BMC Health Services Research

RESEARCH

Open Access

Improved antenatal care services in rural Ethiopia's public health centers through the Enhancing Nutrition and Antenatal Infection Treatment (ENAT) intervention

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Abstract

Background Antenatal care (ANC) in Ethiopia faces quality and content gaps. The Enhancing Nutrition and Antenatal Infection Treatment (ENAT) intervention was designed to improve ANC services in public health facilities by strengthening infection diagnosis, training healthcare providers, supplying equipment, and enhancing counseling. We assessed ENAT's association with improved ANC outcomes, including testing (blood/urine), infection prevention, nutrition supplementation, counseling, and visit adherence.

Methods A quasi-experimental design (QED) was used, with baseline data collected in December 2020 and endline in January 2023 from intervention and comparison areas. We interviewed women who were pregnant within two years preceding the surveys: baseline (comparison = 631, intervention = 705) and endline (comparison = 638, intervention = 719). We examined the association between the intervention and ANC outcomes using Difference-in-Differences (DiD) logit models.

Results The ENAT intervention showed statistically significant improvements in blood sample testing during pregnancy (DiD: +8%, β = 1.03, $p < 0.001$), while urine testing demonstrated a marginally significant association (DiD: +7%, β = 0.60, $p = 0.057$). Notable positive improvements were observed in the administration of iron folate (DiD, + 11%, β = 1.21, $p < 0.001$), tetanus toxoid injections (DiD, + 10%, β = 0.61, $p = 0.042$), and deworming tablets (DiD, + 20%, β = 0.65, $p = 0.032$). Statistically significant improvements were also seen in counseling on nutrition (DiD, + 11%, β = 0.59, $p = 0.001$) and pregnancy complications (DiD, + 9%, β = 0.34, $p = 0.038$). Although four or more ANC visits saw a statistically significant increase in the intervention area (DiD: +9%, β = 1.24, $p = 0.049$), 38% of women remained below this benchmark. Furthermore, the intervention did not significantly improve the timing of the first ANC visit (DiD, + 5%, β = 0.017, $p = 0.928$), with only half of the women initiating ANC in the first trimester.

Conclusion The ENAT intervention improved ANC service contents, quality, and visit frequency while enhancing key counseling topics. These findings demonstrate targeted interventions' potential to strengthen ANC in resource-limited

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settings. However, early ANC initiation remains challenging, with many women not completing the recommended four or more visits. Future programs should address barriers to timely ANC initiation and completion.

Keywords Ethiopia, Antenatal care, ENAT, Quasi-experimental design, Difference-in-difference

Background

Antenatal care (ANC) represents a cornerstone of efforts to ensure maternal and fetal health, offering essential services designed to safeguard the well-being of both mothers and their unborn children [1]. The World Health Organization (WHO) provides a comprehensive framework for ANC that encompasses risk identification, the prevention and management of pregnancy-related or concurrent diseases, and the promotion of healthy behaviors through education [2]. The multifaceted approach of ANC facilitates the timely detection and management of obstetric complications and offers critical interventions, including immunizations against tetanus, nutritional supplementation, and counseling on healthy lifestyle choices during pregnancy [3, 4]. These components are pivotal in ensuring a safe pregnancy and childbirth experience, ultimately enhancing health outcomes for mothers and their newborns.

The coverage and quality of ANC services vary widely across sub-Saharan Africa, contributing to disparities in maternal and neonatal health outcomes. A WHO study found that only 52% of pregnant women in the region attended four or more ANC visits, and fewer than 20% met the recommended eight visits [1]. Limited access to healthcare, shortages of trained professionals, and inadequate resources remain key challenges. Moreover, the quality of ANC often falls short, with critical services such as infection screening, nutritional counseling, and mental health support frequently overlooked [5, 6]. In Ethiopia, these challenges persist despite efforts to strengthen the healthcare system. Nationally, fewer than half of women receive four or more ANC visits during pregnancy, falling far below the WHO recommendation of at least eight visits for optimal maternal and neonatal outcomes. Many pregnant women also miss essential ANC services in health facilities due to critical gaps in diagnostic services [7]. Additionally, shortages of medical supplies—including basic equipment, essential drugs, and diagnostic tools—further hinder the delivery of quality ANC, particularly in rural areas and smaller health centers [8]. These disparities in service availability and infrastructure contribute to suboptimal maternal and neonatal health outcomes, underscoring the urgent need for targeted interventions to improve both ANC accessibility and quality.

To address these challenges, the Enhancing Nutrition and Antenatal Infection Treatment (ENAT) intervention was developed to strengthen ANC services in selected rural areas of Ethiopia. ENAT directly targets key barriers to quality ANC by training healthcare providers to deliver comprehensive services and increasing the availability of essential diagnostics for maternal infections. Recognizing the critical role of maternal nutrition in fetal growth and overall health, the intervention also emphasizes improved nutritional support. By promoting early care initiation, adherence to WHO-recommended ANC visits, and the comprehensive provision of essential services such as blood pressure monitoring, diagnostic tests, and nutrition counseling, ENAT aims to bridge existing gaps in ANC care. Through these targeted efforts, the intervention seeks to enhance maternal and neonatal health outcomes and establish a sustainable model for strengthening ANC services in Ethiopia.

This study used a quasi-experimental design to evaluate ENAT's association with improvements in ANC contents and quality, measured through key indicators including blood/urine testing, infection prevention, nutrition supplementation, counseling, and visit adherence. The findings are expected to provide actionable insights for enhancing ANC services in Ethiopia and other low-resource settings with similar maternal healthcare challenges.

Methods

Study design

The ENAT intervention was implemented between 2020 and 2022 in several rural districts of the Oromia and Amhara regions of Ethiopia, targeting 65 government health centers and their surrounding catchment areas, collectively serving an estimated population of 2 million people. The evaluation of the ENAT intervention aimed to achieve two main objectives: (a) to assess the impact of the intervention on birth weight and (b) to evaluate the coverage, access, and quality of antenatal care (ANC) services. To address these objectives, two distinct study designs were employed. The impact on birth weight was examined using a cluster-randomized controlled trial, the findings of which have been published in a scientific journal [9], while the evaluation of ANC service coverage, access, and quality—the primary focus of this manuscript—was conducted using a quasi-experimental design (QED). The QED design was chosen due to the impracticality of randomizing communities into intervention and comparison groups. Intervention communities were predefined as the catchment areas of 65 health centers where the ENAT intervention was implemented. In contrast, comparison communities were purposefully selected from districts not involved in the ENAT intervention.

To mitigate potential spillover effects, comparison areas were located at least 15 km away from intervention sites. Selection of comparison areas was guided by specific criteria to ensure comparability with intervention sites, including socio-economic status, demographic characteristics, topography, and health service coverage and utilization. Additionally, comparison areas were verified to have no exposure to external interventions beyond the standard government health programs and services. Households in the intervention group were drawn from the catchment areas of the 65 participating health centers, while those in the comparison group were selected from comparable health center catchments outside the ENAT intervention zones. Data collection was conducted in two waves: baseline in December 2020 and endline in January 2023, covering both intervention and comparison areas.

The ENAT intervention is guided by a comprehensive evaluation protocol that integrates multiple aspects of its assessment, incorporating both study designs to ensure a thorough analysis of its effectiveness. The protocol was structured to address distinct objectives, providing an integrated evaluation of the intervention's impact (ENAT evaluation team: Evaluation protocol, unpublished).

ENAT intervention

The ENAT intervention was a bundle of interventions designed to enhance maternal healthcare, particularly ANC services, in rural districts of Ethiopia. This bundle included the strengthening and introduction of point-of-care diagnostic technologies for screening and treating maternal infections, including asymptomatic bacteriuria (ASB), syphilis, and anemia. To ensure the effective use of these technologies, healthcare providers, including midwives, nurses, and laboratory technicians, received comprehensive training. This training focused on improving the quality of ANC services, encompassing comprehensive counseling, infection screening, treatment, and preventive care. In addition to provider training, the ENAT intervention ensured that participating health centers were equipped with essential diagnostic supplies and ANC equipment, including urine dipsticks, syphilis tests, hemoglobin tests, blood pressure monitors, and weighing scales. Regular assessments of these supplies were conducted, with additional procurement support provided as needed to maintain adequate resources. The intervention also introduced strategies to prevent and manage nutritional disorders during pregnancy. Pregnant women were screened for anemia and malnutrition using mid-upper arm circumference (MUAC) measurements, and a tracking system was implemented to monitor the provision of deworming treatments and Iron and Folic Acid (IFA) tablets. Job aids for nutritional counseling and gestational weight monitoring were also developed and distributed to support these efforts.

Box 1 Main components of the ENAT intervention

- Point-of-Care Diagnostic Strengthening
- Healthcare Providers Training
- Provision of Essential Supplies and Equipment
- Nutritional Screening and Management
- Community-Based Maternal Health Strengthening
- Mentoring and Supportive Supervision
- Community Engagement and Continuous Oversight

The interventions extended beyond the health centers to strengthen community-based activities aimed at improving maternal health. The intervention bolstered existing community initiatives to identify pregnant women early and encourage the timely initiation of ANC services. Community health workers played a crucial role in tracking pregnant women, ensuring they adhered to their ANC appointments and received continuous care throughout their pregnancy.

Mentoring and supportive supervision were critical components of the ENAT interventions. A comprehensive checklist guided these activities, ensuring thorough assessments of providers' competencies and the availability of necessary supplies. Full-time ENAT field workers conducted regular mentorship and supportive supervision, visiting health centers at least twice per quarter to address any gaps and offer technical support.

The standard ANC package in the health centers

The standard ANC package adopted by the Ethiopian government is based on the 2002 focused antenatal care guidelines and approach of the World Health Organization. The routine ANC guideline includes various components that include identifying and treating diseases, early detection of potential complications that could impact pregnancy outcomes, and providing prophylaxis and treatment for conditions like anemia, malaria, sexually transmitted infections (STIs) including HIV, urinary tract infections, and tetanus. Moreover, the routine ANC entails offering timely guidance and advice to pregnant women on topics like birth preparedness, nutrition, immunization, personal hygiene, and family planning. It also involves counseling expectant mothers on recognizing danger signs and symptoms that necessitate immediate assistance from a healthcare professional. Both the intervention and comparison health centers had access to the standard services, with the intervention health centers also receiving the additional ENAT intervention.

Outcome measures

This study tracked and evaluated various coverage and quality indicators of ANC services as key outcomes. These indicators included routine services available to pregnant women: weight measurement, blood pressure monitoring, blood and urine tests, provision of iron folate, tetanus toxoid injections (TTIs), and deworming

tablets. For women who delivered in health facilities, newborn weighing was also included as an indicator. Additionally, the study assessed the information and counseling provided during ANC visits, covering topics including nutrition, pregnancy complications, birth preparedness, and low birth weight counseling. The timing of the first ANC visit and the total number of ANC visits were also evaluated as part of the study outcomes.

Sampling and sample size

The baseline and endline surveys employed a stratified multi-stage cluster sampling approach. Within each study arm, Kebeles (the smallest administrative units) were selected as Primary Sampling Units (PSUs) using a probability proportionate to size (PPS) method. Following this, random sampling techniques were used to select households within each designated PSU, and eligible respondents from each household were interviewed. Eligible respondents were defined as women who had been pregnant within the 24 months preceding the interview date.

The sample size for this multi-indicator evaluation was determined based on the lowest coverage rate among the various ANC service indicators. These indicators included the percentage of women receiving four or more ANC visits, the timing of the first ANC visit, and key components of ANC, such as measurements of blood pressure, weight, and height. Additionally, the evaluation considered coverage for iron-folic acid (IFA) supplementation, tetanus toxoid immunization (TTI2), blood tests, urine tests, and counseling on nutrition, pregnancy complications, and birth preparedness. To estimate the required sample size, we used data from the 2019 Ethiopia Mini-DHS [7]. The lowest observed coverage rate, 45%, was associated with the early initiation of antenatal care (within the first three months of pregnancy). This figure served as the benchmark for calculating the sample size, ensuring that the study would have sufficient statistical power to effectively evaluate all indicators. This approach guaranteed that even the indicator with the lowest coverage would be adequately represented, resulting in robust findings across the range of ANC services evaluated.

The sample size was determined using the following standard formula: $N = [4(r)(1-r)(f)(1.1)]/[(e)2(p)(nh)]$ where N is the number of households, r is the anticipated prevalence of the indicator, f is the design effect, e is the margin of error, p is the proportion of the target population (pregnant women in the communities), and nh is the average household size. Using this formula, we calculated the required sample size to be 1,715 households per study arm, ensuring the study had sufficient power to detect meaningful differences in this multi-indicator evaluation. These sample size spread across 49 intervention and 40 comparison Kebeles (PSUs), with equal allocation between the intervention and comparison regions at both baseline and endline. From the sampled households, the eligible women who had been pregnant in the previous two years were interviewed: baseline comparison ($n = 631$), baseline intervention ($n = 705$), endline comparison ($n = 638$), and endline intervention ($n = 719$). Of these women, 434, 444, 487, and 490, respectively, received ANC services at health centers during the previous two years and were the basis for the analysis. Figure 1 presents the study participant flow diagram and sample size by study arm.

Data collection and procedures

The baseline and endline surveys used two interconnected modules for data collection. Module 1 screened for eligible respondents, while Module 2 was the core questionnaire for target respondents. The data collection tools were initially developed in English and then translated into Amharic and Afan Oromo, the local languages of the study areas. Module 2 gathered detailed information on socio-demographics, household wealth, fertility patterns, and ANC-related data, including the number and timing of ANC visits, content and place of ANC services, type of provider, information given to pregnant women, place of delivery, and assistance during delivery. Most questions and indicators were adapted from the standard Demographic and Health Survey. Data was collected using mobile phones equipped with Open Data Kit (ODK).

Ten data collection teams, each consisting of four interviewers and one supervisor—totaling 40 interviewers and 10 supervisors—were responsible for gathering data at both baseline and endline. All interviewers and supervisors were female and recruited from the survey areas. Most had backgrounds in health or social sciences and possessed prior hands-on experience in similar surveys.To ensure data accuracy and consistency, the data collection teams underwent intensive seven-day training sessions at both the baseline and endline phases. Survey supervisors played a critical role in maintaining data quality by conducting spot-checks, reviewing completed questionnaires, and ensuring adherence to data collection protocols and ethical guidelines. Additionally, they were responsible for submitting completed interviews to a Digital Ocean cloud server using the ODK platform.

The interview protocol and questionnaires used in this study were specifically developed for this study and have not been previously published. The interview protocol is provided as a supplementary file (ENAT evaluation team: Interview protocol and data collection manual, unpublished). Likewise, the questionnaires, which were designed for both the baseline (ENAT evaluation team: Baseline questionnaires, unpublished) and endline (ENAT evaluation: Endline questionnaires, unpublished) phases of the study, are also included as supplementary files.

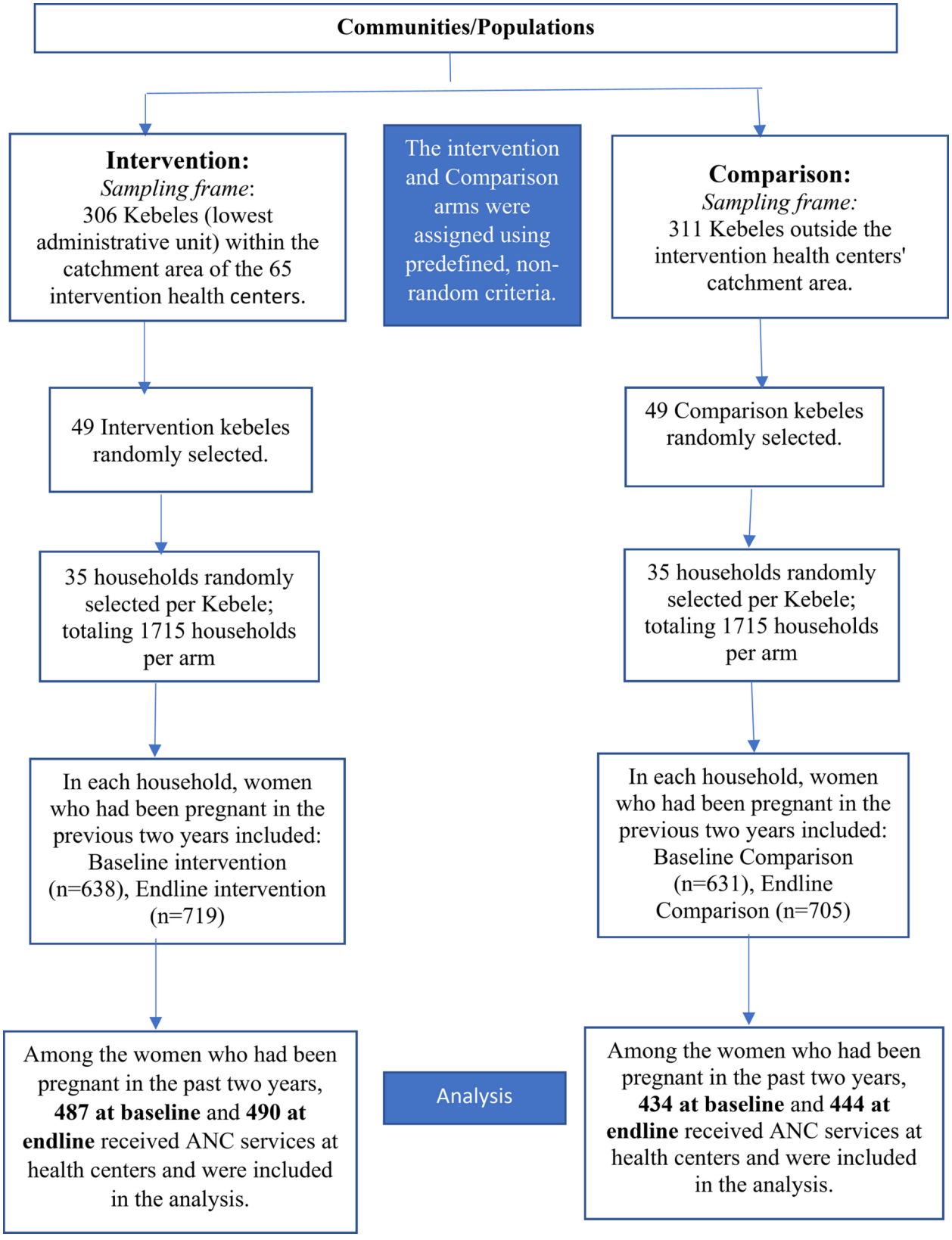

Fig. 1 Flow diagram of study participants and sample size by study arm

Statistical analysis

The analysis presented here draws on data collected at both baseline and endline from the intervention and comparison areas, with the goal of examining temporal trends in key indicators. This analysis was conducted using the Difference-in-Difference (DID) approach to examine the association between the ENAT intervention and ANC outcomes by comparing changes over time in intervention and control areas. The DID method relies on a critical assumption known as the "Parallel Paths" assumption. This assumption posits that, in the absence of the ENAT intervention, the average changes in outcomes in the comparison area would mirror the changes that would have occurred in the intervention area. In other words, the comparison area's trends serve as a counterfactual for what would have happened in the intervention area if the ENAT program had not been implemented. For the DID approach to be valid, it is essential that this assumption holds true.

To estimate the DID values, we applied both univariate and multivariate logit models while accounting for cluste ring. The models included interaction terms between time (baseline and endline) and group (intervention vs. comparison) to capture the DID estimate. The general form of the DID Logit model used in this analysis can be expressed as: $Logit(P(Y = 1)) = \beta 0 + \beta 1 \cdot Intervention + \beta 2 \cdot Time + \beta 3 \cdot (Intervention \times Time) + X'\beta + \epsilon$.

In this model, Logit(P(Y = 1)) represents the log-odds of the probability that the outcome Y equals 1. β_0 is the intercept, indicating baseline log-odds. β_1 represents the effect of being in the intervention group, while β_2 captures the effect of time. The interaction term β_3 (Intervention × Time) measures the Difference-in-Difference (DID) estimate, representing the association attributable to the intervention. X′β include background covariates variables to account for potential confounding factors that could influence the outcomes. These covariates include women's age, education, number of children, and wealth. Additionally, the timing and the number of ANC visits are included as covariates for some specific outcomes to ensure a more accurate analysis. ϵ represents the error term accounting for unexplained variation.

A *p*-value of less than 0.05 indicates statistical significance. We utilized Stata version 17 (Stata Corporation, College Station, TX, USA) for data management and analysis. The Survey command in Stata was employed to define the strata and primary sampling unit. All proportions, rates, and coefficients were weighted to account for sampling probabilities.

Results

Characteristics of the sample population

Table 1 compares the background characteristics of women across four groups: baseline-intervention, baseline-comparison, endline-intervention, and endline-comparison. The demographic profile of ANC users did not change significantly between the baseline and endline periods in both intervention and comparison areas, with no significant differences in age, education, religion, or

Table 1 Baseline and endline background characteristics of respondents who received ANC in health centers during their most recent pregnancy (within the past two Years) in intervention and comparison areas

	Intervention		Comparison	
	Baseline	Endline	Baseline	Endline
	n(%)	n(%)	n(%)	n(%)
Women's age				
15–24	174 (35.7)	180 (36.7)	155 (35.7)	163 (36.7)
25–34	243 (49.8)	213 (43.5)	216 (49.8)	193 (43.5)
35–49	71 (14.5)	97 (19.8)	63 (14.5)	88 (19.8)
Mean age (95% CI)	26.7 (26.3–27.3)	28.2(27.2–28.5)	27.5(27.0–28.0)	27.8(27.1–28.4)
Women's education				
Cannot read/write	246 (50.6)	233 (47.5)	217 (50.0)	234 (52.8)
Grade 1–6	75 (15.5)	84 (17.1)	87 (20.1)	85 (19.1)
Grade 7–9	131 (26.8)	141 (28.8)	105 (24.1)	106 (23.8)
Grade 10+	35 (7.1)	34 (6.9)	25 (5.8)	19 (4.2)
Religion				
Orthodox Christian	370 (75.9)	377 (77.0)	309 (71.3)	313 (70.6)
Muslim	114 (23.4)	111 (22.7)	122 (28.0)	131 (29.4)
Protestant	3 (0.7)	1 (0.3)	3 (0.7)	0 (0.0)
Marital status				
Currently married	472 (97.0)	471 (96.2)	407 (93.7)	427 (96.1)
Divorced/widowed	8 (1.7)	12 (2.4)	20 (4.7)	12 (2.7)
Never married	6 (1.3)	7 (1.4)	7 (1.6)	5 (1.2)

marital status. The mean age of respondents ranged from 26.7 to 28.2 years, with no notable variations in age distribution. Women aged 25–34 years comprised nearly half of the sample across all groups, followed by those aged 20–24 years, who made up approximately a quarter to a third of the respondents.

Educational attainment was consistent across the four groups. Around half of the respondents in both intervention and comparison areas at both time points could not read or write, while just over a quarter had completed 7–9 years of schooling. A smaller proportion (4–7%) had attained 10 or more years of education. Religious affiliation also showed minimal variation over time. The majority of respondents (71–82%) identified as Orthodox Christians, followed by Muslims (16.5–29.4%). Although there were slight shifts in religious distribution between baseline and endline in the intervention areas, these differences were not statistically significant.

Overall, the data indicate that the demographic characteristics of ANC users remained largely stable throughout the study period, suggesting that any observed changes in ANC service utilization or outcomes are unlikely to be influenced by shifts in the background profile of respondents.

Timing and number of ANC visits

Findings from Table 2 indicate mixed outcomes of the intervention on ANC visit patterns. The proportion of women initiating ANC within the first trimester showed minimal change in the intervention group, while the comparison group remained nearly unchanged. The DiD estimate of (+5.0) suggests a small increase in early ANC visits in the intervention areas; however, this change was not statistically significant (β = 0.017, $p = 0.928$), indicating that the intervention had little or no association with earlier ANC initiation.

In contrast, the intervention was associated with a statistically significant increase in completion of four or more ANC visits. While the comparison group experienced a slight decline, the intervention group saw an increase, resulting in a DiD estimate of (+9.0). The adjusted model confirmed that this association was statistically significant (β = 1.241, $p = 0.049$). Nevertheless, by the endline survey, 38% of pregnant women in the intervention area had not achieved the recommended minimum of four ANC visits.

ANC services given during pregnancy

Findings from Table 3 reveal statistically significant improvements in key ANC services in the intervention areas compared to the comparison areas. The intervention area achieved statistically significant improvements across key ANC components—including service contents, utilization, and quality of care—as demonstrated by both Difference-in-Differences (DiD) estimates and significant β coefficients from the adjusted logit model.

The proportion of pregnant women who had blood samples tested increased in the intervention group, the DiD estimate showed a positive association (+8.0% points), with a statistically significant adjusted coefficient (β = 1.18, $p < 0.001$). Similarly, we observed increased urine sample collection (+7.0% points, β = 0.60), though this difference was only marginally significant ($p = 0.057$). The intervention *w*as also associated with improved weight and blood pressure monitoring, with statistically significant DiD estimates (+9.0% points for both) and corresponding adjusted coefficients (β = 1.24, $p < 0.001$ for weight; β = 1.10, $p < 0.001$ for blood pressure).

A core ANC intervention - iron and folic acid supplementation - showed a statistically significant 11.0%-point increase (DiD: +11.0; adjusted β = 1.21, $p < 0.001$), demonstrating strengthened maternal nutrition support.

Table 2 Proportions, difference-in-difference estimates (%), and unadjusted and adjusted did coefficients and P-values from logit models for the timing of first ANC visits and four or more visits in health centers

	Study time		Unadjusted DiD β Coeff. (*p*-value)	Adjusted [$] DiD β Coeff. (*p*-value)
	Baseline	Endline		
Early ANC visit (0–3 months of pregnancy)				
Intervention	45.0	49.0		
Comparison	36.0	35.0		
Difference-in-Difference	*(+)5.0*		*0.15(0.680)*	*0.017(0.928)*
Four or more ANC visits				
Intervention	56.0	62.0		
Comparison	54.0	51.0		
Difference-in-Difference	*(+) 9.0*		*0.376(0.039)*	*1.241 (0.049)*

Analysis Sample: Women who received ANC in health centres within the past two years – Baseline: Intervention ($n = 487$), Comparison ($n = 434$); Endline: Intervention ($n = 490$), Comparison ($n = 444$)

DiD Difference in Difference

DiD effect = interaction effect of exposure (Comparison/intervention) Vs. period (baseline/endline)

[$]Logit model adjusted for age, education, number of children, wealth and cluster

Table 3 Proportions, Difference-in-difference estimates (%), and unadjusted and adjusted did coefficients and *P*-values from logit models for various ANC services/contents provided to pregnant women in health centers

	Study time		Unadjusted DiD β Coeff. (*p*-value)	Adjusted [$] DiD β Coeff. (*p*-value)
	Baseline	Endline		
Women weighed				
Intervention	90.0	95.0		
Comparison	89.0	86.0		
DiD (%)	*(+) 8.0*		*3.27(< 0.001)*	*1.10(< 0.001)*
Blood pressure measured				
Intervention	83.0	97.0		
Comparison	87.0	92.0		
DiD (%)	*(+) 9.0*		*1.24(< 0.001)*	*1.10((< 0.001)*
Blood sample taken				
Intervention	83.0	96.0		
Comparison	86.0	91.0		
DiD (%)	*(+) 8.0*		*1.18(< 0.001)*	*1.03(< 0.001)*
Urine sample taken				
Intervention	88.0	97.0		
Comparison	90.0	92.0		
DiD (%)	*(+) 7.0*		*1.39(< 0.001)*	*0.60((0.057)*
Iron folate given				
Intervention	78.0	93.0		
Comparison	82.0	86.0		
DiD (%)	*(+) 11*		*1.66 (< 0.001)*	*1.21(< 0.001)*
TTI given				
Intervention	79.0	88.0		
Comparison	84.0	83.0		
DiD (%)	*(+) 10.0*		*0.88 (< 0.001)*	*0.61(0.042)*
Deworming given				
Intervention	18.0	49.0		
Comparison	19.0	30.0		
DiD (%)	*(+) 20.0*		*0.830(< 0.001)*	*0.65(0.032)*
New-born weighed (*among delivered in health facilities*[ϕ])				
Intervention	67.0	88.0		
Comparison	71.0	67.0		
DiD (%)	*(+)25.0*		*1.44(< 0.001)*	*1.34(< 0.001)*

Analysis Sample: Women who received ANC in health centres within the past two years – Baseline: Intervention ($n=487$), Comparison ($n=434$); Endline: Intervention ($n=490$), Comparison ($n=444$)

DiD Difference in Difference

DiD effect = interaction effect of exposure (Comparison/intervention) Vs. period (baseline/endline)

[$] Logit model adjusted for age, education, number of children, wealth, timing of first ANC visit, number of ANC visits, cluster

[ϕ] Number delivered in health facilities: intervention baseline ($n=490$); intervention endline ($n=516$); Comparison baseline ($n=408$); Comparison endline ($n=452$)

Similarly, tetanus toxoid immunization (TTI) coverage improved in the intervention areas while declining slightly in the comparison areas, yielding a statistically significant DiD estimate of +10.0 (adjusted β = 0.61, $p=0.042$). Deworming coverage showed the strongest improvement, with a statistically significant DiD estimate of + 20.0% points (adjusted β = 0.65, $p=0.032$) in the intervention group.

Newborn weight measurement at birth - a critical component of newborn care - showed substantial improvement, with a statistically significant increase of 25.0% points (DiD: +25.0; adjusted β = 1.34, $p<0.001$).

Information and counselling during ANC

Table 4 presents the association between the intervention and provision of counseling and health education services during ANC visits. The intervention produced statistically significant improvements in several counseling domains. For nutrition counseling during pregnancy, the DiD estimate showed an 11.0%-point increase (β = 0.59, $p=0.001$), confirming the intervention's effectiveness in enhancing nutrition-related information delivery. Similarly, counseling on pregnancy complications demonstrated a 9.0%-point improvement (DiD estimate + 9.0; β = 0.34, $p=0.038$), reflecting better communication

Table 4 Proportions, difference-in-difference estimates (%), and unadjusted and adjusted did coefficients and P-values from logit models for information and counseling provided to pregnant women during ANC in health centers

	Study time		Unadjusted DiD β Coeff. (*p*-value)	Adjusted [$] DiD β Coeff. (*p*-value)
	Baseline	Endline		
Given nutrition information during pregnancy				
Intervention	71.0	77.0		
Comparison	75.0	70.0		
DiD (%)	(+) 11.0		0.61(0.001)	0.59(0.001)
Told about pregnancy complications				
Intervention	52.0	69.0		
Comparison	57.0	65.0		
DiD (%)	(+)9.0		0.39(0.016)	0.34(0.038)
Information about birth preparedness				
Intervention	65.0	61.0		
Comparison	71.0	61.0		
DiD (%)	(+)6.0		0.26(0.127)	0.24(0.157)
Counselled about low birth weight				
Intervention	46.0	65.0		
Comparison	49.0	50.0		
DiD (%)	(+)18.0		0.76(< 0.001)	0.75(< 0.001)

Analysis Sample: Women who received ANC in health centres within the past two years – Baseline: Intervention ($n = 487$), Comparison ($n = 434$); Endline: Intervention ($n = 490$), Comparison ($n = 444$)

DiD Difference in Difference

DiD effect = interaction effect of exposure (Comparison/intervention) Vs. period (baseline/endline)

[$]Logit model adjusted for age, education, number of children, wealth, timing of first ANC visit, number of ANC visits, cluster

about pregnancy risks. While birth preparedness counseling showed a positive trend with a 6.0%-point gain (DiD estimate + 6.0; β = 0.24, $p = 0.157$), this result was not statistically significant. Most notably, counseling on low birth weight achieved one of the strongest results with an 18.0%-point increase (DiD estimate + 18.0; β = 0.75, $p < 0.001$).

Discussion

The ENAT intervention demonstrated measurable improvements in ANC service coverage, enhancing both clinical service delivery and health education for pregnant women. These improvements are crucial for enhancing maternal and neonatal health outcomes, particularly in resource-limited settings like Ethiopia. The intervention's effectiveness is evident in its positive influence on the frequency of ANC visits, the quality of care provided, and the breadth of information and counseling delivered to expectant mothers.

The recorded increase in the proportion of women completing four or more ANC visits in the intervention area demonstrates that the ENAT intervention effectively promoted frequent and continuous ANC use. This improvement underscores the potential of targeted interventions to positively influence maternal health behaviors, reflecting similar successes in other low-resource settings where focused strategies to enhance ANC access and quality have led to greater adherence to recommended visit schedules [10–13]. However, despite this progress, it is concerning that about two-fifth of pregnant women in the intervention area still did not complete the recommended four ANC visits. Moreover, the ENAT intervention did not yield a comparable improvement in the early initiation of ANC, with only 49% of women having their first ANC visit within the first three months of pregnancy. The lack of statistically significant improvement in early ANC visits suggests that the intervention may not have fully addressed the underlying barriers preventing women from seeking care early in their pregnancies. Studies from sub-Saharan Africa and South Asia have shown that factors such as lack of awareness, cultural beliefs, and accessibility issues often delay the initiation of ANC [14–16]. In Ethiopia, studies suggest that geographic barriers, lack of pregnancy awareness, unplanned pregnancy, absence of prior ANC experience, limited decision-making power, and misconceptions about the appropriate time to start ANC are key factors contributing to delayed initiation [17, 18].

The intervention led to substantial improvements in key ANC practices, especially weight monitoring, blood pressure measurement, and the provision of essential diagnostic tests, including blood tests. Additionally, the intervention enhanced maternal care practices, such as the administration of iron folate, tetanus toxoid immunization, and deworming during pregnancy. These improvements are crucial for early detection and

management of pregnancy-related complications, including maternal anemia, infections, and other conditions that contribute to maternal and neonatal morbidity and mortality in low-resource settings [19–22]. Overall, the intervention demonstrated a statistically significant positive association with the delivery of a range of ANC services, indicating its effectiveness in improving maternal and newborn health outcomes in the intervention areas. These findings are consistent with other successful ANC interventions in sub-Saharan Africa and South Asia, where targeted efforts to enhance service delivery have led to meaningful improvements in maternal and neonatal health [23–25].

The intervention was positively associated with improved provision of nutrition information and counseling on pregnancy complications/low birth weight during ANC visits. The documented increase in the proportion of women receiving nutrition information during ANC visits in the intervention group, compared to a nearly stable trend in the comparison group, underscores the intervention's effectiveness in addressing a critical component of maternal health. The improvement in nutrition counseling observed in this study aligns with findings from other interventions in sub-Saharan Africa and Asia, where focused efforts to enhance ANC services have led to increased awareness and better nutritional practices among pregnant women [26–28]. Counseling on pregnancy complications improved in the intervention group, consistent with findings from other settings where enhanced ANC counseling has been associated with improved health-seeking behaviors and outcomes [29–32]. The intervention also improved counseling on low birth weight, with a notable increase in the intervention group compared to minimal change in the comparison group. This is especially important in sub-Saharan Africa and South Asia, where low birth weight remains a major public health concern due to maternal malnutrition and inadequate prenatal care [33, 34].

The study has strengths, including its use of a robust quasi-experimental design that involved a comparison group, which provides strong evidence of the intervention's effects by controlling for time-related changes and potential confounding variables. The inclusion of both adjusted and unadjusted analyses further strengthens the reliability of the findings. However, there are also limitations to consider. One limitation of this study is the reliance on self-reported data, which may introduce recall bias, particularly given the two years recall period for details on provided services. However, this bias is expected to be non-differential, affecting both the comparison and intervention groups similarly without systematically favoring one over the other. Lastly, although we adjusted for several background characteristics in our analysis, these adjustments cannot be exhaustive. Due to limited data, we were unable to examine the full range of potential confounders that may influence access to and use of ANC services in this study.

Conclusion

The ENAT intervention markedly improved key aspects of ANC by increasing visit frequency, enhancing service quality, and strengthening counseling on essential topics like nutrition, pregnancy complications, and low birth weight. These achievements underscore the potential of targeted interventions to strengthen routine ANC services and improve maternal healthcare in resource-limited settings. However, the intervention was less effective in promoting the early initiation of ANC visits, highlighting persistent challenges in reaching women early in pregnancy and ensuring comprehensive care. While the intervention substantially increased the frequency of ANC visits, a sizeable portion of pregnant women in the intervention area still did not complete the recommended four visits. These findings emphasize the need for future programs to not only sustain and expand service delivery improvements but also address systemic barriers—such as accessibility, cultural norms, and awareness—to encourage early engagement and continuous utilization of ANC services.

Abbreviations

ANC	Antenatal Care
ASB	Asymptomatic Bacteriuria
BW	Birth Weight
CIFF	Children's Investment Fund Foundation
DiD	Difference-in-Difference
ENAT	Enhancing Nutrition and Antenatal Infection Treatment
IRB	Institute Review Board
LBW	Low Birth Weight
MOH	Ministry of Health
MUAC	Mid Upper Arm Circumference
MTCT	Mother TO Child Transmission
ODK	Open Data Kit
PPS	Probability Proportion to Size
PSU	Primary Sampling Unit
STIs	Sexually Transmitted Infections
TTI	Tetanus Toxoid Injection
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-025-12789-4.

Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

Acknowledgements

The ENAT intervention evaluation was supported by the Children's Investment Fund Foundation (CIFF) under the service agreement Ref No. 2001-0472. The views and conclusions expressed in this manuscript are those of the authors and do not necessarily reflect the official position of CIFF. We extend our

heartfelt thanks to the women who made this study possible by agreeing to participate and responding to the interviews. The timely completion of this study would not have been possible without the hard work and dedication of the field team and the support from the Mela Research central office.

Authors' contributions
YM, EW prepared the study protocol, designed the study, analyzed the data and wrote the manuscript. TH, KY, AB, ZM, SA, YT, TT, GA, TN, SK, SG contributed to data collection monitoring, data quality assurance, verification, data management. They also contributed to the preparation of this manuscript. All authrs approved the manuscript.

Funding
This study was financially supported by the Children's Investment Fund Foundation (CIFF).

Data availability
The data used in this study is not publicly available to ensure the privacy of study participants, as per ethical guidelines. However, the raw data can be provided upon request. For inquiries, please contact Dr. Yared Mekonnen at Mela Research, P.O. Box 34422, Addis Ababa, Ethiopia; Email: yared@melareserach.com.

Declarations

Ethics approval and consent to participate
The study obtained informed verbal consent from study participants and this was approved by the ethical board of the Amhara Public Health Institute (APHI). Written consent was not required for this study. The ethical approval number was APHI/RTD/865.
All methods of this study were carried out in accordance with the Helsinki Declaration on the ethical principles for medical research involving human subjects [35]. The study protocol was approved by the Amhara Public Health Institute (APHI) ethical board.
The study did not involve gathering sensitive information from the women, and there was no invasive procedure or test of drugs or procedures used in the ENAT intervention. The ENAT intervention simply improved availability and access of point of care testing and infection prevention which are within the Ethiopia national ANC guideline. The services given to the pregnant women were in accordance with the Ethiopia National ANC guideline [36].
Study data collection teams were specifically instructed on the importance of obtaining informed consent and respecting the voluntary participation of respondents, their privacy, and the confidentiality of the data collected. There was no remuneration to the women who participated in this study. All the information and data were accumulated, organized, stored, analyzed, and retrieved, guaranteeing confidentiality.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 7 September 2024 / Accepted: 22 April 2025
Published online: 08 May 2025

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