

BMJ Open Multilevel spatial analysis of the determinants of advanced maternal age in Ethiopia: a secondary analysis of the 2019 Ethiopian mini demographic and health survey

Wondaya Fenta Zewdia,¹ Maru Zewdu Kassie ²

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WFZ and MZK contributed equally.

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¹Department of Statistics, Bahir Dar University, Bahir Dar, Ethiopia

²Department of Statistics, Assosa University, Assosa, Ethiopia

Correspondence to

Maru Zewdu Kassie;
maruzewdu68@gmail.com

ABSTRACT

Background Advanced maternal age (AMA), defined as giving birth at age 35 or older, is an increasingly significant public health concern worldwide. This study aimed to identify the socio-demographic and economic determinants of giving birth at AMA among women in Ethiopia and to explore the resulting health consequences for both mothers and children.

Methods This study is a secondary analysis of data from 5517 women extracted from the 2019 Ethiopian Mini Demographic and Health Survey (EMDHS), a nationally representative cross-sectional survey. The data were cleaned, weighted using STATA V. 17 and analysed using ArcGIS 10.8 to map AMA. Global and local Moran's Index methods were used to assess clustering and a multilevel binary logistic regression model was fitted to identify predictors of giving birth at AMA.

Results The prevalence of giving birth at AMA was 12.7%, with a Global Moran's I of 0.9964, indicating significant clustering across Ethiopian zones ($p < 0.001$). Significant individual-level factors associated with higher odds of AMA included male child sex (Adjusted Odds Ratio (AOR)=1.08, $p < 0.001$), fewer smaller family size (AOR=1.02, $p < 0.001$), Catholic (AOR=2.61, $p = 0.001$) and Protestant religion (AOR=1.16, $p < 0.001$), higher household wealth index (AOR=1.02, $p < 0.001$) and residence in Addis Ababa (AOR=2.55) or Amhara (AOR=2.73, $p < 0.001$). Factors associated with lower odds of AMA included no education (AOR=0.69, $p < 0.001$), primary education (AOR=0.56, $p < 0.001$), contraceptive use (AOR=0.99, $p = 0.0002$), rural residence (AOR=0.85, $p < 0.001$), adherence to postnatal check-ups (AOR=0.9453, $p < 0.001$), media exposure (AOR=0.9344, $p < 0.001$) and Afar region residence (AOR=0.81, $p < 0.001$).

Conclusion This study found a high prevalence of giving birth at AMA among women with a lifetime birth history, with a spatially non-random distribution, indicated by a positive Moran's Index. Individual and community-level factors such as having a previous male child, small family size, being Catholic or Protestant and residing in Addis Ababa or the Amhara region were positively associated with AMA. Conversely, factors including lower education level (no or primary education), contraceptive use, media access, rural residence adherence to postnatal check-ups and residing in the Afar region were negatively associated

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study used a nationally representative dataset with a large sample size, enhancing the generalisability of the findings to women of reproductive age in Ethiopia.
- ⇒ The application of multilevel modelling and spatial analysis techniques (eg, Global and Local Moran's I) allowed for robust analysis of geographic clustering and hierarchical data structure.
- ⇒ As a secondary analysis of a cross-sectional survey, the study design limits the ability to infer causal relationships between advanced maternal age and its associated factors.
- ⇒ Important clinical and maternal health variables, such as diabetes mellitus, hypertension and birth weight, were not available in the dataset.
- ⇒ Data from eight administrative zones were missing from the 2019 EMDHS, potentially affecting the completeness of national geographic representation.

with AMA. All community-level factors were significantly associated with the outcome.

INTRODUCTION

Advanced maternal age (AMA), typically defined as giving birth at age 35 or older, has become an increasingly significant public health concern worldwide.¹ Recent studies indicate a marked increase in the prevalence of AMA in many parts of the world. According to the Centres for Disease Control (CDC) and Prevention, the percentage of births to women aged 35 and older rose from 10% in 1990 to approximately 20% in 2019 in the United States.² Similar trends have been observed in Europe, where countries like Italy and Spain report significant increases in maternal age at first birth.³ The Centres for Disease Control and Prevention reports a rising trend in pregnancies among women of AMA in the United States, particularly

for those aged 40 and older. By 2014, approximately 9% of first-time births in Ethiopia occurred among women aged 35 years and older, representing a 23% increase compared with the year 2000.⁴

The trend of AMA is particularly evident in low- and middle-income countries, where socioeconomic changes are leading to delayed childbearing.⁵ This demographic trend is influenced by a variety of factors, including socioeconomic status, educational attainment, cultural norms and access to healthcare services.^{5–7} In Ethiopia, the average age at first birth has been rising, influenced by factors such as increased educational attainment, urbanisation and access to family planning services.^{8–10}

Understanding the determinants and consequences of AMA is crucial for developing effective public health strategies, particularly in low- and middle-income countries like Ethiopia. Research indicates that AMA is associated with various health risks for both mothers and their children.^{11–13} Mothers faced increased chances of gestational diabetes, hypertension, pre-eclampsia, placental issues and a higher likelihood of caesarean delivery. They also experienced fertility challenges and an elevated risk of miscarriage.^{12 14} For children, risks include chromosomal abnormalities like Down syndrome, premature birth, low birth weight, congenital anomalies and potential developmental delays. Proper prenatal care is essential to monitor and manage these risks effectively.^{13 15} Studies have shown that older mothers face higher risks of complications during pregnancy and childbirth, including gestational diabetes, hypertension and caesarean delivery.^{16 17} Based on the research,¹⁸ AMA is significantly associated with adverse perinatal outcomes such as abortion, preterm birth and foetal growth restriction. Another study found that pregnant women aged 50–64 years have an increased risk of preterm birth, low birth weight babies, diabetes mellitus, hypertension and hospitalisation.¹⁹ Furthermore, children born to older mothers may experience increased risks of low birth weight, preterm birth and developmental delays.^{20 21}

In Ethiopia specifically, the implications of AMA are compounded by systemic healthcare challenges, including inadequate prenatal care and limited access to skilled birth attendants.^{8 22} The study²³ found that women of AMA had a 1.58-fold higher risk of perinatal mortality and were also at a higher risk for other comorbid conditions. Additionally, research highlights that cultural factors and societal expectations also play a role in the decision to delay childbirth, particularly in rural areas.^{24–26}

Although there has been considerable research on AMA worldwide, it has received less attention in Ethiopia. Additionally, the Ethiopian Demographic and Health Survey (EDHS) data have a hierarchical structure; therefore, this study employed multilevel analysis, treating zones as the higher level and women as the lower level. We also examined the spatial distribution of AMA across Ethiopia using spatial analysis. Consequently, this study used multilevel spatial analysis. The main objective was to identify the socio-demographic and economic determinants of giving

birth at AMA among women in Ethiopia and to explore the subsequent health consequences for both mothers and their children.

METHODS

Data and study setting

The dataset used in this study was obtained from the measure DHS database <https://dhsprogram.com/data/> after getting the approval letter from the DHS programme office for 2019 Ethiopian Mini Demographic and Health Survey (EMDHS). In the survey, 149 093 Enumeration areas (EAs) were created to be used as a census frame. In each EA, on average, there are 30 households. A two-stage stratified sample selection strategy was used to take a total of 305 EAs in the first stage and a fixed number of 30 households from each EA by use of an equal probability systematic selection in the second stage. Then, all women aged 15–49 in each household were interviewed. Finally, the 2019 EMDHS Survey covered 8663 households out of the selected 8794 households, providing a response rate of 99%. About 8885 women completed the interview and 16 583 women were identified for the interview, yielding a response rate of 99%.²⁷ A woman having a birth history in her lifetime was included. Consequently, a total of 5517 eligible women were included after the necessary inclusion–exclusion criteria were applied.

The 2019 EMDHS was designed to be nationally representative, employing a two-stage stratified cluster sampling design. In the first stage, EAs were selected with probability proportional to size, stratified by region and urban–rural residence. In the second stage, a fixed number of households were systematically selected within each EA. All eligible women aged 15–49 in the selected households were interviewed. Sampling weights were applied to adjust for the complex survey design and non-response, thereby ensuring national and regional representativeness of the findings.

Variables

Dependent variable

The dependent variable is (Give birth at AMA). This means that if women who gave birth at an older age, typically defined as 35 years or older, we classify it as “Give birth at AMA”; otherwise, it is not. It is a binary variable coded as:

$$\text{Give Birth at AMA} \begin{cases} 0, & \text{No} \\ 1, & \text{Yes} \end{cases}$$

Independent variables

The independent variables for AMA were selected based on the previous literature and the availability of relevant variables in the 2019 EMDHS dataset. These variables were broadly categorised into two main groups, individual-level and community-level variables aligned for the multilevel analytic approach used in the study.

Individual-level variables

Sex of the previously born child, mother's education level of women, religion, household wealth index, use of modern contraception methods, current marital status, access to media, pregnancy counselling, family size, post-natal check, religion, household wealth index, place of residence, and Region were included as individual-level variables.

Community-level variables

Community-level women's educational status, community-level wealth index, community-level media exposure and antenatal care were considered as community-level variables.

Data management and analysis

Data management was performed using STATA version 17.0, while data analysis was conducted with SAS version 9.4, using PROC LOGISTIC and PROC GLIMMIX with the Laplace approximation method. ArcGIS version 10.8 was used for mapping, spatial autocorrelation and detection of hot spot areas.

To ensure that the findings are nationally representative and reflect the complex survey design of the 2019 EMDHS, all analyses applied appropriate sampling weights. These weights were adjusted for differences in selection probabilities and response rates across the sampling strata. The complex survey structure was accounted for by specifying primary sampling units (clusters) and stratification variables using STATA's svyset command. This approach allowed for design-adjusted variance estimation and ensured the validity of statistical inferences.

In this study, cross-tabulation analysis was applied to determine the percentage of women in AMA based on their socioeconomic, demographic and health characteristics. We also assessed the completeness of the data. Missing data were minimal in the final set of analytic variables. The 2019 EMDHS dataset undergoes extensive preprocessing and cleaning before public release. Variables with substantial missing data were excluded. For the variables used in the final multivariable models, the level of missingness was below 2%, and missing data were assumed to be missing at random (MAR).

Spatial analysis and spatial autocorrelation

In this study, spatial analysis is applied to examine the geographic distribution and patterns of AMA among women in Ethiopia. This approach allows for the identification of regional and zonal variations and spatial dependencies in both the determinants and consequences of AMA, providing valuable insights for targeted interventions and policy decisions. Spatial dependence occurs when values at one location depend on neighbouring observations, leading to unique analysis approaches.²⁸ Spatial autocorrelation measures the correlation of a variable with itself across space, based on a spatial weights matrix (W_{ij}).²⁹⁻³⁰ This statistics is calculated as:

$$I = \left(\frac{n}{\sum \sum w_{ij}} \right) \frac{\sum \sum w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum (x_i - \bar{x})^2} = \left(\frac{n}{s_0} \right) \frac{\sum \sum w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum (x_i - \bar{x})^2} \quad (1)$$

W_{ij} , Elements of the spatial weighted matrix locations i and j .

x_{ij} , Attribute value at the location of concern (location i) or (location j).

$\bar{x}$, The average value of the attribute at the location.

Moran's I is the key statistic used to standardise this measure. Moran's I ranges from -1 to 1 , with positive values indicating similar neighbouring regions and negative values indicating dissimilar ones.

Hot spot and cold spot analysis

Hotspot and coldspot analysis calculates the Getis-Ord G_i^* statistic for each feature in a dataset. This analysis identifies areas with significant clusters of high (hot spots) or low (cold spots) values by examining z-scores and p-values.³¹

Spatial interpolation and kriging

In this study, spatial interpolation was used to estimate the values of a variable at un-sampled locations based on sampled data. Ordinary kriging, a commonly used interpolation method, was also applied to estimate the prevalence of AMA at unsampled locations in Ethiopia. As a Best Linear Unbiased Estimator (BLUE), kriging considers the proximity to the estimated location, the number of nearby data points and the covariance function or semi-variogram of the data.³²⁻³³

Multilevel logistic regression

This model is used in regression analysis to explore the relationship between a categorical response variable and any type of independent variable.³⁴ In this study, the dependent variable 'Give birth at AMA' of women was binary (with two categories), and the data had a hierarchical structure: women nested within households and households nested within clusters. A multilevel binary logistic regression model was applied to assess the association between the independent variables and the dependent variables.

In nested data structures like EDHS, individual observations within a cluster may share common characteristics, leading to some degree of correlation. Ignoring this correlation by considering only individual-level characteristics can violate the assumption of independence between observations. This can result in biased parameter estimates, underestimated standard errors, false significant results and incorrect conclusions about effect sizes. To account for the nested nature of EDHS data, a two-level generalised linear mixed model was used.³⁵⁻³⁶

The goal was to analyse the probability of 'Give birth at AMA' and the influence of both individual and regional characteristics. To achieve this, a two-level mixed-effect logistic regression analysis was conducted, incorporating fixed effects for individual and community-level factors, along with random effects for variation between clusters.

The log of the probability of the j^{th} category of the outcome variable for the i^{th} observation was modelled as follows:

$$\text{logit}(\pi_{ij}) = \log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_{0j} + \beta_{kj}X_{kij} + \gamma_{0q}Z_{qj} \dots \quad (2)$$

where β_{0j} is average intercept γ_{00} plus group-dependent deviation U_{0j} : that is $\beta_{0j} = \gamma_{00} + U_{0j}$ and $\beta_{kj} = \gamma_{k0} + U_{kj}$

Now, the above two-level model (Equation (2)) can be rewritten as more generally, as it contains all levels of variation:

$$\text{logit}(\pi_{ij}) = \log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \gamma_{00} + \gamma_{k0}X_{kij} + \gamma_{0q}Z_{qj} + U_{0j} + U_{kj} \dots \quad (3)$$

where γ_{00} is the average regression intercept, X_{kij} represents the k level-one covariates and Z_{qj} represents the q level-two covariates, whereas, γ_{k0} and γ_{0q} are the corresponding regression coefficients for level-one and level-two explanatory variables, U_{0j} and U_{kj} are the random effect of the model parameters at level two. Akaike's information criterion (AIC) and the Bayesian information criterion (BIC) determine the best multilevel model in this study. It is expected that the vector of random effects $U_{0j}, U_{1j}, U_{2j}, \dots, U_{kj}$ follow a normal distribution with mean zero and variance σ_{u0}^2 .

All fixed effects and random effect variables were tested at a p value < 0.025 . In the final model, adjusted odds ratio (AOR), p value and 95% CI were used to determine the statistical significance of each independent variable. A p value ≤ 0.05 indicated a significant association with Give birth at AMA.

Community-level effects were assessed using the Intra-Class Correlation (ICC) based on community-level variance. Model fitness was evaluated through proportional change in variance (PCV), Pearson and the Likelihood Ratio Test (LRT).

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination plans of this research. This study is a secondary analysis of publicly available DHS data and did not involve direct contact with participants.

RESULTS

Cross-tabulation analysis

Out of a total of 5517 women with a birth history, 699 (12.7%) give birth at an AMA, while 4818 (87.3%) did not. Mothers of AMA exhibit significant variations across various socioeconomic, demographic and health-related factors. For example, 46.8% of children born to older mothers are female, while 53.2% are male, showing a significant difference in the sex distribution ($p=0.000$). Additionally, 52.8% of older mothers have a low birth order and 47.2% have a high birth order ($p=0.000$). Regarding contraceptive use, 59.4% do not use contraceptives, while 40.6% do ($p=0.000$). Media exposure is

also significantly different, with 66.8% of older mothers lacking media exposure ($p=0.000$). The number of children under five is relatively balanced, with 87.0% having fewer children ($p=0.000$). Education levels among older mothers show stark contrasts, as 22.2% have no education, while 56.2% have primary education, 31.3% secondary and 7.6% higher education ($p=0.000$). In terms of child delivery, 51.2% deliver at home and 48.8% at health facilities ($p=0.000$). The majority (90.8%) of older mothers are married ($p=0.000$) and 25.2% received postnatal care ($p=0.000$). Religious affiliation differs, with 39.6% being Muslim, 34.4% Orthodox and 24.5% Protestant ($p=0.000$). Regionally, older mothers are predominantly from Amhara (23.5%) and Oromia (40.0%) ($p=0.000$). Child mortality shows 4.4% of children born to older mothers are deceased ($p=0.000$). Wealth index reveals that 37.1% of older mothers are categorised as rich ($p=0.000$), and most live in rural areas (73.8%) ($p=0.000$). Additionally, access to pregnancy counselling is limited, with 63.5% of mothers reporting no counselling received compared with 36.5% who did ($p=0.000$).

Finally, 63.5% of older mothers did not receive pregnancy counselling ($p=0.000$) and community-level differences in education, wealth and media exposure are statistically significant ($p=0.000$ or 0.001). These findings highlight the distinct characteristics of older mothers compared with their younger counterparts.

Finally, community-level variables like women's education status, wealth index and media exposure by zones also show significant differences, confirming the overall statistical significance of all the analysed factors. In conclusion, the results indicate significant differences between mothers of AMA and younger mothers in all the studied variables based on p -values of 0.000 or 0.001 (table 1).

Spatial distribution of AMA

The map in figure 1 illustrates the spatial distribution of Give birth AMA across various regions and zones in Ethiopia, highlighting regional disparities that may reflect localised socioeconomic or cultural influences. Each coloured circle on the map represents a specific geographic area, with colours ranging from green (indicating lower proportions of AMA) to red (indicating higher proportions).

Regions with higher proportions of AMA, marked in red and dark orange, are concentrated in specific areas, including North Gondar, South Gondar and West Gojjam zones in the Amhara Region, East Shewa and West Arsi zones in the Oromia Region, as well as the Gamo and Wolayita zones in the Southern Nations, Nationalities and Peoples' Region (SNNPR). Addis Ababa also shows significant concentrations, particularly in its central areas. These regions may be influenced by localised socio-economic or cultural factors affecting the age of first childbirth.

Conversely, areas with lower proportions of AMA, shown in green and light yellow, are more widely dispersed. Notably, Zone one and Zone three in the Afar Region, Fafan and Jarar zones in the Somali Region, Assosa and

Table 1 Advanced maternal age usage across their socio-demographic characteristics, EMDHS, 2019

Variables	Category	Advanced Maternal Age		X ² P value
		No	Yes	
		Count (%)	Count (%)	
Birth order of child	Low	2600 (54.0%)	369 (52.8%)	0.000
	High	2219 (46.0%)	330 (47.2%)	
Current contraceptive use	No	2860 (59.4%)	415 (59.4%)	0.000
	Yes	1958 (40.6%)	284 (40.6%)	
Media exposure	No	3169 (65.8%)	467 (66.8%)	0.000
	Yes	1650 (34.2%)	232 (33.2%)	
Family size	Small (≤ 5)	2206 (87.2)	2612 (87.4)	0.000
	Large (≥ 6)	323 (12.8)	376 (12.6)	
Mother's education level	No education	2566 (53.3%)	650 (22.2%)	0.000
	Primary	1730 (35.2%)	393 (56.2%)	
	Secondary	362 (7.5%)	219 (31.3%)	
	Higher	160 (3.3%)	53 (7.6%)	
Current marital status	Not Married	295 (6.1%)	38 (5.4%)	0.000
	Married	4523 (90.2%)	635 (90.8%)	
Postnatal check	No	471 (9.8%)	64 (9.2%)	0.000
	Yes	587 (20.1%)	737 (25.2%)	
Religion of respondent	Orthodox	1618 (33.6%)	240 (34.4%)	0.000
	Catholic	4 (0.3%)	4 (0.6%)	
	Protestant	1287 (26.7%)	170 (24.5%)	
	Muslim	1820 (37.8%)	275 (39.6%)	
	Others	80 (1.7%)	9 (1.3)	
Region of respondents	Tigray	319 (6.6)	52 (7.5)	0.000
	Afar	80 (1.7)	6 (0.9)	
	Amhara	884 (18.3)	164 (23.5)	
	Oromia	1927 (40.4)	279 (40.0)	
	Somalia	358 (7.4)	50 (7.2)	
	Benishangul	58 (1.2)	9 (1.3)	
	SNNPR	985 (20.4)	119 (17.1)	
	Gambella	23 (0.5)	1 (0.1)	
	Harari	15 (0.3)	1 (0.1)	
	Addis Ababa	143 (3.0)	15 (2.1)	
Mortality status of child	Dead	238 (4.9%)	31 (4.4%)	0.000
	Live	4580 (95.1%)	668 (95.6%)	
Wealth index of the household	Poor	2211 (45.9%)	307 (43.9%)	0.000
	Middle	908 (18.8%)	133 (19.0%)	
	Rich	1699 (35.3)	259 (37.1)	
Place of residence	Urban	1179 (24.5%)	183 (26.2%)	0.000
	Rural	3640 (75.5%)	516 (73.8%)	
Pregnancy counselling	No	2999 (62.2%)	444 (63.5%)	0.000
	Yes	1820 (37.8%)	255 (36.5%)	
Community level women's education status by zones	Lower	2949 (61.2%)	444 (63.5%)	0.000
	Higher	583 (38.8%)	255 (36.5%)	

Continued

Table 1 Continued

Variables	Category	Advanced Maternal Age		X ² P value
		No	Yes	
		Count (%)	Count (%)	
Community level wealth index by zones	Lower	2375 (49.3%)	337 (48.2%)	0.000
	Higher	2443 (50.4%)	362 (51.8%)	
Community level media exposure by zones	Lower	2058 (42.7%)	325 (46.5)	0.001
	Higher	2761 (57.3%)	374 (53.5%)	
Community level anti-natal care by zones	Lower	2670 (87.4)	2148 (87.2)	0.000
	Higher	384 (12.6)	3151 (12.8)	

EMDHS, Ethiopian Mini Demographic and Health Survey.

Metekel zones in Benishangul-Gumuz and Gambela Zone and Itang Special Woreda in the Gambela Region display lower AMA proportions. The colour gradient, with the highest proportions (0.2259–0.3134) in red and the lowest proportions (0.0000–0.0625) in green, effectively highlights these variations.

This spatial visualisation aids in identifying regional disparities in AMA, which can guide targeted public health interventions to address the determinants and consequences associated with AMA at childbirth across Ethiopia.

Spatial autocorrelation analysis for AMA

Figure 2 presents the results of a spatial autocorrelation analysis of AMA at childbirth, examining the degree to which the prevalence of AMA is clustered, dispersed or randomly distributed across regions in Ethiopia.

The analysis identifies clusters where regions with similar proportions of AMA are spatially adjacent. High–High clusters (areas with a high proportion of AMA surrounded by regions also showing high proportions) and Low–Low clusters (areas with low proportions of AMA surrounded by other low-AMA regions) reveal patterns of spatial clustering. Such clusters suggest that regional socio-economic, cultural or environmental factors may be influencing similar AMA trends within adjacent areas. In contrast, high-low or low-high clusters, where a region with a high AMA proportion is adjacent to one with a low proportion (or vice versa), may indicate unique, localised factors or transitional zones between different social and health determinants.

Overall, this figure helps identify specific areas that may benefit from targeted interventions or further investigation to understand the underlying factors contributing to higher or lower rates of AMA at childbirth.

Hot spot and cold spot analysis AMA

The map in figure 3 displays a Hot Spot and Cold Spot Analysis for AMA at childbirth across various regions in Ethiopia, using the Gi* statistics (Getis-Ord Gi* analysis) to highlight clusters with high or low values at

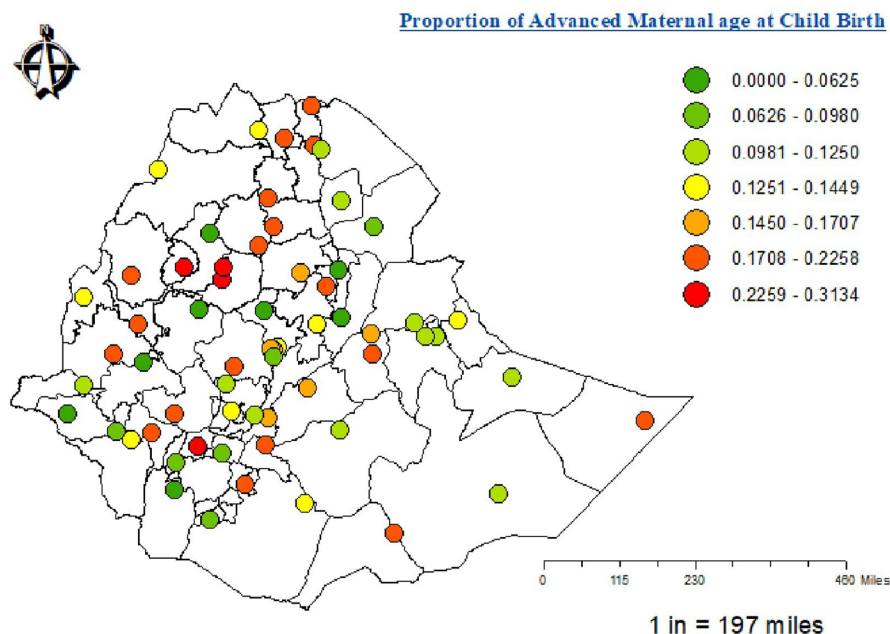


Figure 1 Spatial distribution of advanced maternal age at childbirth. Source Shape file from Ethiopian CSA, 2013.

different confidence levels. Areas marked in shades of blue represent cold spots where AMA at childbirth is significantly lower; specifically, dark blue indicates 99% confidence, medium blue signifies 95% confidence and light blue denotes 90% confidence. In contrast, hot spots are marked in shades of red, representing areas with significantly higher rates of AMA. Dark red indicates 99% confidence, orange-red shows 95% confidence and light orange reflects 90% confidence. Areas represented by grey dots are statistically insignificant, meaning they show no strong clustering of AMA at childbirth. This spatial analysis is valuable for identifying regions with

significantly high or low rates of AMA, providing insights into geographic patterns that could guide health interventions and resource distribution. Additionally, the map scale shows that one inch corresponds to 197 miles, and the shape file source is attributed to CSA Ethiopia 2013.

Interpolation of AMA

The map in figure 4 illustrates an interpolation of AMA at childbirth across various regions in Ethiopia, with a colour gradient representing different ranges of the proportion of AMA, providing a spatial visualisation of its distribution and intensity. Areas in green, ranging from

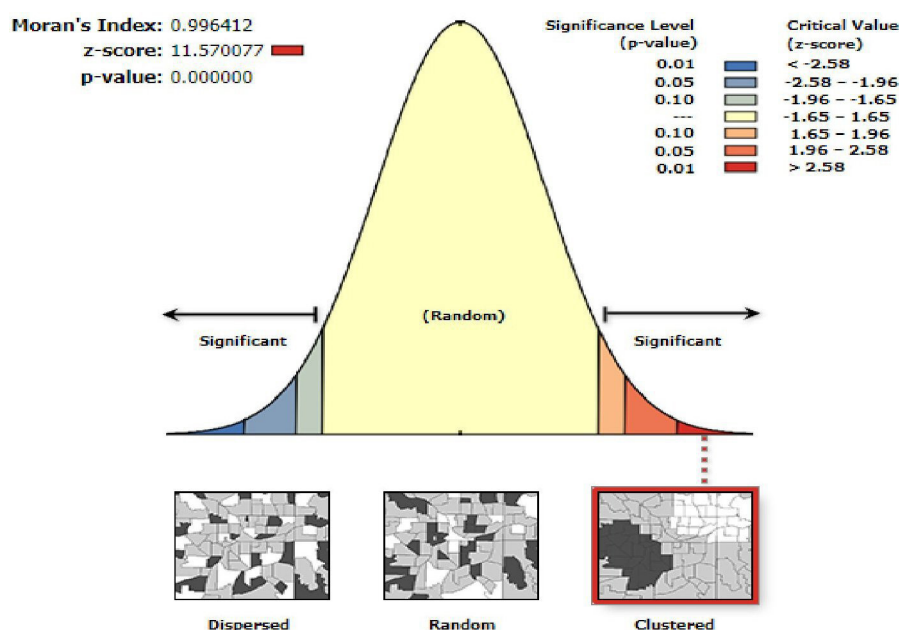


Figure 2 Spatial autocorrelation analysis of advanced maternal age at childbirth. Given the z-core of 11.5700774344, there is a less than 1% likelihood that this clustered pattern could the result of random chance.

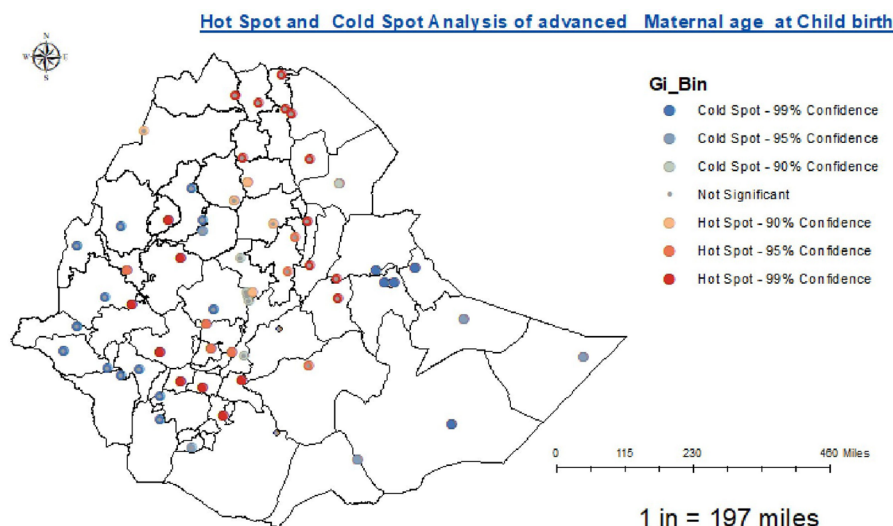


Figure 3 Hot spot and cold spot analysis of advanced maternal age at childbirth. Source Shape file from Ethiopian CSA, 2013.

0 to 0.04478, indicate the lowest proportions of AMA, while light green to yellow areas, ranging from 0.04479 to 0.1791, represent progressively higher proportions, with light green indicating slightly higher rates and yellow showing moderate rates. Regions in orange to red, with values between 0.1792 and 0.3134, signify the highest proportions of AMA, where darker shades (orange and red) indicate increasingly higher rates, with red highlighting the most concentrated areas.

Spatially, the green and yellow areas with lower levels of AMA are mainly spread across central and eastern parts of Ethiopia. In contrast, the orange and red areas, where AMA is more common, are primarily clustered in the northern and southwestern regions. The map scale indicates that one inch represents 197 miles, providing a sense of geographical scale, and the shape file source is cited from CSA Ethiopia 2013. This interpolation map offers insights into the spatial distribution of AMA across Ethiopian regions, identifying high and low-prevalence

areas, which can support targeted public health interventions and inform policy decisions.

Model comparison

The model comparison table evaluates four models (Model I to Model IV) based on variance, ICC, PCV, -2 Log Likelihood and Pearson χ^2/DF . As the models increase in complexity, the variance decreases, from 0.9898 in Model I to 0.3418 in Model IV, indicating greater precision in estimates as more parameters are added. The ICC for Model IV is 0.24, which suggests that 24% of the variance in the outcome can be attributed to clustering effects. Additionally, the PCV for Model IV is 0.65, meaning it explains 65% of the variance compared with the baseline Model I. The -2 Log Likelihood value also decreases steadily from Model I (4171.25) to Model IV (3929.27), indicating an improved fit with each successive model. While the Pearson χ^2/DF remains close to one in simpler models, suggesting a good fit, it slightly increases to 1.21

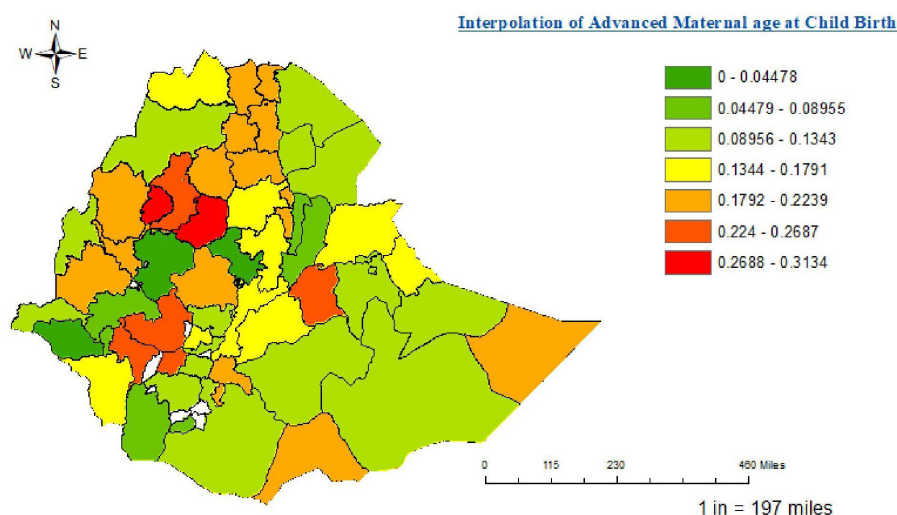


Figure 4 Interpolation of advanced maternal age at childbirth. Source Shape file from Ethiopian CSA, 2013.

Table 2 Model comparison for report among MI, MII, MIII and MIV and variability between variables

Parameter	Model-I	Model-II	Model-III	Model-IV
Variance	0.9898	0.7548	0.59309	0.3418
ICC	Ref			0.24
PCV(R ²)	Ref			0.65
−2 Log Likelihood	4171.25	4134.74	4121.93	3929.27
Pearson χ^2 /DF	0.93	0.94	1.01	1.21

ICC, intra-class correlation; PCV, proportional change in variance.

in Model-IV, which may indicate a slight overdispersion. Overall, Model-IV provides the best explanatory power and model fit despite a minor trade-off in the Pearson χ^2 /DF statistic (table 2).

Parameter estimation

The parameter estimation table reveals the influence of various socio-demographic and community-level variables on the outcome, which seems related to maternal and child health. Starting with the intercept, we observe a baseline AOR of 0.1324 with a highly significant p-value of 0.0001, setting the groundwork for comparisons. Regarding the sex of the child, a woman having previously male child has a slightly higher likelihood (AOR=1.0821, $p<0.001$) of the AMA occurring compared with females. Birth order also plays a role, with children of higher birth orders (more than three) having a marginally increased likelihood (AOR=1.0710, $p=0.0001$) of the AMA compared with those of lower birth orders.

When it comes to maternal education, higher education is associated with a higher likelihood of AMA. Mothers with no education (AOR=0.6902) and primary education (AOR=0.5563) have significantly lower odds of giving birth at an AMA compared with those with higher education ($p<0.001$ for both). Marital status also influences the likelihood, as married mothers show a slight decrease rate of AMA (AOR=0.9326, $p<0.001$) compared with unmarried mothers. Contraceptive use appears protective, with users having a lower outcome likelihood (AOR=0.9916, $p=0.0002$) than non-users. Place of delivery seems to have little impact, with a non-significant increase in the outcome likelihood (AOR=1.0179, $p=0.8567$) for deliveries at health facilities.

Pregnancy counselling significantly reduces the likelihood of the outcome (AOR=0.8564, $p<0.001$), as does media exposure (AOR=0.9344, $p<0.001$). Family size also matters; households with five or fewer members have a slightly higher likelihood of the outcome (AOR=1.022, $p<0.001$). For the number of children under five, households with three or more children show a slight reduction in the outcome likelihood (AOR=0.9972, $p=0.0058$). Differences by religion are also notable, with Catholics (AOR=2.606, $p=0.001$) and Protestants (AOR=1.158, $p=0.0001$) having higher odds of the outcome compared with others.

The household wealth index shows that rich households have a marginally higher outcome likelihood (AOR=1.018, $p<0.001$), while poor households have a slightly reduced likelihood (AOR=0.9831). Place of residence also influences outcomes, with rural residents showing lower odds (AOR=0.8540, $p<0.001$) compared with urban dwellers. The presence of postnatal checks is protective, with a decreased likelihood (AOR=0.9453, $p=0.0001$). Regional variations are pronounced, as regions such as Addis Ababa (AOR=2.552) and Amhara (AOR=2.732) have significantly higher odds ($p<0.001$), whereas Afar (AOR=0.8104) shows lower odds.

Community-level factors also have an impact, with lower levels of education (AOR=0.952, $p<0.001$) and wealth (AOR=0.785, $p<0.001$) being associated with reduced likelihoods. However, lower levels of antenatal care (AOR=1.140, $p=0.0001$) and media access (AOR=1.234, $p=0.0001$) are associated with slight increases in the outcome likelihood. Overall, the table highlights the substantial influence of socio-demographic, economic and community-level variables on the likelihood of the outcome, providing valuable insights for targeted interventions and policy formulation (online supplemental table 1).

DISCUSSIONS

The main objective of this study was to apply spatial multilevel analysis to identify the socio-demographic and economic determinants of AMA childbirth among women in Ethiopia and to explore the subsequent health consequences for both mothers and their children. Approximately, one in eight women in the study population gave birth at an AMA, highlighting a notable public health concern that warrants targeted reproductive health interventions and awareness strategies. The analysis reveals several variables with a statistically significant association with the outcome variable. The sex of the child, birth order, mother's education level, marital status, use of modern contraception, pregnancy counselling, media exposure, family size, number of children under five, religion, place of residence, region, as the community (zonal) education level of mothers and the community (zonal) Wealth Index, the community (Zonal) level ANC and the community (Zonal) level media access were statistically associated with giving birth at an AMA.

As shown in figure 1, the regions with higher proportions of AMA at childbirth include North Gondar, South Gondar and West Gojjam zones in the Amhara Region; East Shewa and West Arsi zones in the Oromia Region; and the Gamo and Wolayita zones in the SNNPR. Addis Ababa also shows significant concentrations, particularly in its central areas. Conversely, areas with lower proportions of AMA include Zone one and Zone three in the Afar Region; Fafan and Jarar zones in the Somali Region; Assosa and Metekel zones in Benishangul-Gumuz; and Gambela Zone and Itang Special Woreda in the Gambela Region. These spatial patterns suggest the importance

of region-specific interventions, especially in areas with high AMA prevalence. Tailored reproductive health strategies, such as enhanced access to family planning and late-pregnancy counselling, should be implemented in high-risk zones.

The prevalence of giving birth at AMA in this study was 12.7%. This finding is largely consistent with a broad study conducted across 359 health facilities in 29 countries in Africa, Asia, Latin America and the Middle East,³⁷ which reported a prevalence of 12.3% (37,787/308,149). However, the prevalence of AMA in this study is lower than that reported in several other studies, including 17.5% in South Africa,⁵ 33.4% in Norway,³⁸ 20% in the United States of America² and 23% in global literature review.⁴ These differences in prevalence rates may be attributed to variations in study populations, healthcare access, socioeconomic factors and regional differences in reproductive health practices. Additionally, the inclusion criteria and the time period of data collection may have influenced the observed prevalence. This difference in prevalence emphasises the need to consider context-specific factors—such as fertility preferences, access to maternal health services and cultural norms—when designing reproductive health policies.

The results of this study showed that the odds of a mother giving birth at an AMA were lower for women with less or no education compared with those with higher education. This finding is consistent with another study,¹² which found that women with higher socioeconomic status (SES) and a higher level of education tend to delay motherhood into their mid-to-late 30s. This study also revealed that the odds of a mother giving birth at an AMA were lower for women who used contraceptives compared with those who did not. This result was consistent with other studies,^{39 40} which found that older women were less likely to use contraception methods than younger women.

This study also revealed that the odds of a mother giving birth at an AMA for women having a small number of children were more likely as compared with those having more children. This result was consistent with other studies.^{41–43} In their findings, mothers with larger families are less likely to give birth at an AMA, as they typically aim to complete childbearing earlier.

Additionally, this study revealed that Protestant and Catholic women are more likely to give birth at an AMA, whereas Orthodox Christian women are less likely to do so. This result is consistent with other studies.^{44–46} Their findings suggest that Protestant and Catholic women, due to varying beliefs around contraception and family size, may have higher fertility across a wider age range, which could contribute to higher rates of childbirth at advanced ages. In contrast, Orthodox communities with more traditional family roles may encourage the earlier completion of childbearing. The result of this study also revealed that the women with higher SES were more likely to give birth at AMA as compared with low economic status. This result was consistent with another study.^{12 47} However, this

result was contradicted by another study.⁴⁸ Their findings suggested that fertility patterns are not solely determined by SES, but are also influenced by cultural, political and economic conditions that might lead to different timing of childbearing across various SES groups. In some cases, lower SES may lead to earlier childbearing due to limited access to resources for delaying birth.

The generalisability of the findings is supported by the use of a nationally representative dataset: the 2019 Ethiopia Mini Demographic and Health Survey (EMDHS), which employed a robust sampling strategy covering a wide geographic area and diverse socio-demographic groups. The large sample size further strengthens the representativeness of the results to women of reproductive age across Ethiopia. This enhances the external validity of the study, making the findings applicable to similar low- and middle-income countries with comparable maternal health challenges. However, caution is warranted due to certain limitations. Specifically, the absence of data from eight administrative zones may restrict the geographic completeness and could potentially bias regional estimates. Moreover, the unavailability of key clinical variables (eg, diabetes, hypertension and birth weight) may limit the applicability of the findings to settings where such factors play a critical role in AMA outcomes. Despite these constraints, the results provide meaningful insights into the distribution and determinants of AMA in Ethiopia and may inform maternal health policies in similar contexts.

We have also acknowledged that sociocultural dynamics and healthcare system developments occurring since the 2019 EMDHS may have influenced maternal health behaviours and outcomes. As a result, inferences drawn from this analysis should be interpreted with caution, considering these potential changes. Future studies should consider these evolving contextual factors by using more recent and comprehensive datasets once they become available.

Conclusion

In this study, the prevalence of giving birth at AMA for the women having birth history was 12.7% and its spatial distribution was non-random with positive Moran's Index. The regions with higher proportions of AMA at childbirth include North Gondar, South Gondar and West Gojjam zones in the Amhara Region; East Shewa and West Arsi zones in the Oromia Region and the Gamo and Wolayita zones in the SNNPR. Addis Ababa also shows significant concentrations, particularly in its central areas. Conversely, areas with lower proportions of AMA include Zone one and Zone three in the Afar Region; Fafan and Jarar zones in the Somali Region; Assosa and Metekel zones in Benishangul-Gumuz; and Gambela Zone and Itang Special Woreda in the Gambela Region. Also, both individual and community-level factors were significantly associated with AMA.

Having a previous male child, a small family size and being Catholic or Protestant, as well as residing in Addis

Ababa or Amhara regions, are positively associated with giving birth at an AMA. In contrast, factors such as the mother's education level (no education or primary education), marital status (married women), contraceptive use, counselling from a doctor, media access and rural residence and adherence to postnatal check-ups are negatively associated with giving birth at AMA. Additionally, all community-level factors were found to have a significant association with the outcome variable.

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

Patient consent for publication Not applicable.

Ethics approval The 2019 Ethiopian Mini Demographic and Health Survey (EMDHS) was conducted by the Ethiopian Public Health Institute (EPHI) in collaboration with ICF, with ethical approval obtained from the Ethiopian Public Health Institute Review Board, the ICF Institutional Review Board, and the Centers for Disease Control and Prevention (CDC). Informed consent was obtained from all participants during the original survey. For this study, we conducted a secondary analysis of the anonymized dataset obtained from the DHS Program. Permission to access and use the data was granted by the DHS Program after submission of a request outlining the purpose of the analysis. No further ethical approval was required for this secondary analysis as it involved only de-identified, publicly available data. All methods were carried out in accordance with the ethical principles of the Declaration of Helsinki.

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Data availability statement Data are available in a public, open access repository. The data underlying the findings of this study are publicly available from the DHS Program website. The data can be accessed at <https://dhsprogram.com/data/> after free registration and approval of the data access request.

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ORCID iD

Maru Zewdu Kassie <http://orcid.org/0000-0001-5291-9623>

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