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Effect of USAID funded obstetric ultrasound service interventions on maternal and perinatal health outcomes at primary health care facilities in Ethiopia

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Abstract

Objective: A dimensional shift in the health service delivery in the primary health care setting is required to raise maternal and child wellbeing. This study aimed to evaluate the effect of USAID-funded obstetric ultrasound service interventions 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 centers located in four regions of Ethiopia.

Participants: We used two years' data of 1,568 mothers from 13 intervention and 13 control primary health centers. Data were obtained from Vscan, antenatal care, delivery, and postnatal care registers.

Intervention: Use of portable obstetric ultrasound service during pregnancy.

Outcome measures: The primary outcome variable includes complete four antenatal care, referral during antenatal care, 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 was decreased after the intervention, and the rest of the indicators, including referral during ANC, institutional delivery, and postnatal care, 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 center level. Furthermore, early detection of compilations and following referral for specialty care was found to be high as a result of obstetric ultrasound intervention. The consistent rise in maternal health service use indicators as a result of the intervention calls for additional trial to test the effect of obstetric ultrasound service in other country locations. Furthermore, evaluating the predictive values, sensitivity, and specificity of the obstetric ultrasound service is important.

Key words: Vscan, Maternal health service, child health, effectiveness evaluation

Strength and Limitations

- In this study we used representative sample from geographically diverse regions of Ethiopia.
- Our study used causality evaluation methods like propensity score matching, differences-in-differences and inverse probability of treatment weighting (IPTW) to see the effect of obstetric ultrasound service in four regions of Ethiopia.
- We used retrospective data from registers available in health facilities. The registers are not exhaustive for variables that may confound the estimate of the analysis. That maight have affected the final estimates of the model

Introduction

Ensuring healthy lives and promoting well-being at all age had been the major target in the millennium development goals and continued to be one of the Sustainable Development Goals (SDGs) target. The SDG 3 also aims to end preventable maternal mortality and neonatal death.[1,2] Henceforth, the global maternal death has been reduced by 2.9% per annum from 2000-2017 and child deaths have decreased considerably. For instance, the average annual rate of reduction (ARR) in global MMR during the 2000–2017 period was 2.9%.[3] However, reducing maternal (SDG3.1) and child (SDG3.2) mortality are far from being reached. Furthermore, the difference between high income and low- and 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 shows maternal mortality ratio of 412 per 100,000 live births and child mortality rate of 67 per 1,000 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 Bain LE et al shows only half of women receive the recommended amount of health care they need.[6] Similarly in Ethiopia, improving access to reproductive, maternal and newborn health care and its utilization and ensuring service equity and quality at facilities level remains a challenge.[7,8] Moreover, services quality are not uniformly distributed between and withing regional states that regions such as Afar, Benishangul Gumuz, Gambella and Somali have recorded lower access to health care health care services and its utilizations as compared to national averages.[9–12] and are exacerbated by shocks like drought, conflict or disease outbreaks, including COVID-19.[13]

Cognizant of these facts, Transform Health in Developing Regions (HDR) is one of the USAID Transform Health Activities, in collaboration with the Ministry of Health (MOH), has designed interevention that further improve maternal and child health in Developing Regional States of Ethiopia. The overall objective of the program was to increase the utilization 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 devise for obstetric scanning at its selected Center of Excellence health facilities- eighteen Health Centers and six hospitals in the four of its target regional states. In addition, a skill-based training was provided for midwives and physicians working at these facilities on Vscan utilization 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 five morbidity and mortality in developing regions of Ethiopia.[16] However, to the best of authors knowledge no study has evaluated effectiveness of these interventions in the study areas and less is known the extent to which introduction of such program would improve maternal and perinatal outcome is less explored in Ethiopia. Such evaluation would have both policy and program relevance. Therefore, the main purposed 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.

Methods

Study setting and design

The study was conducted in emerging regional states of Ethiopia, namely Afar, Benshangul-Gumuz, Gambella and Somali regional states. Early childhood mortality was high in the regions. For instances, under-five child mortality rate in Afar, Benishangul-Gumuz, Gambella and Somali regional states were 144, 98, 88, and 94 respectively compared to 39 in the country's capital, Addis Ababa.[17] Moreover, maternal health service utilization 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%; ANC coverage was 30%, postnatal check-ups in the 2 days after delivery was only 10% in Somali regional states.[18] Thus, 24 health facilities in these regional states (5 from each except 9 from Somali) were selected for interventions of providing ultra sound devises and technical support.

Study Design and sample: Quasi-experimental study design was employed in 13 health facilities as intervention and 13 health facilities as control group to compare maternal health service utilization and perinatal health outcomes.

Sample size and sampling procedure

Totally 13 Vscan implementing (intervention) and 13 non-Vscan implementing (control) health centers were included in this study. We took sample from all the selected intervention and control health centers. We used a double population proportion formula to determine the sample size with the following assumptions: Proportion of delivery without intervention was taken 26.7% from the demographic and health survey of the four regions; proportion of delivery with intervention was taken from other similar study that shown a 6.9% increase in delivery in facilities with Vscan service i.e. 33.6%, power 85 and with 95% level of confidence.

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

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 to intervention and control groups. Before the intervention 395 cases were allocated to each of the intervention and control group. 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 facility. We used systematic random sampling technique to select each of the cases from the registry. For the facility level aggregate data, we took the whole two years before and two years after the intervention.

Study population: All pregnant women who visit health facilities for maternal health care utilization in the selected heath facility as intervention and control in Afar, Benishangul-Gumuz, Gambella and Somali regional states of Ethiopia.

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 centers 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 utilization of high impact and quality reproductive, maternal, neonatal and child health (RMNCH) services. The selected health facilities were provided with a portable ultrasound devices and related installation was performed. The service began in the mid of October 2019 and has continued for more than two years. The obstetric ultrasound devices were regularly maintained as required when problems reported from the health facilities.

The service was provided to mothers by trained midwife nurses. Two midwife nurses were selected from each health facility (HF) and got trained for 11 days by experienced Radiologists, Integrated Emergency Surgical Officer (ISEO) and Gynecology and Obstetrics specialists. This training involved class room discussion and practical sessions in the health facilities using mobile Vscan ultrasound machine. After they complete the class training and demonstration, mentors were assigned for each of the trainee and followed up in three rounds, for two days each. The program 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 midwifes complete the training and mentoring sessions, they started the actual service to pregnant mothers attending ANC in the facility. The recommended frequency of ultrasound scan is once at each trimester. However, practically there were women who were not scanned, scanned once or more because of issues like client over-load, absence of the trained midwife in the facility. The services were regularly given for about two years in the selected 13 primary health care facilities. Follow up of the service has also been critical part of the program which was regularly done by both THDR staff and respective regions public sector experts. There was a frequent reporting of the updates related to mothers who had ultrasound service.

Variables and measurement

Double robust estimation

Outcome

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

Exposure variable

If a women 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 review of registers in the health facility including Vscan register (for the intervention health facilities), ANC register, delivery register and postnatal care (PNC) register. We used data over four years from 2017 to 2021 before and after the Vscan service was initiated in 2019. 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 logbook. Before the intervention we took two years data from 11 October 2017 to October 10 2019; and after the intervention we took two 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; still birth; and death to seven 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 ANC register, then delivery register and finally the PNC register. The same thing was done in the control health centers except the Vscan register. The data from the four sources were matched using a unique identifier variable medical record number (MRN).

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 logbook was cleaned get prepared for analysis. We used a statistical software STATA 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 approach.

For aggregate facility level continuous variables, we checked for the normal distribution of the data on health service indicators prior to fit a model. As we can learn from the histograms [Supplementary file I] 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 propensity score matching 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); Y1i, is treated outcome and Y0i untreated outcome. When we see from the treatment side, untreated outcome (Y0i) is unobservable. This unobserved outcome is a counterfactual to the observed outcome. We used logit model and estimate the propensity score (i.e. 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 uses 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 propensity scores matching (PSM) approach minimize the selection bias by balancing the cases in terms of the confounding variables among treatment and control groups. We used the kernel matching, the radius matching, and inverse probability of treatment weighting (IPTW) [19] We tried various specifications that best reduces the selection bias and creates best balance between treatment and control groups. To check the balance in the treatment and control groups we employed the absolute standardized difference in means (SMD), the absolute difference in means divided by the standard deviation for those observations in the treatment group. Finally, we reported average treatment effect (ATE) and average treatment effect on the treated (ATT) and significant difference among the treatment and control groups was determined with a p-value < 0.05.

Sensitivity analysis

First, we did a difference-in-difference analysis to identify the facility (aggregate) level effect of the introduction of obstetric ultrasound service. We applied a differences-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 cases 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-difference estimate using the “diff” command in stata.

This was followed by use of Inverse probability of treatment weighting (IPTW) estimators and 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 estimating 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 corrects 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 standard errors in the second step to reflect the uncertainty associated with the predicted treatment probabilities.

Patient/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 1,568 study participants, of them 795 were included before the intervention and 773 were after the intervention. Almost 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. Among the study participants the highest proportion had syphilis taste and were non-reactive, similarly most of the study participants were negative for HIV test. The highest proportion in 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).

Table 1: characteristic 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
	Beneshangul 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]	

Description of maternal health service use

There are significant variations in uptake of maternal and new born health between the intervention and control groups both at baseline and after implanting 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 in the uptake of four or more ANC visits, and (c) after intervention in the uptake of four ANC visit and institutional delivery).

Table 2: Uptake of various maternal and new-born health services

Variables	Before		P-value	After		P-value
	Control	Intervention		Control	Intervention	
>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
Institutional delivery	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
Postnatal care	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[1.39]	0[0]	0.14	4[3.48]	1[0.53]	0.13

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 Antenatal care (ANC) was positive in both groups while the proportion of women who received four ANCs declined in the intervention group. Uptake of Institutional delivery and postnatal care 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, proportion of women who completed the continuum of care increased in both groups and the magnitude was higher in the intervention group as compared to the control (Figure 1).

Matching

We calculated the percentage reduction of bias in Radius and Kernel matching methods [Supplementary file II]. 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 standardized difference in means (SMD) plots [Supplementary file III contains SMD plots for the Kernel matching method]. Those on support cases were included in the analysis and off support were excluded from the final treatment effect test [Supplementary file IV].

The effect of Obstetric Ultrasound on Maternal health service use

In order to come up with the results we used propensity score matching 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 minimize bias) indicated that attending four or more ANC was better in the control group as compared to those women who obtained obstetric ultrasound service. All other service uptake indicators were better used by mothers who had obstetric ultrasound service. In the radius matching estimate the direction of effect is same with that of Kernel matching method. However, the significant effects were observed only on four or more ANC and postnatal care (Table 3).

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

Variables	Kernel Matching				Radius Matching				IPTWs			
	ATE	ATT	S.E.	95% CI	ATE	ATT	S.E.	95% CI	ATE	ATT	S.E.	95% CI
Four or more ANC	-0.20	-0.16*	0.04	[-0.23,-0.09]	-0.21	-0.16*	0.04	[-0.23,-0.08]	-0.2	-0.16*	0.04	[-0.23,-0.09]
Institutional delivery	0.24	0.25*	0.05	[0.15,0.34]	0.24	0.25	0.05	[-0.02,0.06]	0.23	0.25*	0.04	[0.17,0.33]
Referral during ANC	0.01	0.02*	0.02	[0.15,0.34]	0.01	0.02	0.02	[-0.02,0.06]	0.01	0.01	0.02	[-0.03,0.06]
Postnatal care	0.26	0.27*	0.04	[0.10,0.37]	0.24	0.27*	0.04	[0.19,0.35]	0.24	0.26*	0.04	[0.18,0.34]
Continuum of care	0.02	0.02	0.02	[-0.02,0.06]	0.01	0.02	0.02	[-0.01,0.06]	0.01	0.02	0.02	[-0.03,0.06]

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 group after the intervention. However the increase in the intervention group is higher than the 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).

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 by far higher than the control group. The median difference-in-difference was found as high as 14.5 in the first ANC indicator and as low as 6 in the delivery indicator (Table 4).

Table 4: Median difference of maternal health service use indicators

Outcomes	Before			After		
	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-value < 0.01

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

Table 5: the effect obstetric ultrasound on maternal and child service and health outcomes

Outcome var.		**Estimates**	**S. Err.**	**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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	-0.18	0.08	2.45	0.01*

Means and Standard Errors are estimated by linear regression

** p<0.01; * p<0.05

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 services.[20] The introduction of the low cost portable ultrasound devices and its associated benefit in terms of early detection of pregnancy related complications made the service to expand fast. There are conflicting evidence related to the effects of the use of obstetric ultrasound for maternal and child service and health outcomes. This study has aimed to check the effect of obstetric ultrasound on maternal health service use and child wellbeing. In this study we did two analyses to see the effect of obstetric ultrasound intervention on maternal health service outcomes. The first analysis used an individual data about the mother and the unit of analysis was individual mothers. The other one was an aggregate facility level monthly data and the unit of analysis was primary health center.

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

Antenatal care use was raised in health facilities that give obstetric ultrasound service over the period after the introduction of obstetric ultrasound service. However, there is inconsistence in the findings of four or more ANC service use. Facility level aggregate data indicates health facilities with obstetric ultrasound services were effective in raising service use for fourth ANC, while in the individual client level data the reverse was true. This could have happened because late initiation of the first ANC in the intervention group. More than 9% of the mothers initiated ANC at 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 a significant shock in the health system. The country in general and specifically conflict affected areas are het by continuing health system stressors and had low performance in many health service indicators. These health system Findings from other different LMICs revealed the use of obstetric ultrasound has increased ANC attendance significantly.[15,21–23] For instance a study conducted in Uganda found a 147% increase in ANC 4 attendance.[22] Similarly, our facility level aggregate finding indicated that there is a significant raise 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 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 counseling to the mother could have increased delivery in a health institution.[24,25] 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.[26,27] Findings from other settings also indicated the use of obstetric ultrasound significantly raised institutional delivery.[15,23,28] For instance use of portable ultrasound has raised the number of births at the interventional sites by 34.1% compared with 29.5% in the non-intervention sites.[22]

Similarly, the obstetric ultrasound was found highly effective in raising postnatal care. Monthly, on average about 13 additional PNC service were seen in an intervention health facility over the control health facility. There are a lot of evidence that indicate mothers who give birth in a health facility are more likely to have postnatal care.[29] Therefore, obstetric ultrasound service would have a direct as well as an indirect effect to postnatal care through raising the institutional delivery.

The other major service indicator we gave a due emphasis was referral during ANC. This variable was considered as a proxy to early detection of pregnancy related complications. Referral during ANC was raised significantly for mothers who had obstetric ultrasound services during their ANC. The average treatment effect on the treated was 0.25. This finding directly relies with the main aim of introducing obstetric ultrasound services which is early detecting and anticipating potential complications on the mother and the child. The services being delivered in health centers in Ethiopia are limited to preventive and basic curative services with a very limited admission services. Most of complications could not be managed at the health center level. Therefore, if some kind of compilations are detected with the ultrasound scan they will be referred for specialty care. There are sufficient evidence that indicate use of obstetric ultrasound service during ANC facilitates early detection of complications and facilitates immediate action for a better wellbeing of the mother and child.[22,30,31]

On the other hand, we found that perinatal death was reduced significantly in health facilities with the obstetric ultrasound service. The difference-in-difference estimate indicate that, there was 0.18 average reduction of perinatal death in the intervention health facilities. The reduction of death was attributable to the introduction of obstetric ultrasound service. As mentioned above, using obstetric ultrasound aids the service provider to identify danger signs and make a better and informed decision. Consequently, the mother could use a better service to raise the wellbeing of her child. There are evidence that reported obstetric ultrasound does not have an effect to maternal or child health outcomes.[32,33]

Limitations

In the propensity score matching analysis we used retrospective data from registers available in health facilities. We have got too few variables in 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 center level. Despite the fact that ANC 4 attendance has decreased for those who had ultrasound services those who had ANC 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 an expected decrease in ANC 4 attendance. Among the continuum of maternity care components, the intervention resulted the highest average treatment effect on postnatal care use.

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

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

Funding

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Acknowledgments

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Conflict of Interest

The authors declare that they have no any conflict of interest.

Data availability

Data used in this study can be accessed with a reasonalble request to AMREF Health Africa.

Ethics Approval

Not applicable

Authors' contribution

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

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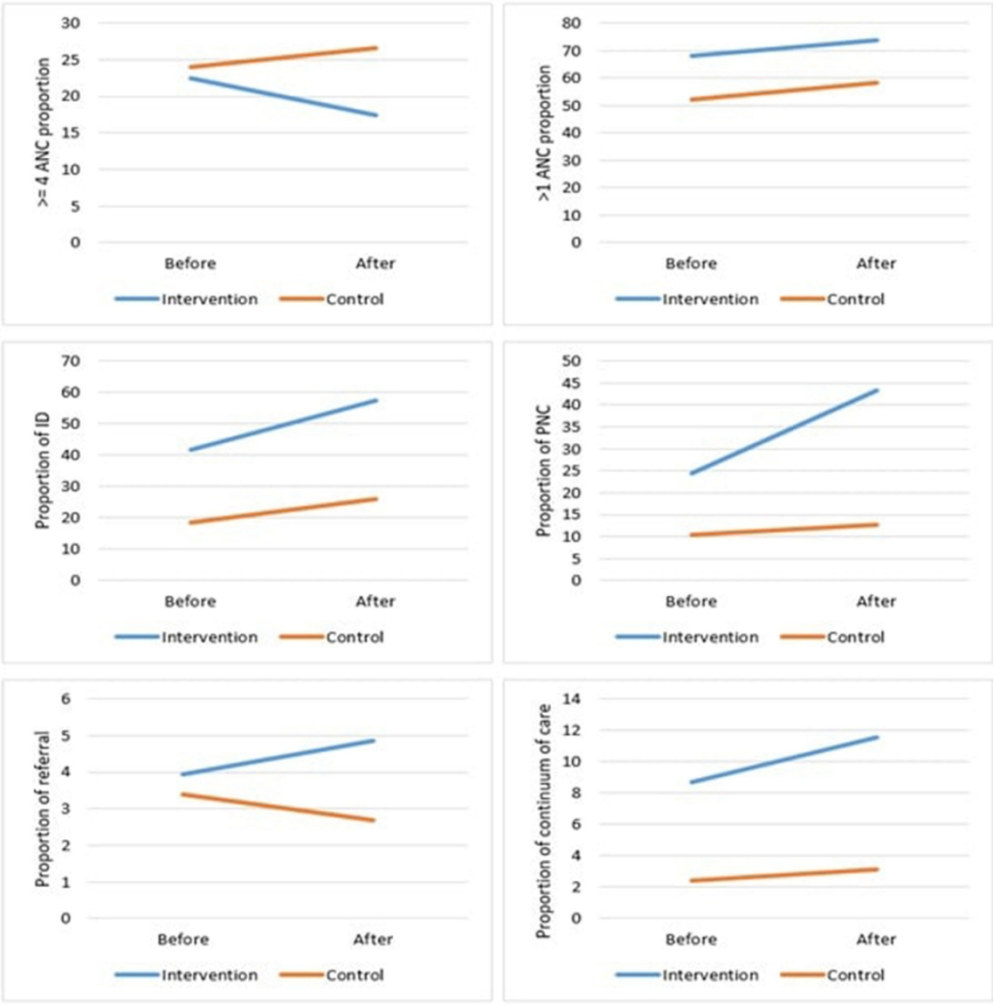
Figure Legends

Figure 1: Change in maternal health service use before and after the introduction of obstetric ultrasound service.

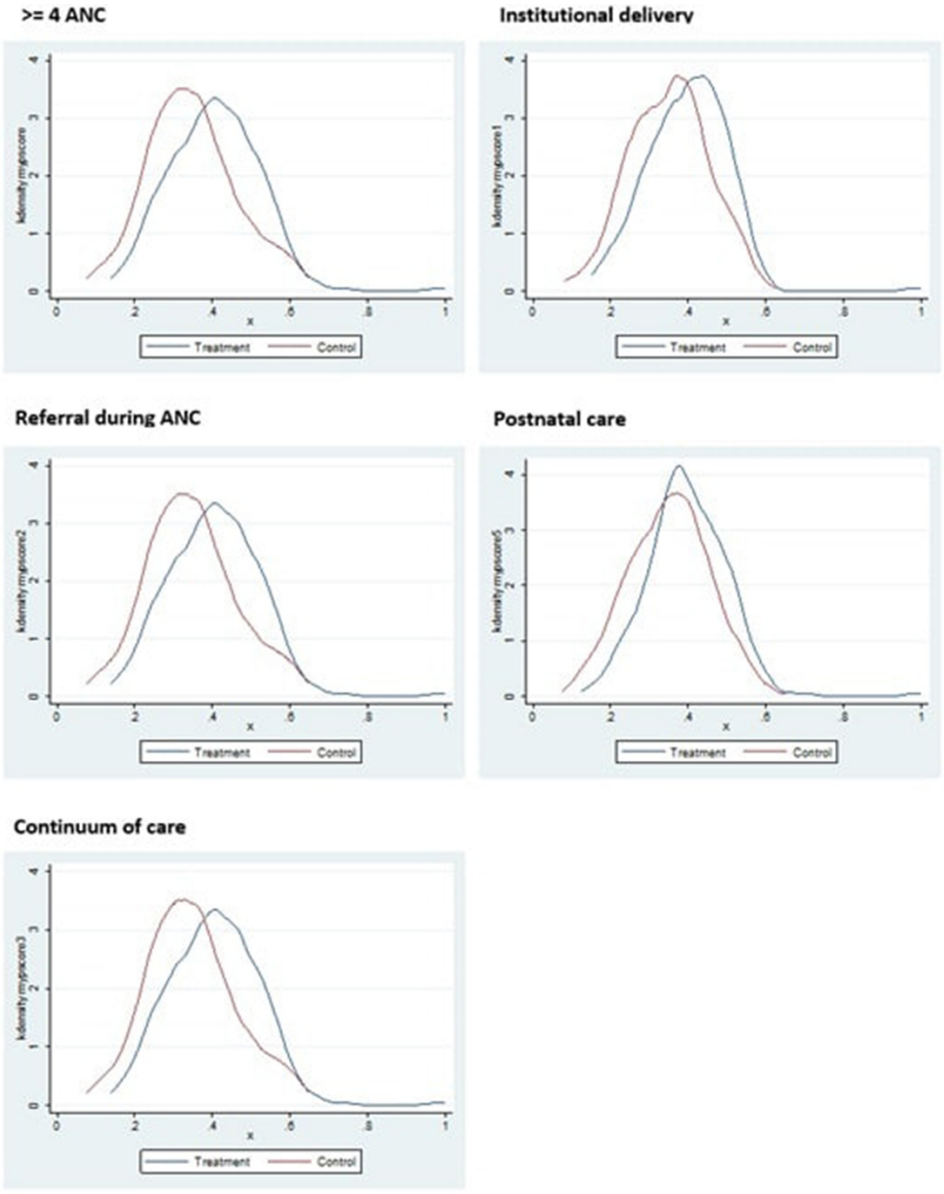
Figure 2: Common Support figures for the treatment and control groups

Figure 3: Median monthly health service use change in maternal health service use in intervention and control health facilities.



Change in maternal health service use before and after the introduction of obstetric ultrasound service.

107x109mm (300 x 300 DPI)



Common Support figures for the treatment and control groups

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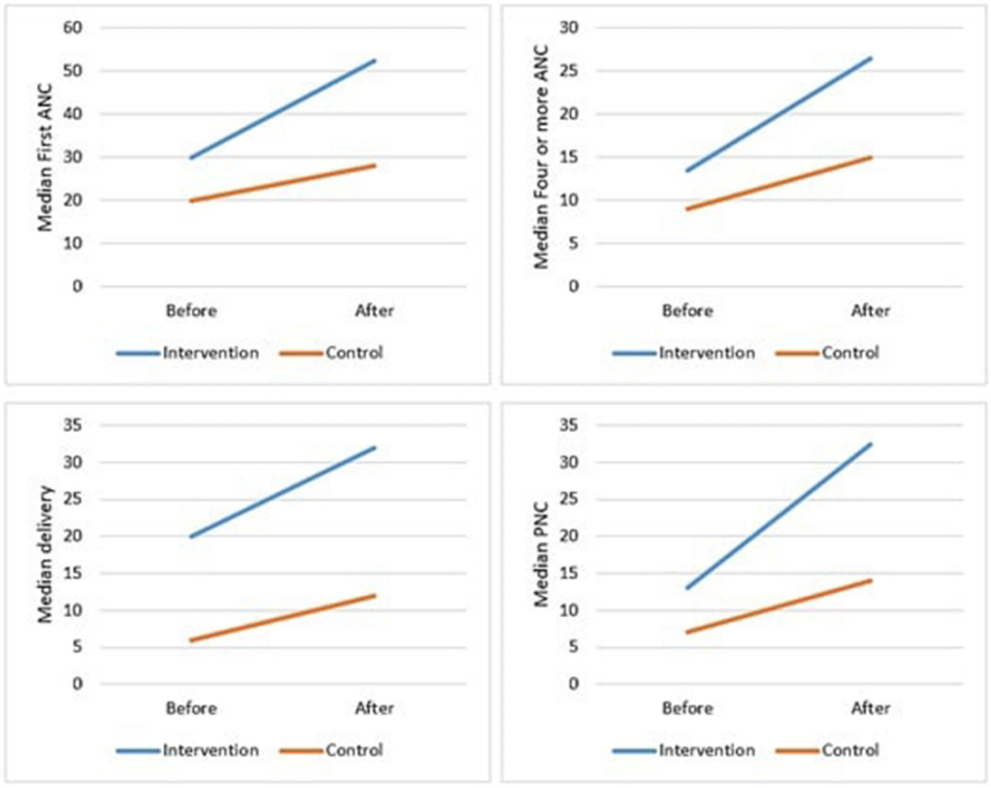
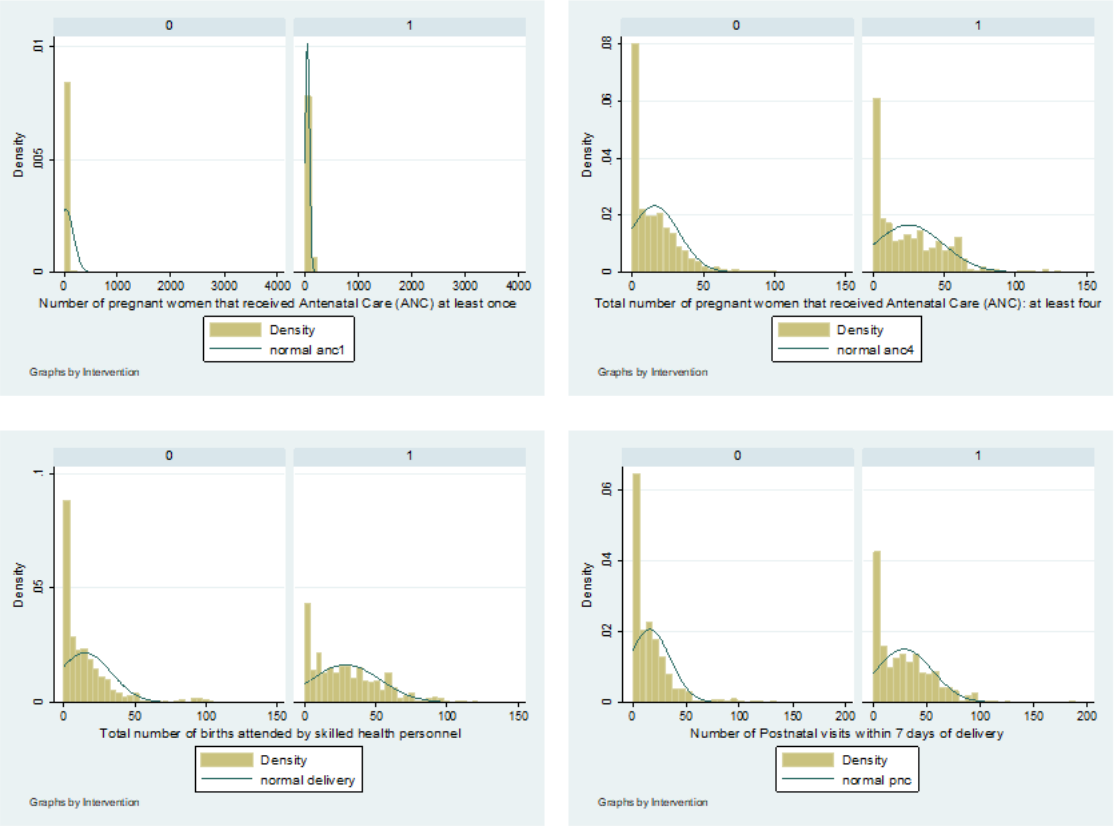


Median monthly health service use change in maternal health service use in intervention and control health facilities

93x74mm (300 x 300 DPI)

Supplementary files

Supplementary file I: Normality test of the maternal health service use variables



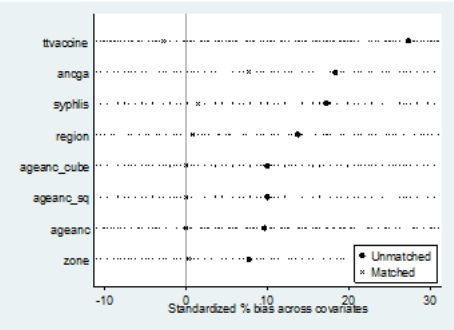
Supplementary file II: Assumption checking: common Support

Table 1: Percentage reduction in bias as a result of propensity score matching

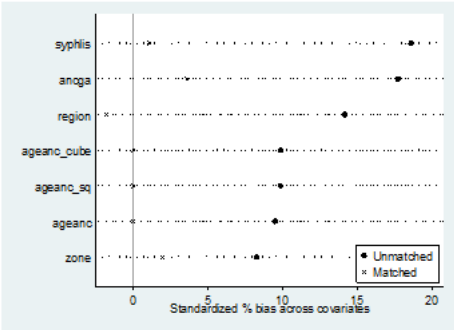
Outcomes	Matching variables	Radius		Kernel	
		% reduction of bias	P-value	% reduction of bias	P-value
Four or More ANC	Age of the mother	99.4	0.69	99.8	0.90
	Age squared	100	0.68	100	0.91
	Age cubed	100	0.68	100	0.91
	Gestational age	82.3	0.74	58.1	0.44
	Syphilis test	77.9	0.70	91.7	0.88
	TT Vaccine	81.3	0.62	89.5	0.78
	Region	97.2	0.97	94.1	0.93
	Zone	51.2	0.70	96.1	0.98
Institutional delivery	Age of the mother	99.8	0.91	99.6	0.80
	Age squared	100	0.96	100	0.82
	Age cubed	100	0.98	100	0.85
	Gestational age	95.5	0.93	79.6	0.71
	Syphilis test	93.9	0.91	94.1	0.91
	Region	92.2	0.91	87.4	0.85
	Zone	94.1	0.96	76.5	0.84
Referral during ANC	Age of the mother	99.6	0.80	99.4	0.67
	Age squared	100	0.81	100	0.68
	Age cubed	100	0.83	100	0.69
	Gestational age	60.1	0.47	71.4	0.60
	Syphilis test	92.3	0.89	86.7	0.81
	Region	89.8	0.88	99.1	0.99
	Zone	97.6	0.99	91.2	0.94
Postnatal care	Age of the mother	99.2	0.60	99.6	0.80
	Age squared	100	0.61	100	0.81
	Age cubed	100	0.62	100	0.83
	Gestational age	82.9	0.75	60.1	0.47
	Syphilis test	78	0.69	92.3	0.89
	TT Vaccine	76.6	0.55	85.1	0.70
	Region	97.3	0.97	89.8	0.88
	Zone	41.8	0.64	97.6	0.99
Continuum of care	Age of the mother	99.2	0.60	99.6	0.80
	Age squared	100	0.61	100	0.81
	Age cubed	100	0.62	100	0.83
	Gestational age	82.9	0.75	60.1	0.47
	Syphilis test	78	0.69	92.3	0.89
	TT Vaccine	76.6	0.55	85.1	0.70
	Region	97.3	0.97	89.8	0.88
	Zone	41.8	0.64	97.6	0.99

Supplementary file III: standardized difference in means (SMD) plots for Kernel Matching approach

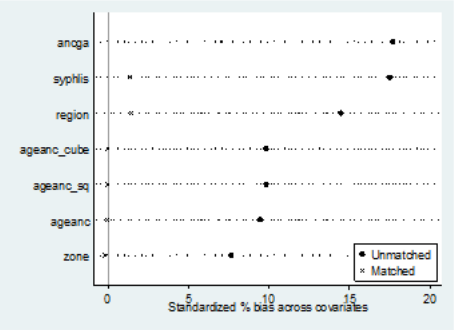
>= 4 ANC



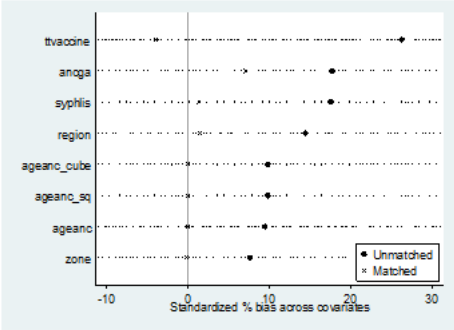
Institutional deliverv



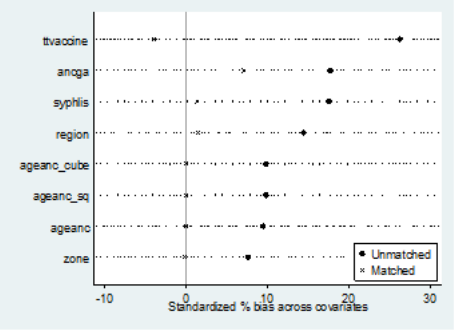
Referral during ANC



Postnatal care

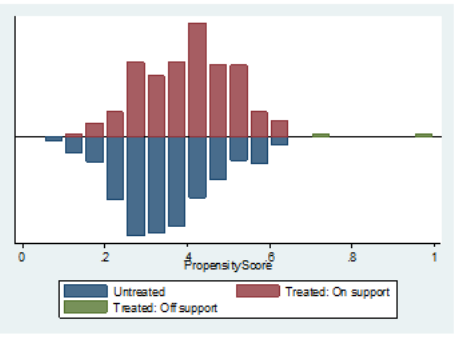


Continuum of care

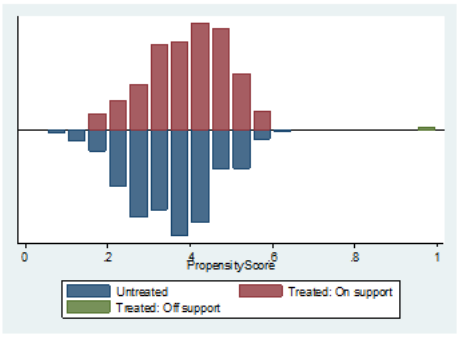


Supplementary file IV: Plot of on support and off support of matching cases

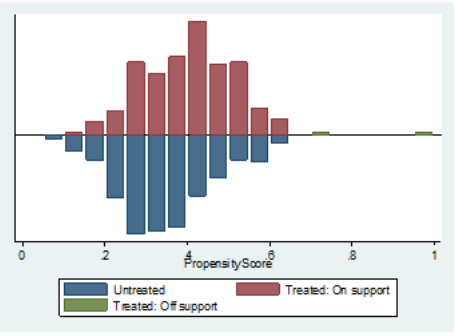
>= 4 ANC



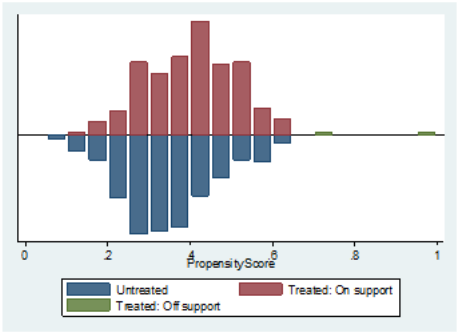
Institutional delivery



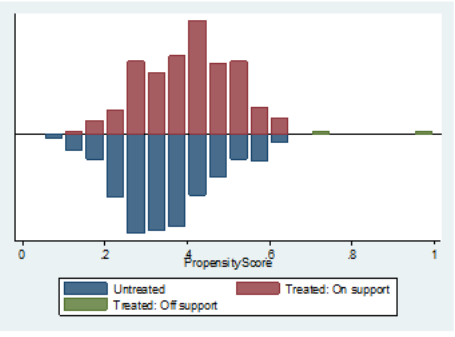
Referral during ANC



Postnatal care



Continuum of care



STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any pre-specified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5 – 7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5, 7, 8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	8 – 9
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	8

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	8 – 9
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	10
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10 – 11
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	14 – 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14 – 15
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Effect of USAID funded obstetric ultrasound service interventions on maternal and perinatal health outcomes at primary health care facilities in Ethiopia: A Propensity Score Matching Analysis

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Manuscript ID	bmjopen-2022-065351.R1
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Effect of USAID funded obstetric ultrasound service interventions on maternal and perinatal health outcomes at primary health care facilities in Ethiopia: A Propensity Score Matching Analysis

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Abstract

Objective: A dimensional shift in the health service delivery in the primary health care setting is required to raise maternal and child wellbeing. This study aimed to evaluate the effect of USAID-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 centers located in four regions of Ethiopia.

Participants: We used two years' data of 1,568 mothers from 13 intervention and 13 control primary health centers. Data were obtained from Vscan, antenatal care, delivery, and postnatal care registers.

Intervention: Use of portable obstetric ultrasound service during pregnancy.

Outcome measures: The primary outcome variable includes complete four antenatal care, referral during antenatal care, 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 was decreased after the intervention (ATE: -0.20; 95% CI, -0.23,-0.09), and the rest of the indicators, including referral during ANC (ATE: 0.01; 95% CI: 0.15,0.34), institutional delivery (ATE: 0.24; 95% CI: 0.15,0.34), and postnatal care (ATE: 0.26; 95% CI: 0.10,0.37), 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 center level. Furthermore, early detection of compilations and following referral for specialty care was 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 country locations. Furthermore, evaluating the predictive values, sensitivity, and specificity of the obstetric ultrasound service is important.

Key words: Vscan, Maternal health service, child health, effectiveness evaluation

Strength and Limitations

- In this study we used representative sample from geographically diverse regions of Ethiopia.
- Our study used causality evaluation methods like propensity score matching, differences-in-differences and inverse probability of treatment weighting (IPTW) to see the effect of obstetric ultrasound service in four regions of Ethiopia.
- We used retrospective data from registers available in health facilities. The registers are not exhaustive for variables that may confound the estimate of the analysis. That maight have affected the final estimates of the model

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 Goals (SDGs) 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 2000-2017, and child deaths have decreased considerably. For instance, the average annual rate of reduction (ARR) in global MMR during the 2000–2017 period was 2.9%.[3] However, reducing maternal (SDG3.1) and child (SDG3.2) mortality is far from being reached. Furthermore, the difference between high-income and low- and 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 maternal mortality ratio of 412 per 100,000 live births and child mortality rate of 67 per 1,000 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 health care they need.. Similarly in Ethiopia, improving access to reproductive, maternal, and newborn health care and its utilization and ensuring service equity and quality at the facilities level remains a challenge.[7,8] Moreover, services 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 utilizations as compared to national averages.[9–12] and are exacerbated by shocks like drought, conflict or disease outbreaks, including COVID-19.[13]

Cognizant of these facts, Transform Health in Developing Regions (HDR) is one of the USAID Transform Health Activities, in collaboration with the Ministry of Health (MOH), which has designed intereventions that further improve maternal and child health in developing regional states of Ethiopia. The overall objective of the program was to increase the utilization 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 devise for obstetric scanning at its selected Centers of Excellence health facilities- eighteen Health Centers and six 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 utilization 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 five 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 program would improve maternal and perinatal outcomes in a low income setting like Ethiopia. Such evaluation would have both policy and program 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.

Methods

Study setting and design

The study was conducted in emerging regional states of Ethiopia, namely Afar, Benshangul-Gumuz, Gambella, and Somali regional states. Early childhood mortality was high in the regions. For instance, the under-five child mortality rate per 1000 live births in Afar, Benishangul-Gumuz, Gambella, and Somali regional states were as high as 144, 98, 88, and 94 respectively compared to 39 in the country's capital, Addis Ababa.[17] Moreover, maternal health service utilization 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%; 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 (5 from each except 9 from Somali) were selected for interventions of providing ultrasound devices and technical support.

Study Design and sample: Quasi-experimental study design was employed in 13 health facilities as an intervention and 13 health facilities as a control group to compare maternal health service utilization and perinatal health outcomes.

Sample size and sampling procedure

Totally 13 Vscan implementing (intervention) and 13 non-Vscan implementing (control) health centers were included in this study. We took samples from all the selected intervention and control health centers. 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; the proportion of delivery with the intervention was taken from another similar study that shown a 6.9% increase in delivery in facilities with Vscan service i.e. 33.6%, power 85 and with 95% level of confidence.

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

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. The sampling interval was determined by dividing the total number of first ANC by the sample size allocated to the health center.For the facility level aggregate data, we took the whole two years before and two years after the intervention, both retrospectivelly.

Study population: All pregnant women who visit health facilities for maternal health care utilization 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 centers 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 centers 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 utilization of high-impact and quality reproductive, maternal, neonatal, and child health (RMNCH) services. The selected health facilities were provided with a portable ultrasound device and related installation was performed. The service began in the mid of October 2019 and has continued for more than two 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 (HF) and got trained for 11 days by experienced Radiologists, Integrated Emergency Surgical Officer (ISEO), and Gynecology 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 and post assessment exams. After they complete the classroom training and demonstration, mentors were assigned for each of the trainees and followed up in three rounds, for two days each. The mentors had been remotely monitoring the activities of the trained midwife nurses throughout the first three months' mentoring period. In each of the two days follow-up the midwife nurses were assessd by competency assessment tools. The program 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 World Health Organization (WHO) recommends at least one ultrasound scan during a women's pregnancy. In this project pregnant women attending ANC were scanned with obstetric ultrasound device at least once. In addition to that, mother 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 two years in the selected 13 primary health care facilities. Follow-up of the service has also been a critical part of the program which was regularly done by both Transform HDR staff and 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, delivery in a health facility, having postnatal care (PNC), and continuum of care. A mother who took four ANC, 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 seven days from delivery. The other variable was early detection of complications measured with a proxy variable referral during ANC.

Exposure variable

If a woman 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 postnatal care (PNC) register. We used data over four years from 2017 to 2021 before and after the Vscan service was initiated in 2019. The data were collected from 04th to 27th of 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 logbook. Before the intervention we took two years of data from 11 October 2017 to 10 October 2019; and after the intervention, we took two 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 seven 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 centers except for the Vscan register. The data from the four sources were matched using a unique identifier variable medical record number (MRN).

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 logbook was cleaned 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 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 [Supplementary file I] 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 propensity score matching 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); Y1i, is the treated outcome and Y0i untreated outcome. When we see from the treatment side, untreated outcome (Y0i) is unobservable. This unobserved outcome is counterfactual to the observed outcome. We used the logit model and estimate the propensity score (i.e. 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 uses 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 propensity scores matching (PSM) approach minimize 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 create the best balance between treatment and control groups. To check the balance in the treatment and control groups we employed the absolute standardized difference in means (SMD), the absolute difference in means divided by the standard deviation for those observations in the treatment group. Finally, we reported average treatment effect (ATE) and average treatment effect on the treated (ATT), and a significant difference between the treatment and control groups was determined with a p-value < 0.05.

Sensitivity analysis

First, we did a difference-in-difference analysis to identify the facility (aggregate) level effect of the introduction of obstetric ultrasound service. We applied a differences-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 cases 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-difference estimate using the “diff” command in STATA.

This was followed by the use of inverse probability of treatment weighting (IPTW) estimators and 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 estimating 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 standard errors in the second step to reflect the uncertainty associated with the predicted treatment probabilities.

Patient/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 1,568 study participants, of them 795 (50.7%) were included before the intervention, and 773 (49.3%) were after the intervention. Almost 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. Among the study participants, the highest proportion had syphilis taste 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).

Table 1: characteristic 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
	Beneshangul 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]	

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

Table 2: Uptake of various maternal and new-born health services

Variables	Before		P-value	After		P-value
	Control	Intervention		Control	Intervention	
>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
Institutional delivery	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
Postnatal care	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[1.39]	0[0]	0.14	4[3.48]	1[0.53]	0.13

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 ANCs declined in the intervention group. Uptake of Institutional delivery and postnatal care 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 to the control (Figure 1).

Matching

We calculated the percentage reduction of bias in Radius and Kernel matching methods [Supplementary file II]. 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 standardized difference in means (SMD) plots [Supplementary file III 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 [Supplementary file IV].

The effect of Obstetric Ultrasound on Maternal health service use

In order to come up with the results, we used propensity score matching 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 minimize bias) indicated that attending four or more ANC was better in the control group as compared to 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 and postnatal care (Table 3).

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

Variables	Kernel Matching				Radius Matching				IPTWs			
	ATE	ATT	S.E.	95% CI	ATE	ATT	S.E.	95% CI	ATE	ATT	S.E.	95% CI
Four or more ANC	-0.20*	-0.16	0.04	[-0.23,-0.09]	-0.21*	-0.16	0.04	[-0.23,-0.08]	-0.2*	-0.16	0.04	[-0.23,-0.09]
Institutional delivery	0.24*	0.25	0.05	[0.15,0.34]	0.24	0.25	0.05	[-0.02,0.06]	0.23*	0.25	0.04	[0.17,0.33]
Referral during ANC	0.01*	0.02	0.02	[0.15,0.34]	0.01	0.02	0.02	[-0.02,0.06]	0.01	0.01	0.02	[-0.03,0.06]
Postnatal care	0.26*	0.27	0.04	[0.10,0.37]	0.24*	0.27	0.04	[0.19,0.35]	0.24*	0.26	0.04	[0.18,0.34]
Continuum of care	0.02	0.02	0.02	[-0.02,0.06]	0.01	0.02	0.02	[-0.01,0.06]	0.01	0.02	0.02	[-0.03,0.06]

*p-value < 0.05

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 the 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).

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-difference was found as high as 14.5 in the first ANC indicator and as low as 6 in the delivery indicator (Table 4).

Table 4: Median difference of maternal health service use indicators

Outcomes	Before			After		
	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-value < 0.01

The model estimated the mean and standard deviation 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 at 5% level of significance. Similarly, for postnatal care there was a positive significant effect at 1%. On the contrary, the intervention significantly decreased perinatal death at 5% level (Table 5).

Table 5: the effect obstetric ultrasound on maternal and child service and health outcomes

Outcome var.		**Estimates**	**S. Err.**	**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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	-0.18	0.08	2.45	0.01*

Means and Standard Errors are estimated by linear regression

** p<0.01; * p<0.05

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 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 evidences 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 wellbeing. 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 center.

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.

Antenatal care 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 service use. Facility level aggregate data indicates health facilities with obstetric ultrasound services were effective in raising service use for fourth ANC, 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. These health system Findings from other different LMICs revealed the use of obstetric ultrasound has increased ANC attendance significantly.[15,21–23] For instance a study conducted in Uganda found a 147% increase in ANC 4 attendance.[22] Similarly, our facility level aggregate finding indicated that there is a significant raise 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 counseling to the mother could have increased delivery in a health institution.[24,25] 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.[26,27] Findings from other settings also indicated the use of obstetric ultrasound significantly raised institutional delivery.[15,23,28] For instance use of portable ultrasound has raised the number of births at the interventional sites by 34.1% compared with 29.5% in the non-intervention sites.[22]

Similarly, the obstetric ultrasound was found highly effective in raising postnatal care. 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 postnatal care.[29] Therefore, obstetric ultrasound service would have a direct as well as an indirect effect on postnatal care 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 mothers who had obstetric ultrasound services during their ANC. The average treatment effect on the treated was 0.25. This finding directly relies on the main aim of introducing obstetric ultrasound services which is early detecting and anticipating potential complications f the mother and the child. The services being delivered in health centers 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 center level. Therefore, if some kind of compilations are 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.[22,30,31]

On the other hand, we found that perinatal death was reduced significantly in health facilities with the obstetric ultrasound service. The difference-in-difference 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. There are pieces of evidence that reported obstetric ultrasound does not have an effect to maternal or child health outcomes.[32,33]

Limitations

In the propensity score matching 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 center level. Despite the fact that ANC 4 attendance has decreased for those who had ultrasound services, the rate of ANC attendance more than once hsa 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 average treatment effect on postnatal care use.

Our finding also indicated 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 wellbeing of the baby. Consistently, perinatal death was found lower in the treatment group.

The findings of this study have got some policy, program, and research implications. The consistent raise 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 taking more relevant covariates into account. A longitudinal study that targeted to examine the predictive values, sensitivity, and specificity of the obstetric ultrasound service at primary health care in improving diagnostic capacities of the health care providers is paramount important.

Funding

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Acknowledgments

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Conflict of Interest

The authors declare that they have no any conflict of interest.

Data availability

Data used in this study can be accessed with a reasonalble request to AMREF Health Africa.

Ethics Approval

Not applicable

Authors' contribution

Design of the study: MJG, YKA, KY, AlT, GM, DT, AfT, ST, YA; Data collection: AlT, DT, MA, AI, SE, MB, AM, MS, HO, AS; Data analysis and interpretation: KY, MJG; Drafting the article: KY; Critical revision of the article: KY, MJG, AfT, AlT, GM, DT, ST. All the authors gave their approval for the final version of the manuscript and its submission to the journal.

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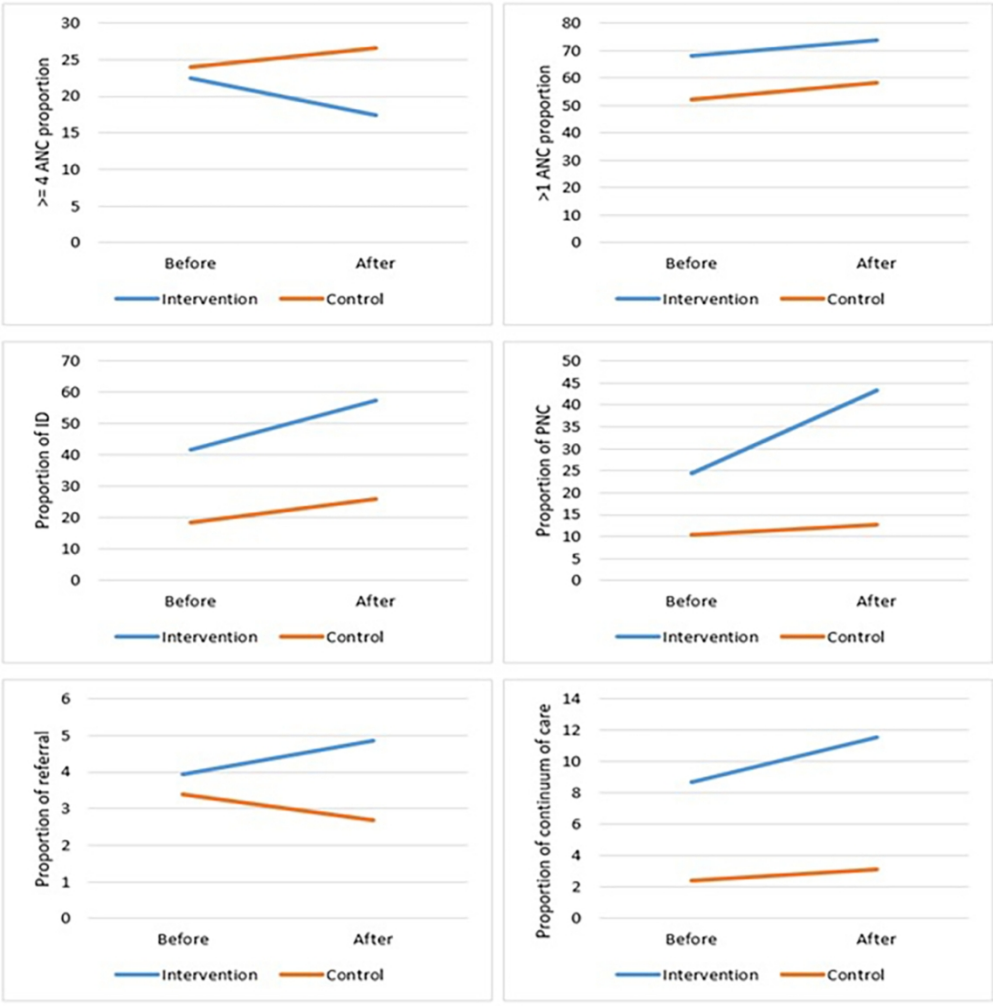
Figure Legends

Figure 1: Change in maternal health service use before and after the introduction of obstetric ultrasound service.

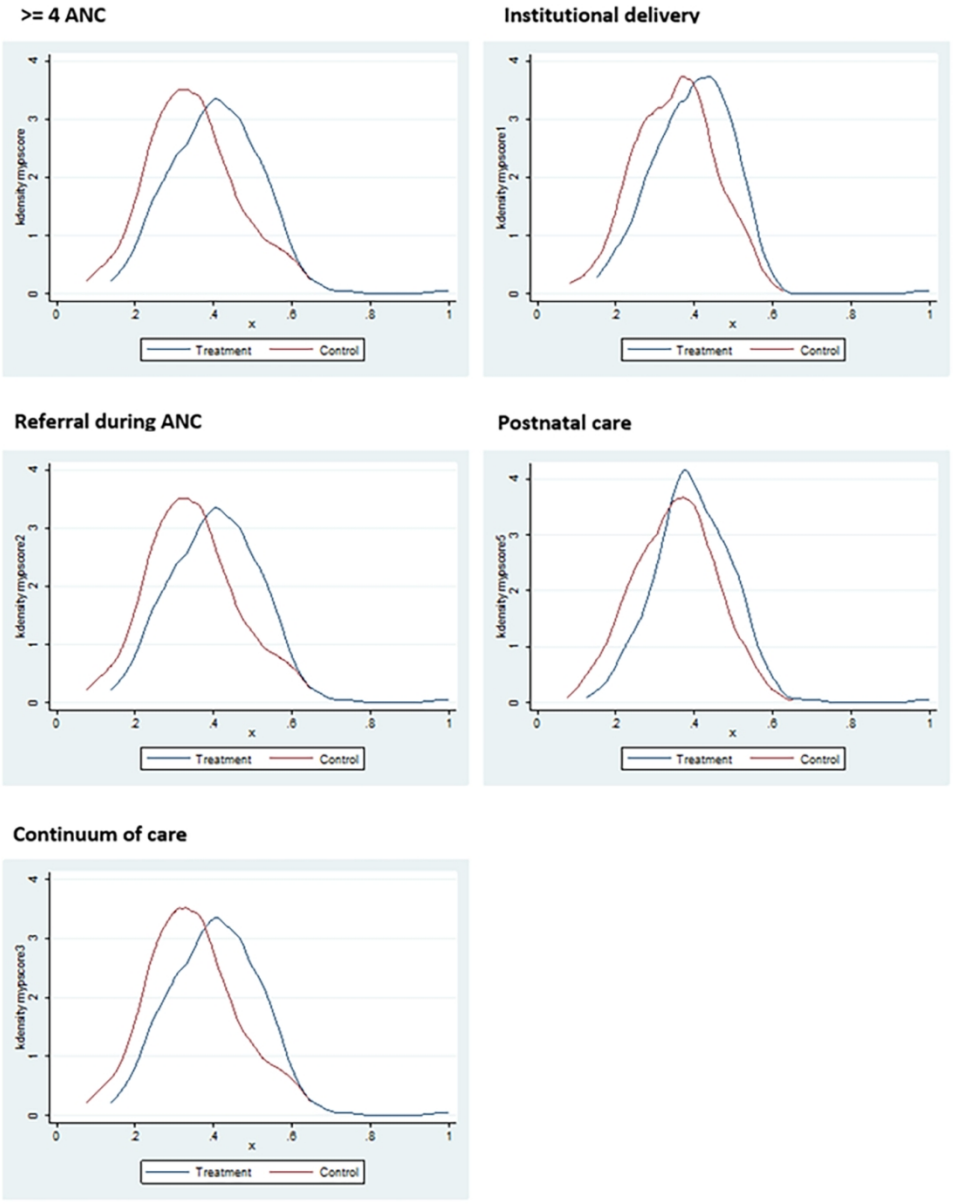
Figure 2: Common Support figures for the treatment and control groups

Figure 3: Median monthly health service use change in maternal health service use in intervention and control health facilities.



Change in maternal health service use before and after the introduction of obstetric ultrasound service

107x109mm (300 x 300 DPI)



Common Support figures for the treatment and control groups

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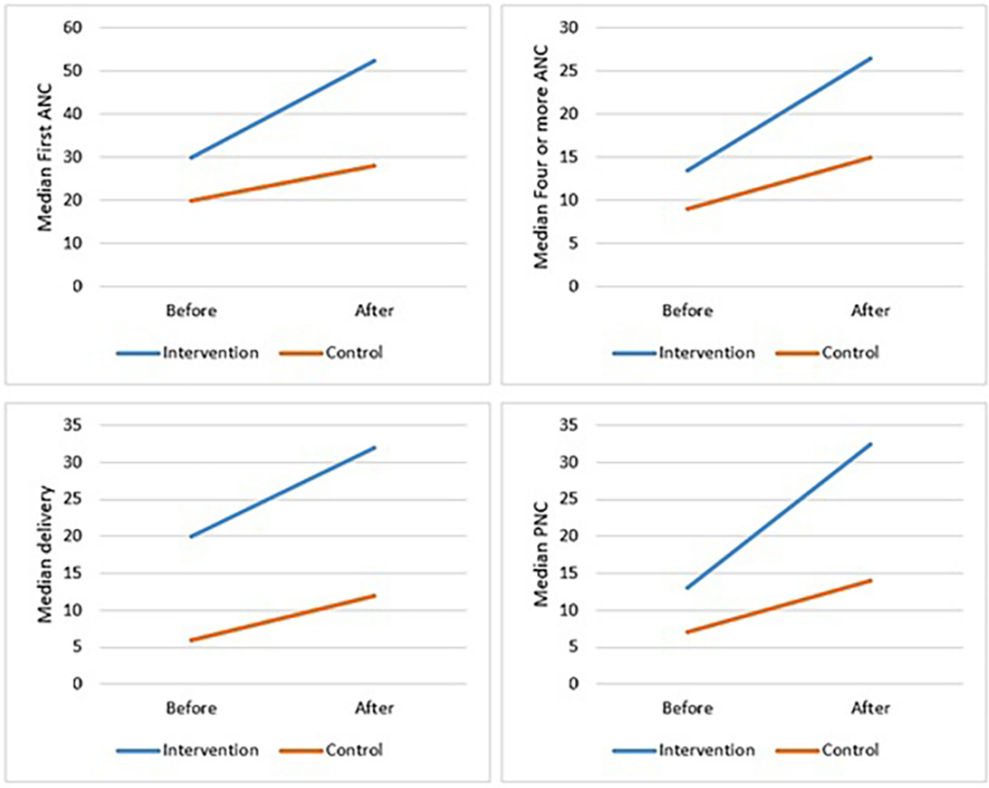
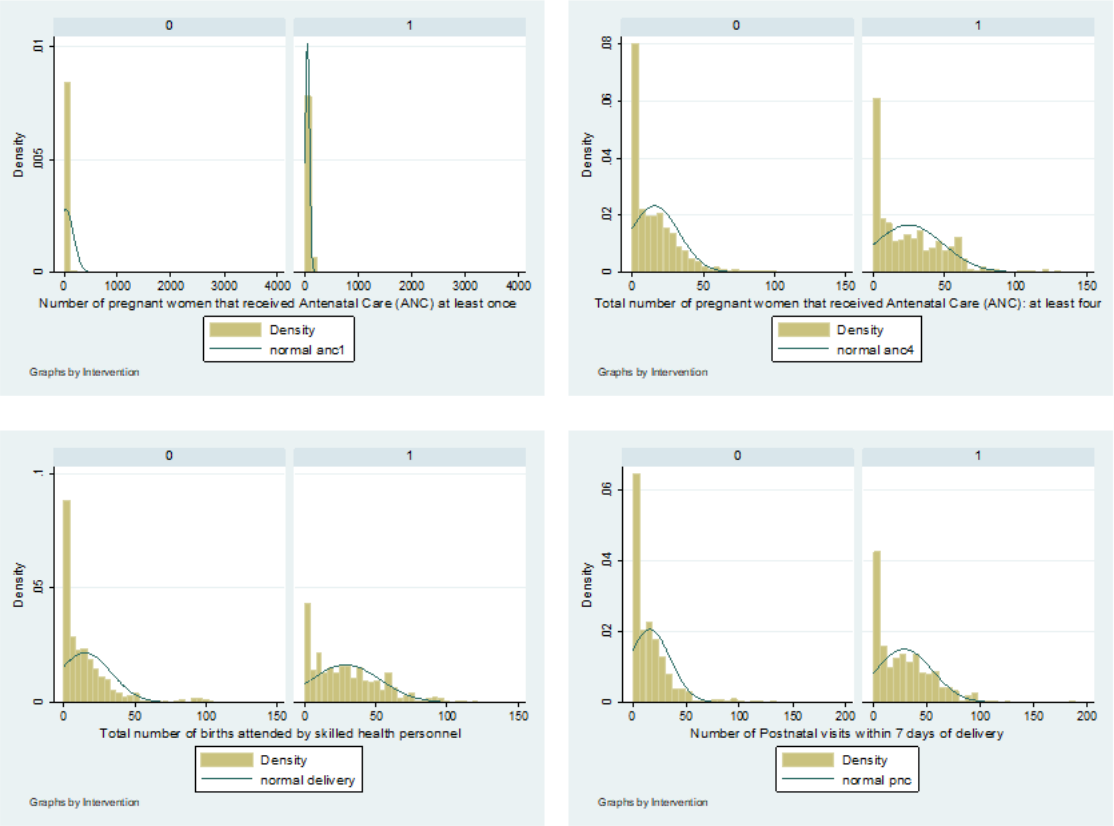


Median monthly health service use change in maternal health service use in intervention and control health facilities

93x74mm (300 x 300 DPI)

Supplementary files

Supplementary file I: Normality test of the maternal health service use variables



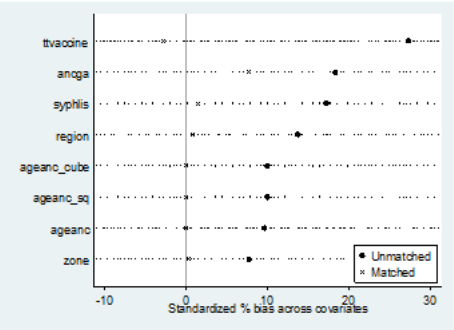
Supplementary file II: Assumption checking: common Support

Table 1: Percentage reduction in bias as a result of propensity score matching

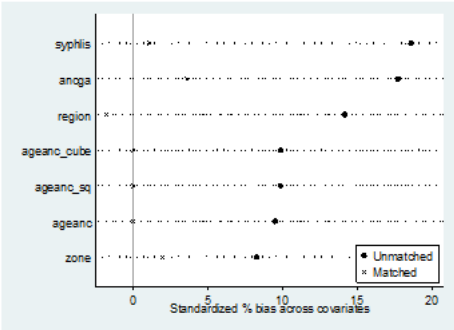
Outcomes	Matching variables	Radius		Kernel	
		% reduction of bias	P-value	% reduction of bias	P-value
Four or More ANC	Age of the mother	99.4	0.69	99.8	0.90
	Age squared	100	0.68	100	0.91
	Age cubed	100	0.68	100	0.91
	Gestational age	82.3	0.74	58.1	0.44
	Syphilis test	77.9	0.70	91.7	0.88
	TT Vaccine	81.3	0.62	89.5	0.78
	Region	97.2	0.97	94.1	0.93
	Zone	51.2	0.70	96.1	0.98
Institutional delivery	Age of the mother	99.8	0.91	99.6	0.80
	Age squared	100	0.96	100	0.82
	Age cubed	100	0.98	100	0.85
	Gestational age	95.5	0.93	79.6	0.71
	Syphilis test	93.9	0.91	94.1	0.91
	Region	92.2	0.91	87.4	0.85
	Zone	94.1	0.96	76.5	0.84
Referral during ANC	Age of the mother	99.6	0.80	99.4	0.67
	Age squared	100	0.81	100	0.68
	Age cubed	100	0.83	100	0.69
	Gestational age	60.1	0.47	71.4	0.60
	Syphilis test	92.3	0.89	86.7	0.81
	Region	89.8	0.88	99.1	0.99
	Zone	97.6	0.99	91.2	0.94
Postnatal care	Age of the mother	99.2	0.60	99.6	0.80
	Age squared	100	0.61	100	0.81
	Age cubed	100	0.62	100	0.83
	Gestational age	82.9	0.75	60.1	0.47
	Syphilis test	78	0.69	92.3	0.89
	TT Vaccine	76.6	0.55	85.1	0.70
	Region	97.3	0.97	89.8	0.88
	Zone	41.8	0.64	97.6	0.99
Continuum of care	Age of the mother	99.2	0.60	99.6	0.80
	Age squared	100	0.61	100	0.81
	Age cubed	100	0.62	100	0.83
	Gestational age	82.9	0.75	60.1	0.47
	Syphilis test	78	0.69	92.3	0.89
	TT Vaccine	76.6	0.55	85.1	0.70
	Region	97.3	0.97	89.8	0.88
	Zone	41.8	0.64	97.6	0.99

Supplementary file III: standardized difference in means (SMD) plots for Kernel Matching approach

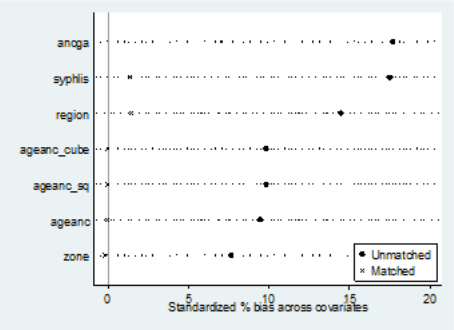
>= 4 ANC



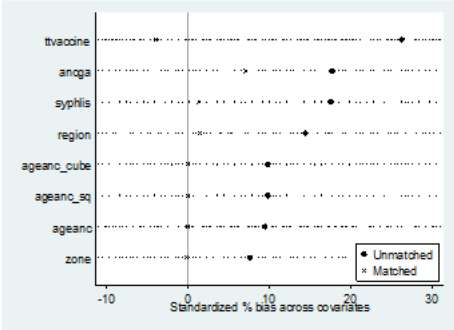
Institutional deliverv



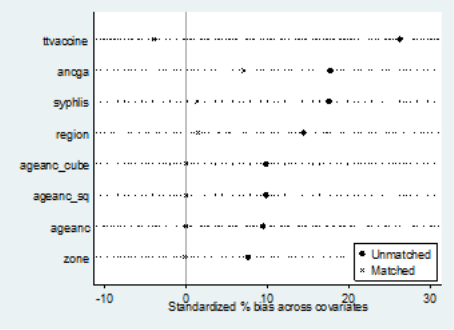
Referral during ANC



Postnatal care

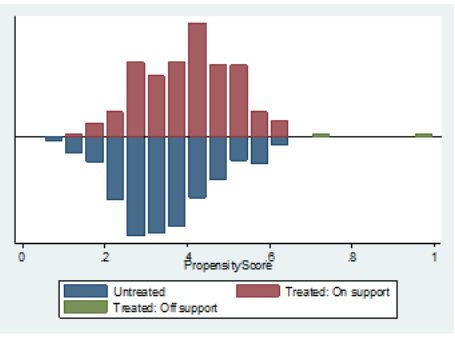


Continuum of care

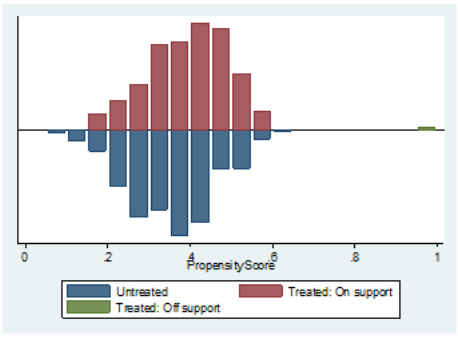


Supplementary file IV: Plot of on support and off support of matching cases

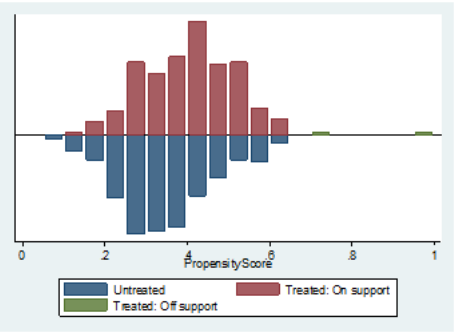
>= 4 ANC



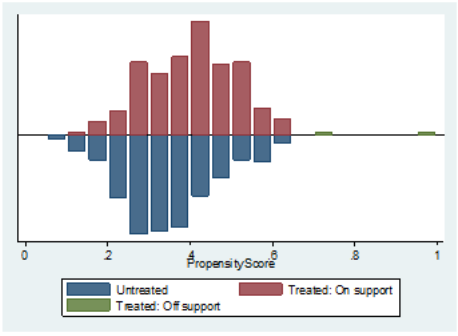
Institutional delivery



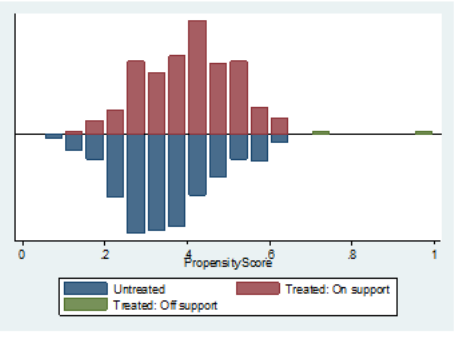
Referral during ANC



Postnatal care



Continuum of care



STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any pre-specified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5 – 7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5, 7, 8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	8 – 9
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	8

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	8 – 9
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	10
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10 – 11
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	14 – 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14 – 15
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Effect of USAID funded obstetric ultrasound service interventions on maternal and perinatal health outcomes at primary health care facilities in Ethiopia: A Propensity Score Matching Analysis

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Effect of USAID funded obstetric ultrasound service interventions on maternal and perinatal health outcomes at primary health care facilities in Ethiopia: A Propensity Score Matching Analysis

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Abstract

Objective: A dimensional shift in the health service delivery in the primary health care setting is required to raise maternal and child wellbeing. This study aimed to evaluate the effect of USAID-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 centers located in four regions of Ethiopia.

Participants: We used two years' data of 1,568 mothers from 13 intervention and 13 control primary health centers. Data were obtained from Vscan, antenatal care, delivery, and postnatal care registers.

Intervention: Use of portable obstetric ultrasound service during pregnancy.

Outcome measures: The primary outcome variable includes complete four antenatal care, referral during antenatal care, 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 was decreased after the intervention (ATE: -0.20; 95% CI, -0.23,-0.09), and the rest of the indicators, including referral during ANC (ATE: 0.01; 95% CI: 0.15,0.34), institutional delivery (ATE: 0.24; 95% CI: 0.15,0.34), and postnatal care (ATE: 0.26; 95% CI: 0.10,0.37), 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 center level. Furthermore, early detection of compilations and following referral for specialty care was 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 country locations. Furthermore, evaluating the predictive values, sensitivity, and specificity of the obstetric ultrasound service is important.

Key words: Vscan, Maternal health service, child health, effectiveness evaluation

Strength and Limitations

- 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, differences-in-differences and inverse probability of treatment weighting (IPTW) 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 berought 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 Goals (SDGs) 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 2000-2017, and child deaths have decreased considerably. For instance, the average annual rate of reduction (ARR) in global MMR during the 2000–2017 period was 2.9%.[3] However, reducing maternal (SDG3.1) and child (SDG3.2) mortality is far from being reached. Furthermore, the difference between high-income and low- and 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 maternal mortality ratio of 412 per 100,000 live births and child mortality rate of 67 per 1,000 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 health care they need.. Similarly in Ethiopia, improving access to reproductive, maternal, and newborn health care and its utilization and ensuring service equity and quality at the facilities level remains a challenge.[7,8] Moreover, services 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 utilizations as compared to national averages.[9–12] and are exacerbated by shocks like drought, conflict or disease outbreaks, including COVID-19.[13]

Cognizant of these facts, Transform Health in Developing Regions (HDR) is one of the USAID Transform Health Activities, in collaboration with the Ministry of Health (MOH), which has designed intereventions that further improve maternal and child health in developing regional states of Ethiopia. The overall objective of the program was to increase the utilization 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 devise for obstetric scanning at its selected Centers of Excellence health facilities- eighteen Health Centers and six 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 utilization 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 five 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 program would improve maternal and perinatal outcomes in a low income setting like Ethiopia. Such evaluation would have both policy and program 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 and design

The study was conducted in emerging regional states of Ethiopia, namely Afar, Benshangul-Gumuz, Gambella, and Somali regional states. Early childhood mortality was high in the regions. For instance, the under-five child mortality rate per 1000 live births in Afar, Benishangul-Gumuz, Gambella, and Somali regional states were as high as 144, 98, 88, and 94 respectively compared to 39 in the country's capital, Addis Ababa.[17] Moreover, maternal health service utilization 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%; ANC coverage was 30%, and postnatal check-up in the two 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 six were hospitals and the remaining 18 were primary health centers.

Study Design and sample: Quasi-experimental study design was employed in 13 primary health centers as an intervention and 13 primary health centers as a control group to compare maternal health service utilization and perinatal health outcomes.

Sample size and sampling procedure

Totally 13 Vscan implementing (intervention) and 13 non-Vscan implementing (control) primary health centers were included in this study. We took samples from all the selected intervention and control health centers. 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.

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

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 two years before the intervention and two years after the intervention with intervals. The sampling interval was determined by dividing the total number of first ANC by the sample size allocated to the health center. 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 have

not complete data we chose the next cases on the register. For the facility level aggregate data, we took the whole two years before and two years after the intervention, both retrospectivelly.

Study population: All pregnant women who visit health facilities for maternal health care utilization 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 centers 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 centers 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 utilization of high-impact and quality reproductive, maternal, neonatal, and child health (RMNCH) services. The selected health facilities were provided with a portable ultrasound device and related installation was performed. The service began in the mid of October 2019 and has continued for more than two 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 (HF) and got trained for 11 days by experienced Radiologists, Integrated Emergency Surgical Officer (ISEO), and Gynecology 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 and post assessment exams. After they complete the classroom training and demonstration, mentors were assigned for each of the trainees and followed up in three rounds, for two days each. The mentors had been remotely monitoring the activities of the trained midwife nurses throughout the first three months' mentoring period. In each of the two days follow-up the midwife nurses were assessd by competency assessment tools. The program 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 World Health Organization (WHO) recommends at least one ultrasound scan during a women's pregnancy. In this project pregnant women attending ANC were scanned with obstetric ultrasound device at least once. In addition to that, mother 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 two years in the selected 13 primary health care facilities. Follow-up of the service has also been a critical part of the program which was regularly done by both Transform HDR staff and 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, delivery in a health facility, having postnatal care (PNC), and continuum of care. A mother who took four ANC, 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 seven days from delivery. The other variable was early detection of complications measured with a proxy variable referral during ANC.

Exposure variable

If a woman 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 postnatal care (PNC) register. We used data over four years from 2017 to 2021 before and after the Vscan service was initiated in 2019. The data were collected from 04th to 27th of 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 logbook. Before the intervention we took two years of data from 11 October 2017 to 10 October 2019; and after the intervention, we took two 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 seven 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 centers except for the Vscan register. The data from the four sources were matched using a unique identifier variable medical record number (MRN).

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 logbook was cleaned 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 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 [Supplementary file I] 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 propensity score matching 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); Y1i, is the treated outcome and Y0i untreated outcome. When we see from the treatment side, untreated outcome (Y0i) is unobservable. This unobserved outcome is counterfactual to the observed outcome. We used the logit model and estimate the propensity score (i.e. 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 uses 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 propensity scores matching (PSM) approach minimize 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 create the best balance between treatment and control groups. To check the balance in the treatment and control groups we employed the absolute standardized difference in means (SMD), the absolute difference in means divided by the standard deviation for those observations in the treatment group. Finally, we reported average treatment effect (ATE) and average treatment effect on the treated (ATT), and a significant difference between the treatment and control groups was determined with a p-value < 0.05.

Sensitivity analysis

First, we did a difference-in-difference analysis to identify the facility (aggregate) level effect of the introduction of obstetric ultrasound service. We applied a differences-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 cases 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-difference estimate using the "diff" command in STATA.

This was followed by the use of inverse probability of treatment weighting (IPTW) estimators and 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 estimating 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 standard errors in the second step to reflect the uncertainty associated with the predicted treatment probabilities.

Patient/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 1,568 study participants, of them 795 (50.7%) were included before the intervention, and 773 (49.3%) were after the intervention. Almost 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. Among the study participants, the highest proportion had syphilis taste 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).

Table 1: characteristic 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
	Beneshangul						
	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]	

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

Table 2: Uptake of various maternal and new-born health services

Variables	Before		P-value	After		P-value
	Control	Intervention		Control	Intervention	
>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
Institutional delivery	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
Postnatal care	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[1.39]	0[0]	0.14	4[3.48]	1[0.53]	0.13

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 ANCs declined in the intervention group. Uptake of Institutional delivery and postnatal care 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 to the control (Figure 1).

Matching

We calculated the percentage reduction of bias in Radius and Kernel matching methods [Supplementary file II]. 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 standardized difference in means (SMD) plots [Supplementary file III 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 [Supplementary file IV].

The effect of Obstetric Ultrasound on Maternal health service use

In order to come up with the results, we used propensity score matching 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 minimize bias) indicated that attending four or more ANC was better in the control group as compared to 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 and postnatal care (Table 3).

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

Variables	Kernel Matching				Radius Matching				IPTWs			
	ATE	ATT	S.E.	95% CI	ATE	ATT	S.E.	95% CI	ATE	ATT	S.E.	95% CI
Four or more ANC	-0.20*	-0.16	0.04	[-0.23,-0.09]	-0.21*	-0.16	0.04	[-0.23,-0.08]	-0.2*	-0.16	0.04	[-0.23,-0.09]
Institutional delivery	0.24*	0.25	0.05	[0.15,0.34]	0.24	0.25	0.05	[-0.02,0.06]	0.23*	0.25	0.04	[0.17,0.33]
Referral during ANC	0.01*	0.02	0.02	[0.15,0.34]	0.01	0.02	0.02	[-0.02,0.06]	0.01	0.01	0.02	[-0.03,0.06]
Postnatal care	0.26*	0.27	0.04	[0.10,0.37]	0.24*	0.27	0.04	[0.19,0.35]	0.24*	0.26	0.04	[0.18,0.34]
Continuum of care	0.02	0.02	0.02	[-0.02,0.06]	0.01	0.02	0.02	[-0.01,0.06]	0.01	0.02	0.02	[-0.03,0.06]

*p-value < 0.05

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 the 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).

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-difference was found as high as 14.5 in the first ANC indicator and as low as 6 in the delivery indicator (Table 4).

Table 4: Median difference of maternal health service use indicators

Outcomes	Before			After		
	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-value < 0.01

The model estimated the mean and standard deviation 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 at 5% level of significance. Similarly, for postnatal care there was a positive significant effect at 1%. On the contrary, the intervention significantly decreased perinatal death at 5% level (Table 5).

Table 5: the effect obstetric ultrasound on maternal and child service and health outcomes

Outcome var.		**Estimates**	**S. Err.**	**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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	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**
	Diff-in-Diff	-0.18	0.08	2.45	0.01*

Means and Standard Errors are estimated by linear regression

** p<0.01; * p<0.05

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 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 evidences 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 wellbeing. 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 center.

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.

Antenatal care 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 service use. Facility level aggregate data indicates health facilities with obstetric ultrasound services were effective in raising service use for four or more ANC, 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 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 raise 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 counseling 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 interventional sites by 34.1% compared with 29.5% in the non-intervention sites.[22]

Similarly, the obstetric ultrasound was found highly effective in raising postnatal care. 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 postnatal care.[30] Therefore, obstetric ultrasound service would have a direct as well as an indirect effect on postnatal care 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 mothers who had obstetric ultrasound services during their ANC. The average treatment effect on the treated 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 centers 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 center level. Therefore, if some kind of compilations are 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-difference 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 there are pieces of evidence that reported it does not have an effect to maternal or child health outcomes,[33,34] obstetric ultrasound service resulted in a dimentional change to safe mother hood and batter child wellbeing.[24,35]

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

Limitations

In the propensity score matching 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 center level. Despite the fact that ANC 4 attendance has decreased for those who had ultrasound services, the rate of ANC attendance more than once hsa 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 average treatment effect on postnatal care use.

Our finding also indicated 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 wellbeing 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, program, and research implications. The consistent raise 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 taking more relevant covariates into account. A longitudinal study that targeted to examine the predictive values, sensitivity, and specificity of the obstetric ultrasound service at primary health care in improving diagnostic capacities of the health care providers is paramount important.

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Conflict of Interest

The authors declare that they have no any conflict of interest.

Data availability

Data used in this study can be accessed with a reasonalble request to AMREF Health Africa.

Ethics Approval

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

Authors' contribution

Design of the study: MJG, YKA, KY, AlT, GM, DT, AfT, ST, YA; Data collection: AlT, DT, MA, AI, SE, MB, AM, MS, HO, AS; Data analysis and interpretation: KY, MJG; Drafting the article: KY; Critical revision of the article: KY, MJG, AfT, AlT, GM, DT, ST. All the authors gave their approval for the final version of the manuscript and its submission to the journal.

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Figure Legends

Figure 1: Change in maternal health service use before and after the introduction of obstetric ultrasound service.

Figure 2: Common Support figures for the treatment and control groups

Figure 3: Median monthly health service use change in maternal health service use in intervention and control health facilities.

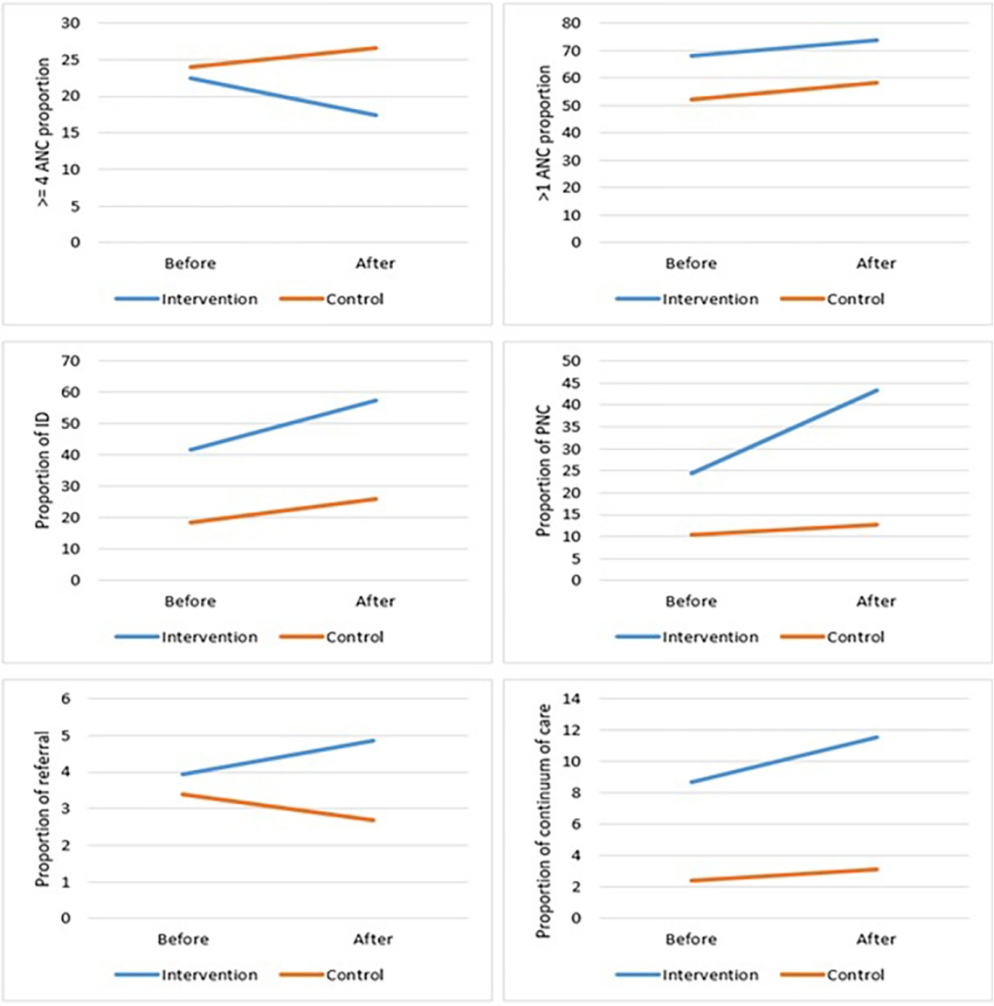

Figure 1: Change in maternal health service use before and after the introduction of obstetric ultrasound service.

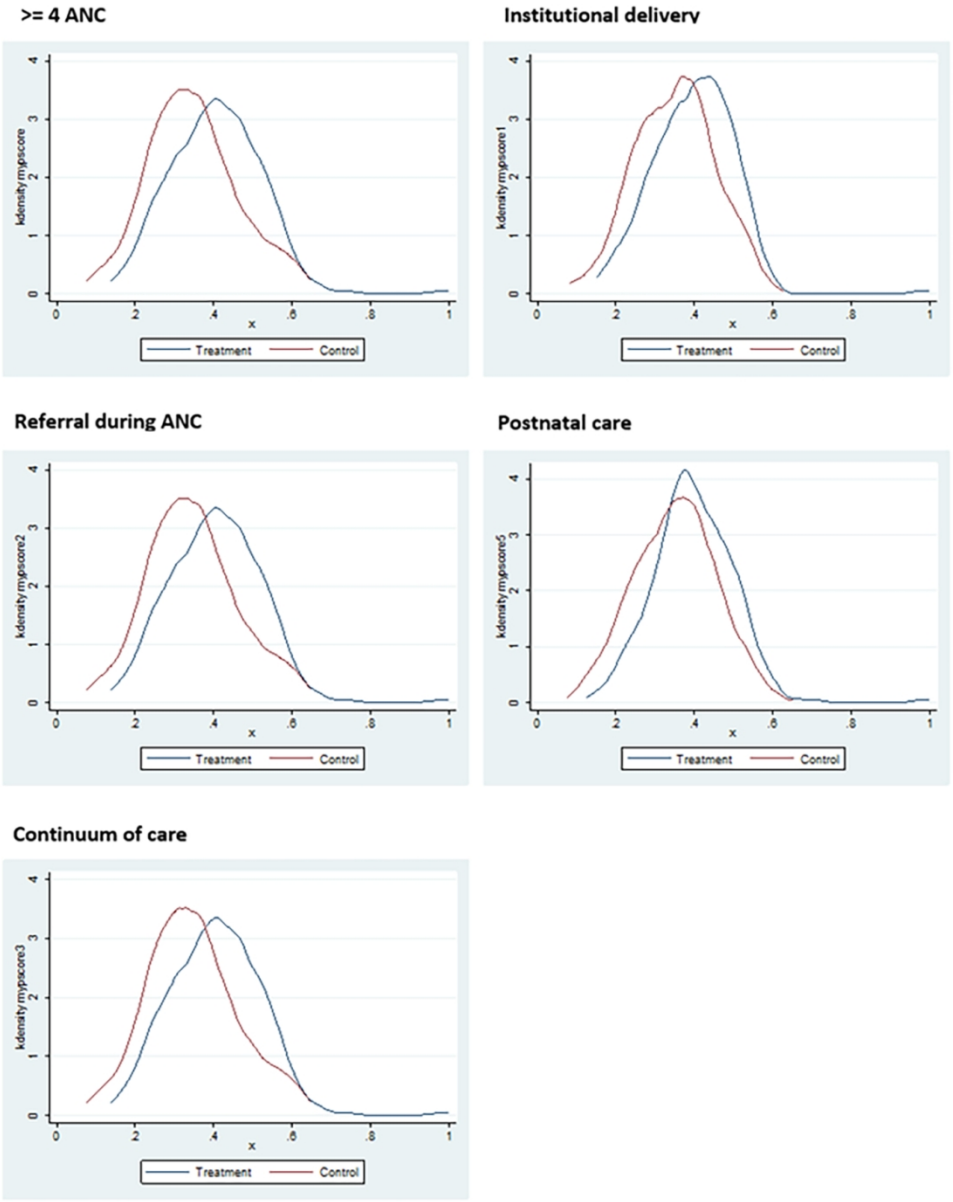

Figure 2: Common Support figures for the treatment and control groups

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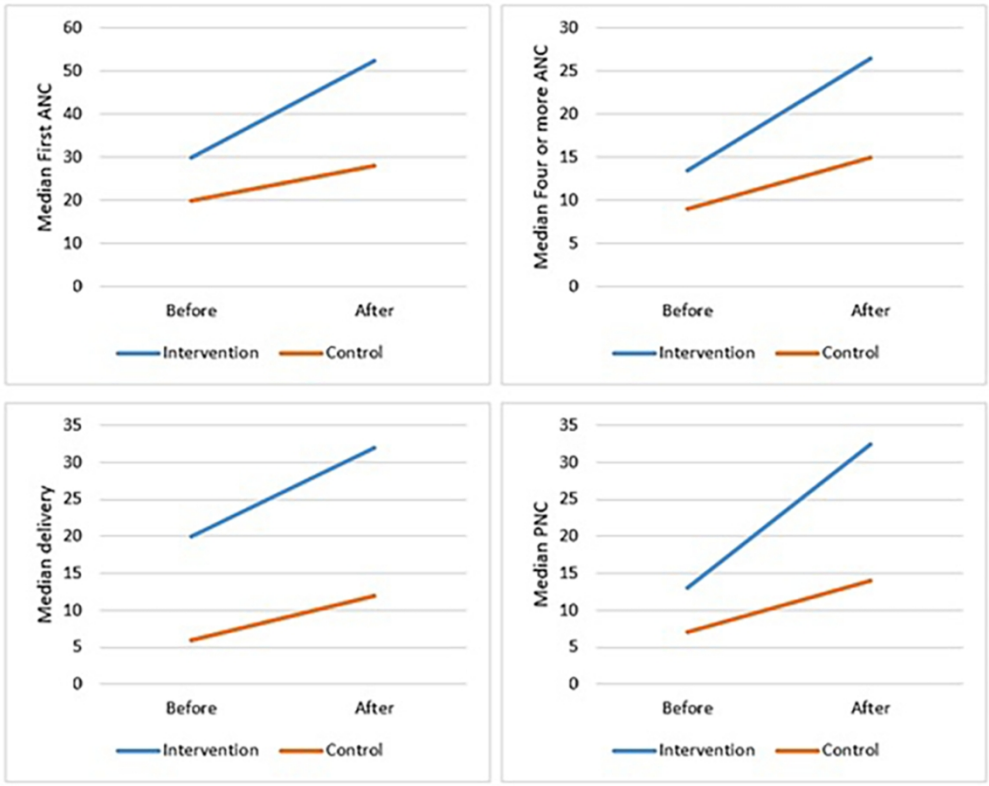
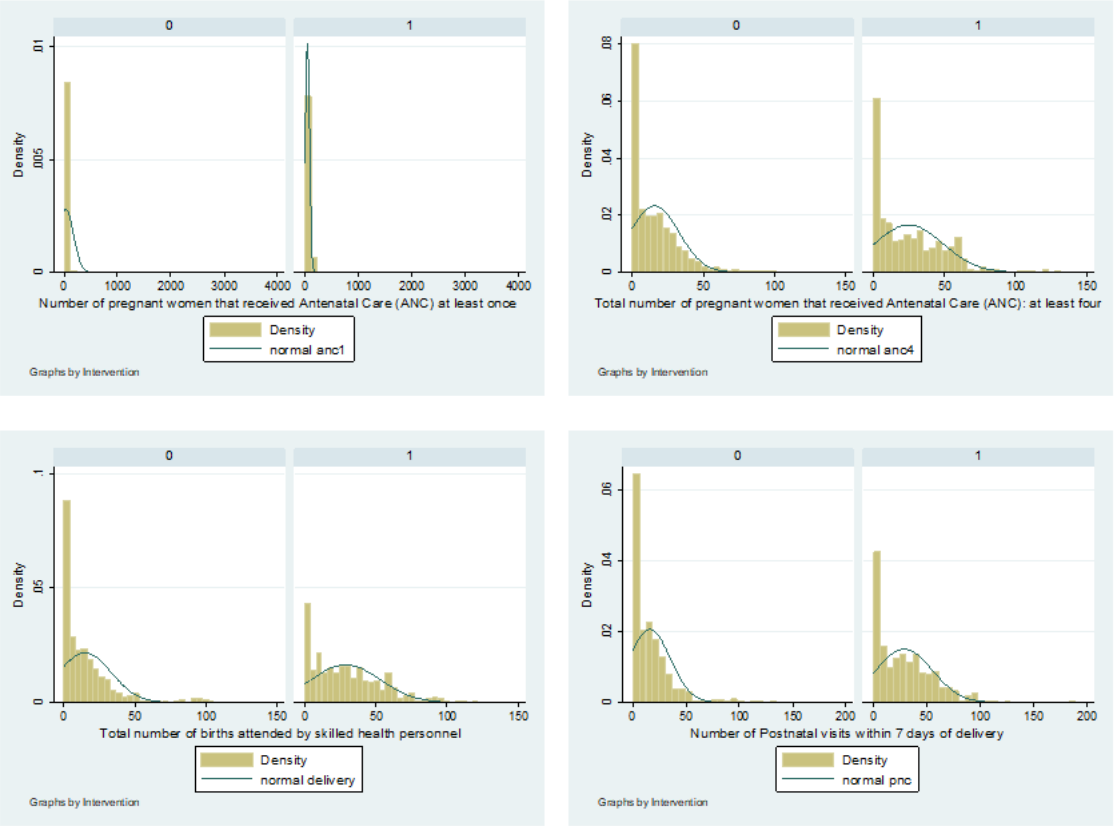


Figure 3: Median monthly health service use change in maternal health service use in intervention and control health facilities.

Supplementary files

Supplementary file I: Normality test of the maternal health service use variables



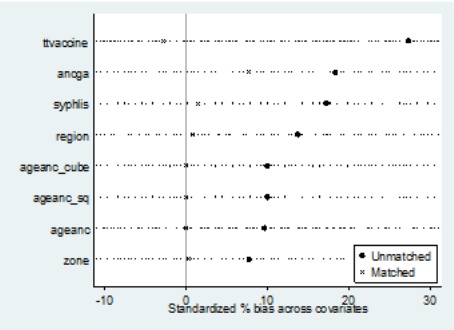
Supplementary file II: Assumption checking: common Support

Table 1: Percentage reduction in bias as a result of propensity score matching

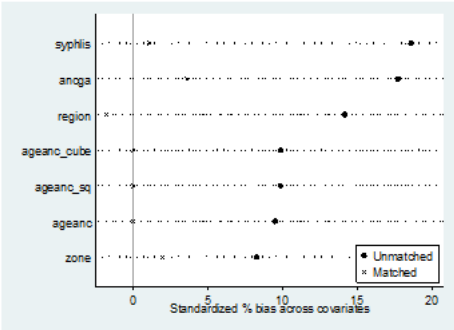
Outcomes	Matching variables	Radius		Kernel	
		% reduction of bias	P-value	% reduction of bias	P-value
Four or More ANC	Age of the mother	99.4	0.69	99.8	0.90
	Age squared	100	0.68	100	0.91
	Age cubed	100	0.68	100	0.91
	Gestational age	82.3	0.74	58.1	0.44
	Syphilis test	77.9	0.70	91.7	0.88
	TT Vaccine	81.3	0.62	89.5	0.78
	Region	97.2	0.97	94.1	0.93
	Zone	51.2	0.70	96.1	0.98
Institutional delivery	Age of the mother	99.8	0.91	99.6	0.80
	Age squared	100	0.96	100	0.82
	Age cubed	100	0.98	100	0.85
	Gestational age	95.5	0.93	79.6	0.71
	Syphilis test	93.9	0.91	94.1	0.91
	Region	92.2	0.91	87.4	0.85
	Zone	94.1	0.96	76.5	0.84
Referral during ANC	Age of the mother	99.6	0.80	99.4	0.67
	Age squared	100	0.81	100	0.68
	Age cubed	100	0.83	100	0.69
	Gestational age	60.1	0.47	71.4	0.60
	Syphilis test	92.3	0.89	86.7	0.81
	Region	89.8	0.88	99.1	0.99
	Zone	97.6	0.99	91.2	0.94
Postnatal care	Age of the mother	99.2	0.60	99.6	0.80
	Age squared	100	0.61	100	0.81
	Age cubed	100	0.62	100	0.83
	Gestational age	82.9	0.75	60.1	0.47
	Syphilis test	78	0.69	92.3	0.89
	TT Vaccine	76.6	0.55	85.1	0.70
	Region	97.3	0.97	89.8	0.88
	Zone	41.8	0.64	97.6	0.99
Continuum of care	Age of the mother	99.2	0.60	99.6	0.80
	Age squared	100	0.61	100	0.81
	Age cubed	100	0.62	100	0.83
	Gestational age	82.9	0.75	60.1	0.47
	Syphilis test	78	0.69	92.3	0.89
	TT Vaccine	76.6	0.55	85.1	0.70
	Region	97.3	0.97	89.8	0.88
	Zone	41.8	0.64	97.6	0.99

Supplementary file III: standardized difference in means (SMD) plots for Kernel Matching approach

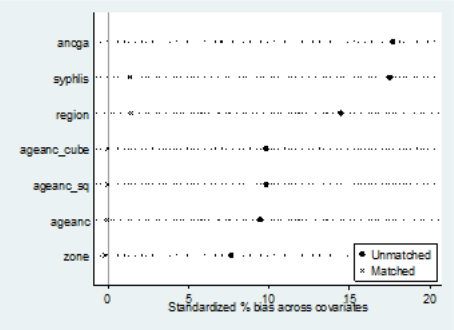
>= 4 ANC



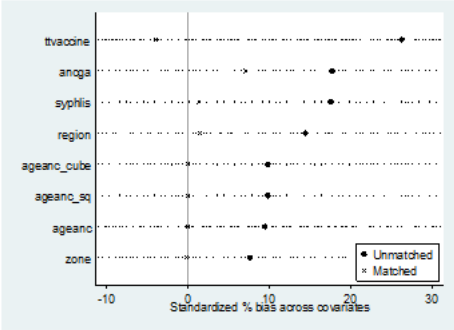
Institutional deliverv



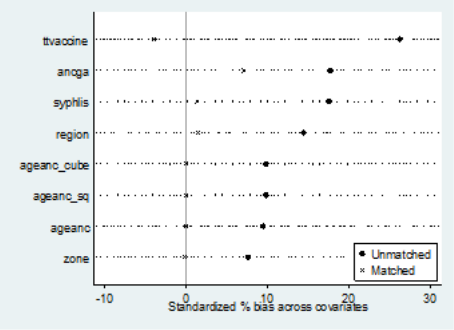
Referral during ANC



Postnatal care

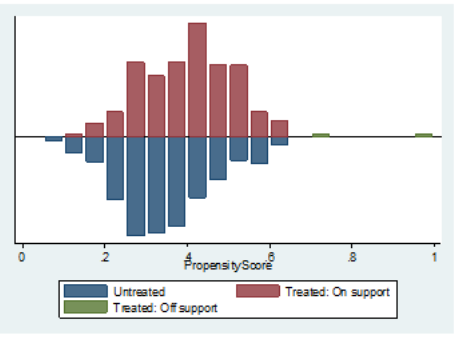


Continuum of care

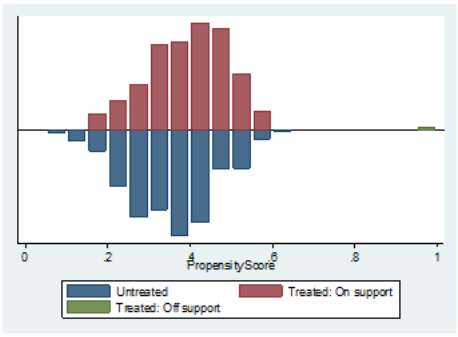


Supplementary file IV: Plot of on support and off support of matching cases

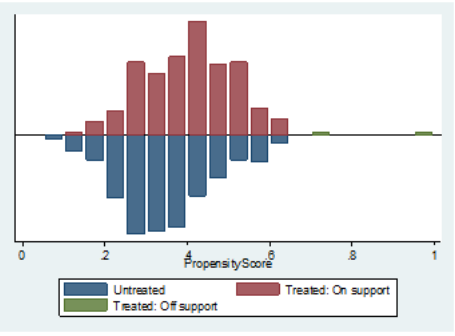
>= 4 ANC



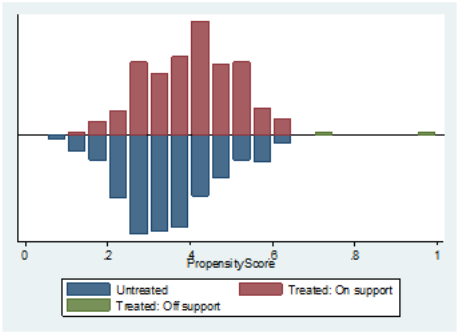
Institutional delivery



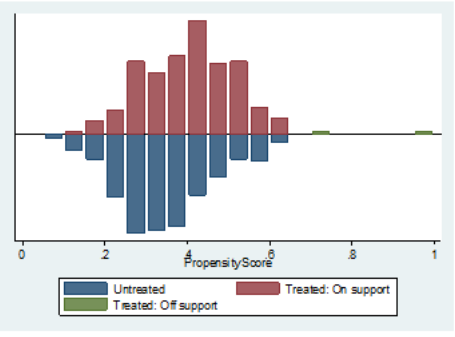
Referral during ANC



Postnatal care



Continuum of care



STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any pre-specified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5 – 7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5, 7, 8
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	8 – 9
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable
		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	8

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	8 – 9
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Not applicable
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	10
		Cross-sectional study—Report numbers of outcome events or summary measures	Not applicable
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10 – 11
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	14 – 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14 – 15
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.