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Bayesian Modeling of Antenatal Care Utilization and Key Maternal Risk Factors in Mogadishu, Somalia

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Abstract: Antenatal care (ANC) is a critical intervention in reducing maternal and neonatal mortality, particularly in low-resource settings. Despite global recommendations by the World Health Organization (WHO) for at least four ANC visits during pregnancy, the utilization of ANC services remains suboptimal in Somalia. This study investigates the key maternal risk factors affecting ANC utilization among 294 mothers in Mogadishu, Somalia, using Bayesian logistic regression. The objective of this study was to identify sociodemographic and maternal factors that significantly influence ANC attendance. The findings reveal that higher maternal age and greater parity were significantly associated with decreased ANC utilization. Conversely, higher educational attainment and employment status were positively correlated with increased ANC visits. The analysis also demonstrated that women with higher levels of education, especially those with secondary or tertiary education, were more likely to attend ANC visits as recommended. Additionally, socioeconomic factors such as household income and decision-making autonomy played an important role in ANC utilization. The Bayesian model displayed excellent convergence and predictive accuracy, highlighting the complex, multifactorial nature of ANC utilization. These results emphasize the importance of improving access to healthcare services, educational interventions, and economic empowerment to enhance maternal health outcomes. The study also emphasizes the potential of Bayesian methods in providing valuable insights for policymakers in fragile healthcare systems, such as that of Somalia.

Keywords: Bayesian Modelling, Antenatal Care, Bayesian Logistic Regression, Maternal Risk Factors

1. Introduction

Maternal health is a critical global issue, underscored by alarmingly high maternal mortality rates in various regions. According to a 2021 World Health Organization (WHO) report, preventable maternal deaths related to pregnancy and childbirth claim over 800 women's lives daily [1]. In developed countries, access to basic healthcare transforms childbirth into a positive and fulfilling experience. In stark contrast, many women in developing nations face suffering, health complications, and even death during pregnancy [2]. Implementing simple, affordable maternal care services like Antenal Care (ANC) could significantly reduce these pregnancy-related fatalities [3]. Despite a notable increase in ANC utilization in underdeveloped regions, only a small fraction of pregnant women attends the recommended four ANC consultations [4].

Antenatal care encompasses routine visits to healthcare providers during pregnancy, allowing for monitoring of pregnancy progress, early detection of potential complications, and essential health education [5]. As one of the "four pillars" of safe motherhood initiatives, ANC plays a vital role in promoting maternal and infant health during pregnancy and the early postpartum period. High-quality ANC services enhance survival rates and overall health for both mothers and their babies. Furthermore, these visits foster communication between women and healthcare providers, increasing the likelihood of using skilled birth attendants [3].

The WHO's focused ANC model previously recommended

at least four ANC visits for healthy pregnancies [24]. However, the 2016 WHO guidelines expanded this to a minimum of eight visits to improve care quality, reduce stillbirth risks, and ensure positive pregnancy experiences [23]. Yet, many countries, particularly in developing regions, still adhere to the outdated four-visit model [6]. Additionally, pregnant women in these regions, including Somalia, often begin ANC later than recommended [5].

Globally, while 86% of pregnant women access ANC with skilled personnel at least once, only 65% receive the recommended four visits [7]. In developing regions like sub-Saharan Africa and South Asia, where maternal mortality rates are fourteen times higher than in high-income countries, only 52% and 46% of pregnant women, respectively, receive adequate ANC. In sub-Saharan Africa, about 80% attend at least one ANC visit, but only 52% complete the recommended four visits [6].

Somalia, with one of the highest maternal mortality ratios in sub-Saharan Africa, has yet to meet the recommended ANC visit guidelines [8]. The country experiences high rates of maternal and newborn deaths, compounded by low ANC utilization [5]. With a maternal mortality rate of 692 deaths per 100,000 live births, the urgent need for improved maternal healthcare services is evident [26]. The Somalia Demographic and Health Survey [25] reveals that only 31% of women aged $15 - 49$ received ANC from skilled personnel during their last pregnancy, with just 24% attending the recommended four or more visits. Furthermore, only 26% of pregnant women received at least one ANC visit in a timely manner [25].

Research in sub-Saharan Africa has identified various sociodemographic factors impacting ANC utilization, including age, education, geographical location, parity, marital status, and wealth status [11]. For instance, studies from Ethiopia and other parts of sub-Saharan Africa indicate that poorer women are less likely to receive ANC due to financial constraints, lack of skilled providers in rural areas, and inadequate health services [3, 10]. In Kenya, a study employing logistic regression highlighted the significant influence of socioeconomic and demographic characteristics on maternal healthcare utilization [9]. However, this research did not explore the relative contributions of these factors using Bayesian logistic regression, which can provide deeper insights.

Given the limited health research capacity in logistic regression study [8], there is a lack of studies modeling ANC utilization and identifying key maternal risk factors using Bayesian methods. This study aims to fill that gap by employing a Bayesian approach to identify the critical determinants of ANC utilization in Mogadishu, Somalia. The insights gained will be crucial for enhancing maternal health services, improving utilization rates, and ultimately reducing maternal mortality rates.

2. Methods and Materials

2.1. Study Area

The study area for this research is SOS Hospital, located in Mogadishu, Somalia. SOS hospital is a prominent healthcare facility that serves a diverse population within the capital city, providing various medical services, including antenatal care, maternal health services, and emergency care. Established to address the healthcare needs of the community, SOS hospital plays a crucial role in enhancing health outcomes for mothers and children in the region. The hospital is equipped with trained medical personnel and essential resources, ensuring quality care for its patients. Its strategic location within Mogadishu allows for accessibility to a significant number of residents, making it an essential institution for healthcare delivery in the area. The study will focused on understanding antenatal care utilization among mothers accessing services at SOS Hospital, highlighting the challenges and determinants that influence their healthcare experiences.

2.2. Study Design and Data Source

This study used a cross-sectional design that comprised of women in the reproductive age group (15 to 49 years old), residing in Mogadishu city, and who attend ANC from SOS hospital. A semi-structured questionnaire was designed and confidentiality was assured to the participants. To ensure that the questions were clear and could be understood by both the enumerators and the respondents, the questionnaire was pretested and further refined based on the results.

2.3. Sample Size Calculation and Sampling Technique

The sample size was determined using Cochran's (1977) formula, which is widely used for calculating sample sizes when dealing with large populations:

$$n = \frac{Z^2 * p*(1-p)}{e^2}$$

Where: n is the sample size, Z is the Z-score corresponding to the desired confidence level $(1.96 for 95\%$ confidence), p is the estimated proportion of pregnant women utilizing ANC services. According to the Somali Demographic and Health Survey [25], only $24\%(p = 0.24)$ of pregnant women had four or more antenatal care visits for their most recent live births, $1-p$ is the acceptable deviation from the assumed proportion, which is $(1 - 0.24 = 0.76)$, is the margin of error (typically 5%), Therefore, by substituting the variables and calculating the sample size,

$$n = \frac{1.96^2 * 0.24*(1-0.24)}{0.05^2} = 280$$

Adding 5% of 280 pregnant mothers (thus $280 * 0.05 = 14$), to compensate non-response rate during data collection, a total sample size of $294(280 + 14 = 294)$ pregnant mothers was recruited for the study. The study used consecutive sampling because it involves recruiting all of the people from an accessible population who meet the eligibility criteria over a specific time interval, or for a specified sample size [12].

2.4. Bayesian Logistic Regression Model

In this study, the effect of the independent variables on the dependent variables were investigated using Bayesian logistic regression model since the dependent variable was a binary variable (0= not attended ANC services at a least 4 times) and (1= attended ANC services at least 4 times)

$$Y_i = \begin{cases} 1, & \text{if the } i^{th} \text{ woman utilizing atleast 4 ANC services} \\ 0, & \text{if the } i^{th} \text{ woman not utilizing atleast 4 ANC services.} \end{cases} \tag{1}$$

2.4.1. Model Specification

The Bayesian logistic regression model expresses the probability that woman utilizing at least 4 ANC services (i.e $Y_i = 1$)

$$P(Y_i = 1|X_i) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik})}} \tag{2}$$

In this study, Y_i is assumed to hava a Bernoulli distribution. The logit transformation is therefore as follows:

$$logit(P(Y_i = 1|X_i)) = log\left(\frac{P(Y_i = 1|X_i)}{1 - P(Y_i = 1|X_i)}\right) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik} \tag{3}$$

where:

$P(Y_i = 1|X_i)$, the probability that the i^{th} woman utilizing at least 4 ANC.

$1-P(Y_i = 1|X_i)$, the probability of i^{th} woman not utilizing at least 4 ANC.

$X_{i1}, X_{i2}, \cdots .X_{ik}$, the independent variables (maternal age, parity, education level, socioeconomic status, and access to healthcare).

β_0 the intercept and $\beta_1, \beta_2, \cdots, \beta_k$, the coefficients for the corresponding independent variables.

2.4.2. Prior Distribution

In Bayesian analysis, prior distributions are specified for each parameter:

$$\beta_j \sim N(\mu_{\beta j}, \sigma^2_{\beta j}), \text{for}, j = 1, 2, \cdots, k \tag{4}$$

This study assumes that each β_j is normally distributed with mean $\mu_{\beta j}$ and variance $\sigma^2_{\beta j}$. Non-informative priors was used, where $\mu_{\beta j} = 0$ and $\sigma^2_{\beta j}$ is large (1000), indicating little prior knowledge about the parameter values.

$$\beta_j \sim N(0, 1000), \text{for}, j = 1, 2, \cdots, k \tag{5}$$

where, the intercept β_0, and $\beta_1, \beta_2, \cdots, \beta_k$ regression coefficients for non-informative priors.

2.4.3. Likelihood Function

In Bayesian analysis, the likelihood function reflects information about the parameters contained in the data, and the prior distribution, which quantifies what is known about the parameters before observing data [13]. The likelihood function represents the probability of the observed data given the parameters:

$$L(Y_i|X_i, \beta) = P(Y_i = 1|X_i, \beta)^{Y_i} \times (1 - P(Y_i = 1 - P(Y_i = 1|X_i, \beta))^{1-Y_i} \tag{6}$$

substituting for $P(Y_i = 1|X_i, \beta)$

$$L(\beta|Y, X) = \prod_{i=1}^{n} \left(\frac{1}{1 + e^{-(\beta_9 + \sum_{j-0}^{k} \beta_j X_{ij})}}\right)^{Y_j} \times \left(\frac{e^{-(\beta_9 + \sum_{j-0}^{k} \beta_j X_{ij})}}{1 + e^{-(\beta_9 + \sum_{j-0}^{k} \beta_j X_{ij})}}\right)^{1-Y_j} \tag{7}$$

2.4.4. The Posterior Distribution

The posterior distribution combines the prior distribution with the likelihood function using Bayes‘ theorem:

$$P(\beta|Y, X) = \frac{P(Y|X, \beta) * P(B)}{P(Y|X)} \tag{8}$$

Where, $P(\beta|Y, X)$ is the the posterior distribution of the parameters β given the observed data Y and X, $P(Y|X, \beta)$ the likelihood of the data given the parameters β, $P(\beta)$ the prior distribution of the parameters β, and $P(Y|X)$ the marginal likelihood, which ensures the posterior distribution integrates to 1.

In Bayesian inference, the marginal likelihood $P(Y|X)$ is often ignored due to it’ s difficult to compute. Therefore,

$$P(\beta|Y,X) \propto P(Y|X,\beta) \times P(\beta) \quad (9)$$

This means the posterior distribution is proportional to the product of the likelihood observed from the collected data and the prior distribution.

2.4.5. Posterior Predictive Distribution

The posterior predictive distribution was used to predict the probability of ANC utilization for new data (X_{new}) :

$$P(Y_{new} = 1|X_{new}, Y, X) = \int P(Y_{new} = 1|X_{new}, \beta) \times P(\beta|Y, X)d\beta. \quad (10)$$

where, $P(Y_{new} = 1|X_{new}, Y, X)$ is the predicted probability for the new observation given the parameters β, $P(Y_{new} = 1|X_{new}, \beta)$ the posterior distribution of the parameters based on the observed data Y and X.

The posterior predictive distribution was computed using Markov Chain Monte Carlo (MCMC) sampling methods, allowing samples to be drawn from the posterior distribution of β.

$$P(Y_{new} = 1|X_{new}, Y, X) = \frac{1}{N}\sum_{s=1}^{N} P(Y_{new} = 1|X_{new}, \beta^{(s)}) \quad (11)$$

Where $\beta^{(s)}$ are samples drawn from the posterior distribution $P(\beta|Y, X)$ and S is the number of posterior samples used.

2.5. Descriptive Statistics

Data was entered into Microsoft Excel, coded, cleaned, and finally imported into R-software version 4.4.2 for analysis. The researcher used Bayesian Logistic Regression analyses to identify the key maternal risk factors of ANC service utilization among mothers in Mogadishu, Somalia.

Table 1 presents the socio-demographic characteristics of the respondents. The average age of the participants was 28 years, with 31.6% of mothers falling within the $25 - 29$ year age range, closely followed by 27.9% aged $20 - 24$ years. In terms of marital status, a substantial majority of respondents were married (70.1%), while 19.4% were divorced, 7.1% were widowed, and the remaining 3.4% identified with other marital statuses. t Regarding educational attainment, 30.6% of mothers reported no formal education, 20.4% had completed primary education, 30.6% possessed secondary education, and 18.4% had achieved tertiary education. For parity, the distribution of children among respondents indicated that 37.1% had $0 - 2$ children, 43.2% had between $3 - 5$ children, and 19.7% had six or more children.

Occupationally, the majority of mothers were housewives (51.7%), followed by 17.3% who were unemployed, 19.0% who were employed in various sectors, and 11.9% who were self-employed.

Table 1. *Socio-Demographic Characteristics of the Respondents.*

Variables	Categories	Frequency	Percentage
Age of mother	15-19	18	6.1
	20-24	82	27.9
	25-29	93	31.6
	30-24	62	21.1
	55-39	39	13.3
Marital staus	Married	206	70.1
of mothers	Divorced	57	3.4
	Widowed	21	7.1
	Others	10	3.4
Education level	No formal education	90	30.6
of mothers	Primary	60	20.4
	Secondary	82	27.9
Parity	0-2	109	37.1
	3-5	127	43.2
	6or more	58	197
Occupation	House wife	152	51.7
	Unemployed	51	17.3
	employed	56	19.0
	Self employed	35	11.9
Monthly family	$<$ \$200	80	27.2
Income	$\$(300 < 400)$	135	45.9
	$\$400 - \$600$	51	17.3
	$>$ \$600	28	9.5
Decision making	Myself	224	76.2
on ANC	my spouse	41	13.9
	other family member	29	9.9

In relation to family income, a significant proportion of mothers (45.9%) reported a monthly income ranging from \$200 to \$400 per month. Additionally, 27.2% had an income below \$200, 17.3% earned between 400 and \$600 , and the remaining 9.5% reported an income exceeding \$600. Finally, regarding decision-making processes for ANC, a notable majority (76.2%) indicated that they made decisions independently. In contrast, 13.9% of mothers cited their spouse as the decision-maker, while 9.9% identified another family member as influential in the decision-making process. Table 2 summarizes the responses of participants regarding the accessibility of ANC services. The majority of respondents (85.0%) resided in urban areas, while 15.0% lived in rural areas. When examining the distance to ANC services, 17.0%

of respondents reported living less than 1 km from the nearest facility, with 42.5% residing between $1-5$ km away. Additionally, 28.2% lived $6-10$ km from ANC services, and 12.3% reported a distance greater than $10km$. In terms of transportation methods utilized to access ANC services, 62.2% of mothers relied on public transport, 23.8% traveled on foot, and 14.0% used private vehicles. Regarding waiting times at ANC facilities, 13.6% of respondents indicated wait times of less than 30 minutes, 59.5% reported wait times between 30 minutes and 1 hour, and 26.9% experienced wait times exceeding 1 hour. When asked about the cost of ANC services, a notable proportion of respondents (69.4%) perceived the cost as inexpensive, while 30.6% considered it to be expensive. Finally, the quality of ANC services was evaluated by respondents, with 16.3% rating the services as excellent, 72.8% as good, 9.2% as fair, and 1.7% as poor. Figure 1 shows the number of respondents who had attended ANC visits per WHO recommendations. The results showed that a significant number of mothers 60% attended ANC while the rest, 40%, did not. Figure 2 reports the various reasons that the respondents provided to explain why they did not visit ANC services. These barriers included the long distance to the ANC services, financial constraints, long-lasting waiting time for the services, lack of knowledge about ANC services, and cultural or family restrictions. All Rhat values were 1.00 or very close to it, alongside high $Bulk_ESS$ and $Tail_ESS$ values, which confirm the convergence and stability of the model. Consequently, these results demonstrate a significant decline in ANC utilization among older maternal age cohorts, particularly for those aged $30-49$, while younger age groups did not present significant deviations from the reference group.

Table 2. *Means of access to ANC.*

Variables	Categories	Frequency	Percentage
1Residence	Urban	250	85.0
	Riral	44	15.0
Distance to ANC	$<$ than 1km	50	17.0
services	1-5 km	1.25	42.5
	6-10 km	83	28.5
	more than 19km	36	12.3
Means of transport	waking	70	23.8
to ANC	Public means	183	62.2
	10 Private	41	14.0
Waiting time	$<$ 30 minutes	40	13.6
for ANC services	3-1nour	1.75	59.5
	more than 1 hour	36	26.9
Cost of ANC services	inexpensive	204	69.4
	Expenxive	90	36.6
Quality of	Excellent	48	16.3
services	Goodo	32.4	72.8
	Fair	27	9.2
	Poor	5	1.7

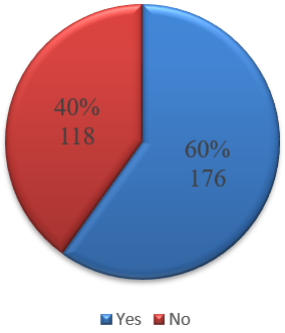

Figure 1. *The Proportion of mothers who visited ANC at least four visits.*

Figure 3 illustrates the posterior distributions and trace plots for the intercept and the effects of the specified age groups $(20-24, 25-29, 30-34$, and $35-49$ years) on ANC utilization. The posterior distributions indicate that most estimates for the age groups cluster around zero or slightly negative, suggesting minimal or weak effects relative to the reference age group. The coefficients for older age groups $(30-34$ and $35-49)$ display more pronounced negative distributions, further indicating a lower likelihood of ANC utilization compared to the $15-19$ age group. The trace plots demonstrate effective mixing and stable sampling across chains, affirming model convergence and the reliability of the results.

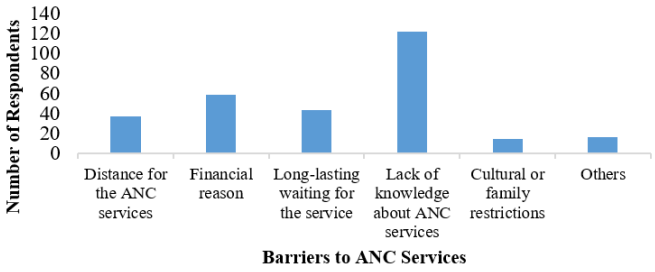

Figure 2. *Barriers to ANC utilization.*

2.6. Bayesian Analysis

Table 3 presents Bayesian estimates quantifying the relationship between maternal age and ANC utilization, using the $15-19$ age group as the reference category. The intercept estimate (β_0 of $0.23(95\%$ CI: -0.59 to $1.04)$ represents the baseline log odds of ANC utilization for this reference group. Mothers aged $20-24$ experienced a modest, non-significant increase in ANC utilization, with an estimate of $0.34(95\%$ CI: -0.56 to $1.26)$. In contrast, those aged $25-29$ exhibited a significant negative association with ANC utilization (estimate $= -0.70, 95\%$ CI: -1.62 to $-0.20)$. Notably, substantial negative associations were observed in the $30-34$ and $35-49$ age groups, with estimates of $-1.21(95\%$ CI: -2.16 to $-0.24)$ and $-1.05(95\%$ CI: -2.05 to $-0.01)$, respectively. These findings indicate a decreased likelihood of ANC utilization in these older maternal age groups compared to the reference category.

All Rhat values were 1.00 or very close to it, alongside high $Bulk_{ESS}$ and $Tail_{ESS}$ values, which confirm the convergence and stability of the model. Consequently, these results demonstrate a significant decline in ANC utilization among older maternal age cohorts, particularly for those aged $30-49$, while younger age groups did not present significant deviations from the reference group.

Table 3. *Bayesian estimates quantifying the relationship between maternal age and ANC utilizatio.*

Variables	Categories	Estimates	Est.Error	95% CI		Rhat	Bulk	Tail
				Lower	Upper		ESS	ESS
β_0 Intercept		0.23	0.42	-0.59	1.04	1.01	1236	1389
Age	15-19(ref)					1.00		
	20-24	0.34	0.47	-0.56	1.26	1.10	1372	1897
	25-29	-0.70	0.473	-0.62	-0.20	1.01	1350	1441
	30-34	-1.21	0.49	-2.16		1.00	1441	1801
	35-49	-1.05	0.52	0.52	-2.05	1.00	1514	2109

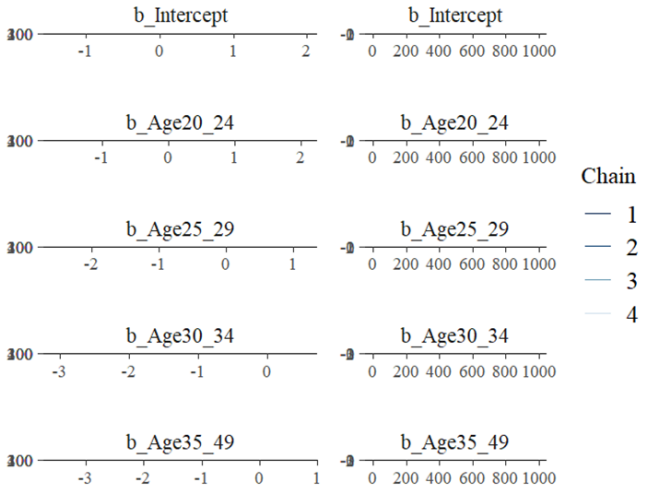

Figure 3. *Posterior Distributions and Trace Plots of Age Groups.*

Table 4 presents Bayesian estimates for the relationship between parity and ANC utilization, with a parity of 0-2 serving as the reference category. The intercept β is estimated at $0.19(95\%CI\ :\ -0.14\ to\ 0.52)$, reflecting the baseline log-odds of ANC utilization for women with $0-2$ previous births. For women with a parity of $3-5$, the estimate is -0.64 (Est. Error $= 0.23$, 95% CI: -1.09 to -0.19), indicating a statistically significant decrease in ANC utilization compared to the reference group. Moreover, for women with a parity of 6 or more, the estimate is -0.99 (Est. Error $= 0.32, 95\%$ CI: -1.62 to -0.37), demonstrating an even stronger negative association with ANC utilization. All Rhat values are 1.00, and the high Bulk Effective Sample Size (ESS) and Tail ESS values confirm model convergence and stability, indicating reliable results. These findings suggest that higher parity is linked to lower ANC utilization.

Figure 4 illustrates the posterior distributions and trace plots for the Bayesian model's intercept and parity group coefficients regarding ANC utilization. Each density plot showcases the posterior distribution, highlighting the range and central tendency of each coefficient, while the trace plots display the sampling progression across four chains. The intercept exhibits a distribution centered around positive values, consistent with the estimate presented in Table 4, indicating a baseline propensity for ANC utilization in the reference parity group $(0-2)$. In contrast, the coefficients for Parity $3-5$ and Parity 6 or more reveal negative distributions, reinforcing the negative association between higher parity and ANC utilization. The trace plots demonstrate well-mixed and stable chains for all coefficients, further confirming model convergence. Table 4 provides insightful Bayesian estimates regarding the relationship between ANC utilization and the educational background of mothers. The intercept of the model indicates the baseline log-odds of ANC utilization for mothers without any formal education, estimated at -1.27. This estimate falls within a 95% credible interval . of -1.71 to -0.83, suggesting that ANC utilization is significantly lower in this group compared to those with formal education. The model further delineates the effects of education on ANC utilization. For mothers who have completed primary education, the estimate is -0.19, accompanied by a 95% CI of -0.93 to -0.50. This minimal yet statistically significant improvement in ANC utilization relative to the uneducated cohort suggests that even a primary education can confer some benefits in accessing antenatal care services. Notably, the impact of higher education becomes more pronounced. Mothers with secondary education exhibited a considerable increase in ANC utilization, reflected by an estimate of 2.81 and a credible interval ranging from 2.17 to 3.47. This strong positive association underscores the critical role that secondary education plays in enhancing access to and utilization of ANC services.

Table 4. *Estimates regarding the relationship between ANC and educational background.*

Variables	Categories	Estimates	Est.Error	95% CI		Rhat	Bulk	Tail
				Lower	Upper		ESS	ESS
β_0 Intercept		-1.27	0.23	=0.21	-0.83	1.00	2775	2855
level	No formal educati					1.00		
	Primary	-0.19	0.37	-0.93	-0.50	1.00	3047	3058
	Secondary	2.81	0.33	2.17	3.47	1.00	3087	3249
	Tertiary	1.85	0.53	1.21	2.51	1.00	3075	3321

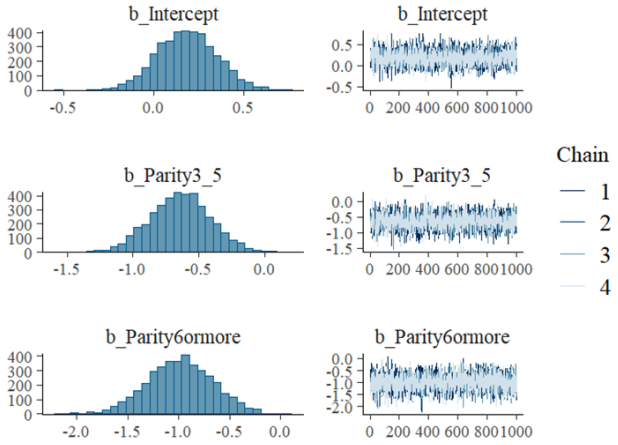

Figure 4. *Posterior Distributions and Trace Plots Parity Group*

Moreover, mothers with tertiary education also demonstrated a positive association with ANC utilization, with an estimate of 1.85 and a CI of 1.21 to 2.51. Although this impact is significant, it is slightly less robust than that observed for mothers with secondary education, indicating that while higher education continues to be beneficial, the transition from secondary to tertiary education may yield diminished returns in terms of ANC utilization.

The model's convergence is supported by Rhat values of 1.00 and robust Bulk Effective Sample Size and Tail Effective Sample Size. These statistics affirm the reliability of the estimates, indicating that the model has adequately converged and provides stable parameter estimates.

Figure 5 visualizes this analysis through posterior distributions and trace plots for the intercept and each educational category's effects (primary, secondary, and tertiary). The unimodal and symmetric nature of these posterior distributions suggests that the estimates for each parameter are well-defined and reliable. The effect of primary education centers near zero, indicating a minimal impact compared to secondary and tertiary education, which show pronounced positive effects, suggesting means around 3.0 and 2.0, respectively.

The trace plots further enhance the credibility of these findings, illustrating good mixing across the four chains without evidence of convergence issues or autocorrelation. Collectively, these results advocate that higher education levels, particularly secondary and tertiary, are significantly correlated with increased utilization of antenatal care.

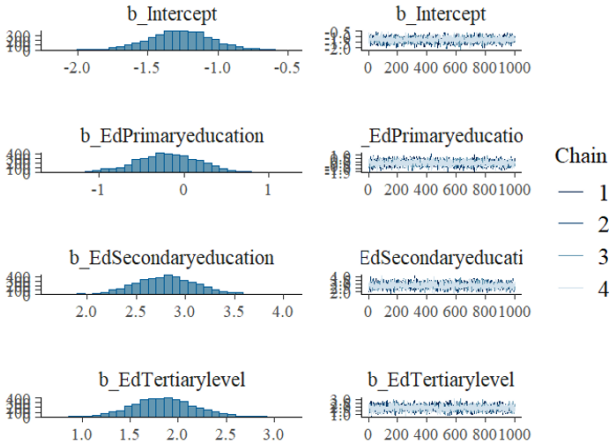

Figure 5. *Posterior Distributions and Trace Plots Education Levels*

Such insights may guide public health strategies aimed at improving maternal health outcomes through educational interventions. Table 5 presents a Bayesian analysis examining the relationship between ANC utilization and various socio-economic predictors. The intercept (β_0) is estimated at -1.53, indicating a baseline level of ANC utilization when all other predictors are at their reference categories. Notably, being unemployed is associated with a decrease in ANC utilization by 0.36 compared to housewives. Conversely, employed and self-employed individuals exhibit significant increases in ANC utilization, with estimates of 2.99 and 2.72, respectively, suggesting that employment status substantially enhances the likelihood of attending ANC services.

Table 5. *ANC utilization and various socio-economic predictors.*

Variables	Categories	Estimates	Est.Error	95% CI		Rhat	Bulk	Tail
				Lower	Upper		ESS	ESS
β_0 Intercept		-1.53	0.32	-2.20	0.92	1.00	3098	3198
Occupation	House wife					1.00		

Variables	Categories	Estimates	Est.Error	95% CI		Rhat	Bulk	Tail
				Lower	Upper		ESS	ESS
	Unemployed	-0.36	0.37	-1.10	0.34	1.00	7230	3334
	Employed	2.99	0.39	2.25	3.78	1.00	6336	3265
	self employed	2.72	0.44	1.87	3.62	1.00	5827	3067
Monthly Income	$<$ \$200(ref)					1.00		
	$<$ \$200	0.61	0.33	-0.03	1.29	1.00	4041	3177
	\$200 $-$ \$400	0.25	0.42	0.62	1.06	1.00	4813	3075
	\$400 $-$ \$600	1.11	0.51	0.12	2.12	1.00	5253	3625
Decision on ANC	Myself(ref)					1.00		
	Myselfd	-0.34	0.39	-1.10	0.44	1.00	6334	3245
	My spouse	-0.09	0.43	-0.94	0.73	1.00	6154	3339

Table 6. *Bayesian Impact Analysis of Delayed ANC Initiation on Maternal Health Outcomes.*

Variables	Categories	Estimates	Est.Error	95% CI		Rhat	Bulk	Tail
				Lower	Upper		ESS	ESS
β_0 Intercept		1.22	0.25	0.74	1.74	1.00	1947	1934
Delayed ANC	First Trimmester(1					1.00		
	Second trimmster	-2.48	0.32	-3.10	-1.86	1.00	1947	1907
	Third trimmester	-2.67	0.33	-3.34	-2.04	1.00	1975	2191

Regarding monthly income, individuals earning above \$600 demonstrate a noteworthy increase of 1.11 in ANC utilization relative to those earning less than \$200. This finding indicates a trend toward higher ANC utilization as income rises. Decision-making authority also plays a role; women who make their own decisions about ANC utilization serve as the reference group, while decision-making by spouses or other family members shows marginal negative associations with ANC attendance ($\beta = -0.34$ and -0.09, respectively), although these effects are not strongly significant.

The Rhat values, all around 1.00, indicate good convergence of the Bayesian model, with robust estimates supported by the Bulk and Tail Effective Sample Sizes (ESS). Figures $6 - 7$ illustrate the posterior distributions and trace plots for the socio-economic predictors. The density plots reveal central tendencies and variability of each coefficient, while the trace plots confirm convergence stability across four Markov Chain Monte Carlo (MCMC) chains.

The intercept's distribution is centered on a negative value, aligning with preliminary findings, which suggest a baseline inclination toward low ANC utilization in the reference group. Employment status, with posterior means around 3.5 for employed and 3.0 for self-employed women, indicates a strong positive correlation with ANC utilization. In contrast, the unemployed group's distribution is centered near zero, signaling a weaker connection.

Income levels reveal that women earning above \$600 display a substantial positive association with ANC utilization, while those in the \$400 $-$ \$600 range show modest positive effects. In contrast, women earning \$200 $-$ \$400 exhibit distributions closer to zero, indicating less pronounced ANC use. The coefficients for decision-making authority held by "My spouse" or "Other family members" are also near zero, highlighting a potential minor reduction in ANC access when decision-making is external to the woman.

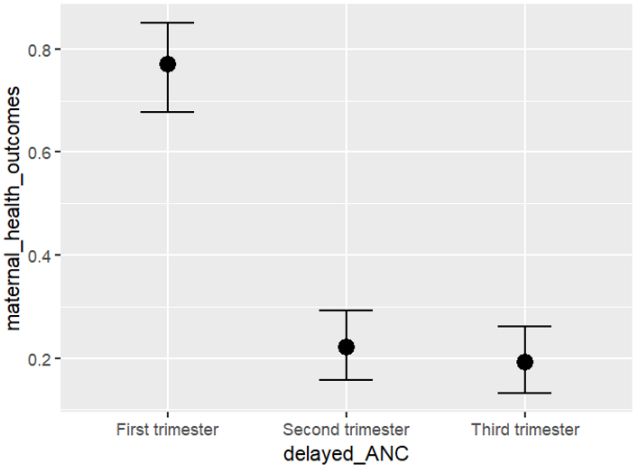

Figure 6. *Predicted Maternal Health Outcomes Based on Timing of ANC Initiation.*

Figure 6 visualizes the predicted probabilities of positive maternal health outcomes based on ANC timing. Women who initiated ANC in the first trimester had the highest probability of favorable outcomes (around 0.8), while delays to the second and third trimesters significantly reduced these probabilities, highlighting the negative impact of late ANC initiation.

3. Discussion of Findings

This study utilized Bayesian logistic regression to analyze ANC utilization against various maternal risk factors in Mogadishu, Somalia. The dataset comprised 294 mothers,

and the analysis identified that maternal age, education level, parity, socioeconomic status, and healthcare access emerged as significant determinants of ANC service utilization.

The findings reveal that maternal age correlates significantly with ANC attendance. Specifically, younger mothers (ages $15 - 24$) demonstrated higher rates of ANC utilization compared to their older counterparts. This observation aligns with existing research in sub-Saharan Africa, where younger women tend to initiate and maintain ANC visits more consistently [14, 15]. The trend may be attributed to heightened pregnancy-related concerns and increased awareness gained through contemporary health education initiatives.

Additionally, these results are consistent with studies conducted in Nepal where maternal age significantly influenced ANC attendance [6]. Targeted ANC education programs for younger mothers may have resulted in this increased utilization, emphasizing a potential gap in outreach to older women, who may rely on past childbirth experience rather than formal healthcare support.

Parity also exhibited a significant relationship with ANC service utilization, corroborating findings from prior research [20, 21]. The study showed that mothers experiencing their first or second pregnancies were more likely to access ANC services compared to those with six or more children. This pattern is echoed in findings from Ethiopia, where women with multiple previous pregnancies often perceive ANC as less critical, drawing on past experiences instead of consistently seeking healthcare for each pregnancy [16]. The demands associated with larger families may contribute to decreased healthcare attendance as mothers juggle increased responsibilities and time constraints. Educational attainment emerged as another pivotal factor influencing ANC service utilization. The study uncovered that mothers with primary education were less likely to utilize ANC services compared to those with secondary education or higher. This disparity suggests that mothers with limited or no formal education face barriers in seeking maternal healthcare, largely due to a lack of knowledge concerning maternal health and ANC services. Similar findings were reported by [17], who noted that women with higher educational levels are more likely to complete the recommended four ANC visits. Educated women generally demonstrate greater awareness of healthcare services and their benefits, indicating that enhancing women's education can significantly improve health-seeking behaviors. These findings are consistent with research conducted in Pakistan, which illustrated that higher education levels positively influence health-seeking behaviors and enable women to exert greater control over their pregnancies [18].

Furthermore, the study highlighted a strong association between socioeconomic status and ANC utilization in Mogadishu. Specifically, the occupation and income level of mothers were found to significantly impact ANC attendance. Notably, over half of the respondents (51.6%) identified as housewives and did not attend ANC services, underscoring a potential link between occupation and healthcare access. Similar conclusions were drawn in Ghana, where maternal occupation was deemed a significant predictor of ANC attendance [19]. Furthermore, economic factors played a critical role, as 27.3% of respondents reporting a household income below $\$200$ did not utilize ANC services. This trend reflects the financial barriers that often accompany ANC access, which includes both direct costs (e.g., service fees) and indirect costs (e.g., transportation). Research by [18] substantiated these findings, indicating that women from higher-income households were three times more likely to receive ANC services compared to those from lower-income households.

Additionally, geographic proximity to healthcare facilities was identified as a significant predictor of ANC utilization in this study. Findings revealed that women residing $6 - 10$ km or more than 10 km from ANC centers were considerably less likely to attend the recommended number of ANC visits. This outcome is consistent with research conducted in Kenya and Uganda, where increased distance to health facilities negatively impacted ANC attendance, attributable to higher transportation costs and the time burden associated with lengthy travel [22]. Overall, the results underscore that both distance and travel time significantly influence maternal health service utilization, revealing the critical importance of geographic accessibility in enhancing ANC utilization.

In summary, this study underscores the complex interplay between maternal characteristics, sociodemographic factors, and ANC service utilization. These findings highlight the need for targeted interventions that address educational gaps, socioeconomic barriers, and accessibility challenges, ultimately promoting improved maternal healthcare outcomes in Mogadishu and similar contexts.

4. Conclusion

Based on the results, the study concluded that maternal age, educational level, parity, socioeconomic status, and healthcare access significantly influenced the likelihood of ANC utilization. The Bayesian analysis provided robust insights into how maternal age, parity, education level, socioeconomic status, and healthcare access influence ANC attendance. Women with higher educational attainment, younger, lower parity, and better socioeconomic status were more likely to utilize ANC services, while Women aged $30 - 34$ and $35 - 49$ years, those with higher parity, and those with no formal education were less likely to attend ANC services.

Abbreviations

ANC	Antenal Care
WHO	World Health Organisation
SDHS	Somalia Demographic Health Survey
aOR	Adjusted Odds Ratio
CL	Confidence Interval
ESS	Effective Sample Size
MCMC	Monte Carlo Markov Chain

Ethical Consideration

Approval to conduct the study was sought from the school of Mathematics and Computing at Kampala International University to conduct the study. Ethical approval was received from the Research & Ethical Committee at the Federal Ministry of Health & Human Services in Somalia. Letter of introduction was also obtained from the Director of Higher Research to formally introduce the researcher to relevant authorities, who then granted permission to carry out the study in the selected area.

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Consent for Publication

Not applicable

Conflicts of Interest

Authors have no competing interests.

References

[1] Rambliere, Lison and Leservoisier, Clémentine and Bedo, Ysé and Macalli, Melissa and Lebugle, Amandine and Douay, Caroline and Guénée, Lorraine (2023). Major depressive disorder in post-secondary students attending foodbanks in France. *Frontiers Media SA* 11(27), 1177617. https://doi.org/10.3389/fpubh.2023.1177617

[2] Mehari, Kassu and Wencheko, Eshetu (2013). Factors affecting maternal health care services utilization in rural Ethiopia: a study based on the 2011 EDHS data, *Ethiopian Journal of Health Development* 1(27), 16–24. https://doi.org/10.4314/ejhd.v27i1.3

[3] Tekelab, Tesfalidet and Chojenta, Catherine and Smith, Roger and Loxton, Deborah, (2019). The impact of antenatal care on neonatal mortality in sub-Saharan Africa: A systematic review and meta-analysis. *Public Library of Science San Francisco, CA USA*, 9(14), e0222566. https://doi.org/10.1371/journal.pone.0222566

[4] Konje, Eveline Thobias and Magoma, Moke Tito Nyambita and Hatfield, Jennifer and Kuhn, Susan and Sauve, Reginald S and Dewey, Deborah Margret (2028). Missed opportunities in antenatal care for improving the health of pregnant women and newborns in Geita district, Northwest Tanzania, *Springer*, 18, 1–13. https://doi.org/10.1186/s12884-018-2014-8

[5] Miikkulainen, Alli and Abdirahman Mohamud, Ibrahim and Aqazouz, Majda and Abdullahi Suleiman, Bishara and Sheikh Mohamud, Omar and Ahmed Mohamed, Abdifatah and Rossi, Rodolfo, (2023). Antenatal care utilization and its associated factors in Somalia: a cross-sectional study. *Springer*, 23(1), 581. https://doi.org/10.1007/s12345-023-08431-1

[6] Chikako, Teshita Uke and Bacha, Reta Habtamu and Hagan Jr, John Elvis and Seidu, Abdul-Aziz and Kuse, Kenenisa Abdisa and Ahinkorah, Bright Opoku, (2022). Multilevel modelling of the individual and regional level variability in predictors of incomplete antenatal care visit among women of reproductive age in Ethiopia: Classical and Bayesian approaches, *MDPI*, 19(11), 6600. https://doi.org/10.3390/ijerph19116600

[7] Basha, Garoma Wakjira,Factors affecting the utilization of a minimum of four antenatal care services in Ethiopia, *Wiley Online Library*, (2029), 2019(1), 5036783. https://doi.org/10.1002/jid.5036783

[8] Dalmar, Abdirisak Ahmed and Hussein, Abdullahi Sheik and Walhad, Said Ahmed and Ibrahim, Abdirashid Omer and Abdi, Abshir Ali and Ali, Mohamed Khalid and Ereg, Derie Ismail and Egal, Khadra Ali and Shirwa, Abdulkadir Mohamed and Aden, Mohamed Hussain and others, (2027). Rebuilding research capacity in fragile states: the case of a Somali–Swedish global health initiative: Somali–Swedish Action Group for Health Research and Development, *Taylor & Francis*, 10(1) (1348693). https://doi.org/10.1080/16549716.2017.1348693

[9] Kitabo, Cheru Atsmegiorgis and Damtie, Ehit Tesfu, (2020). Research Article Bayesian Multilevel Analysis of Utilization of Antenatal Care Services in Ethiopia.

[10] wosu, Chijioke O and Ataguba, John E(2019), Socioeconomic inequalities in maternal health service utilisation: a case of antenatal care in Nigeria using a decomposition approach,*Springer*,19, 1–11. https://doi.org/doi.org/10.1186/s12889-019-7840-8

[11] Tessema, Zemenu Tadesse and Teshale, Achamyeleh Birhanu and Tesema, Getayeneh Antehunegn and Tamirat, Koku Sisay (2021). Determinants of completing recommended antenatal care utilization in sub-Saharan from 2006 to 2018: evidence from 36 countries using Demographic and Health Surveys,*Springer*, 21, 1–12. https://doi.org/10.1186/s12884-021-03669-w

[12] Polit, Denise F(2017)Clinical significance in nursing research: A discussion and descriptive analysis, *Elsevier*, 73, 17–23.

[13] Bodnar, Olha and Muhumuza, Rebecca Nalule and Possolo, Antonio (2020). Bayesian inference for heterogeneity in meta-analysis, *IOP Publishing* 57(6), 064004. https://doi.org/10.1088/1681-7575/abb064

[14] Alqadi, Samar Abdulhafed and Mutahar, Dua'a Jamal Ahmed and Al-Moyed, Khaled Abdul-Karim A and Assabri, Ali Mohammed and Al-Shamahy, Hassan Abdulwahab and Al-Ankoshy, Azhar Azher Mohammed and Al-Hadad, Ahmed Mohamed(2022). Prevalence And Factors Affecting The Utilization Of Antenatal Care In Sana'a City, Yemen, *Universal Journal of Pharmaceutical Research*. https://doi.org/10.22270/ujpr.v7i4.789

[15] Obare, Francis and Warren, Charlotte and Njuki, Rebecca and Abuya, Timothy and Sunday, Joseph and Askew, Ian and Bellows, Ben (2013). Community-level impact of the reproductive health vouchers programme on service utilization in Kenya, *Oxford University Press* 24(2), 165–175. https://doi.org/10.1093/heapol/czs033

[16] Woldeyohannes, Birhanu and Yohannes, Zemene and Likassa, Habte T and Mekebo, Gizachew G and Wake, Senahara K and Sisay, Assefa L and Gondol, Ketema B and Argaw, Abebe and Diriba, Gezahagn and Irana, Tariku(2023). Count regression models analysis of factors affecting antenatal care utilization in Ethiopia, *LWW*, 85(10), 4882–4886.

[17] Nisar, N and White, F (2023) Factors affecting utilization of antenatal care among reproductive age group women (15-49 years) in an urban squatter settlement of Karachi, *Journal of Pakistan Medical Association*, 53(2), 47, 2003. https://pubmed.ncbi.nlm.nih.gov/12705483/

[18] Babalola, Stella (2014) Women's education level, antenatal visits and the quality of skilled antenatal care: a study of three African countries, *Johns Hopkins University Press*, 25(1), 161–179. https://doi.org/10.1353/hpu.2014.0049

[19] Seidu, Abdul-Aziz and Ameyaw, Edward Kwabena and Sambah, Francis and Baatiema, Linus and Oduro, Joseph Kojo and Budu, Eugene and Appiah, Francis and Opoku Ahinkorah, Bright (2022). Type of occupation and early antenatal care visit among women in sub-Saharan Africa, *Springer*, 22(1), 1118. https://doi.org/10.1186/s12889-022-13306-6

[20] Simkhada, Bibha and Teijlingen, Edwin R van and Porter, Maureen and Simkhada, Padam (2008). Factors affecting the utilization of antenatal care in developing countries: systematic review of the literature, *Wiley Online Library*, 61(3), 244–260. https://doi.org/10.1111/j.1365-2648.2007.04532.x

[21] Meryanti, Novi and Anggraini, Helni and Ramadhani, Sendy Pratiwi (2022). The Relationship Between Mileage, Parity, And Occupation With The Frequency Of Antenatal Care Visits According To Standards In The Work Area Of The Wanaya Public Health Center, Lahat Regency In 2021, *Science Midwifery*, 10(3), 2139–2144. https://doi.org/10.35335/midwifery.v10i3.623

[22] Luyiga, Raymond Kyakuwa (2017) Utilisation of antenatal care services by women of reproductive age at Kyabugimbi Health Center Iv, Bushenyi District. https://www.uncst.go.ug/

[23] World Health Organization and others (2007). WHO recommended interventions for improving maternal and newborn health: integrated management of pregnancy and childbirth. https://www.who.int/publications/i/item/ $WHO_MPS_07.05$

[24] World health statistics 2010 *World Health Organization*. https://somalia.unfpa.org/sites/default/files/pub-pdf/FINAL

[25] Directorate of National Statistics, Federal Government of Somalia 2020. The Somali Health and Demographic Survey *SHD Survey 2020 Somalia*, 462, 2020.Somali National Bureau of Statistics (NBS): https://nbs.gov.so/somali-health-and-demographic-survey-2020/

[26] WHO. (2021). World health statistics 2021: Monitoring health for the SDGs, sustainable development goals. https://apps.who.int/iris/bitstream/handle/10665/342703/9789240027053-eng.pdf