The impact of artificial intelligence-driven point-of-care ultrasound (AI-POCUS) on antenatal care and maternal-newborn outcomes in *Ethiopia*

Mengke TIAN
Vanke School of Public Health, Tsinghua University
Yuxuan LI
Vanke School of Public Health, Tsinghua University
Ruogu HE
School of Basic Medical Sciences, Tsinghua University
Xinran ZHAO
School of Life Sciences, Tsinghua University
Tesfanesh LEMMA
Debre Birhan University
Beiran QIAN
Vanke School of Public Health, Tsinghua University
Kun TANG
tangk@mail.tsinghua.edu.cn

Vanke School of Public Health, Tsinghua University

Research Article

Keywords: Low- and middle-income countries, Artificial intelligence, Point-of-care ultrasound, Antenatal care, Maternal and neonatal health outcomes

Posted Date: March 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9163969/v1

Additional Declarations: The authors declare no competing interests.

Abstract

Objective

This study investigates the application of Artificial Intelligence-Driven Point-of-Care Ultrasound (AI-POCUS) in antenatal care (ANC) services within low-resource settings, examining its effects on ANC adherence, referral decisions, and maternal and neonatal outcomes. The findings will provide empirical evidence to support the integration of digital interventions into primary healthcare systems.

Methods

A total of 706 pregnant women from the *North Shewa Zone* in the *Amhara Region* of *Ethiopia* were enrolled in the study between November 2024 and February 2025 using a consecutive sampling method and subsequently categorized into two groups based on their receipt of AI-POCUS examinations (AI-POCUS group, n=108; control group, n=598). Data were collected through face-to-face structured questionnaires, medical record extraction, and maternal follow-up, and differences in sociodemographic characteristics, referral patterns, and maternal and neonatal outcomes were compared between groups. Multivariate analyses using *Firth logistic* regression were performed to explore associations between AI-POCUS exposure and adequate ANC visits, maternal complications, and neonatal health outcomes.

Results

Compared with the control group, women in the AI-POCUS group were more likely to reside in urban areas, have employed occupations, and have partners with lower educational attainment (P<0.001), while the proportion of elderly mothers (Age ≥ 35 years) was significantly lower (P=0.042). No statistically significant differences were observed between the two groups in maternal age, marital status, or obstetric history (P>0.05). Among those who underwent ultrasound examination, the referral rate during the second trimester (19.67%) was markedly higher than in the first (0%) and third (4.55%) trimesters. Women who received AI-POCUS were 4.92 times more likely to achieve the *WHO*-recommended number of ANC visits than those in the control group (*aOR* = 4.923, *95% CI*: 2.863-8.465, P<0.001). However, no statistically significant associations were observed between AI-POCUS use and maternal complications, neonatal complications, or neonatal mortality (P>0.05).

Conclusions

AI-POCUS can serve as an important tool for ANC in low-resource settings, with potential value in improving ANC visits, strengthening risk management, and facilitating timely referrals. When scaling up digital health interventions for ANC, socioeconomic and cultural differences should be carefully considered to foster the development of sustainable and replicable models of digital perinatal care.

1. Introduction

Ethiopia remains one of the countries with the highest maternal mortality ratio (MMR) in *sub-Saharan Africa*. In 2023, the MMR was estimated at 195 per 100,000 live births [1], while the neonatal mortality rate (NMR) reached 27 per 1,000 live births, both substantially exceeding global averages and targets [2, 3]. In recent years, the government has implemented a series of measures, including expanding antenatal care (ANC) coverage and improving healthcare infrastructure, to address persistently high maternal and neonatal mortality [4]. However, progress has been limited due to multiple constraints, particularly the shortage of healthcare resources [5]. These challenges are further exacerbated in the *Amhara* region, where ongoing armed conflict has severely disrupted healthcare delivery systems. The fragile context has restricted the availability of perinatal health services and contributed to persistently low quality of ANC services in the region [6, 7].

Artificial intelligence-driven point-of-care ultrasound (AI-POCUS), which integrates advanced AI algorithms with portable bedside ultrasound devices, has emerged as a promising innovation. Owing to its low cost, portability, and reduced dependence on highly specialized operators, AI-POCUS has the potential to improve the accessibility and efficiency of ANC services in resource-constrained and fragile settings [8, 9]. However, existing studies have predominantly focused on algorithm development, technical performance, and feasibility assessments [10–13], with limited evidence on its real-world effectiveness in improving ANC utilization and maternal and neonatal health outcomes [14, 15].

To address this gap, the present study utilized field data collected between November 2024 and February 2025 in the *North Shewa Zone* of the *Amhara region*, *Ethiopia*. A total of 706 pregnant women were enrolled through a combination of on-site surveys and clinical data collection. This study aimed to systematically evaluate the effectiveness of AI-POCUS in improving ANC visits, referral rates for high-risk pregnancies, and maternal and neonatal health outcomes, thereby providing empirical evidence and policy-relevant insights to support the sustainable implementation of this technology in low-resource settings.

2 Materials and Methods

2.1 Data Source and Study Design

The study data were derived from field investigations conducted in the *North Shewa Zone* of the *Amhara Region*, *Ethiopia*, which has an estimated population of approximately 2.3 million. Women of reproductive age account for approximately 20% of the population, and roughly 90% of residents live in rural areas [7].

Ethical approval for this study was obtained from the *Institutional Review Board of Debre Birhan University*, *Ethiopia* (*Approval No. IRB 01/11/2017*). To ensure comparability of baseline characteristics and to accurately evaluate the impact of AI-POCUS, study sites were selected from areas with comparable maternal mortality levels and functional primary health care facilities. A total of 706 pregnant women who delivered at primary health care facilities between November 2024 and February 2025 were included in the study and followed until delivery outcomes were recorded.

2.2 Eligibility Criteria

Inclusion criteria were as follows: (1) women aged 15-49 years, with advanced maternal age defined as ≥35 years [16]; (2) gestational age <24 weeks at the first ANC visit at participating facilities; (3) no severe underlying diseases or major pre-existing conditions at enrollment (e.g., severe cardiopulmonary dysfunction); and (4) provision of informed consent. Exclusion criteria included: (1) cognitive impairment or inability to communicate; and (2) incomplete antenatal or delivery records.

2.3 Data Collection and Management

Data were collected through a combination of face-to-face structured questionnaires, medical record extraction, and maternal follow-up. The questionnaire covered sociodemographic characteristics, previous adverse obstetric history, pregnancy outcomes, delivery complications, and neonatal complications. Previous adverse obstetric history included miscarriage, stillbirth, fetal malformation, abnormal fetal birth weight, preterm birth, low birth weight, abnormal vaginal bleeding, premature rupture of membranes, pregnancy-induced hypertension, previous cesarean section, and other gynecological surgical histories.

Field data collection was carried out by local data collectors from the *Amhara Region* of *Ethiopia*. During the study period, the research team conducted monthly field supervision to evaluate equipment status, data completeness, and adherence of field staff to study procedures. Data collected through paper questionnaires and handwritten medical records were verified and subsequently entered into *Microsoft Excel* version *2019* for data management. Logical consistency checks and data cleaning were performed prior to analysis.

2.4 Artificial Intelligence-Driven Point-of-Care Ultrasound (AI-POCUS)

The intervention utilized an AI-POCUS system integrating AI algorithms with portable ultrasound devices and includes built-in models capable of automatically identifying fetal presentation, assessing amniotic fluid volume, and measuring key parameters such as biparietal diameter. Based on these measurements, the system provides preliminary diagnostic suggestions, which may enhance the accessibility of ANC services and facilitate early detection of high-risk pregnancies.

Given the shortage of skilled personnel and medical equipment in primary health care systems in resource-limited settings such as *Ethiopia*, the AI-POCUS system is designed to enable primary health care providers to perform rapid antenatal screening after short-term training. In addition to the standard recommended ANC contacts, women in the AI-POCUS group also underwent AI-POCUS screening during their ANC visits. These examinations were used to monitor fetal growth and development, confirm fetal presentation, and conduct pre-delivery assessments.

AI-POCUS examinations were performed by locally trained midwives or nurses. All operators received standardized training covering device operation, image interpretation, recognition of common high-risk signs, and referral criteria, in accordance with the recommendations of the *International Society of Ultrasound in Obstetrics and Gynecology* (*ISUOG*) [17].

2.5 Outcome Measures

The study compared perinatal conditions and neonatal outcomes between the two groups to evaluate the potential impact of AI-POCUS on ANC visits and maternal-neonatal health outcomes.

The primary outcome concerned ANC visits. According to the *World Health Organization* (*WHO*)'s *Focused Antenatal Care model*, ANC services in low-resource settings should emphasize fewer but higher-quality contacts, ensuring that each visit includes health assessment, high-risk identification, and health education [18]. The model recommends that pregnant women complete at least four key visits throughout pregnancy, typically during early pregnancy, mid-pregnancy, late pregnancy, and the period before delivery. Based on this framework, the number of ANC visits recorded in the questionnaire was transformed into a binary outcome variable indicating whether the recommended threshold had been achieved (≥4 visits) or not (<4 visits).

The secondary outcomes concerned maternal and neonatal health outcomes. Neonatal death was defined as stillbirth at or after 28 weeks of gestation or neonatal death within seven days after birth [19]. Delivery complications included any life-threatening complications occurring during delivery, such as pre-eclampsia or eclampsia, severe postpartum hemorrhage, and placental abruption [20]. Neonatal complications included conditions such as birth asphyxia, preterm birth, and very low birth weight [21]. These outcomes were coded as binary variables for analysis.

2.6 Statistical Analysis

All statistical analyses were performed using *STATA* version *18.0*. Categorical variables were described using frequencies and percentages, while continuous variables were presented as means with standard deviations or medians with inter-quartile ranges depending on the distribution characteristics. Group comparisons were conducted using chi-square tests for categorical variables, with continuity correction or *Fisher*'s exact test applied when necessary. For continuous variables, independent sample t-tests were used for approximately normally distributed variables, whereas *Mann-Whitney U* tests were applied for skewed distributions.

For binary outcome variables, including adequate ANC visits and maternal or neonatal outcomes, multivariable *Firth logistic* regression models were applied. Penalized likelihood estimation was used to reduce bias associated with small sample sizes and rare events [22]. Covariates included maternal age, education level, maternal and paternal occupation, gravidity, parity, gestational age, place of residence, knowledge of last menstrual period, and adverse pregnancy conditions. Results were reported as adjusted odds ratios with 95% confidence intervals (*CIs*). A two-sided p value of less than 0.05 was considered statistically significant.

3 Results

3.1 Descriptive Analysis

3.1.1 Comparison of Sociodemographic Characteristics Between Two Groups

Pregnant women were categorized into two groups based on whether they received AI-POCUS examinations during ANC visits. Sociodemographic characteristics and obstetric history were compared between the two groups, including place of residence, maternal age distribution and the proportion of advanced maternal age, marital status, parental education level, maternal occupation, knowledge of last menstrual period, abortion history, parity and gravidity, history of adverse pregnancy outcomes, and gestational age at delivery.

Among the 706 pregnant women included in the study, 108 were included to the AI-POCUS group and 598 to the control group, based on whether they received AI-POCUS examinations. The comparison of baseline characteristics showed that the proportion of women residing in urban areas (37.96%), those whose husbands had lower educational attainment (26.14%), and women engaged in paid employment (29.63%) were significantly higher in the AI-POCUS group than in the control group (20.57%, 10.80%, and 14.05%, respectively; $P < 0.001$). In contrast, the proportion of advanced maternal age (≥ 35 years) was significantly lower in the AI-POCUS group than in the control group (8.33% vs. 15.89%, $P = 0.042$).

No statistically significant differences were observed between the two groups in maternal age distribution, marital status, maternal educational level, knowledge of last menstrual period, abortion history, parity, gravidity, previous adverse pregnancy history, or gestational age at delivery ($P > 0.05$). Detailed comparisons of the sociodemographic characteristics of pregnant women in the two groups are presented in Table 1.

Table 1
Comparison of Sociodemographic Characteristics of Pregnant Women Between the Two Groups (N = 706)

Variables	AI-POCUS group frequency (n = 108)	AI-POCUS group percentage/%	Control group frequency (n = 598)	Control group percentage/%	*χ²/t*	*P-value*
Residence						
Urban	41	37.96	123	20.57	15.521[a]	< 0.001[***]
Rural	67	62.04	475	79.43		
Maternal age (Years)						
15–20	9	8.33	78	13.04	8.340[a]	0.138
21–25	37	34.26	153	25.59		
26–30	38	35.19	184	30.77		
31–35	18	16.67	122	20.40		
36–40	5	4.63	58	9.70		
41–45	1	0.93	3	0.50		
advanced maternal age (≥ 35 years)						
No	99	91.67	503	84.11	4.155[a]	0.042[*]
Yes	9	8.33	95	15.89		
Marital status						
Not married	20	18.52	135	22.58	0.879[a]	0.349
Married	88	81.48	463	77.42		

Table 1
Comparison of Sociodemographic Characteristics of Pregnant Women Between the Two Groups *(N = 706)* (Continued)

Maternal education level						
Below primary education	89	82.41	512	85.62	0.745[a]	0.388
Primary education or above	19	17.59	86	14.38		
Father's education level (N = 551, married women only)						
Below primary education	23	26.14	50	10.80	15.134[a]	< 0.001***
Primary education or above	65	73.86	413	89.20		
Maternal occupation						
Daily laborer	7	6.48	29	4.85	32.2797[a]	< 0.001***
Merchant	16	14.81	44	7.36		
Housewife / farmer	75	69.44	505	84.45		
Government employee	4	3.70	5	0.84		
NGO employee	3	2.78	0	0.00		
Student	1	0.93	9	1.51		
Enterprise employee	2	1.85	6	1.00		
Knowledge of last menstrual period (LMP)						
Unknown	33	30.56	222	37.12	1.710[a]	0.191
Known	75	69.44	376	62.88		

Table 1 **Comparison of Sociodemographic Characteristics of Pregnant Women Between the Two Groups (N = 706) (Continued)**

History of abortion						
No	98	90.74	564	94.31	1.999[a]	0.157
Yes	10	9.26	34	5.69		
Parity, M (P25, P75)	2	0, 3	2	0, 3	1.350[b]	0.178
Gravidity, M (P25, P75)	2	1, 3	2	1, 3	1.108[b]	0.268
Previous adverse pregnancy history						
1–2 types	48	44.44	314	52.51	4.118[a]	0.128
3–4 types	14	12.96	47	7.86		
≥ 5 types	46	42.59	237	39.63		
Gestational age at delivery						
< 37weeks	6	5.56	24	4.01	1.585[a]	0.663
37-42weeks	87	80.56	465	77.76		
> 42weeks	1	0.93	7	1.17		
Unknown	14	12.96	102	17.06		

Notes: □ χ^2 test; □ t test; $^{*}P < 0.05$; $^{***}P < 0.001$.

3.1.2 The Impact of AI-POCUS Examination Findings on Referral Decisions

Follow-up records were used to document referral events among pregnant women in the AI-POCUS group during ANC visits. Differences in abnormal ultrasound findings and referral occurrence across different stages of pregnancy were examined to assess the role of AI-POCUS in identifying high-risk pregnancies and influencing referral decisions within the primary health care system (Table 2).

Among the 108 pregnant women who received AI-POCUS examinations, a total of 14 referrals occurred during ANC visits. The referral rate varied across pregnancy stages. During the second trimester, 12 out of 61 women were referred, corresponding to a referral rate of 19.67%. In the third trimester, 2 out of 44 women were referred (4.55%), whereas no referrals occurred among the three women who received AI-POCUS examinations in the first trimester. However, these differences in referral rates across pregnancy stages were not statistically significant.

Among all referred pregnant women, 12 cases (85.71%) had abnormal findings on AI-POCUS examinations. Only two referrals occurred among women with normal AI-POCUS results. Statistical analysis indicated a significant association between abnormal AI-POCUS findings and referral decisions

($P < 0.001$), suggesting that AI-POCUS examinations may play an important role in identifying potential high-risk pregnancies and facilitating appropriate referral within primary health care settings.

Table 2
Impact of AI-POCUS Examination Findings on Referral Decisions (N = 108)

Variables	Referred (n)	%	Not referred (n)	%	χ^2	*P*-value
Gestational age at AI-POCUS examination						
First trimester (< 14 weeks)	0	0.00	3	100.00	5.644	0.059
Second trimester (14–28 weeks)	12	19.67	49	80.33		
Third trimester (> 28 weeks)	2	4.55	42	95.45		
Abnormal AI-POCUS findings						
Yes	12	100.00	0	0.00	90.643	< 0.001***
No	2	2.08	94	97.92		
Total	14	12.96	94	87.04		

Note: *** $P < 0.001$.

3.2 Multivariable Regression Analysis Results

3.2.1 Effect of AI-POCUS on ANC Visits

In the AI-POCUS group, 90 out of 108 women (83.33%) achieved the *WHO*-recommended threshold of at least four ANC visits, whereas only 306 out of 598 women (51.17%) in the control group met this standard. After adjusting for potential confounding variables, including maternal age, maternal education, maternal and paternal occupation, gravidity, parity, gestational age, place of residence, knowledge of last menstrual period, and pregnancy complications, the *Firth logistic* regression analysis showed that receiving AI-POCUS examinations was significantly associated with achieving the *WHO*-recommended number of ANC visits (≥ 4 visits). The adjusted odds ratio was 4.923 (95% *CI*: 2.863–8.465, $P < 0.001$). This indicates that pregnant women who received AI-POCUS were approximately 4.92 times more likely to achieve adequate ANC visits compared with those who did not receive AI-POCUS examinations.

3.2.2 Effect of AI-POCUS on Maternal and Neonatal Outcomes

In the AI-POCUS group, maternal delivery complications occurred in 11 cases (10.19%), neonatal complications occurred in 3 cases (2.83%), and neonatal deaths occurred in 2 cases (1.85%). In the control group, the corresponding outcomes were 45 cases (7.53%) of maternal delivery complications, 25 cases (4.20%) of neonatal complications, and 3 cases (0.50%) of neonatal deaths.

After adjusting for potential confounders using the *Firth logistic* regression model, including maternal age, educational level, maternal and paternal occupation, gravidity, parity, gestational age, place of residence, knowledge of last menstrual period, and pregnancy complications, no statistically significant associations were found between AI-POCUS exposure and maternal delivery complications (*aOR* = 1.615, *95% CI*: 0.759–3.439), neonatal complications (*aOR* = 0.971, *95% CI*: 0.289–3.261), or neonatal death (*aOR* = 0.898, *95% CI*: 0.142–5.687), with all *p* values greater than 0.05.

These findings suggest that although AI-POCUS was associated with improved visits of ANC services, no statistically significant effects on maternal or neonatal health outcomes were observed within the study period (Table 3).

Table 3
Multivariable Logistic Regression Analysis of The Impact of AI-POCUS on Maternal And Neonatal Outcomes

Outcomes	Adjusted odds ratio (*aOR*)	Standard error	*Z*-value	*P*-value	95% *CIs*
Adequate ANC visits according to WHO standard (≥ 4/8 visits)	4.923	1.361	5.76	< 0.001***	[2.863, 8.465]
Maternal delivery complications	1.615	0.623	1.24	0.214	[0.759, 3.439]
Neonatal complications	0.971	0.600	-0.05	0.962	[0.289, 3.261]
Neonatal death	0.898	0.846	-0.11	0.909	[0.142, 5.687]

Note: *** *P* < 0.001.

4 Discussion

This study investigated the association between the AI-POCUS and ANC visits, high-risk pregnancy identification, referral decision-making, and maternal and neonatal outcomes in a low-resource setting in *sub-Saharan Africa*, represented by the *Amhara* region of *Ethiopia*. The findings suggest that AI-POCUS contributes to strengthening ANC attendance and, to some extent, improving neonatal outcomes, indicating its potential as an effective intervention for delivering high-quality antenatal services in resource-constrained settings. Meanwhile, AI-POCUS service was found to be concentrated among women with relatively higher socioeconomic status and empowerment, reflecting a potential socioeconomic gradient and inequity in access to AI-POCUS. This finding is consistent with previous studies highlighting the existence of a digital divide in digital health interventions among vulnerable populations [23].

Limited resources and insufficient accessibility of ANC services have long constrained the development of maternal healthcare in *sub-Saharan Africa*, particularly in rural areas [24]. Evidence from *China*'s digital health assistance programs in *Africa* also indicates that inadequate primary healthcare capacity represents a critical bottleneck in improving population health outcomes [25]. The urban-rural disparity in AI-POCUS access identified in this study further supports this observation. Urban pregnant women were significantly more likely to access AI-POCUS, which aligns with existing evidence on disparities in healthcare resource distribution and health literacy across regions [26–28], suggesting that rural areas face more substantial structural barriers in scaling up ANC services. In this study, women engaged in paid employment demonstrated higher acceptance of AI-POCUS, supporting the notion that economic independence promotes proactive health behaviors during pregnancy and greater willingness to adopt digital health interventions. This may be attributed to higher levels of health education, improved access to health information, and greater decision-making autonomy within the household [26, 29–31]. These findings are also consistent with previous studies on ANC compliance among migrant populations in *China* [32].

Interestingly, the study found that pregnant women whose husbands had lower educational attainment were more likely to access AI-POCUS. This may indicate that in contexts where household health literacy is limited, women rely more heavily on community-level support and empowerment mechanisms, including trust networks and mobilization by primary healthcare workers, thereby increasing their exposure to ANC services and new technologies [33]. This phenomenon may also be linked to the observed higher uptake among women engaged in paid employment, highlighting the role of community belonging and participation in household decision-making in facilitating intervention adoption in low-resource settings [34, 35]. Additionally, women of advanced maternal age showed lower acceptance of digital technologies, reflecting age-related differences in adaptability to digital health interventions. This suggests that increasing age may reduce digital literacy and confidence in technology use, thereby affecting the effectiveness of intervention implementation [36, 37].

Referral analysis indicated that AI-POCUS effectively identifies pregnancy-related abnormalities and facilitates necessary referrals. Its impact was particularly pronounced during the second trimester, a critical period for fetal anomaly screening and a key focus of training and quality control within primary healthcare systems [38, 39]. This trend may also be influenced by stronger healthcare-seeking motivation among women of higher gestational age [40]. The introduction of AI-POCUS has the potential to serve as a powerful tool for improving referral systems and ANC services, consistent with findings from previous studies on handheld ultrasound devices [41, 42].

Regression analysis further demonstrated that the use of AI-POCUS was significantly associated with achieving the *WHO*-recommended minimum of four ANC visits, indicating its potential to improve ANC adherence. Prior to the implementation of this intervention, although some healthcare facilities were equipped with conventional ultrasound devices through international aid, the lack of professional training and technical support limited their effective use, particularly among rural women. This resulted in low ANC adherence and suboptimal referral rates [43]. AI-POCUS, characterized by its portability, affordability, and ease of use, can reduce the workload of primary healthcare providers, enhance patient trust and engagement, and improve the quality of antenatal follow-up and high-risk identification, ultimately contributing to long-term improvements in maternal and neonatal health outcomes [44].

However, this study did not find significant associations between AI-POCUS exposure and direct clinical outcomes, including maternal complications, neonatal mortality, and neonatal complications. This may be partly due to the relatively low incidence of adverse events in the study population. It also suggests that digital health interventions centered on handheld ultrasound may not produce immediate improvements in delivery-related endpoints in the short term. Instead, their primary value lies in enhancing high-risk identification, follow-up management, and long-term health benefits.

Overall, AI-POCUS appears to effectively increase ANC visits and optimize referral pathways in low-resource settings. Its uptake is influenced by sociodemographic factors, indicating that policymakers should carefully consider local cultural and socioeconomic contexts when promoting this technology. In resource-limited rural areas, integrating antenatal ultrasound services with existing primary healthcare interventions may generate synergistic effects and improve overall system efficiency [45], highlighting the adaptability and practical value of AI-POCUS in strengthening ANC services [46].

5 Conclusion

This study, based on field data from a conflict-affected region in *Ethiopia*, systematically evaluated the effectiveness of AI-POCUS in low-resource settings. The results indicate that this technology can improve ANC adherence and strengthen the capacity of primary healthcare providers in high-risk identification and referral. Sociodemographic disparities significantly influence access to AI-POCUS, suggesting that policymakers should account for local healthcare resources and socioeconomic conditions when scaling up such interventions. Most importantly, this study provides empirical evidence to support the global expansion of similar artificial intelligence-driven medical technologies. It highlights that, in the process of international deployment, the provision of hardware alone is insufficient to ensure intervention effectiveness. Comprehensive systems for training, maintenance, and technical support are essential to achieve sustainable implementation and long-term impact.

References

1. World Bank Group Maternal mortality ratio (modeled estimate, per 100,000 live births) - Ethiopia [Internet]. 2025 [cited 2025 Nov 4]. Available from: https://data.worldbank.org/indicator/SH.STA.MMRT?locations=ET
2. World Health Organization SDG Target 3.1 maternal mortality [Internet]. Geneva: World Health Organization; [cited 2026 Jan 30]. Available from: https://www.who.int/data/gho/data/themes/topics/sdg-target-3-1-maternal-mortality
3. World Bank Mortality rate, neonatal (per 1,000 live births) [Internet]. Washington, DC: The World Bank; [cited 2026 Jan 30]. Available from: https://data.worldbank.org/indicator/SH.DYN.NMRT

4. United Nations International Children's Emergency Fund Ethiopia Appeal: Humanitarian Action for Children [Internet]. 2024 Dec [cited 2025 Oct 31]. Available from: https://www.unicef.org/appeals/ethiopia
5. World Bank Group. Unlocking the Development Potential of Public Debt in Sub-Saharan Africa [Internet] (2023) Dec 15 [cited 2025 Oct 31]. Available from: https://www.worldbank.org/en/results/2023/12/15/unlocking-the-development-potential-of-public-debt-in-sub-saharan-africa
6. Alibhai KM, Ziegler BR, Meddings L, Batung E, Luginaah I (2022) Factors impacting antenatal care utilization: a systematic review of 37 fragile and conflict-affected situations. Confl Health 16(1):33. 10.1186/s13031-022-00459-9
7. Teshome HN, Ayele ET, Hailemeskel S, Yimer O, Mulu GB, Tadese M (2022) Determinants of maternal near-miss among women admitted to public hospitals in North Shewa Zone, Ethiopia: a case-control study. Front Public Health 10:996885. 10.3389/fpubh.2022.996885
8. Abbattista T, Meloni MF, Ferraioli G, Pirri C (2024) The urgent need to extend the appropriate use of ultrasound in Africa and worldwide: overview, experiences and perspectives. Front Public Health 12:1363134. 10.3389/fpubh.2024.1363134
9. Delft Care BabyChecker: Smartphone-Based Ultrasound for Maternal Health [Internet]. [cited 2025 Nov 4]. Available from: https://delft.care/babychecker-2/
10. Horgan R, Nehme L, Abuhamad A (2023) Artificial intelligence in obstetric ultrasound: a scoping review. Prenat Diagn 43(9):1176–1219. 10.1002/pd.6411
11. Wenli L, Ning L, Yihua W et al (2025) Visualization analysis of research hotspots and trends in AI in ultrasound medicine based on CiteSpace. J Clin Ultrasound Med 27(10):833–840. 10.16245/j.cnki.issn1008-6978.2025.10.011
12. Kim S, Fischetti C, Guy M, Hsu E, Fox J, Young SD (2024) Artificial Intelligence (AI) Applications for Point-of-Care Ultrasound (POCUS) in Low-Resource Settings: A Scoping Review. Diagnostics 14(15):1669. 10.3390/diagnostics14151669
13. Slimani S, Hounka S, Mahmoudi A et al (2023) Fetal biometry and amniotic fluid volume assessment end-to-end automation using Deep Learning. Nat Commun 14(1):7047. 10.1038/s41467-023-42438-5
14. Pokaprakarn T, Prieto JC, Price JT et al (2022) AI Estimation of Gestational Age from Blind Ultrasound Sweeps in Low-Resource Settings. NEJM Evid 1(5):evidoa2100058. 10.1056/evidoa2100058
15. Stringer J, Pokaprakarn T, Prieto J et al (2024) Diagnostic Accuracy of an Integrated AI Tool to Estimate Gestational Age from Blind Ultrasound Sweeps. JAMA 332(8):649–657. 10.1001/jama.2024.10770
16. Long L, Xuemei A, Jie Z et al (2024) The Detection Rate of Postpartum Depression in Advanced Maternal Age in China: a Meta-analysis. Chin Gen Pract. ;27(11):1363–1369. DOI: 13.1222.R.20231201.1059.004

17. International Society of Ultrasound in Obstetrics and Gynecology. ISUOG Basic Training Curriculum [Internet]. London: ISUOG (2019) [cited 2025 Oct 31]. Available from: https://www.isuog.org/education/basic-training.html
18. Tareke AA, Mittiku YM, Tamiru AT et al (2021) Underutilization of the recommended frequency of focused antenatal care services in Northwest Ethiopia: using Andersen's healthcare service utilization model approach. Clin Epidemiol Glob Health 11:100746. 10.1016/j.cegh.2021.100746
19. Jung D, Kim B (2024) The effect of health facility births on newborn mortality in Malawi. Int J Health Econ Manag 24(3):393–406. 10.1007/s10754-023-09348-x
20. Leta B, Abebe T, Mulugeta E et al (2022) Obstetric emergencies and adverse maternal-perinatal outcomes: a systematic review and meta-analysis in Ethiopia. BMC Pregnancy Childbirth 22(1):711. 10.1186/s12884-022-05025-1
21. Zhang D, Allotey J, Zafaran-Nahar A et al (2023) Maternal and neonatal morbidity and mortality among pregnant women with and without COVID-19 infection: a systematic review and meta-analysis. Pediatr Res 93(4):867–876. 10.1038/s41390-022-02421-0
22. Heinze G, Schemper M (2002) A solution to the problem of separation in logistic regression. Stat Med 21(16):2409–2419. 10.1002/sim.1047
23. Girmay M (2024) Digital health divide: Opportunities for reducing health disparities and promoting equitable care for maternal and child health populations. Int J MCH AIDS 13(e026):1–5. 10.25259/IJMA_41_2024
24. Luntsi G, Ugwu AC, Nkubli FB et al (2020) Achieving universal access to obstetric ultrasound in resource-constrained settings: a narrative review. Radiography 27(2):709–715. 10.1016/j.radi.2020.10.010
25. Xiayang L, Chaoyue L, Xiaorong L et al (2023) Application of digital twin technology in training medical aid teams to work in foreign countries. Acad J Naval Med Univ 44(02):245–250. 10.16781/j.CN31-2187/R.20220275
26. Yuezhu L, Bo S, Jiangli D, Qi Y (2021) Awareness of maternal health knowledge and its influencing factors among pregnant women in some regions of China. Chin J Public Health 37(7):1143–1148. 10.11847/zgggws1134617
27. Susu B, Temesgen K, Ayalew S et al (2023) Prenatal ultrasound utilization and associated factors among pregnant women attending antenatal care in South Wollo Zone public hospitals, Northeast Ethiopia, 2023. Front Digit Health 7:1547547. 10.3389/fdgth.2023.1547547
28. Molla W, Mengistu N, Wudneh A (2022) Pregnant women's knowledge, attitude, and associated factors toward obstetric ultrasound in public hospitals, Ethiopia, 2021: Multi-centered cross-sectional study. Womens Health 18:17455057. 10.1177/17455057221091357
29. Mengistie B, Ayele S, Tsehaye W, Mazengia A, Wolde M (2023) Assessment of knowledge and attitude of pregnant women towards antenatal ultrasound in University of Gondar Comprehensive Specialized Hospital at antenatal care clinic, Northwest Ethiopia. PLoS ONE 18(11):e0292496. 10.1371/journal.pone.0292496

30. Haile ZW, Gurmu AG (2024) Knowledge, attitude, barriers, and associated factors of obstetric ultrasound among pregnant women in public hospitals, Ethiopia, 2022: a cross-sectional study. J Ultrasound 27:31–40. 10.1007/s40477-023-00783-7
31. Imo CK (2022) Influence of women's decision-making autonomy on antenatal care utilisation and institutional delivery services in Nigeria: evidence from the Nigeria Demographic and Health Survey 2018. BMC Pregnancy Childbirth 22:141. 10.1186/s12884-022-04478-5
32. Huijuan Y, Rufeng S, He L, Fang H, Hui D (2007) Study on management model for fluid pregnant women in Beijing. Chin J Public Health 23(7):845–846. 10.11847/zgggws2007-23-07-38
33. Nichols C (2021) Self-help groups as platforms for development: The role of social capital. World Dev 146(1):105575. 10.1016/j.worlddev.2021.105575
34. Mengesha EW, Alene GD, Amare D et al (2021) Social capital and maternal and child health services uptake in low- and middle-income countries: mixed methods systematic review. BMC Health Serv Res 21:1142. 10.1186/s12913-021-07129-1
35. Closser S, Napier H, Maes K et al (2019) Does volunteer community health work empower women? Evidence from Ethiopia's Women's Development Army. Health Policy Plan 34(4):298–306. 10.1093/heapol/czz025
36. Zeyu Y, Yifei Z, Tianyi P, Ziyu W, Yanhua H, Xuejin B (2025) Factors influencing digital literacy and difficulties in using digital devices among older adults in Qiqihar city: a cross-sectional survey. Chin J Public Health 41(2):165–169. 10.11847/zgggws1145122
37. Schroeder T, Dodds L, Georgiou A et al (2023) Older Adults and New Technology: Mapping Review of the Factors Associated with Older Adults' Intention to Adopt Digital Technologies. JMIR Aging 6:e44564. 10.2196/44564
38. Kariman S, van den Heuvel JFM, Adriaanse BME, Oepkes D, Bekker MN (2025) The Potential of Tele-Ultrasound, Handheld and Self-Operated Ultrasound in Pregnancy Care: A Systematic Review. Prenat Diagn 45:906–920. 10.1002/pd.6679
39. Yahya RH, Roman A, Grant S et al (2024) Antenatal screening for fetal structural anomalies: routine or targeted practice? Best Pract Res Clin Obstet Gynaecol 96:102521. 10.1016/j.bpobgyn.2024.102521
40. Abdo R, Demelash M, Seid AM et al (2023) First trimester antenatal care contact in Africa: a systematic review and meta-analysis of prevalence and contributing factors. BMC Pregnancy Childbirth 23:742. 10.1186/s12884-023-06034-1
41. Franklin HL, Mirza W, Swanson DL et al (2018) Factors influencing referrals for ultrasound-diagnosed complications during prenatal care in five low- and middle-income countries. Reprod Health 15:204. 10.1186/s12978-018-0647-8
42. Dalmacion GV, Reyles RT, Habana AE et al (2018) Handheld ultrasound to avert maternal and neonatal deaths in 2 regions of the Philippines: an iBuntis® intervention study. BMC Pregnancy Childbirth 18:32. 10.1186/s12884-018-1658-8

43. Roro MA, Aredo AD, Kebede T et al (2022) Enablers and barriers to introduction of obstetrics ultrasound service at primary care facilities in a resource-limited setting: a qualitative study in four regions of Ethiopia. BMC Pregnancy Childbirth 22:278. 10.1186/s12884-022-04609-y
44. Della RS, Santos N, Walker D (2025) AI-enabled obstetric point-of-care ultrasound as an emerging technology in low- and middle-income countries: provider and health system perspectives. BMC Pregnancy Childbirth 25:729. 10.1186/s12884-025-07796-6
45. Swanson DL, Franklin HL, Swanson JO et al (2019) Including ultrasound scans in antenatal care in low-resource settings: Considering the complementarity of obstetric ultrasound screening and maternity waiting homes in strengthening referral systems in low-resource, rural settings. Semin Perinatol 43(5):273–281. 10.1053/j.semperi.2019.03.017
46. Abrokwa SK, Ruby LC, Heuvelings CC, Bélard S (2022) Task shifting for point of care ultrasound in primary healthcare in low- and middle-income countries: a systematic review. eClinicalMedicine 45:101333. 10.1016/j.eclinm.2022.101333