BMJ Open

Effect of USAID-funded obstetric ultrasound service interventions on maternal and perinatal health outcomes at primary healthcare facilities in Ethiopia: a propensity score matching analysis

Kiddus Yitbarek ,[1] Alemu Tuji,[2] Yibeltal Kiflie Alemayehu,[1,3] Derebe Tadesse ,[2] Afework Tadele ,[4] Sentayehu Tsegaye,[2] Yared Abera,[2] Mohammed Abrar,[5] Ahmed Ibrahim,[6] Salah Esmael,[7] Mebrie Belete,[8] Abdella Mohammed,[5] Muktar Shekabdulahi,[6] Hundessa Olani,[7] Arab Selamu,[8] Girmay Medhin,[9] Mulusew J Gerbaba[10]

To cite: Yitbarek K, Tuji A, Alemayehu YK, *et al*. Effect of USAID-funded obstetric ultrasound service interventions on maternal and perinatal health outcomes at primary healthcare facilities in Ethiopia: a propensity score matching analysis. *BMJ Open* 2022;**12**:e065351. doi:10.1136/bmjopen-2022-065351

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-065351).

Received 07 June 2022
Accepted 23 September 2022

For numbered affiliations see end of article.

Correspondence to
Kiddus Yitbarek;
kiddus.yitbarek@yahoo.com

ABSTRACT

Objective A dimensional shift in the health service delivery in the primary healthcare setting is required to raise maternal and child well-being. This study aimed to evaluate the effect of US Agency for International Development-funded obstetric ultrasound service on maternal and perinatal health outcomes at Ethiopia's primary healthcare facilities.

Design We employed a quasi-experimental study design.

Setting The study was conducted in primary health centres located in four regions of Ethiopia.

Participants We used 2 years' data of 1568 mothers from 13 intervention and 13 control primary health centres. Data were obtained from Vscan, antenatal care (ANC), delivery and postnatal care registers.

Intervention Use of portable obstetric ultrasound service during pregnancy.

Outcome measures The primary outcome variables include complete four ANC visits, referral during ANC, delivery in a health facility and having postnatal care and continuum of care. The secondary outcome variable was perinatal death.

Results With the kernel matching approach, we have found that having four or more ANC visits was decreased after the intervention (average treatment effect (ATE): −0.20; 95% CI: −0.23 to −0.09), and the rest of the indicators, including referral during ANC (ATE: 0.01; 95% CI: 0.15 to 0.34), institutional delivery (ATE: 0.24; 95% CI: 0.15 to 0.34) and postnatal care (ATE: 0.26; 95% CI: 0.10 to 0.37), were significantly raised because of the intervention. Similarly, we have found that perinatal death dropped considerably due to the intervention.

Conclusion The findings show a consistent increase in maternal health service use because of the introduction of obstetric ultrasound services at the primary health centre level. Furthermore, early detection of complications and following referral for specialty care were found to be high. The consistent rise in maternal health service use indicators calls for additional trial to test the effect of obstetric ultrasound service in other locations of the country. Furthermore, evaluating the predictive values, sensitivity and specificity of the obstetric ultrasound service is important.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We considered a current and relevant health issue, which was not well studied before, with a strong methodological approach.
⇒ In this study, we used representative sample from geographically diverse regions of Ethiopia.
⇒ Our study used causality evaluation methods like propensity score matching, difference-in-differences and inverse probability of treatment weighting to see the effect of obstetric ultrasound service in four regions of Ethiopia.
⇒ The use of both before–after and intervention–control data in this study brought a better finding.
⇒ The retrospective nature of the data that were collected from registers available in health facilities limited us to get exhaustive data for variables that may confound the estimate of the analysis.

INTRODUCTION

Ensuring healthy lives and promoting well-being at all ages had been the major target of the millennium development goals and continued to be one of the Sustainable Development Goal (SDG) targets. SDG 3 also aims to end preventable maternal mortality and neonatal death.[1 2] Henceforth, global maternal death has been reduced by 2.9% per annum from 2000 to

2017, and child deaths have decreased considerably.[3] However, reducing maternal (SDG 3.1) and child (SDG 3.2) mortality is far from being reached. Furthermore, the difference between high-income and low/middle-income countries (LMICs) is so huge that sub-Saharan Africa and Southern Asia accounted for approximately 86% (254 000) of the estimated global maternal deaths in 2017.[4 5] Ethiopia is one of the high MMR burden countries that the recent estimates show MMR of 412 per 100 000 live births and child mortality rate of 67 per 1000 live births.[4]

Proven maternal and child health interventions are said to reduce morbidities and mortalities in LMICs. However, several studies depict the use of maternal and neonatal health services is less than optimum. For instance, a study by Bain *et al*[6] reported only half of women receive the recommended amount of healthcare they need. Similarly in Ethiopia, improving access to reproductive, maternal, and newborn healthcare and its utilisation and ensuring service equity and quality at the facility level remain a challenge.[7 8] Moreover, service qualities are not uniformly distributed between and within regional states, such that regions like Afar, Benishangul-Gumuz, Gambella, and Somali have recorded lower access to health services and its utilisation as compared with national averages,[9–12] and are exacerbated by shocks like drought, conflict or disease outbreaks, including COVID-19.[13]

Cognisant of these facts, Transform Health in Developing Regions (HDR) is one of the US Agency for International Development (USAID) Transform Health Activities, in collaboration with the Ministry of Health, which has designed intereventions that further improve maternal and child health in developing regional states of Ethiopia. The overall objective of the programme was to increase the utilisation of high-impact and quality reproductive, maternal, neonatal and child health (RMNCH). To improve access, quality, and equity for basic maternal and neonatal health services, Transform HDR introduced Vscan access, a small portable, ultrasound device for obstetric scanning at its selected Centers of Excellence health facilities—18 health centres and 6 hospitals in the four of its target regional states. In addition, skill-based training was provided for midwives and physicians working at these facilities on Vscan utilisation followed by post-training mentoring and follow-up.[14 15]

This intervention is expected to contribute to increasing the number of healthy mothers with successful birth outcomes and sustaining gains of reduction in under 5 morbidities and mortality in developing regions of Ethiopia.[16] However, to the best of authors' knowledge, no study has evaluated the effectiveness of these interventions in the study areas and less is known about the extent to which the introduction of such programme would improve maternal and perinatal outcomes in a low-income setting like Ethiopia. Such evaluation would have both policy and programme relevance. Therefore, the main purpose of this study was to investigate the effects of Vscan access on maternal and perinatal health outcomes, uptake of antenatal, delivery and perinatal services among Transform HDR-supported health facilities.

MATERIALS AND METHODS

Study setting

The study was conducted in emerging regional states of Ethiopia, namely Afar, Benishangul-Gumuz, Gambella and Somali regional states. Early childhood mortality was high in the regions. For instance, the under-5 child mortality rates per 1000 live births in Afar, Benishangul-Gumuz, Gambella and Somali regional states were as high as 144, 98, 88 and 94, respectively, compared with 39 in the country's capital, Addis Ababa.[17] Moreover, maternal health service utilisation was disproportionately low in these regions; for instance, according to the 2019 Ethiopian Demographic and Health Surveys, the percentage of institutional deliveries was only 17%, antenatal care (ANC) coverage was 30%, and postnatal check-up in the 2 days after delivery was only 10% in Somali regional state.[18] Thus, 24 health facilities in these regional states (five from each except nine from Somali) were selected for interventions of providing ultrasound devices and technical support. Among the health facilities, 6 were hospitals and the remaining 18 were primary health centres.

Study design

Quasi-experimental study design was employed in 13 primary health centres as an intervention and 13 primary health centres as a control group to compare maternal health service utilisation and perinatal health outcomes.

Sample size and sampling procedure

Totally, 13 Vscan implementing (intervention) and 13 non-Vscan implementing (control) primary health centres were included in this study. We took samples from all the selected intervention and control health centres. We used a double population proportion formula to determine the sample size with the following assumptions: proportion of delivery without intervention was taken at 26.7% from the Demographic and Health Survey of the four regions[18]; the proportion of delivery with the intervention was taken 33.6% which indicates a 6.9% increase in delivery in facilities with Vscan service,[15] power 85 and with 95% level of confidence.

$$n = \left(Z_{\alpha/2} + Z_{\beta}\right)^2 \times \left(p_1\left(1-p_1\right) + p_2\left(1-p_2\right)\right) / \left(p_1 - p_2\right)^2$$

Finally, the calculated sample size became 790. We then allocated 790 cases before the intervention and 790 cases after the intervention. The sample size was equally divided into intervention and control groups. Before the intervention, 395 cases were allocated to each of the intervention and control groups. The same thing was repeated after the intervention. The calculated sample size was proportionally allocated to the size of institutional delivery in each of the facilities. We used a systematic random sampling

technique to select each of the cases from the registry. We traced back 2 years before the intervention and 2 years after the intervention with intervals. The sampling interval was determined by dividing the total number of first ANC visit by the sample size allocated to the health centre. We selected the first case with a lottery method and added the sampling interval to get the next sample. In cases when the selected sample has no complete data, we chose the next cases on the register. For the facility-level aggregate data, we took the whole 2 years before and 2 years after the intervention, both retrospectively.

Study population

All pregnant women who visit health facilities for maternal healthcare utilisation in the selected health facility as intervention and control in Afar, Benishangul-Gumuz, Gambella and Somali regional states of Ethiopia. A total of 42 632 women visited the health facilities in the intervention and control health centres for maternal health services.

Intervention

Transform HDR Project, which is funded by the USAID, has introduced an obstetric ultrasound service for pregnant women in selected 24 health facilities (18 health centres and 6 hospitals) situated in four emerging regions of Ethiopia including Afar, Benishangul-Gumuz, Gambella and Somali regions. The objective of the intervention was to increase the utilisation of high-impact and quality RMNCH services. The selected health facilities were provided with a portable ultrasound device and related installation was performed. The service began in mid-October 2019 and has continued for more than 2 years. The obstetric ultrasound devices were regularly maintained as required when problems were reported from the health facilities.

The service was provided to mothers by trained midwife nurses. Two midwife nurses were selected from each health facility and got trained for 11 days by experienced radiologists, integrated emergency surgical officer, and gynaecology and obstetrics specialists. This training involved classroom discussion and practical sessions in the health facilities using a mobile Vscan ultrasound machine. This phase of training had pre-assessment and post-assessment examinations. After they complete the classroom training and demonstration, mentors were assigned for each of the trainees and followed up in three rounds, for 2 days each. The mentors had been remotely monitoring the activities of the trained midwife nurses throughout the first 3 months' mentoring period. In each of the 2-day follow-up, the midwife nurses were assessed by competency assessment tools. The programme allows trainees to have several exposures to ultrasound scanning before they complete the course and provide the service independently in their respective health facilities.

As soon as the trained midwives complete the training and mentoring sessions, they started the actual service to pregnant mothers attending ANC in the facility. The WHO recommends at least one ultrasound scan during a woman's pregnancy. In this project, pregnant women attending ANC were scanned with obstetric ultrasound device at least once. In addition to that, mothers with some pregnancy-related complications or a danger sign during their first scan were repeatedly scanned as required. The services were regularly given for about 2 years in the selected 13 primary healthcare facilities. Follow-up of the service has also been a critical part of the programme which was regularly done by both Transform HDR staff and the respective region's public sector experts. There was frequent reporting of the updates related to mothers who had ultrasound services.

Variables and measurement

Double robust estimation

Outcome

The primary outcome variable includes components like complete four ANC visits, delivery in a health facility, having postnatal care (PNC) and continuum of care. A mother who took four ANC visits, delivered in a health facility and had PNC from the health facility where she delivered was considered as a mother with complete continuum of care. The secondary outcome variable was perinatal death. This variable involves stillbirth after 28 weeks of gestation and the death of a child within 7 days from delivery. The other variable was early detection of complications measured with a proxy variable referral during ANC.

Exposure variable

The woman who received ultrasound services during her latest pregnancy is coded 1 and 0 otherwise.

Covariates

The analysis was controlled by variables including having first ANC visit, age of the women during pregnancy, gestational age, having tetanus toxoid vaccine, region and zone where the facility is located.

Data

Data source

In this study, we used two data sources. The first one is a review of registers in the health facility including the Vscan register (for the intervention health facilities), ANC register, delivery register and PNC register. We used data over 4 years from 2017 to 2021 before and after the Vscan service was initiated in 2019. The data were collected from 4 April to 27 April 2022. Relevant maternal and child health service and outcomes-related data are registered in the facility using the pre-prepared forms including ANC registry, delivery register, PNC register and Vscan log book. Before the intervention, we took 2 years of data from 11 October 2017 to 10 October 2019; and after the intervention, we took 2 years' data from 12 October 2019 to 10 October 2021.

The second one was the electronically registered facility-level aggregate data. We also took the facility-level

aggregate data on ANC 1 and 4; institutional delivery; postnatal delivery; stillbirth and death to 7 days from birth.

Method of data collection

In the first data source, we extracted data from four relevant registers: (1) Vscan register, (2) ANC register, (3) delivery register and (4) PNC register. In the intervention health facilities, the data collection was started from the Vscan register and continued to the ANC register, then the delivery register and finally the PNC register. The same thing was done in the control health centres except for the Vscan register. The data from the four sources were matched using a unique identifier variable medical record number.

We have got the centrally available aggregate data of the same intervention and control health facilities. The data were downloaded in Excel spreadsheets and used for analysis.

Method of data analysis

Descriptive analysis

The extracted data from databases and maternal log book were cleaned to get prepared for analysis. We used the statistical software STATA (StataCorp, USA) for analysis. First, descriptive analysis was performed to see the proportion difference in each indicator of maternal and child health service outcomes and perinatal death among treated and untreated groups.

To identify potential confounders, variables that are associated with the exposure or outcome of interest, we did a binary logistic regression. We then balanced the data with the confounding variables using a propensity score matching (PSM) approach.

For aggregate facility-level continuous variables, we checked for the normal distribution of the data on health service indicators prior to fitting a model. As we can learn from the histograms (online supplemental file 1), the data have a longer right tail. Therefore, we went for the non-parametric two-sample Wilcoxon rank-sum (Mann-Whitney) test.

Matching

We employed PSM methods to estimate the treatment effect of ultrasound exposure and was measured by calculating the difference in the outcome among those who received the intervention with those who did not.

$$D_i = Y_{1i} - Y_{0i}$$

Where, Di is the difference between the outcomes i with and without treatment (ultrasound exposure in our case); Y_{1i} is the treated outcome and Y_{0i} untreated outcome. When we see from the treatment side, untreated outcome (Y_{0i}) is unobservable. This unobserved outcome is counterfactual to the observed outcome. We used the logit model and estimate the propensity score (ie, estimates a maximum likelihood model of the conditional probability of treatment, usually a logit or probit so as to ensure that the fitted values are bounded between 0 and 1), and used the predicted values from that estimation to collapse those covariates into a single scalar called the propensity score using the treatment model adjusting for pretreatment characteristics (confounders) that may affect the treatment. These covariates include age, first ANC visit, age of the women during pregnancy, gestational age, syphilis test results, having tetanus toxoid vaccine, region and zone where the facility is located. The PSM approach minimises the selection bias by balancing the cases in terms of the confounding variables among treatment and control groups. We used kernel matching, radius matching and inverse probability of treatment weighting (IPTW).[19] We tried various specifications that best reduce the selection bias and created the best balance between treatment and control groups. To check the balance in the treatment and control groups, we employed the absolute standardised difference in means (SMD), the absolute difference in means divided by the SD for those observations in the treatment group. Finally, we reported average treatment effect (ATE) and ATE on the treated (ATT), and a significant difference between the treatment and control groups was determined with a p value of <0.05.

Sensitivity analysis

First, we did a difference-in-differences analysis to identify the facility (aggregate)-level effect of the introduction of obstetric ultrasound service. We applied a difference-in-differences approach to see the effect of obstetric ultrasound service at the facility level. These methods are panel data methods that are used to see treatment effects in group means in case one or more groups are exposed to treatment and others are not exposed. The difference between these groups can then be considered as the causal effect of interest. We did a standard difference-in-differences estimate using the 'diff' command in STATA.

This was followed by the use of IPTW estimators which use estimated probability weights to correct for the missing data problem arising from the fact that each subject is observed in only one of the potential outcomes. Its estimators use a two-step approach to estimate treatment effects: (1) they estimate the parameters of the treatment model and compute the estimated inverse probability weights; (2) they use the estimated inverse probability weights to compute weighted averages of the outcomes for each treatment level. The contrasts of these weighted averages provide the estimates of the ATEs. These steps correct the missing potential outcomes and produce consistent estimates of the effect parameters because the treatment is assumed to be independent of the potential outcomes after conditioning on the covariates. The overlap assumption ensures that predicted inverse probability weights do not get too large. In fact, the model uses an estimation technique that implements both steps at once so that we do not need to correct the SEs in the second step to reflect the uncertainty associated with the predicted treatment probabilities.

Table 1 Characteristics of participants in the intervention and control group, 2022, Ethiopia

Characteristics	Response category	Before intervention			After intervention		
		Control	Intervention	P value	Control	Intervention	P value
Region	Afar	128 (30.99)	43 (11.32)	<0.01	111 (25)	42 (12.77)	<0.01
	Benishangul-Gumuz	49 (11.86)	78 (20.53)		30 (6.76)	27 (8.21)	
	Gambella	53 (12.83)	143 (37.63)		45 (10.14)	133 (40.43)	
	Somali	183 (44.31)	116 (30.53)		258 (58.11)	127 (38.6)	
Age category of the woman	≤20	120 (29.06)	100 (26.32)	0.85	104 (23.42)	94 (28.57)	0.02
	21–25	116 (28.09)	113 (29.74)		106 (23.87)	98 (29.79)	
	26–30	126 (30.51)	120 (31.58)		173 (38.96)	108 (32.83)	
	>30	51 (12.35)	47 (12.37)		61 (13.74)	29 (8.81)	
HIV test result	Negative	330 (99.1)	312 (99.68)	0.35	330 (99.7)	267 (98.52)	0.11
	Positive	3 (0.9)	1 (0.32)		1 (0.3)	4 (1.48)	
TT vaccination	Not vaccinated	26 (6.3)	10 (2.63)	<0.01	43 (9.68)	2 (0.61)	<0.01
	TT1	244 (59.08)	120 (31.58)		224 (50.45)	116 (35.26)	
	TT2	94 (22.76)	156 (41.05)		126 (28.38)	160 (48.63)	
	TT3	25 (6.05)	61 (16.05)		31 (6.98)	39 (11.85)	
	TT4	11 (2.66)	19 (5)		7 (1.58)	7 (2.13)	
	TT5	13 (3.15)	14 (3.68)		13 (2.93)	5 (1.52)	

TT, tetanus toxoid.

Patient and public involvement

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

RESULTS

Characteristics of study participants

We have included a total of 1568 study participants, of them 795 (50.7%) were included before the intervention, and 773 (49.3%) were included after the intervention. Nearly 90% of the study participants consistently before and after the intervention and in the intervention and control groups were below the age of 31 years. Among the study participants, the highest proportion had syphilis tests and were non-reactive; similarly, most of the study participants were negative for HIV tests. The highest proportion of the controls both before and after the intervention had one dose of tetanus toxoid vaccine. On the other hand, among the intervention group participants, the highest proportion had two doses of tetanus toxoid vaccine (table 1).

Description of maternal health service use

There are significant variations in uptake of maternal and newborn health between the intervention and control groups both at baseline and after implementing the interventions (table 2). The only non-significant difference was observed in the (a) referral during ANC at baseline and after the intervention, (b) at baseline

Table 2 Uptake of various maternal and newborn health services

Variables	Before			After		
	Control	Intervention	P value	Control	Intervention	P value
>1 ANC	206 (52.02)	257 (67.99)	0.00	254 (58.12)	238 (73.91)	0.00
Four or more ANC	95 (23.99)	85 (22.49)	0.62	116 (26.54)	56 (17.39)	0.00
ID	74 (18.59)	156 (41.16)	0.00	114 (25.85)	187 (57.19)	0.00
Continuum (4 ANC+ID)	19 (4.60)	43 (11.32)	0.00	43 (9.68)	45 (13.68)	0.08
PNC	43 (10.41)	94 (24.74)	0.00	56 (12.61)	142 (43.16)	0.00
Continuum (4 ANC+ID+PNC)	10 (2.42)	33 (8.68)	0.00	14 (3.15)	38 (11.55)	0.00
Referral during ANC	14 (3.39)	15 (3.95)	0.68	12 (2.70)	16 (4.86)	0.11
Perinatal death	1 (1.3)	0 (0)	0.14	4 (3.4)	1 (0.5)	0.13

ANC, antenatal care; ID, institutional delivery; PNC, postnatal care.

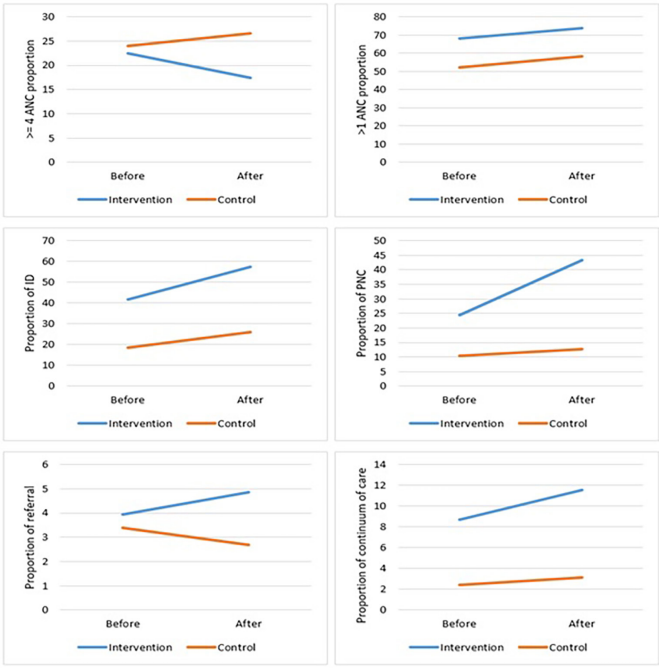

Figure 1 Change in maternal health service use before and after the introduction of obstetric ultrasound service. ANC, antenatal care; ID, institutional delivery; PNC, postnatal care.

in the uptake of four or more ANC visits, and (c) after intervention in the uptake of four ANC visits and institutional delivery.

There was a significant change in the proportion of women taking maternal health services both in the intervention and control groups after the implementation of the intervention. The change in ANC was positive in both groups while the proportion of women who received four ANC visits declined in the intervention group. Uptake of institutional delivery and PNC increased in both groups with a higher magnitude being in the intervention group. The proportion of referral cases during ANC decreased among the control group and increased in the intervention group. Overall, the proportion of women who completed the continuum of care increased in both groups and the magnitude was higher in the intervention group as compared with the control (figure 1).

Matching

We calculated the percentage reduction of bias in radius and kernel matching methods (online supplemental file 2). The minimum percentage reduction of bias in the radius matching method was 41.8 and in the kernel matching was 58.1. We also visually presented the balance between the treatment and control groups in terms of the matching variables using absolute SMD plots (online supplemental file 3 contains SMD plots for the kernel matching method). Those in support cases were included in the analysis and off support were excluded from the final treatment effect test (online supplemental file 4).

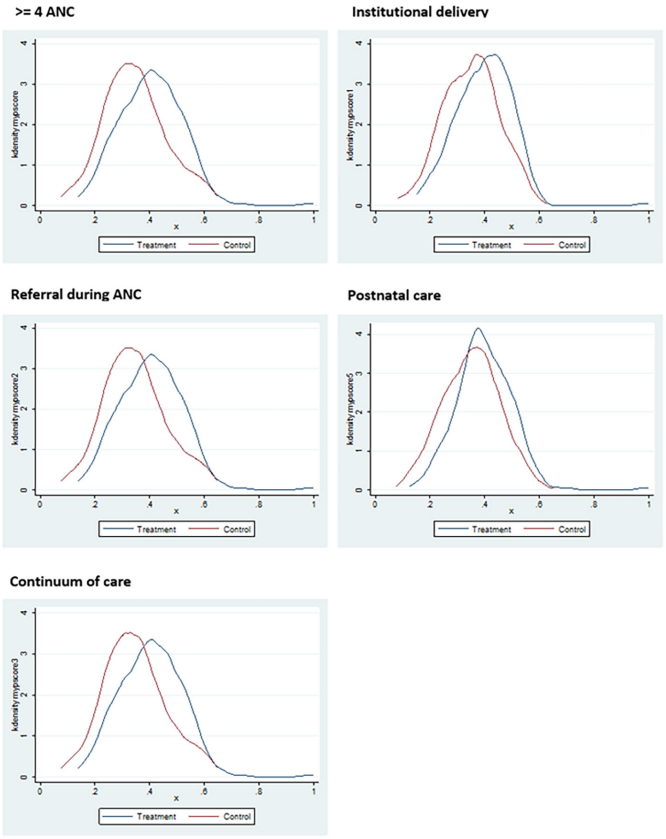

Figure 2 Common support figures for the treatment and control groups. ANC, antenatal care.

The effect of obstetric ultrasound on maternal health service use

In order to come up with the results, we used PSM with two specifications including kernel matching and radius matching. We tested the common support assumption and the result indicates the propensity scores are common for both the intervention and control groups, therefore the treatment effect is acceptable (figure 2).

The result of the kernel matching methods (the estimate that better minimises bias) indicated that attending four or more ANC visits was better in the control group as compared with those women who obtained obstetric ultrasound service. All other service uptake indicators were better used by mothers who had obstetric ultrasound services. In the radius matching estimate, the direction of effect is the same as that of the kernel matching method. However, the significant effects were observed only on four or more ANC visits and PNC (table 3).

Facility-level aggregate information

As we see from the facility level, in all of the maternal health service indicators, there was an increase in both the intervention and control groups after the intervention. However, the increase in the intervention group is higher than in control ones. For instance, the average monthly first ANC increased by 8 in the control group versus by 22 in the intervention group (figure 3).

Table 3 The effect of obstetric ultrasound on maternal health service outcome

	Kernel matching				Radius matching				IPTW			
Variables	ATE	ATT	SE	95% CI	ATE	ATT	SE	95% CI	ATE	ATT	SE	95% CI
Four or more ANC	−0.20*	−0.16	0.04	−0.23 to −0.09	−0.21*	−0.16	0.04	−0.23 to −0.08	−0.2*	−0.16	0.04	−0.23 to −0.09
Institutional delivery	0.24*	0.25	0.05	0.15 to 0.34	0.24	0.25	0.05	−0.02 to 0.06	0.23*	0.25	0.04	0.17 to 0.33
Referral during ANC	0.01*	0.02	0.02	0.15 to 0.34	0.01	0.02	0.02	−0.02 to 0.06	0.01	0.01	0.02	−0.03 to 0.06
Postnatal care	0.26*	0.27	0.04	0.10 to 0.37	0.24*	0.27	0.04	0.19 to 0.35	0.24*	0.26	0.04	0.18 to 0.34
Continuum of care	0.02	0.02	0.02	−0.02 to 0.06	0.01	0.02	0.02	−0.01 to 0.06	0.01	0.02	0.02	−0.03 to 0.06

*P<0.05.
ANC, antenatal care; ATE, average treatment effect; ATT, average treatment effect on the treated; IPTW, inverse probability of treatment weighting.

The results indicate that there is a significant median difference between intervention and control groups both before and after the intervention. The magnitude of increase in the intervention group is far higher than the control group. The median difference-in-differences was found as high as 14.5 in the first ANC indicator and as low as 6 in the delivery indicator (table 4).

The model estimated the mean and SD using linear regression. We did 10 000 bootstrap replication for the perinatal death indicator to get a better estimate since the variable has a minimal amount of cases. Accordingly, the intervention has resulted in a positive significant effect for variables like at least one ANC and four or more ANC visits at 5% level of significance. Similarly, for PNC, there was a positive significant effect at 1%. On the contrary, the intervention significantly decreased perinatal death at 5% level (table 5).

DISCUSSION

Recently, many low-income countries are introducing obstetric ultrasound services in the primary healthcare setting, where most of the mothers in the country use these services.[20] The introduction of the low-cost portable ultrasound device and its associated benefit in terms of early detection of pregnancy-related complications made the service expand fast. There are conflicting pieces of evidence related to the effects of using obstetric ultrasound for maternal and child health services and health outcomes. This study has aimed to check the effect of obstetric ultrasound on maternal health service use and child well-being. In this study, we did two analyses to see the effect of obstetric ultrasound intervention on maternal health service outcomes. The first analysis used individual data about the mother and the unit of analysis was individual mothers. The other one was aggregate facility-level monthly data and the unit of analysis was the primary health centre.

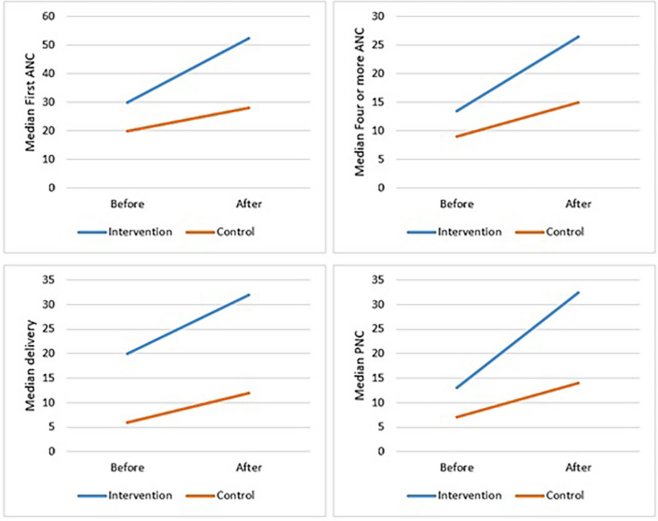

Figure 3 Median monthly health service use change in maternal health service use in intervention and control health facilities. ANC, antenatal care; PNC, postnatal care.

Overall, the completion of the continuum of maternal health service among mothers was raised in both the intervention and control groups over time. The rate of increase in the intervention group was higher than in the non-obstetric ultrasound users even if this effect was not statistically significant. Despite this fact, there are significant differences between the obstetric ultrasound and the control group in terms of the specific components of the continuum of maternity care.

ANC use was raised in health facilities that give obstetric ultrasound services over the period after the introduction of obstetric ultrasound services. However, there is inconsistency in the findings of four or more ANC services use. Facility-level aggregate data indicate health facilities with obstetric ultrasound services were effective in raising service use for four or more ANC visits, while in the individual client-level data, the reverse was true. This could have happened because of late initiation of the first ANC in the intervention group. More than 9% of the mothers initiated ANC in the first trimester of pregnancy in the control group, while only about 5% started ANC in the first trimester. On the other hand, the COVID-19 pandemic and the continuing conflict in some of the intervention areas have resulted in a significant shock in the health system. The country in general and specifically conflict-affected areas are hit by continuing health system stressors and had low performance in many health service indicators. Findings from other different LMICs revealed the use of obstetric ultrasound has increased ANC attendance significantly.[15 21–24] For instance, a study conducted

Table 4 Median difference of maternal health service use indicators

	Before			After		
Outcomes	Intervention	Control	Difference	Intervention	Control	Difference
First ANC	30.00	20.00	10**	52.50	28.00	24.5**
Four or more ANC	13.50	9.00	4.5**	26.50	15.00	11.5**
Delivery	20.00	6.00	14**	32.00	12.00	20**
Postnatal care	13.00	7.00	6**	32.50	14.00	18.5**

Two-sample Wilcoxon rank-sum (Mann-Whitney) test.
**P<0.01.
ANC, antenatal care.

in Uganda found a 147% increase in ANC 4 attendance.[22] A study done in northern Nigeria also reported limited obstetric ultrasound service can increase ANC attendance.[24] Similarly, our facility-level aggregate finding indicated that there is a significant rise in both first ANC and fourth ANC in the intervention health facilities because of the intervention.

There was a significant increase in delivery service use in the institution because of the obstetric ultrasound service introduction. This might have happened because of two reasons. Primarily, when mothers are having the ultrasound service during their ANC, their ANC attendance coupled with additional evidence-based counselling to the mother could have increased delivery in a health institution.[25 26] On the other hand, detection of danger signs with obstetric ultrasound makes the mother cautious about her health and seek more health services and deliver in a health facility.[27 28] Findings from other settings also indicated the use of obstetric ultrasound significantly raised institutional delivery.[15 23 29] For instance, use of portable ultrasound has raised the number of births at the intervention sites by 34.1% compared with 29.5% in the non-intervention sites.[22]

Similarly, the obstetric ultrasound was found highly effective in raising PNC. Monthly, on average, about 13 additional PNC services were seen in an intervention health facility over the control health facility. There is a lot of evidence that indicates mothers who give birth in a health facility are more likely to have PNC.[30] Therefore, obstetric ultrasound service would have a direct as well as an indirect effect on PNC through raising the institutional delivery.

The other major service indicator we gave due emphasis on was referral during ANC. This variable was considered a proxy for early detection of pregnancy-related complications. Referral during ANC was raised significantly for

Table 5 The effect of obstetric ultrasound on maternal and child service and health outcomes

Outcome variable		Estimates	SE	t	P>t
At least one ANC	Before: diff (T-C)	2.80	8.31	0.34	0.74
	After: diff (T-C)	26.13	8.31	3.14	0.00**
	Difference-in-differences	23.33	11.76	1.98	0.05*
Four or more ANC	Before: diff (T-C)	6.86	1.61	4.28	0.00**
	After: diff (T-C)	11.61	1.61	7.24	0.00**
	Difference-in-differences	4.75	2.27	2.09	0.04*
Delivery	Before: diff (T-C)	12.28	1.64	7.48	0.00**
	After: diff (T-C)	15.73	1.64	9.58	0.00**
	Difference-in-differences	3.45	2.32	1.49	0.14
Postnatal care	Before: diff (T-C)	9.32	1.77	5.26	0.00**
	After: diff (T-C)	15.94	1.77	8.99	0.00**
	Difference-in-differences	6.62	2.51	2.64	0.01**
Perinatal death	Before: diff (T-C)	0.10	0.07	1.37	0.17
	After: diff (T-C)	−0.09	0.02	3.55	0.00**
	Difference-in-differences	−0.18	0.08	2.45	0.01*

Means and SEs are estimated by linear regression.
**P<0.01; *p<0.05.
T - Treatment; C - Control
ANC, antenatal care.

mothers who had obstetric ultrasound services during their ANC. The ATT was 0.25. This finding directly relies on the main aim of introducing obstetric ultrasound services which is early detecting and anticipating potential complications for the mother and the child. The services being delivered in health centres in Ethiopia are limited to preventive and basic curative services with very limited admission services. Most of the complications could not be managed at the health centre level. Therefore, if some kind of compilations is detected with the ultrasound scan, they will be referred for specialty care. There is sufficient evidence that indicates the use of obstetric ultrasound service during ANC facilitates early detection of complications and facilitates immediate action for better well-being of the mother and child.[22 31 32]

On the other hand, we found that perinatal death was reduced significantly in health facilities with the obstetric ultrasound service. The difference-in-differences estimate indicates that there was a 0.18 average reduction of perinatal death in the intervention health facilities. The reduction in death was attributable to the introduction of obstetric ultrasound services. As mentioned above, using obstetric ultrasound aids the service provider to identify danger signs and make a better and more informed decision. Consequently, the mother could use a better service to raise the well-being of her child. Despite of the fact that there are pieces of evidence that reported it does not have an effect on maternal or child health outcomes,[33 34] obstetric ultrasound service resulted in a dimensional change to safe motherhood and better child well-being.[24 35]

Generally speaking, the use of obstetric ultrasound service has a potential to raise maternal health service users. It also helps for early detection of complications that would result in safe motherhood and childhood. In many LMICs, obstetric ultrasound service is not accessible to the vast majority of the population who use the primary healthcare.[20 36] Given their low economic status, the health systems in low-income countries would prioritise access to service instead of raising the quality. However, the future benefits of raising the quality of maternity care outweigh its current costs.[37] Availing these services at the primary healthcare level is a good strategy to address most of the population with a better service and a well-informed decision.

Limitations

In the PSM analysis, we used retrospective data from registers available in health facilities. We have got too few variables in the treatment and outcome models. The registers are not exhaustive for variables that may confound the estimate of the analysis. Therefore, unobserved variable bias might have been introduced in the analysis and therefore PSM may not give us robust estimates.

CONCLUSION

In conclusion, the findings of this study have shown that there is a consistent increase in maternal health service use because of the introduction of obstetric ultrasound at the primary health centre level. Despite the fact that ANC 4 attendance has decreased for those who had ultrasound services, the rate of ANC attendance more than once has shown an increasing pattern. The decrease in health service use following the COVID-19 pandemic and continuing conflicts in some of the intervention areas could have resulted in an expected decrease in ANC 4 attendance. Among the continuum of maternity care components, the intervention resulted in the highest ATE on PNC use.

Our finding also indicated that early detection of pregnancy-related complications was high among the treatment group. The increased referral of mothers at their ANC for specialty care results in safe motherhood and better well-being of the baby. Consistently, perinatal death was found lower in the treatment group.

Implications for research and practice

The findings of this study have got some policy, programme and research implications. The consistent rise in maternal health service use indicators as a result of the intervention invites additional trials to test the effect of obstetric ultrasound service in other locations of the country. Furthermore, since the issue is of interest for policy recommendation and building a good evidence base, we recommend further study that takes more relevant covariates into account. A longitudinal study that is targeted to examine the predictive values, sensitivity and specificity of the obstetric ultrasound service at primary healthcare in improving diagnostic capacities of the healthcare providers is of paramount importance.

Author affiliations
[1]Department of Health Policy and Management, Faculty of Public Health, Jimma University, Jimma, Ethiopia
[2]USAID Transform Health in Developing Regions, Amref Health Africa, Addis Ababa, Ethiopia
[3]MERQ Consultancy PLC, Addis Ababa, Ethiopia
[4]Department of Population and Family Health, Jimma University, Jimma, Ethiopia
[5]USAID Transform Health in Developing Regions, Amref Health Africa, Semera, Afar, Ethiopia
[6]USAID Transform Health in Developing Regions, Amref Health Africa, Jigjiga, Somali, Ethiopia
[7]USAID Transform Health in Developing Regions, Amref Health Africa, Asosa, Benishangul-gumuz, Ethiopia
[8]USAID Transform Health in Developing Regions, Amref Health Africa, Gambela, Ethiopia
[9]Aklilu Lemma Institute of Pathology, Addis Ababa University, Addis Ababa, Ethiopia
[10]Department of Epidemiology, Faculty of Public Health, Jimma University, Jimma, Ethiopia

Twitter Derebe Tadesse @derebe

Acknowledgements We would like to thank USAID Transform Health, led by Amref Ethiopia for funding this study. Our heartfelt thank also goes to MERQ Consultancy for facilitating the write-up of the manuscript. In addition, we would like to acknowledge study participants and data collectors.

Contributors Design of the study—MGJ, YKA, KY, ATuji, GM, DT, ATadele, ST and YA. Data collection—ATuji, DT, MA, AI, SE, MB, AM, MS, HO and AS. Data analysis and interpretation—KY and MGJ. Drafting the article—KY. Critical revision of the article—KY, MGJ, ATuji, ATadele, GM, DT and ST. Guarantor— DT, KY, AT, MGJ, YKA. All the authors gave their approval for the final version of the manuscript and its submission to the journal.

Funding The US Agency for International Development (USAID) funded this study through USAID Transform Health in Developing Regions Activity with award number AID-663-A-17-00006.

Disclaimer The authors' views expressed in this publication do not necessarily reflect the USAID and the US Government.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval The intervention was part of a big project implemented in the four regions of Ethiopia for about 4 years. Before its implementation, the intervention has obtained ethical approval. In the case of this paper, we used secondary data from registers and databases. In order to get relevant data, we followed the necessary steps across all the regional and facility administrations for permission. We obtained anonymous data that did not have any personal identifier.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data used in this study can be accessed with a reasonalble request to AMREF Health Africa.

ORCID iDs
Kiddus Yitbarek http://orcid.org/0000-0001-8662-7434
Derebe Tadesse http://orcid.org/0000-0002-9972-9146
Afework Tadele http://orcid.org/0000-0001-5682-6117

REFERENCES

1 Sustainable TH, Goals D. The health-related sustainable development goals, 2020. Available: https://apps.who.int/iris/bitstream/handle/10665/349982/9789290619512-eng.pdf;sequence=1
2 Cerf ME. The sustainable development goals: Contextualizing Africa's economic and health landscape. *Glob Chall* 2018;2:1800014.
3 World Health Organization, UNICEF, UNFPA, The World Bank. Trends in the United nations population division, 2019. Available: https://ww.bing.com/search?q=annual+rate+of+reduction+(ARR)+in+global+MMR+during+the+2000–2017&cvid=43d98d4debbe4b1ea213daee5cb9347&aqs=edge.69i57.936j0j4&FORM=ANAB01&PC=LCTS
4 WHO, UNICEF, UNFPA, And WBG, Division United Nations Population. Trends in maternal mortality, 2019. Available: https://www.who.int/reproductivehealth/publications/maternal-mortality-2000-2017/en/
5 Musarandega R, Nyakura M, Machekano R, *et al*. Causes of maternal mortality in Sub-Saharan Africa: a systematic review of studies published from 2015 to 2020. *J Glob Health* 2021;11:04048.
6 Bain LE, Aboagye RG, Dowou RK, *et al*. Prevalence and determinants of maternal healthcare utilisation among young women in sub-Saharan Africa: cross-sectional analyses of demographic and health survey data. *BMC Public Health* 2022;22:647.
7 Wuneh AD, Medhanyie AA, Bezabih AM, *et al*. Wealth-based equity in maternal, neonatal, and child health services utilization: a cross-sectional study from Ethiopia. *Int J Equity Health* 2019;18:201.
8 Bobo FT, Yesuf EA, Woldie M. Inequities in utilization of reproductive and maternal health services in Ethiopia. *Int J Equity Health* 2017;16:105.
9 United Nations Children's Fund (UNICEF). *Situation analysis of children and women*. Afar Region, 2019.
10 United Nations Children's Fund (UNICEF). *Situation analysis of children and women*. Somali Region, 2020.
11 United Nations Children's Fund (UNICEF). *Situation analysis of children and women*. Gambella Region, 2020.
12 United Nations Children's Fund (UNICEF). *Situation analysis of children and women*. Benishangul-Gumuz Region, 2018.
13 USAID. *Ethiopia fact sheet maternal and child health*, 2019.
14 U.S. Agency for International Development Global (USAID). Global health research and development strategy, 2017. Available: https://www.usaid.gov/sites/default/files/documents/1864/USAIDGlobalHealthRDStrategy_2017-2022.pdf
15 Ross AB, DeStigter KK, Rielly M, *et al*. A low-cost ultrasound program leads to increased antenatal clinic visits and attended deliveries at a health care clinic in rural Uganda. *PLoS One* 2013;8:e78450.
16 Amref Health Africa. USAID transform: health in developing regions activity, 2020. Available: https://amref.org/wp-content/uploads/2020/11/Amref-Ethiopia-USAID-Transform-HDR-Program-Bulletin-2020.pdf
17 Central Statistical Agency [Ethiopia] and ICF International. *Ethiopia demographic and health survey 2016*, 2016.
18 EPHI, Ministry of Health. *Ethiopian mini demographic and health survey 2019*, 2019.
19 Cunningham S. *Causal inference: the Mixtape*. Yale University Press, 2021.
20 Kim ET, Singh K, Moran A, *et al*. Obstetric ultrasound use in low and middle income countries: a narrative review. *Reprod Health* 2018;15:129.
21 Cherniak W, Anguyo G, Meaney C, *et al*. Effectiveness of advertising availability of prenatal ultrasound on uptake of antenatal care in rural Uganda: a cluster randomized trial. *PLoS One* 2017;12:e0175440.
22 Kawooya MG, Nathan RO, Swanson J, *et al*. Impact of introducing routine antenatal ultrasound services on reproductive health indicators in Mpigi district, central Uganda. *Ultrasound Q* 2015;31:285–9.
23 Mbuyita S, Tillya R, Godfrey R, *et al*. Effects of introducing routinely ultrasound scanning during Ante natal care (Anc) clinics on number of visits of ANC and facility delivery: a cohort study. *Arch Public Health* 2015;73:36.
24 Luntsi G, Ugwu AC, Ohagwu CC, *et al*. Impact of ultrasound scanning on pregnant women's compliance with attendance at antenatal care visits and supervised delivery at primary healthcare centres in northern Nigeria: initial experiences. *Radiography* 2022;28:480–6.
25 Nigusie A, Azale T, Yitayal M, *et al*. Institutional delivery and associated factors in rural communities of central Gondar zone, Northwest Ethiopia. *PLoS One* 2021;16:e0255079.
26 Pathak P, Shrestha S, Devkota R, *et al*. Factors associated with the utilization of institutional delivery service among mothers. *J Nepal Health Res Counc* 2018;15:228–34.
27 Yosef T, Tesfaye M. Pregnancy danger signs: knowledge and health-seeking behavior among reproductive age women in Southwest Ethiopia. *Womens Health* 2021;17:174550652110632.
28 Weldemariam S, Kiros A, Welday M. Utilization of institutional delivery service and associated factors among mothers in North West Ethiopian. *BMC Res Notes* 2018;11:194.
29 Huang K, Tao F, Raven J, *et al*. Utilization of antenatal ultrasound scan and implications for caesarean section: a cross-sectional study in rural eastern China. *BMC Health Serv Res* 2012;12:93.
30 Worku AG, Yalew AW, Afework MF. Factors affecting utilization of skilled maternal care in Northwest Ethiopia: a multilevel analysis. *BMC Int Health Hum Rights* 2013;13:20.
31 Whitworth M, Bricker L, Mullan C. Ultrasound for fetal assessment in early pregnancy. *Cochrane Database Syst Rev* 2015:CD007058.
32 Whitworth M, Bricker L, Neilson JP, *et al*. Ultrasound for fetal assessment in early pregnancy. *Cochrane Database Syst Rev* 2010:CD007058.
33 Henrichs J, Verfaille V, Jellema P, *et al*. Effectiveness of routine third trimester ultrasonography to reduce adverse perinatal outcomes in low risk pregnancy (the iris study): nationwide, pragmatic,

multicentre, stepped wedge cluster randomised trial. *BMJ* 2019;367:l5517.
34 Goldenberg RL, Nathan RO, Swanson D, *et al*. Routine antenatal ultrasound in low- and middle-income countries: first look - a cluster randomised trial. *BJOG: Int J Obstet Gy* 2018;125:1591–9.
35 Abawollo HS, Tsegaye ZT, Desta BF, *et al*. Contribution of portable obstetric ultrasound service innovation in averting maternal and neonatal morbidities and mortalities at semi-urban health centers of Ethiopia: a retrospective facility-based study. *BMC Pregnancy Childbirth* 2022;22:368.
36 Seffah JD, Adanu RMK. Obstetric ultrasonography in low-income countries. *Clin Obstet Gynecol* 2009;52:250–5.
37 Pinto NM, Nelson R, Puchalski M, *et al*. Cost-effectiveness of prenatal screening strategies for congenital heart disease. *Ultrasound Obstet Gynecol* 2014;44:50–7.