3–2). The y-axis shows the standard error of each study while the x-axis the estimate of effect size of the each study. The vertical line denotes the no effect. The square represents the effect size of each study and the line across the square is confidence interval of each study.

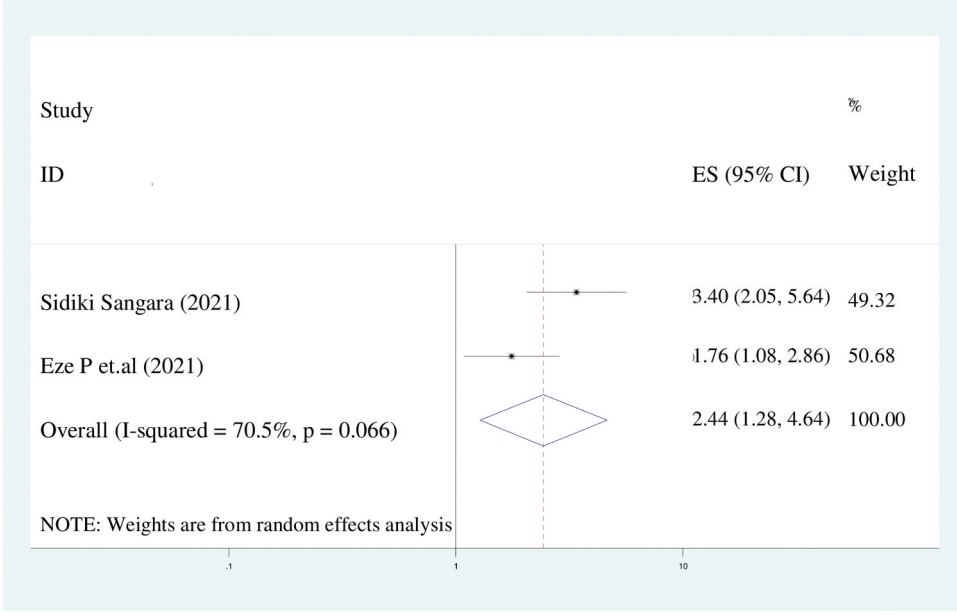

Figure 9. The forest plot of pooled odds ratios showed the association between lack of knowledge of immunization and incomplete immunization with the height of the diamond is the overall effect size (2.4) while the width is the confidence interval at 95% (1.3–4.6). The y-axis shows the standard error of each study while the x-axis the estimate of effect size of the each study. The vertical line denotes the no effect. The square represents the effect size of each study and the line across the square is confidence interval of each study.

Ethiopia that involved a systematic review and meta-analysis.[61] The explanation might come from the fact that rural women lack better knowledge of the value of immunization. However, studies conducted in Sub-Saharan Africa and India found that urban women were more likely than rural women to have children who had only had a partial immunization. This result is in contradiction to those findings.[58,71] The difference could be caused by the existence of impoverished children who live in urban slums with little access to vaccination programs.

Mothers who did not receive antenatal care were 2.6 times more likely than women who did to have children who were just partially vaccinated. This outcome is consistent with research carried out in Ethiopia.[61] This is because prenatal care gives opportunities for mother and healthcare professional to communicate about the advantages of childhood immunization, which motivates parents to thoroughly immunize their children.

Women with no education had a 1.6 times greater chance of their children receiving only a partial immunization than those

with secondary education or higher. The finding is in agreement with research from India,[58] Ethiopia,[61] Indonesia,[65] Pakistan,[66,67] a systematic review of low- and middle-income countries,[70] and studies in Sub-Saharan Africa[71] This might be due to the fact that uneducated women are not aware of the value of immunization, are resistant to change and stiff to new ideas, and find it difficult to make decisions on their health, including immunization.

Women who were less knowledgeable about child immunization were 4.6 times less likely than their counterparts to have provided their children the vaccines. This is supported by the fact that vaccinations and understanding about children's health have gained widespread acceptance.[72]

To handle a large variance that occurred in between-study heterogeneity, a random-effect model was used in this research. We conducted leave-one-out sensitivity, and the results reveal that no single study had a substantial effect on the overall prevalence of incomplete immunization. We assessed the possible variability source via sub-group analysis using the study sub-region, sample size, publication and age of children. The high heterogeneity might be due to differences in the sample populations, paper qualities, or socio-cultural, ethnic, and regional differences.

Conclusion

In conclusion, there was a high rate of incomplete immunization in Africa (35.5%). Additionally, the prevalence of incomplete immunization differed by study sub-region, sample size, publication, and child age. Home birth, no antenatal visits, lack of immunization knowledge, maternal illiteracy, and rural residency were factors for incomplete immunization. The prevalence of incomplete immunization was highest in the Western region of Africa. It has been recommended that women have access to maternal education and maternal health services, such as prenatal care visits and institutional delivery services. To reach rural areas, it's also a good idea to organize a sizable campaign and engage the local population.

Strength and limitation of study

This study has some limitations. First, articles were restricted to only being published in the English language. Second, all of the included studies were cross-sectional, which might affect the outcome variable because of other confounding factors.

This research has some strength. First, compressive electronic online international searching engines were used. Second, our review incorporated gray literature as part of the primary studies.

Third, prevalence incomplete immunization predictors were discovered.

Authors' contributions

NAG conceptualized the study: NAG and KDT contributed during data extraction and analysis: NAG and KAG wrote result interpretation: NAG and KDT, Prepared the first draft: NAG, KDT, GAA, MMG and BAA contributed during the conceptualization and interpretation of results and substantial revision: NAG, KAG, KDT, GAA, MMG and BAA. Revised and finalized the final draft manuscript. All the authors read and approved the final version of the manuscript.

Authors' information

NAG: School of Midwifery, College of Medicine and Health Sciences, Wolaita Sodo University, Sodo, Ethiopia. KAG: School of Midwifery, College of Medicine and Health Sciences, Wolaita Sodo University, Sodo, Ethiopia. KDT: Department of Comprehensive Nursing, College of Medicine and Health Science, Wollo University, Dessie, Ethiopia. GAA: Department of Reproductive Healths, College of Medicine and Health Science, Wolaita Sodo University, Sodo, Ethiopia. BAA: Department of Anesthesia, College of Medicine and Health Science, Gondar University, Gondar, Ethiopia. MMG: Department of Midwifery, College of Medicine and Health Science, Wolaita Sodo University, Sodo, Ethiopia.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The authors received no specific funding for this work.

Data Availability statement

All relevant data are within the Manuscript and its Supporting Information files.

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