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Impact of health facility delivery and antenatal care on neonatal mortality in Sub-Saharan Africa: a propensity score matching analysis

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Abstract

Background Even though global neonatal mortality has shown a remarkable reduction, it still constitutes 42% of the global under-five mortality. Nearly three-fourths of these deaths occurred in sub-Saharan Africa (SSA). Antenatal Care (ANC) and health facility delivery are the best-recommended strategies to prevent neonatal mortality. Previously published studies showed a significant association between ANC and health facility delivery with neonatal mortality. However, none of them examined the actual causal impact of health facility delivery and ANC on neonatal mortality in SSA using Propensity Score Matching (PSM) analysis. Therefore, our study examined the causal effect of ANC and health facility delivery on neonatal mortality in SSA using the Propensity Score Matched (PSM) analysis approach. This study adds new knowledge to the existing literature by evaluating the actual effect of health facility delivery and antenatal care on neonatal mortality by controlling confounding via matching. Which in turn enable decision makers in evaluating the effectiveness of these services in reducing neonatal mortality in SSA.

Methods We used the Demographic and Health Survey (DHS) data of 28 sub-Saharan African countries. About 351,940 live births were considered for this study. STATA version 18 statistical software was used for data management and analysis. We employed the Propensity Score Matching (PSM) analysis to examine the causal effect of ANC and health facility delivery on neonatal mortality. The logit model was fitted to estimate the propensity score. In the final PSM model, the average treatment effect of ANC and health facility delivery on neonatal mortality were reported. The quality of matching was checked to ensure the robustness of the results. We did sensitivity analysis to test hidden bias using the Mantel-Haenzel (MH) test statistic.

Results Neonatal mortality in SSA was 27.36 (95%: 26.83, 27.90) per 1000 live births. The Average Treatment Effect on the treated (ATT) in the PSM analysis demonstrated that ANC and health facility delivery decrease the risk of neonatal mortality by 1.04% and 0.22%, respectively. Similarly, the Average Treatment Effect on the Population (ATE) showed that ANC and health facility delivery reduce neonatal mortality by 1.04% and 0.22%, respectively. The quality of matching was good and the results were not sensitive to hidden bias. The treatment and control groups were well comparable for the baseline confounders after matching (p-value > 0.05).

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Conclusion Our study found that ANC and health facility delivery significantly contributed to the reduction of neonatal mortality after matching the treatment and control groups by observed variables. These findings highlighted that maternal and newborn health care programs and policies could enhance maternal health service utilization in SSA to reduce neonatal mortality.

Keywords Neonatal mortality, Sub-Saharan Africa, Propensity Score Matching analysis, Demographic and Health Survey

Background

According to the World Health Organization (WHO), neonatal mortality is defined as the death of neonates within 28 days of life. Globally, an estimated 5 million under-five mortality were observed in 2020 with half of those deaths were occurred in the first 28 days of life [1]. Neonatal mortality was responsible for 45% of under-five mortality and neonatal mortality was higher than that of infant and child mortality rates [2]. Despite the global reduction of neonatal mortality, sub-Saharan Africa (SSA) continued to have the highest mortality rates [3, 4]. The Neonatal Mortality rate (NMR) was 18 per 1000 live births worldwide, with approximately 1 million deaths occurring on the first day of births [5]. An estimated 3,100 neonatal deaths are observed every day in Africa [6]. Research revealed that the highest neonatal mortality rate in the SSA is caused by the underutilization of ANC and delivery in health facilities [7, 8]. An estimated 3 million babies could be saved if maternal healthcare services like antenatal care and in-hospital deliveries were used efficiently and on schedule [9].

About two-thirds of neonatal mortality could be prevented if all pregnant women and newborns had access to maternal healthcare services during pregnancy and delivery [10, 11]. The neonatal period is the most critical period in which the child is most vulnerable to death [12]. It is an indicator of newborn care and directly reflects antenatal, intrapartum, and newborn care [13]. Reducing neonatal mortality is indeed a critical component of the third Sustainable Development Goal (SDG), which aims to ensure healthy lives and promote well-being for all at all ages [14]. The specific target related to neonatal mortality under SDG 3 is to reduce the neonatal mortality rate to 12 or fewer deaths per 1,000 live births by the year 2030 [15]. Following that, the goal of sub-Saharan African nations was to eliminate all preventable newborn deaths by making prenatal, delivery, and postnatal care services easily accessible. Neonatal mortality, however, continues to be the main issue with public health in SSA [7, 16].

Evidence showed that undernutrition and infectious diseases such as pneumonia, diarrhea, and malaria along with prematurity and other adverse pregnancy outcomes remain the leading causes of mortality [17]. Neonatal mortality is primarily caused by pregnancy-related complications, including birth trauma, sepsis, and other related comorbidities [18]. These complications can be avoided by having access to basic life-saving interventions, such as Antenatal Care (ANC), delivery in a health facility, early initiation of breastfeeding, and essential newborn care [7, 19]. To reduce neonatal mortality, the World Health Organisation (WHO) promotes universal health coverage so that all expectant mothers can obtain the medical attention they need throughout their pregnancy and delivery [20].

Previous studies showed that ANC and health facility delivery reduce the occurrence of neonatal mortality [10, 21]. Evaluating the actual impact of ANC and health facility delivery is crucial for tackling neonatal-related issues and creating affordable interventions that can lower neonatal mortality, particularly in developing regions like SSA. As advocated by the WHO, ANC use and health facility delivery are the most effective strategies to reduce neonatal mortality in low-and middle-income countries [10]. Numerous studies evidenced the association between maternal healthcare services such as ANC & health facility delivery, and neonatal mortality [7, 10, 21, 22]. However, the findings obtained from these studies did not reflect the actual effect of ANC and health facility delivery as it could be due to confounding since the participants may differ across known and unknown factors to influence neonatal mortality. Therefore, traditionally to control for such confounding, the association between maternal healthcare services (ANC & health facility delivery) and neonatal mortality in statistical analysis has been done via regression analysis. However, bias (residual confounding or hidden bias) persists, as the distribution of confounding variables might differ across the control and treatment groups at baseline.

Therefore, this study aimed to investigate the causal effect of ANC and health facility delivery on neonatal mortality in SSA using a Propensity Score Matching (PSM) analysis. PSM is a methodological technique that aims to remove bias by matching treated (ANC/health facility delivery) and untreated (did not have ANC/home delivery) live births with similar conditional probability of receiving the treatment (ANC/health facility delivery). In this study, we matched live births born to mothers who had ANC or health facility delivery to live births born to mothers who did not have ANC or home delivery. Then, it can be reasoned that any difference in neonatal mortality is attributed to ANC or health facility delivery only. However, as to our search of the literature, there is no published study on the causal effect of ANC and health facility delivery on neonatal mortality using PSM analysis.

Methods and materials

Study setting and design

This study utilized Demographic and Health Survey (DHS) data from 28 Sub-Saharan African countries (see Table 1). Each country was divided into counties or regions, which were then further categorized into urban and rural strata. Using each country's National Population and Housing Census (NPHC), each stratum was subdivided into Enumeration Areas (EAs). An EA is defined as a geographical area consisting of 80–100 households, assigned to an enumerator for the purpose of conducting a census count.

Table 1 Weighted sample size in 28 sub-Saharan African countries

Country	Weighted frequency	Percentage (%)
Angola	26,641	7.57
Burkina Faso	48,230	13.70
Benin	13,571	3.86
Burundi	13,604	3.87
Cote d'ivoire	9,762	2.77
Cameroon	10,057	2.86
Ethiopia	11,041	3.14
Gabon	6,074	1.73
Ghana	8,572	2.44
Gambia	7,647	2.17
Guinea	7,920	2.25
Kenya	17,482	4.97
Liberia	5,259	1.49
Lesotho	3,134	0.89
Madagascar	12,335	3.50
Mali	10,307	2.93
Malawi	17,410	4.95
Mozambique	5,492	1.56
Nigeria	34,178	9.71
Rwanda	8,345	2.37
Sierra Leone	9,783	2.78
Chad	18,748	5.33
Togo	6,752	1.92
Tanzania	10,905	3.10
Uganda	15,300	4.30
South Africa	3,577	1.02
Zambia	9,814	2.79
Total	351,940	100

Data source and study design

The data used for our study were obtained from the DHS of 28 countries in SSA. DHS is a nationally representative community based cross-sectional survey regularly implemented to monitor the progress of health and health-related indicators in developing countries including sub-Saharan African countries. We obtained the data from the official DHS website measure/DHS/The data were accessed from the measure DHS program https://dhsprogram.com/. The DHS data is a large dataset containing household, birth, child, reproductive-age women, men, and couple datasets. For the current study, we have used the Birth Record (BR) dataset.

Source of population and study population

The source of population were all live births of reproductive age women within five years preceding the survey in sub-Saharan Africa while all live births of reproductive age women within five years preceding the survey in the selected EAs were the study population. Participants who have had data on place of delivery, antenatal care visit and survival status of live births were included.

Sampling method and sample size determination

The DHS statisticians used a complex survey design to recruit the sample for the survey. A stratified two-stage cluster sampling technique was employed to obtain representative samples. The primary and secondary sampling units were EA and households, respectively. A total sample of 351,940 live births of reproductive-age women in SSA were used (Table 1). The detailed methodologies are available here https://www.dhsprogram.com/Data/Guide-to-DHS-Statistics/index.cfm.

Variable measurements

Dependent variable

Neonatal mortality status was the dependent variable. In DHS mothers of newborns were asked the question"child is alive?"and"date of death?". We used these two DHS questions to generate the variable neonatal mortality. It was defined as neonatal mortality if the baby died within 28 days of birth.

Treatment variables

We have two treatment variables such as ANC use and place of delivery. Both ANC and place of delivery were binary outcomes coded as “No” and “Yes”. According to previous studies ANC and health facility delivery were found significant predictors that reduced the risk of neonatal mortality and identified as a key intervention strategy to reduce neonatal mortality. Two separate models were fitted (model 1: a model fitted to examine the causal impact of ANC on neonatal mortality & model 2: a model fitted to examine the causal impact of health facility delivery on neonatal mortality). For model 1: the treatment group was those who had ANC while the control group was those who did not have ANC. For model 2: the treatment and control groups were live births born at a health facility and those born at home, respectively.

Confounding variables

The DHS is an observational study where randomization was not employed and therefore, the treatment and control groups were not comparable. Based on our literature review and preliminary analysis, mothers'baseline characteristics that could affect the outcome and treatment variables were considered for the PSM analysis. Variables that significantly influence ANC use, health facility delivery, and neonatal mortality at the same time were considered confounders. The assumed inter-relationship between confounding, treatment, and outcome variables was shown using the Direct Acyclic Graph (DAG) using DAGitty version 3 software (Fig. 1) [23]. Confounding variables considered for matching were residence, maternal education, age, sex of household head, household wealth status, media exposure, maternal working status, birth order, age at first birth, preceding birth interval, and marital status. Finally, variables that had statistically significant associations with ANC, health facility delivery, and neonatal mortality were considered for generating propensity scores to match the treatment and control groups.

Statistical analysis

The data management and analysis was based on the STATA version 18 statistical software. This study was conducted based on the DHS data, which is an observational study where the treatment and control groups were not randomly created. Due to this the control and treatment groups were not comparable. Therefore, the treatment and control variables were not balanced for the confounding variables at baseline. This can bias and influence the causal effect of ANC and health facility delivery on neonatal mortality. The propensity score was generated as a function of the confounding variables to balance the treatment and control groups concerning the confounders.

The Propensity Score Matching (PSM) analysis was applied to balance the control and treatment groups based on the propensity score generated as a function of the observed confounding variables. The difference in the under-five mortality between treatment and control groups was balanced for the confounding variables using PSM analysis to obtain unbiased estimates. The propensity score is the likelihood that a mother had an ANC visit (had ANC vs did not have ANC) and health facility delivery (health facility delivery vs home delivery). The propensity score is the likelihood of being treated (ANC or health facility delivery) that ranges from 0 to 1. A propensity score near 1 indicates mothers are more likely to have ANC visits or health facility delivery.

To ensure the quality of matching we have assessed the common support assumption both statistically and graphically as well as the selection of unobservable was tested using stratified analysis. The difference in the distribution of the confounding variables across treatment

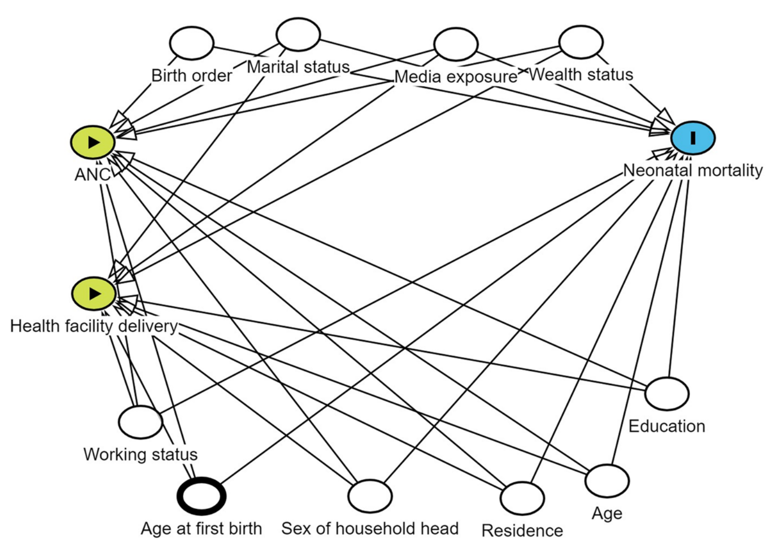

Fig. 1 Direct acyclic graph to show relationship between treatment, outcome and confounding variables

and control groups using the chi-square test or logistic regression. We fitted the multilevel modified Poisson regression analysis to identify the confounding variables for matching. In the PSM analysis, treatment variables (ANC or health facility delivery) are considered outcome variables, and treat confounding variables as explanatory variables. According to the association between the exposure and outcome variables, there are three types of variables such as variables only related to exposure, variables that have a significant association with both treatment and outcome variables, and variables that have a significant association with the outcome variable only.

To generate the propensity score we considered only the confounding variables. Of the various matching methods [24–26], the PSM method is most frequently used for causal inference in observational studies such as DHS. Its main objective is the mimic the concept of randomization in experimental studies to observational studies where the treatment and control groups couldn't be created randomly. The propensity score generated for each study participant denotes the probability of the mothers having ANC or health facility delivery given the confounders. Since the treatment variables are dichotomous (had ANC vs did not have ANC and health facility delivery vs home delivery), the logistic regression was used to generate propensity scores;

$$Logitp(x) = B0 + B1X1 + B2X2 + B3X3 + \ldots BnXn$$

where p (x) represents the probability of receiving treatment "ANC/health facility delivery". Then, the PSM analysis was used to obtain the average treatment effect of ANC and health facility delivery on neonatal mortality. It forms matching sets of control and treatments of individuals whose propensity scores are similar.

The confounding variables were selected as matching variables based on the significance status. The psmatch2 STATA package was used to match the control and treatment groups for the confounders and the quality of matching was assessed using the pstest STATA package.

We aim to estimate the average effect of ANC and health facility delivery on the treatment. Assume AiT to be neonatal mortality for those ith births born to mothers who had ANC or health facility delivery (treatment group), and AiC denotes neonatal mortality for mothers who did not have ANC or home delivery.

Several matching techniques were fitted and the Nearest Neighbour Matching (NNM) with calipers from 0.01 was chosen as the best matching technique based on the quality of matching and power of the study. We used a caliper in nearest neighbor matching to improve the quality of matching by matching the treated groups with untreated groups that have the very closet propensity score within the caliper radius [27]. Finally, we estimated the Average Treatment effect among the population (ATE), Average Treatment effect among Treated (ATT), and Average Treatment effect among Untreated (ATU) were reported to declare the statistical significance and magnitude of the causal effect of ANC and health facility delivery on neonatal mortality. The mean of every study subject-specific effect this is called the average treatment effect as it is in the overall population (ATE), while the average effect that would be observed if the overall population were to be treated (versus if it were to be untreated), it is in the subpopulation in which the treatment was intended, which is called the average treatment in the treated, ATT) [28]. ATE is used to measure the impact of the intervention (i.e. health facility delivery and antenatal care) in reducing neonatal mortality in the general population while ATT measures the impact of intervention (i.e. health facility delivery and antenatal care) in reducing neonatal mortality on those who actually received the intervention.

Standardized bias was used to evaluate the quality of matching. It is the sample mean difference between the control and treatment groups [29]. In addition, the Likelihood Ratio (LR) and R^2 were used to declare the quality of matching. The robustness of the results was assessed for the presence of selection on unobservable or hidden bias [30].

Ethical considerations

There was no need for ethical clearance as the research did not interact with respondents. The data used was obtained from the MEASURE DHS Program, and permission for data access was obtained from the Measure DHS program through an online request from http://www.dhsprogram.com. The data used for this study were publicly available with no personal identifier. For details about the ethical considerations of the DHS, the program sees https://dhsprogram.com/methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

Results

Baseline characteristics of the study population

A total of 351,940 live births were included. Of them, about 237,016 (67.35%) births occurred in rural areas. More than one-third (42.75%) and 30.40% of mothers did not attend formal education and primary level of education, respectively. Regarding the mother's age, 88,212 (25.06%) and 72,641 (20.64%) were between 25–29 years and 30–34 years, respectively. About 79,815 (22.68%) and 76,264 (21.67%) live births were belonged to the poorest and poorer household wealth, respectively. Above one-third (34.72%) of the mothers give their first birth before reaching 18 years and the majority (60.83%) of them

Table 2 Characteristics of the study participants in SSA

Variables		Frequency	Percentage (%)
Residence	**Urban**	**114,924**	**32.65**
	Rural	**237,016**	**67.35**
Highest educational level	No formal education	150,444	42.75
	Primary	107,002	30.40
	Secondary	80,155	22.78
	Higher	14,339	4.07
Maternal age	15–19	18,916	5.37
	20–24	72,467	20.59
	25–29	88,212	25.06
	30–34	72,641	20.64
	35–39	55,391	15.74
	40–44	30,144	8.57
	45–49	14,169	4.03
Media exposure	No	130,645	37.12
	Yes	221,295	62.88
Marital status	Single	22,312	6.34
	Married	305,901	86.92
	Divorced/widowed	23,727	6.74
Sex of household head	Male	284,568	80.86
	Female	67,372	19.14
Household wealth status	Poorest	79,815	22.68
	Poorer	76,264	21.67
	Middle	71,740	20.38
	Richer	66,545	18.91
	Richest	57,576	16.36
Birth order	1 st	81,902	23.27
	2nd – 4 th	172,297	48.96
	5 th or above	97,740	27.77
Age at first birth	< 18	120,297	34.72
	18–21	146,709	42.35
	22–29	72,720	20.99
	≥ 30	6,723	1.94
Preceding birth interval	First birth	84,653	24.05
	< 12 months	4,104	1.17
	12–23 months	49,093	13.95
	≥ 24 months	214,089	60.83
Respondent working status ($n = 351,666$)	No	123,612	35.15
	Yes	228,054	64.85
Perceived distance to the health facility	Not a big problem	192,959	59.93
	A big problem	129,025	40.07
Perceived birth size ($n = 273,172$)	Very large	34,076	12.47
	Larger than average	58,098	21.27
	Average	138,338	50.64
	Smaller than average	27,996	10.25
	Very small	14,663	5.37
The child is a twin or single birth	Single	339,583	96.49
	Twin	12,357	3.51
ANC visit ($n = 202,366$)	No	23,080	11.41
	Yes	179,285	88.59
Place of delivery	Home	96,606	27.45
	Health facility	255,334	72.55
Neonatal mortality	No	342,311	97.26
	Yes	9,626	2.74

Table 3 Association between baseline characteristics of the study participants with ANC, place of delivery and neonatal mortality

Variable	ANC			Place of delivery			Neonatal mortality		
	No	Yes	*p*-value	Home	HFD	*p*-value	No	Yes	*p*-value
Residence									
Urban	5.09	94.81	< 0.01	15.38	84.62	< 0.01	97.44	2.56	< 0.001
Rural	14.79	85.21		33.30	66.70		97.18	2.82	
Highest educational level									
No formal education	22.84	77.16	< 0.001	33.67	62.33	< 0.001	97.12	2.88	< 0.001
Primary	7.12	92.88		26.63	73.37		97.26	2.74	
Secondary	3.22	96.78		13.60	86.40		97.43	2.57	
Higher	1.01	98.99		3.81	96.19		97.85	2.15	
Mothers' age									
15–19	11.66	88.34	< 0.001	33.23	66.77	< 0.01	96.06	3.94	< 0.001
20–24	10.01	89.99		29.12	70.88		97.25	2.75	
25–29	10.87	89.13		29.00	71.00		97.61	2.39	
30–34	10.90	89.10		27.10	72.90		97.50	2.50	
35–39	12.31	87.69		25.51	74.49		97.18	2.82	
40–44	14.77	85.23		24.16	75.84		96.93	3.07	
45–49	18.68	81.32		17.91	82.09		96.59	3.41	
Media exposure									
No	20.61	79.39	< 0.001	42.26	57.74	< 0.001	97.26	2.74	0.958
Yes	6.05	93.95		18.70	81.30		97.26	2.74	
Marital status									
Single	7.10	92.90	< 0.001	19.09	80.91	< 0.001	97.30	2.70	0.060
Married	11.96	88.04		28.21	71.79		97.27	2.73	
Divorced/widowed	10.14	89.86		25.44	74.56		97.11	2.89	
Sex of household head									
Male	12.01	87.99	< 0.001	28.37	71.63	< 0.001	97.21	2.79	< 0.001
Female	9.20	90.80		23.55	76.45		97.49	2.51	
Household wealth status									
Poorest	19.91	80.09	< 0.001	41.67	58.33	< 0.001	97.15	2.85	< 0.001
Poorer	14.99	85.01		35.14	64.86		97.20	2.80	
Middle	10.16	89.84		26.78	73.22		97.22	2.78	
Richer	6.81	93.19		18.57	81.43		97.17	2.83	
Richest	3.20	96.80		8.66	91.34		97.67	2.33	
Birth order									
1 st	7.28	92.72	< 0.001	18.02	81.98	< 0.001	96.82	3.18	< 0.001
2nd – 4 th	9.90	90.10		25.37	74.63		97.75	2.25	
5 th or above	16.81	83.19		39.02	60.98		96.77	3.23	
Age at first birth									
< 18	15.73	84.27	< 0.001	36.54	63.46	< 0.001	97.01	2.99	< 0.001
18–21	9.58	90.42		25.30	74.70		97.32	2.68	
22–29	8.15	91.85		18.61	81.39		97.49	2.51	
≥ 30	9.39	90.61		16.64	83.36		97.08	2.92	
Preceding birth interval									
First birth	7.48	92.52	< 0.001	17.70	82.30	< 0.001	96.73	3.27	< 0.001
< 12 months	19.64	80.36		42.02	57.98		91.74	8.26	
12–23 months	16.98	83.02		38.55	61.45		95.81	4.19	
≥ 24 months	11.64	88.36		28.48	71.52		97.91	2.09	
Mothers working status									
Not working	14.70	85.30	< 0.001	29.47	70.53	< 0.001	97.38	2.62	< 0.001

Table 3 (continued)

Variable	ANC			Place of delivery			Neonatal mortality		
	No	Yes	*p*-value	Home	HFD	*p*-value	No	Yes	*p*-value
Working	9.55	90.45		26.31	73.69		97.20	2.80	
Distance to access health facility									
Not a big problem	15.61	84.39	< 0.001	34.35	65.65	< 0.001	97.24	2.76	0.023
A big problem	7.60	92.40		21.41	78.59		97.23	2.77	
The child is a twin or single birth									
Single	11.45	88.55	< 0.001	27.65	72.35	< 0.001	97.62	2.38	< 0.001
Twin	9.40	90.60		21.89	78.11		87.41	12.59	

had a preceding birth interval of 24 months or above (Table 2).

Neonatal mortality, ANC visit and health facility delivery in SSA

In SSA, the overall neonatal mortality in SSA was 27.36 (95%: 26.83, 27.90) per 1000 live births, ANC visit was 88.59% (95% CI: 88.46%, 88.73%) and health facility delivery was 72.55% (95% CI: 72.40%, 72.69%). In the chi-squared test of association result; residence, mothers'highest educational level, maternal age, birth order, age at first birth, preceding birth interval, distance to access health facility, sex of household head, and household wealth status were found to significantly associated with ANC, health facility delivery and neonatal mortality. Therefore, they were considered confounders and used for matching (Table 3).

Estimations of propensity scores

The variables that had significant association with both the exposure (ANC and health facility delivery) and outcome (neonatal mortality) were considered for matching using the logit model. The psmatch2 command generated the propensity score given the confounding variables and the nearest neighbor matching was the best-matching technique for our study. The propensity score for ANC and health facility delivery was estimated. As presented in Table 4, the strength of association, and the direction of association of the confounding variables with currently available evidence. The strength of the association, the direction of the association, and the significance of the estimates were in line with previous researcher findings (Table 5).

The causal effect of ANC use and health facility delivery on neonatal mortality

We estimated the causal effect of ANC and health facility delivery on neonatal mortality by estimating the difference in neonatal mortality between the treated groups (had ANC or health facility delivery) and matched control groups (did not have ANC or home delivery). The nearest neighbor matching with a caliper width of 0.0001 had the best quality of matching (Figs. 2 and 3, and Tables 5 and 6). The Average Treatment effect of ANC or health facility delivery among the Treated (ATT), Average Treatment effect of ANC or health facility delivery among the population (ATE), and Average Treatment effect of ANC or health facility delivery among Untreated (ATU) were reported.

Before matching, neonatal mortality among live births born to mothers who had ANC visits and health facility delivery decreased by 1.10% and 0.28%, respectively. The ATE of ANC use and health facility delivery on neonatal mortality was − 1.04% and − 0.22%, respectively. This indicated having ANC visits and health facility delivery reduced the risk of neonatal mortality by 1.04% and 0.22% among the population, respectively. The ATT values for ANC and health facility delivery were − 1.04% and − 0.22%, respectively, which showed that live births born to mothers who had ANC and health facility delivery led to a reduction in the risk of neonatal mortality by 1.04% and 0.22% among the treated groups, respectively.

Moreover, the difference in estimated treatment effect of ANC and health facility delivery among untreated groups in the treated and control groups was − 1.04% and − 0.23%, respectively. Showing that if the untreated groups were treated the risk of neonatal mortality could be reduced by 1.04% for ANC and 0.23% for health facility delivery (Table 7).

Common support assumption

We plot a propensity score graph to visualize the distributions of propensity scores and the distributions of the propensity scores were comparable (Figs. 2 and 3). The presence of significant overlap between the characteristics of the treated and control groups proves the validity of the common support assumption. The common support assumption was assessed graphically

Table 4 The association between confounding variables and treatment variables

Variables		ANC		HFD	
		Coef	*p*-value	OR	*p*-value
Residence	Urban	Ref		Ref	
	Rural	– 0.30 (– 0.34, – 0.25)	< 0.01	– 0.23 (– 0.25, – 0.21)	< 0.01
Highest educational level	No	Ref		Ref	
	Primary	1.20 (1.16, 1.23)	< 0.01	0.50 (0.48, 0.52)	< 0.01
	Secondary	1.55 (1.50, 1.61)	< 0.01	0.84 (0.81, 0.86)	< 0.01
	Higher	2.28 (2.06, 2.50)	< 0.01	1.51 (1.42, 1.61)	< 0.01
Birth order	First	Ref		Ref	
	2–4	0.57 (0.35, 0.80)	< 0.01	0.57 (0.35, 0.80)	< 0.01
	≥ 5	– 0.42 (– 0.64, – 0.19)	< 0.01	– 0.42 (– 0.64, – 0.19)	< 0.01
Household wealth status	Poorest	Ref		Ref	
	Poorer	0.12 (0.08, 0.15)	< 0.01	0.12 (0.10, 0.14)	< 0.01
	Middle	0.33 (0.29, 0.38)	< 0.01	0.36 (0.33, 0.38)	< 0.01
	Richer	0.38 (0.33, 0.43))	< 0.01	0.57 (0.55, 0.60)	< 0.01
	Richest	0.62 (0.54, 0.69)	< 0.01	0.98 (0.94, 1.02)	< 0.01
Respondent working status	Not working	Ref		Ref	
	Working	0.49 (0.46, 0.52)	< 0.01	0.12 (0.10, 0.14)	< 0.01
Media exposure	No	Ref		Ref	< 0.01
	Yes	0.76 (0.73, 0.79)	< 0.01	0.65 (0.63, 0.67)	< 0.01
Age at first birth	< 18	Ref		Ref	
	18–21	0.29 (0.26, 0.33)	< 0.01	0.11 (0.09, 0.13)	< 0.01
	22–29	0.20 (0.15, 0.25)	< 0.01	– 0.10 (– 0.13, – 0.08)	< 0.01
	≥ 30	– 0.26 (– 0.38, – 0.14)	< 0.01	– 0.89 (– 0.96, – 0.82)	< 0.01
Preceding birth interval	First birth	Ref		Ref	
	< 12 months	– 1.36 (– 1.83, – 0.88)	< 0.01	0.11 (0.09, 0.13)	< 0.01
	12–23 months	– 1.18 (– 1.64, – 0.71)	< 0.01	– 0.10 (– 0.13, – 0.08)	< 0.01
	≥ 24 months	– 0.76 (– 1.22, – 0.29)	< 0.01	– 0.89 (– 0.96, – 0.82)	< 0.01
Mothers age	15–19	Ref		Ref	
	20–24	0.09 (0.03, 0.16)	0.005	0.41 (0.37, 0.44)	< 0.01
	25–29	0.14 (0.06, 0.21)	< 0.01	0.81 (0.76, 0.85)	< 0.01
	30–34	0.32 (0.24, 0.40)	< 0.01	1.37 (1.33, 1.42)	< 0.01
	35–39	0.35 (0.25, 0.44)	< 0.01	1.77 (1.72, 1.82)	< 0.01
	40–44	0.21 (0.11, 0.31)	< 0.01	2.05 (1.99, 2.11)	< 0.01
	45–49	0.11 (– 0.01, 0.23)	0.085	2.52 (2.46, 2.59)	< 0.01
Marital status	Single	Ref		Ref	
	Married	0.27 (0.21, 0.33)	< 0.01	– 0.02 (– 0.06, – 0.001)	< 0.01
	Widowed/divorced	0.22 (0.31, 0.30)	< 0.01	– 0.02 (– 0.06, – 0.001)	< 0.01

and statistically (Figs. 2, and 3, Tables 5 and 6), and the assumption was met. Tables 6 and 7 showed the difference in the distribution of the confounding variables across the treatment and control groups at baseline before and after matching. Before matching the distribution of confounding variables across the treatment and control groups had a significant imbalance ($p < 0.05$) while after matching there was no statistical difference in the distribution of confounding variables across the treatment and control groups ($p > 0.05$).

Sensitivity analysis

The Rosenbaum bounding method was employed to ascertain the extent to which unmeasured variables, or hidden bias, impact the selection process and, consequently, the implications of the matching analysis. Strong evidence that ANC and health facility delivery reduce neonatal mortality would be found in all of the analyses, in a study free of bias, that is, where $\Gamma = 1$. The upper bound on the significance level for $\Gamma = 1.05, 1.1, 1.15……2$

Table 5 Performance of propensity score matching analysis: quality measurement

Variable	Sample	mean		%bias	%bias reduction	t-test	
		Treated	Control			t-statistic	p-value
Residence	Unmatched	1.6464	1.8377	− 44.8		− 59.78	< 0.001
	Matched	1.8567	1.8582	− 0.4	99.2	− 0.46	0.643
Highest educational level	Unmatched	1.0516	0.3514	90.4		117.85	< 0.001
	Matched	0.35318	0.35214	0.1	99.9	0.17	0.864
Sex of household head	Unmatched	1.2248	1.1936	7.7		10.95	< 0.001
	Matched	1.1648	1.1637	0.3	96.5	0.31	0.758
Household wealth status	Unmatched	2.8753	2.1091	59.0		81.16	< 0.001
	Matched	2.0855	2.0803	0.4	99.3	0.47	0.640
Mothers working status	Unmatched	0.65302	0.52783	25.7		38.10	< 0.001
	Matched	0.54025	0.54097	− 0.7	99.4	− 0.15	0.881
Media exposure	Unmatched	0.65721	0.32477	70.5		102.25	< 0.001
	Matched	0.33001	0.33016	0.0	100.0	− 0.03	0.973
Age at first birth	Unmatched	0.93147	0.73466	24.8		36.24	< 0.001
	Matched	0.70324	0.70442	− 0.1	99.4	− 0.16	0.872
Birth order	Unmatched	1.067	1.2826	− 30.5		− 44.12	< 0.001
	Matched	1.2807	1.2814	− 0.1	99.7	− 0.11	0.912
Birth interval	Unmatched	2.1914	2.3423	− 13.1		− 18.09	< 0.001
	Matched	2.3788	2.3797	− 0.1	99.4	− 0.09	0.930
Mothers age	Unmatched	2.4021	2.5314	− 8.5		− 12.76	< 0.001
	Matched	2.4956	2.4931	0.2	98.0	0.18	0.861
Marital status	Unmatched	0.98284	1.001	− 4.7		− 6.57	< 0.001
	Matched	1.0007	1.0004	0.1	98.0	0.12	0.903

Matching approach: Nearest neighbor matching

Mean bias: Unmatched—34.5

Median bias: Unmatched—25.7

Matched – 0.2

Matched—0.1

Pseudo R2: Unmatched—0.144

Matched – 0

LR chi-square: Unmatched – 21,306.12

Matched – 0.78

Significance test (p > chi2): Unmatched—< 0.001

Matched – 1.00

were significant and showed that the study is insensitive to hidden bias (Tables 8 and 9).

Discussion

In public health, healthcare decision-makers attempted to assess how the public health interventions among the treated populations have changed in the absence of the program. Our study examined the causal effect of ANC and health facility delivery on neonatal mortality using the most popular PSM method. The findings obtained from the classical regression analysis are prone to confounding bias and unable to infer the actual impact of exposure. In observational studies such as DHS where treatment and control groups are not created randomly. In this case, PSM analysis is a novel statistical approach to infer the causal effect of ANC and health facility delivery on neonatal mortality by making the comparison groups comparable given the confounders. Studies conducted so far have reported a statistically significant association between ANC and health facility delivery with neonatal mortality. However, these studies failed to estimate the actual causal effect of these variables. Therefore, the current study examined the actual causal effect of ANC and health facility delivery on neonatal mortality by making the treatment and control groups comparable using propensity scores.

In this study, the neonatal mortality rate in SSA was 27.36 (95%: 26.83, 27.90) per 1000 live births. This finding

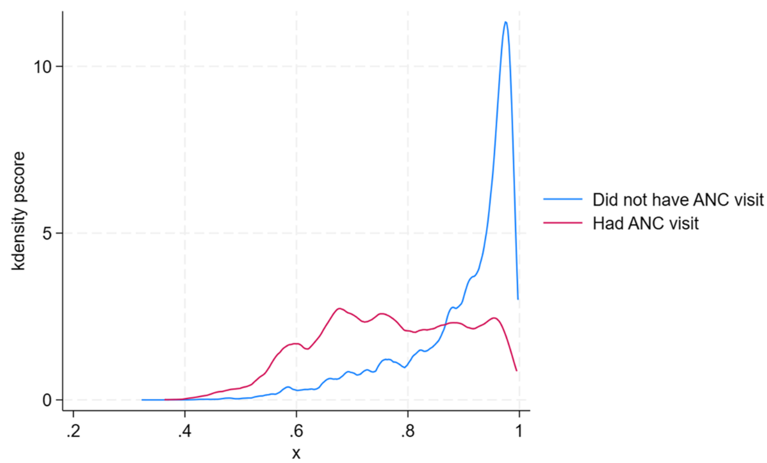

Fig. 2 Propensity score distribution of ANC after matching

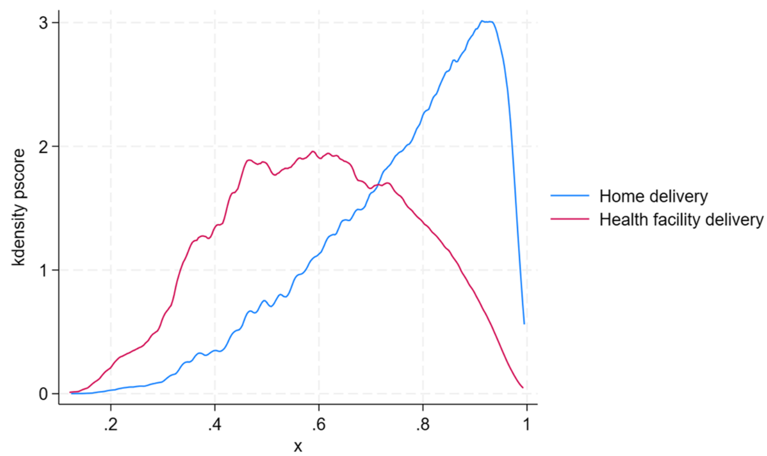

Fig. 3 Propensity score distribution of health facility delviery after matching

was higher than studies reported in Indonesia [31] and USA [32]. The higher neonatal mortality in SSA compared to developed nations could be limited access to healthcare such as maternal health services during pregnancy, delivery, and neonatal period in many sub-Saharan African countries [33, 34]. This plays a significant role in increasing neonatal mortality [35, 36]. In addition, SSA holds the huge burden of maternal malnutrition [37, 38], and infectious diseases [39, 40] complicate pregnancy and childbirth, which in turn increases the risk of newborn mortality in the first 28 days of birth.

Residence, maternal education, age, sex of household head, household wealth status, media exposure, maternal working status, birth order, age at first birth, preceding birth interval, and marital status were significantly correlated with ANC and health facility delivery. This might be due to the abovementioned maternal characteristics being proxy indicators of maternal health-seeking behavior and their awareness about healthcare programs. Research has indicated that mothers who were educated, wealthy, and belonged to urban areas were more likely to use ANC services and health facility delivery [41, 42]. In addition, the media is the primary source of information about maternal health services and it is a potent tool for influencing the public's perceptions and behavior regarding health [43]. Simultaneously they influenced neonatal mortality and therefore the treatment and control groups were matched for those confounders.

The average treatment effect of ANC and health facility delivery on neonatal mortality was − 1.04% and − 0.22%, respectively. Indicated that ANC and health facility delivery reduced the risk of neonatal mortality by 1.04% and 0.22%, respectively. The reason behind these results could be that early detection, prevention, and management of

Table 6 Quality of matching for effect of health facility delivery on neonatal mortality

Variable	Sample	mean		%bias	%bias reduction	*t*-test	
		Treated	Control			*t*-statistic	*p*-value
Residence	Unmatched	1.6337	1.8183	– 42.3		– 108.40	< 0.001
	Matched	1.816	1.8161	0	99.9	– 0.05	0.959
Highest educational level	Unmatched	0.97636	0.51698	56.1		142.87	< 0.001
	Matched	0.59018	0.59018	0	100	0	0.999
Sex of household head	Unmatched	1.204	1.1813	5.8		15.28	< 0.001
	Matched	1.1566	1.1566	0	100	0	1.00
Household wealth status	Unmatched	2.9639	2.1789	60.6		157.09	< 0.001
	Matched	2.22	2.2205	0	100	– 0.09	0.929
Mothers working status	Unmatched	0.65564	0.61004	9.5		25.53	< 0.001
	Matched	0.65412	0.65406	0	99.9	0.03	0.979
Media exposure	Unmatched	0.6932	0.41697	57.9		157.37	< 0.01
	Matched	0.4803	0.48035	0	100	– 0.02	0.984
Age at first birth	Unmatched	0.96279	0.72126	31.2		82.94	< 0.001
	Matched	0.74729	0.7479	– 0.1	99.7	– 0.16	0.869
Birth order	Unmatched	0.9841	1.2348	– 35.7		– 95.41	< 0.01
	Matched	1.2018	1.2019	0	99.9	– 0.04	0.968
Birth interval	Unmatched	2.0758	2.3008	– 18.9		39.62	< 0.001
	Matched	2.315	2.3152	0	99.9	– 0.03	0.975
Mothers age	Unmatched	2.6994	2.4757	14.9		39.62	< 0.001
	Matched	2.5129	2.5132	0	99.9	– 0.03	0.975
Marital status	Unmatched	0.9976	1.0129	– 4.3		– 11.30	< 0.001
	Matched	1.0118	1.0117	0	99.8	0.02	0.987

Matching approach: Nearest neighbor matching

Mean bias: Unmatched – 30.7

Median bias: Unmatched – 31.2

Matched – 0

Matched—0

Pseudo R2: Unmatched—0.140

Matched – 0

LR chi-square: Unmatched – 59,090.67

Matched – 0.06

Significance test (p > chi2): Unmatched—< 0.001

Matched – 1.00

pregnancy-related complications, as well as access to skilled care during childbirth and the immediate postnatal period, are made possible by antenatal care and health facility delivery, which also contributes to favorable pregnancy and neonatal outcomes [20].

The World Health Organization (WHO) recognizes the importance of ANC in reducing neonatal mortality [44]. With the use of ANC, healthcare providers can screen for high-risk pregnancies, including those having infections, gestational diabetes, hypertension, and fetal growth restriction [45, 46]. Therefore, early identification of high-risk pregnancies allows for timely management and interventions that can prevent or minimize unfavorable outcomes for the newborn and the pregnant woman [47].

Similarly, health facility delivery ensures access to timely and appropriate obstetric and neonatal care [48]. When skilled birth attendants are present, complications like postpartum hemorrhage, obstructed labor, and birth asphyxia all of which are major causes of neonatal mortality can be promptly managed [49]. Also, it makes it easier for the mother and the baby to get access to prompt postnatal care, which includes assessment, thermal support, breastfeeding assistance, and management of common neonatal conditions.

The results of this study should be interpreted in the context of the following limitations, even though it indicates the impact of ANC and health facility delivery on neonatal mortality. There is a possibility of residual

Table 8 Quality of matching for the impact of ANC on neonatal mortality

Gamma (Γ)	Test statistics		Significance level	
	Over-estimation (Q_mh +)	Under-estimation (Q_mh-)	Over-estimation (p_mh +)	Under-estimation (p_mh-)
1	7.34593	7.34593	< 0.05	< 0.05
1.05	8.810311	6.59301	< 0.05	< 0.05
1.1	8.82916	5.87846	< 0.05	< 0.05
1.15	9.5271	5.19845	< 0.05	< 0.05
1.2	10.1995	4.54965	< 0.05	< 0.05
1.25	10.8484	3.92914	< 0.05	< 0.05
1.3	11.4759	3.33443	< 0.05	< 0.05
1.35	12.0836	2.76329	< 0.05	< 0.05
1.4	12.673	2.21381	< 0.05	< 0.05
1.45	13.2454	1.68426	< 0.05	< 0.05
1.5	13.802	1.17313	< 0.05	0.120372
1.55	14.344	0.679059	< 0.05	0.24855
1.6	14.8722	0.200844	< 0.05	0.42041
1.65	15.3874	0.196079	< 0.05	0.422274
1.7	15.8906	0.645512	< 0.05	0.259298
1.75	16.3824	1.08205	< 0.05	0.139616
1.8	16.8634	1.50648	< 0.05	0.065971
1.85	17.3343	1.91956	< 0.05	< 0.05
1.9	17.7956	2.32195	< 0.05	< 0.05
1.95	18.2477	2.71426	< 0.05	< 0.05
2	18.6912	3.09706	< 0.05	< 0.05

Table 9 Quality of matching for the impact of health facility delivery on neonatal mortality

Gamma (Γ)	Test statistics		Significance level	
	Over-estimation (Q_mh +)	Under-estimation (Q_mh-)	Over-estimation (p_mh +)	Under-estimation (p_mh-)
1	2.65755	2.65755	0.003936	0.003936
1.05	4.25267	1.06391	< 0.05	< 0.05
1.1	5.77572	0.424407	< 0.05	< 0.05
1.15	7.23372	1.87599	< 0.05	< 0.05
1.2	8.63274	3.26657	< 0.05	< 0.05
1.25	9.97802	4.60165	< 0.05	< 0.05
1.3	11.2741	5.88602	< 0.05	< 0.05
1.35	12.5251	7.12388	< 0.05	< 0.05
1.4	13.7344	8.31892	< 0.05	< 0.05
1.45	14.9053	9.47443	< 0.05	< 0.05
1.5	16.0405	10.5933	< 0.05	0.120372
1.55	17.1425	11.6782	< 0.05	0.24855
1.6	18.2136	12.7314	< 0.05	0.42041
1.65	19.2558	13.755	< 0.05	0.422274
1.7	20.2709	14.7509	< 0.05	0.259298
1.75	21.2606	15.7209	< 0.05	0.139616
1.8	22.2264	16.6665	< 0.05	0.065971
1.85	23.1697	17.5892	< 0.05	< 0.05
1.9	24.0917	18.4902	< 0.05	< 0.05
1.95	24.9936	19.3707	< 0.05	< 0.05
2	25.8764	20.2319	< 0.05	< 0.05

Gamma: odds of differential assignment due to unobserved factors

Q_mh +: Mantel–Haenszel statistic (assumption: overestimation of treatment effect)

Q_mh-: Mantel–Haenszel statistic (assumption: underestimation of treatment effect)

p_mh +: significance level (assumption: overestimation of treatment effect)

p_mh-: significance level (assumption: underestimation of treatment effect)

confounding (unobserved variables) because the matching was done solely using the observed variables. By using sensitivity analyses, we tried to reduce and investigate the possibility of bias. These results are robust and bias-insensitive, according to tests for unobserved confounding and various matching approaches. Moreover, DHS is a cross-sectional study and it's prone to social desirability and recall bias. Despite the abovementioned limitations, the study has the following strengths. First, this study is based on nationally representative DHS data with a high response rate. Secondly, DHS uses the standardized questionnaire for the data collection which is consistent across nations and time. Furthermore, this study is the adjustment for potential confounders using the PSM approach in the estimation of the impact of health insurance and maternal healthcare service utilization.

Table 7 A propensity score-matched analysis of the impact of birth intervals on adverse pregnancy outcomes

Impact of birth interval on pregnancy birth outcomes		Treated (%)	Control (%)	Difference (%)	Standard error	t-statistic
Effect of ANC on neonatal mortality	Unmatched	1.80	2.89	− 1.10	0.000943	− 11.61
	ATT	1.73	2.77	− 1.04	0.0014	− 7.36
	ATU	2.77	1.73	− 1.04		
	ATE			− 1.04		
Effect of health facility delivery on neonatal mortality	Unmatched	2.65	2.93	− 0.28	0.00061	− 4.53
	ATT	2.64	2.86	− 0.22	0.0008	− 2.69
	ATU	2.88	2.65	− 0.23		
	ATE			− 0.22		

Conclusion

Neonatal mortality remains a major public health problem in SSA. In conclusion, ANC and health facility delivery reduces neonatal mortality. These findings evidenced that public health programs targeting reducing neonatal mortality should enhance ANC and health facility delivery in SSA. Maternal and reproductive health intervention programs and government policies that encourage health be considered to achieve Ethiopia's universal health care coverage plan and the SDG targets by 2030.

Abbreviations

ANC	Antenatal Care
CI	Confidence Interval
DHS	Demographic and Health Survey
PSM	Propensity Score Matching
SSA	Sub-Saharan Africa
WHO	World Health Organization

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Author's contributions
MMB, BMF, ZAA, AAA, HAA, YMN & BLS conceived the study. MMB, BMF, ZAA, AAA, HAA, YMN & BLS analyzed the data, drafted the manuscript, and reviewed the article. MMB, BMF, ZAA, AAA, HAA, YMN & BLS extensively reviewed the article. All authors read and approved the final manuscript.

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Data availability
Data is available online and you can access it from www.measuredhs.com.

Declarations

Ethics approval and consent to participate
Since the study was a secondary data analysis of publicly available survey data from the MEASURE DHS program, ethical approval and participant consent were not necessary for this particular study. We requested DHS Program and permission was granted to download and use the data for this study from http://www.dhsprogram.com. There are no names of individuals or household addresses in the data files.

Consent for publication
Not applicable since the study was a secondary data analysis.

Competing interests
The authors declare no competing interests.

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