Original Paper

The Timing of Early First Birth Among Women in Lesotho: Shared Gamma Frailty Analysis

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Abstract

Background: Early childbearing continues to be an important public health issue in Lesotho and is often linked to adverse outcomes, including physical health complications, interruptions in educational attainment, and difficulties in marital or social relationships. Despite these concerns, understanding the factors associated with the timing of early first birth remains important for informing targeted interventions and reproductive health policies in Lesotho.

Objective: The study examined factors associated with the timing of early first birth, defined as a first live birth occurring before the age of 20 years. The analysis focused specifically on the risk of experiencing a first birth before the age of 20 years rather than on time to first birth across the entire reproductive life course.

Methods: Data were extracted from the 2023-2024 Lesotho Demographic and Health Survey, comprising a weighted sample of 6413 women aged 15 to 49 years. Kaplan-Meier survival curves were used to describe the timing of early first birth, and differences between survival curves were assessed using the log-rank test. A shared gamma frailty model was fitted to identify factors associated with the hazard of experiencing an early first birth while accounting for within-cluster correlation.

Results: Among the 6413 women included in the analysis, 28.7% (n=1838) experienced an early first birth before the age of 20 years, with a median age at first birth of 18 (IQR 17-19) years among those who experienced an early first birth. The adjusted shared gamma frailty model showed that higher education (adjusted hazard ratio [AHR]=0.18, 95% CI 0.10-0.29), middle (AHR=0.85, 95% CI 0.75-0.97) and rich (AHR=0.70, 95% CI 0.60-0.81) wealth status, and having heard about family planning at community meetings or events (AHR=0.85, 95% CI 0.76-0.96) were associated with a lower hazard of early first birth. Women from female-headed households had a higher hazard (AHR=1.10, 95% CI 1.00-1.22). The adjusted frailty variance was 0.0424 (*P*=.007), indicating modest residual cluster-level heterogeneity, while the shared frailty model demonstrated better fit based on lower Akaike information criterion (31,194.68) and Bayesian information criterion (31,252.37) values than the standard Cox model (Akaike information criterion=33874.92; Bayesian information criterion=34004.12).

Conclusions: This study provides evidence that early first birth remains prevalent among women in Lesotho, highlighting the need for targeted policies and interventions to improve reproductive health outcomes. Strengthening educational opportunities, improving access to reproductive health and family-planning information, and addressing socioeconomic disadvantage may help reduce the occurrence of early first birth. These findings underscore the importance of context-specific strategies to support women in delaying first birth and improving their long-term health and socioeconomic well-being.

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Keywords: adolescent childbearing; early first birth; demographic and health surveys; DHS; Lesotho; shared frailty; survival analysis

Introduction

The birth of a first child marks a pivotal moment in a woman's life, as it signifies the beginning of motherhood and the responsibilities of childcare. This event also has a lasting influence on a woman's future life and well-being [1,2]. In recent years, an increasing number of women have given birth to their first child before marriage, a pattern associated with various health risks, including a higher likelihood of HIV infection [3]. Evidence suggests that pregnancy in the late twenties to early thirties is associated with comparatively lower maternal and perinatal risks, while pregnancies at 35 years and above carry higher probabilities of complications such as cesarean delivery and hypertensive disorders [3]. Younger mothers often face bigger career challenges because having children early interrupts the time when their careers would normally grow the fastest. Unplanned pregnancies can make this even harder, as they stop young women from gaining important skills and work experience at the beginning of their careers [4]. Delaying sexual activity and childbirth increases the likelihood that young women will complete higher levels of education, thereby contributing to improved lifestyle outcomes for their children [5]. Conversely, early-age pregnancy is associated with numerous adverse outcomes that limit a young woman's opportunities to improve her present and future life circumstances. It is frequently linked to higher rates of unemployment and poverty among young mothers, and children born to adolescent mothers often receive inadequate care, further reinforcing the cycle of poverty [6,7]. Taken together, these findings highlight the importance of supporting young women in making informed reproductive choices to enhance their health, educational attainment, and long-term socioeconomic well-being.

Approximately 12 million young women aged 15 to 19 years give birth to their first child each year globally, resulting in an adolescent birth rate of roughly 41 births per 1000 girls in this age group. About 95% of these births occur in low-income countries [8,9]. In sub-Saharan Africa (SSA), nearly 6.1 million girls aged 15 to 19 years give birth each year, corresponding to an adolescent birth rate of about 97 per 1000 girls [9]. In Lesotho, adolescent childbearing is similarly high, with an estimated 94 births per 1000 girls aged 15 to 19 years, and approximately 14% of girls giving birth before the age of 18 years [10]. More than half a million women aged 15 to 49 years die each year worldwide from preventable pregnancy-related complications, underscoring persistent global inequalities in maternal health outcomes [11]. Furthermore, the report indicates that young women under 15 years are 5 times more likely to die, and those between 15 and 19 years are 2 times more likely to die from pregnancy or childbirth complications compared to women aged 20 to 24 years [12].

A study based on birth certificates for 3.6 million births registered across all the United States and the District of Columbia in 2023 found that the general fertility rate declined by 3% from 2022 to 54.5 births per 1000 women aged 15 to 44 years. The birth rate among women aged 15 to 19 years fell by 4% from 2022 to 2023. In contrast, rates increased by less than 1% for women aged 20 to 24 years, declined by 1% to 3% for those aged 25 to 44 years, and remained unchanged for women aged 10 to 14 years and 45 to 49 years [13]. Similarly, in SSA, adolescent childbearing remains a significant concern. A study using data from 22 low- and middle-income SSA countries, each with at least 3 Demographic and Health Surveys (DHS) since 1990, examined levels and trends of first births among adolescents under 19 years. It found that in some countries, over 20% of women had their first birth before the age of 16 years (eg, Mali and Niger) and that adolescent first births were more common among poorer women and those living in rural areas [14]. Furthermore, an analysis of data from 31 SSA countries with high maternal mortality rates, focusing on adolescents aged 15 to 19 years, confirmed that early adolescent childbearing remains prevalent in countries with extremely high and very high maternal mortality. However, Lesotho was negatively associated with early adolescent childbearing, with an adjusted odds ratio (AOR) of 0.73 (95% CI 0.58-0.95), indicating that adolescents in Lesotho had lower odds of experiencing early childbearing compared with those in other countries studied [15].

Factors affecting the age at first childbirth are diverse and operate at multiple levels. At the individual and household level, findings from a study conducted in Indonesia indicate that a woman's age, level of education, place of residence, employment status, and contraceptive use are all associated with the timing of first birth [16]. Similarly, at the community and social level, a study in Lesotho among 50 teenage girls aged 16 to 19 years found that sexual abuse, cultural influences, early independence, peer pressure, and the use of drugs and alcohol increased the likelihood of teenage pregnancy [17]. A study analyzing secondary data from the 2014 Lesotho Demographic and Health Survey (LDHS) used survival analysis to estimate the timing of the first antenatal visit. It found that only 24% of mothers began antenatal care within the first 12 weeks of pregnancy, as recommended by the World Health Organization [18], and this low percentage highlighted the need for interventions to promote earlier antenatal attendance in Lesotho.

Complications related to pregnancy and childbirth are still among the leading causes of death among women under 19 years of age in low-income countries [8]. Early-age pregnancy in Africa is associated with increased maternal mortality [6]. This study uses the 2023-2024 LDHS dataset to account for unobserved heterogeneity (ie, differences not captured by the observed variables) among women from different regions or households. Childbearing in Lesotho often begins at an early age, with some girls as young as 13 years giving their first birth, and about 20% of young women aged 15 to 19 years have had at least one birth or are pregnant with their first child [19].

For the purposes of this study, early first birth was operationalized as a first live birth occurring before the age of 20 years. The age of 20 years was selected as a public health and epidemiological threshold corresponding broadly to the upper boundary of adolescence (15-19 years) and the transition into adulthood, rather than as a biological boundary at which the risk of pregnancy or childbirth changes suddenly. This threshold is widely used in reproductive health research to distinguish adolescent childbearing from childbearing in adulthood and is consistent with the World Health Organization's definition of adolescence as the period from 10 to 19 years. The focus on early first birth is particularly relevant because pregnancy and childbirth during adolescence are associated with distinct health and social consequences, including higher risks of certain pregnancy-related complications and adverse educational outcomes [8,19].

Although previous studies have examined adolescent childbearing and age at first birth in Lesotho and other SSA settings, limited evidence is available on the timing of first birth specifically within the adolescent period while accounting for unobserved cluster-level heterogeneity. Existing studies have largely relied on binary measures of adolescent childbearing or conventional regression approaches, which may not adequately capture the timing of the event or account for correlation among women living within the same communities. The present study addresses this gap by applying a shared gamma frailty survival model to nationally representative data from the 2023-24 LDHS, thereby accounting for unobserved heterogeneity at the enumeration-area level.

Therefore, this study aimed to examine the timing of early first birth and identify factors associated with the hazard of experiencing a first live birth before the age of 20 years among women aged 15 to 49 years in Lesotho, using a shared gamma frailty survival model to account for unobserved cluster-level heterogeneity. The findings are expected to inform government and policymakers in designing targeted interventions to reduce early childbearing among young women in the country.

Methods

Data Sources, Populations, and Samples

This study used cross-sectional data from the 2023-2024 LDHS, which is the fourth DHS conducted in Lesotho since 2004. The DHS is a nationally representative, population-based survey collected using standardized questionnaires. The protocol for the 2023-2024 LDHS received clearance from both the ICF (informed consent form) Institutional Review Board ethics committee and the Lesotho Ministry of Health Research and Ethics Committee. The survey design used clusters as the primary sampling units (PSUs), based on enumeration areas (EAs), and used a 2-stage stratified cluster sampling design with 400 clusters: 118 in urban areas and 282 in rural areas.

This study included all women of reproductive age (15-49 years). Eligible participants were either usual members of the selected households or had spent the night preceding the survey in those households. Women younger than 15 years and those aged 50 years and above were excluded from the study. The study focused on women aged 15 to 49 years, the conventional reproductive-age group used in demographic and reproductive health research. Women in this age group are conventionally defined as being of reproductive age, consistent with both biological fertility and demographic standards. This age range is consistent with standard demographic and reproductive health reporting and allows the study to capture women across different stages of the reproductive life course. Additionally, women within this age range experience diverse social pressures and life transitions, such as schooling and labor force participation, making them an ideal population for examining heterogeneity in the timing of motherhood.

Data collection was conducted over a 3-month period, from November 27, 2023, to February 29, 2024, across the 10 districts of Lesotho. The 2023-24 LDHS household sample was stratified and selected independently using a 2-stage sampling design. In the first stage, EAs were selected, which served as the PSUs, were treated as clusters in the shared frailty model. The second stage, a fixed number of 25 households per cluster were selected using equal-probability systematic sampling from the newly compiled household listing. A total of 9976 households were selected for the survey, of which 9853 were occupied. Among occupied households, 9810 were successfully interviewed, yielding a response rate of over 99%. Among the interviewed households, a weighted sample of 6413 women aged 15 t0 49 years was identified as eligible for individual interviews, which formed the basis of the analysis. The details of the recorded data are available at the Ministry of Health's website [20].

The survey comprised 400 EAs, of which 118 were urban and 282 were rural. These EAs corresponded to the PSUs used in the 2023-24 LDHS and were specified as the clustering units in the shared gamma frailty model. Based on the weighted analytical sample of 6413 women, the average number of women per cluster was approximately 16.0.

Data Management and Analysis

Overview

Data were extracted from the 2023-2024 LDHS, cleaned, and coded using the SPSS (version 30.0). Descriptive statistics were analyzed using the weighted study sample, and the results were presented as frequencies and percentages. Variables included in the analysis were selected based on their relevance to the study objectives and evidence from previous literature. Multicollinearity among the selected explanatory variables was assessed using the variance inflation factor (VIF) and tolerance statistics as premodeling diagnostic measures. Although VIF is traditionally used in linear regression settings, it was used here as a general diagnostic to identify potentially strong correlations among the explanatory variables prior to multivariable

survival modeling. The highest observed VIF was 1.944, and the lowest tolerance was 0.514, suggesting no evidence of problematic multicollinearity based on the adopted criteria [21]. No missing values were identified among the variables included in the analysis; therefore, no imputation was performed..

After checking the data and conducting descriptive analyses of the study population, survival outcomes were compared across categorical variables using the log-rank test [22]. The Kaplan-Meier (KM) method was used to estimate the probability of remaining free from an early first birth up to a given age [23]. The proportional hazards (PH) assumption was checked both graphically and using a global test based on Schoenfeld residuals.

Accounting for the Complex Survey Design

The complex sampling design of the 2023-24 LDHS was considered in the analysis. The individual women's sampling weight was applied to the descriptive analyses to account for unequal probabilities of selection and differential nonresponse and to obtain population-representative estimates. The DHS sampling weights were divided by 1,000,000 to obtain the normalized weights prior to their application in the descriptive analyses. The EA identifier was used to identify the PSUs, and the EA was specified as the clustering unit in the shared gamma frailty model to account for unobserved cluster-level heterogeneity among women residing within the same cluster. The shared gamma frailty term was therefore used to model within-cluster dependence in the survival analysis. The sampling weights were applied to the descriptive analyses but were not incorporated into the shared gamma frailty model, and the survey stratification variable was not explicitly incorporated into the frailty model. Thus, the frailty model should not be interpreted as a fully design-based survey survival analysis incorporating sampling weights, PSUs, and stratification simultaneously. The distinction between adjustment for the complex survey design in the descriptive analyses and modeling of unobserved cluster-level heterogeneity in the survival analysis is therefore maintained in the interpretation of the findings.

Study Variables

The primary outcome of interest was early first birth, defined as having a first live birth before the age of 20 years. The age of 20 years was selected as the cutoff because it corresponds to the transition from adolescence (15-19 years) to adulthood and is widely used in public health and demographic research to identify adolescent childbearing [19]. The cutoff was therefore selected as a public health and epidemiological threshold rather than as a biological boundary at which reproductive risk changes abruptly. The cutoff was chosen to operationalize adolescent/early childbearing as the study outcome, not because the age of 20 years represents a biological transition in fertility risk. For the binary analysis, women were classified as having experienced an early first birth if their first live birth occurred before the age of 20 years (coded 1). Women were classified as not having experienced an early first birth (coded 0) if they had no first live birth before the age of 20 years, including women whose first birth occurred at the age of 20 years or later and women who had not yet experienced a first birth. For the survival analysis, the risk period was defined from the age of 15 years until the occurrence of a first live birth before the age of 20 years or until the 20th birthday, whichever occurred first. Because the LDHS is a cross-sectional survey, the timing of first birth was retrospectively reconstructed from respondents' reported age at first birth.

Women aged 20 to 49 years at the time of the survey were therefore eligible for the analysis because their reproductive histories allowed their experience of the risk period before the age of 20 years to be determined. Women whose first birth occurred at the age of 20 years or later, as well as women who had not experienced a first birth by the age of 20 years, were treated as having no early first birth and were administratively censored at the age of 20 years. Thus, a woman aged 25 years who reported her first birth at the age of 18 years contributed an event at the age of 18 years, whereas a woman whose first birth occurred at the age of 25 years was censored at the age of 20 years for the specific early-first-birth analysis. The selection of potential covariates for the analysis was guided by their availability in the 2023-24 LDHS dataset and evidence from relevant literature [24-26]. A complete list of the variables included in the analysis is provided in Table 1. The media exposure variable was constructed using questions on the frequency of exposure to radio, television, and newspapers. Women were classified as having media exposure if they reported accessing at least one of these media sources at least once per week. The variable was coded as 1 for media exposure and 0 for no media exposure.

Table 1. Variables considered in the analysis of time to early first birth in Lesotho.

Variables	Categories
Outcome (early first birth)	0="no first live birth before age 20 years" and 1="first live birth before age 20 years"
Place of residence	Urban or rural
Education level	No formal education, primary, secondary, tertiary
Ethnicity	Basotho, Maxhosa, Bathepu, and other
Sex of household head	Male or female
Literacy	Cannot read at all, able to read only parts of sentence, able to read whole sentence
Self-reported health status	Good, moderate, and bad
Wealth index	Poor, middle, and rich

Variables	Categories
Smokes cigarettes	Yes or no
Marital status	Single, married, living with partner, widowed, divorced, and no longer living together/ separated
Currently working	Yes or no
Media exposure	Exposed or not exposed
Heard of family planning at community meetings or events	Yes or no

Inclusion and Exclusion Criteria

The study included women aged 15 to 49 years who participated in the 2023-2024 LDHS. Women outside the eligible age range of 15 to 49 years were excluded from the analysis.

Rationale for Using Survival Analysis and Shared Gamma Frailty Modeling

Time-to-event analysis was used to examine the occurrence and timing of early first birth, defined as a first live birth occurring before the age of 20 years. Age was used as the underlying time scale, with the risk period extending from the age of 15 years until the occurrence of an early first birth or the age of 20 years, whichever came first. Women whose first birth occurred at the age of 20 years or later, as well as those who had not experienced a first birth by the age of 20 years, were treated as not having experienced the specific early-first-birth event and were administratively censored at the age of 20 years. Thus, the analysis specifically estimated factors associated with the hazard of experiencing a first birth before the age of 20 years and should not be interpreted as modeling the timing of first birth across the entire reproductive life course [27].

KM methods were used to estimate the probability of remaining free from early first birth up to a given age, and survival functions were compared using the log-rank test. A Cox PH model was initially fitted to identify factors associated with the hazard of early first birth [28]. The PH assumption was assessed using Schoenfeld residuals. Variables showing evidence of nonproportionality were handled through stratification in the subsequent Cox model. Because the 2023-24 LDHS used a clustered sampling design in which women were sampled within EAs, women within the same cluster may share unmeasured contextual characteristics that could result in correlated outcomes. A shared gamma frailty model was therefore fitted to account for unobserved cluster-level heterogeneity, with the EA specified as the clustering unit. The model included a cluster-specific random effect that acts multiplicatively on the baseline hazard [29]:

$$h_{ij}(t \mid x_{ij},\ z_i) = z_i h_0(t) \times \exp(\beta^T x_{ij})$$

where h_{ij} $(t|x_{ij}, z_i)$ is the hazard for individual j in cluster i at time t, $h_0(t)$ is the baseline hazard, β is the vector of regression coefficients, x_{ij} is the vector of observed covariates, and z_i is the shared frailty term for cluster i. The frailty term was assumed to follow a gamma distribution with mean 1 and variance θ, such that $z_i \sim \text{Gamma}\left(\frac{1}{\theta}, \frac{1}{\theta}\right)$ under the shape-rate parameterization. A larger frailty variance indicates greater unobserved heterogeneity between clusters. The degree of within-cluster dependence was assessed using Kendall's rank correlation, calculated as [30]:

$$\tau = \frac{\theta}{\theta + 2}, \text{where} \tau \varepsilon \left[0, 1\right]$$

The shared gamma frailty model was selected to account for residual cluster-level heterogeneity that may not be explained by the observed covariates [31-33]. Model performance was compared with the standard Cox PH model using the Akaike information criterion (AIC), Bayesian information criterion (BIC), and log-likelihood. All analyses were conducted using the R statistical software (version 4.5.2; R Foundation for Statistical Computing), with statistical significance assessed at the 5% level.

Ethical Considerations

This study involved a secondary analysis of data from the 2023-24 LDHS. The 2023-24 LDHS received ethical clearance from the ICF Institutional Review Board and the Lesotho Ministry of Health Research and Ethics Committee. Informed consent was obtained from participants during the original survey data collection. The present study used deidentified secondary data and did not involve direct contact with participants or access to personally identifiable information. Permission to access and use the LDHS dataset was obtained from the Demographic and Health Surveys Program. The details of the recorded data are available at the Ministry of Health's website [20]. All analyses were conducted in accordance with the DHS data-use requirements and principles of confidentiality and privacy.

Results

Distribution of Participants by Background Characteristics

A weighted sample of 6413 women was analyzed in this study, and the sampling procedure used for this study is indicated in Figure 1. Of these, 54.5% (n=3495) resided in rural areas, while 45.5% (n=2918) were from urban areas (Table 2). More than half (n=3682, 57.4%) of the women had secondary level of education. In terms of ethnicity, most participants (n=6233, 97.2%) were Basotho. Household head was predominantly male (n=3653, 57.0%), compared to 43.0% (n=2760) female-headed households. Additionally, most women (n=5867, 91.5%) reported being able to read a

full sentence, while only 1.7% (n=110) participants indicated that they were unable to read at all.

Figure 1. Diagram of the sampling procedures for the study on time to first birth among women aged 15 to 49 years in Lesotho, 2023-2024 Lesotho Demographic and Health Survey (LDHS).

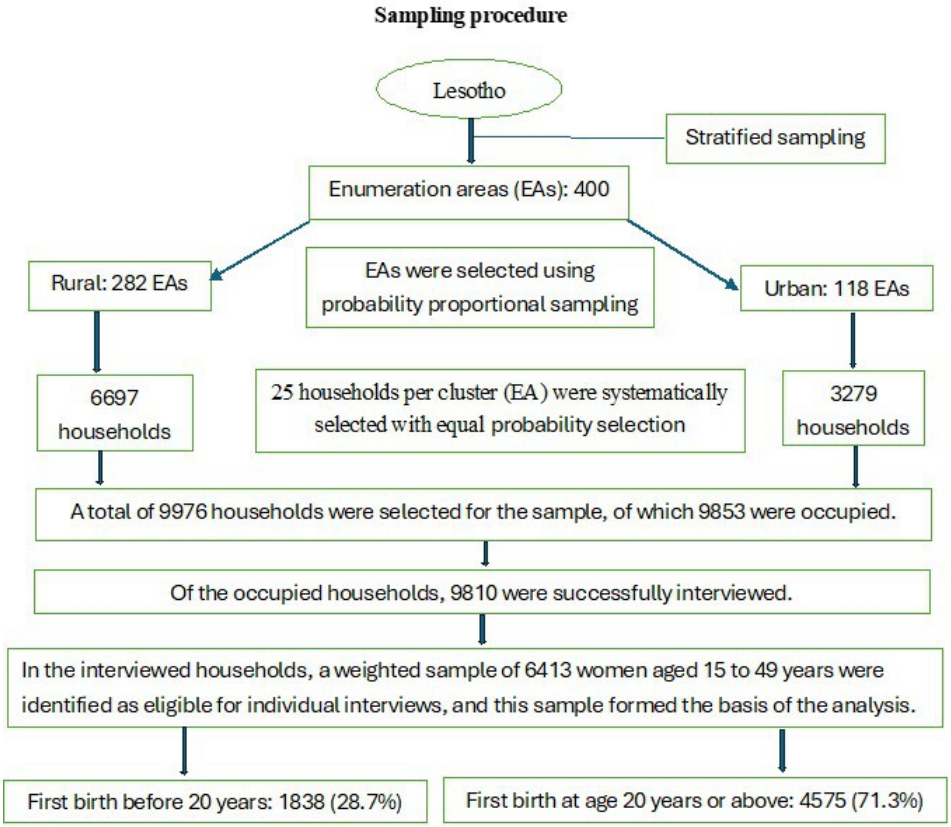


Table 2. Weighted background characteristics of the study participants in Lesotho (n=6413), with log-rank test results.

Background characteristics and categories	Total, n (%)	Women's age at first birth		Log-rank test
		No early first birth by the age of 20 years, n (%, 95% CI)	Early first birth (<20 y), n (%, 95% CI)	χ^2 (*df*; *P* value)
Place of residence				56.6 (1; <.001)
Urban	2918 (45.5)	2201 (75.4, 73.8-77.0)	717 (24.6, 23.0-26.2	
Rural	3495 (54.5)	2374 (67.9, 66.4-69.4)	1121 (32.1, 30.6-33.6)	
Education level				356.7 (3; <.001)
No education	39 (0.6)	21 (53.8, 38.2-69.4)	18 (46.2, 30.6-61.8)	
Primary	1596 (24.9)	804 (50.4, 47.9-52.9	792 (49.6, 47.1-52.1)	
Secondary	3682 (57.4)	2723 (74.0, 72.6-75.4)	958 (26.0, 24.6-27.4)	
Higher	1097 (17.1)	1026 (93.6, 92.2-95.0)	958 (6.4, 5.0-7.8)	
Ethnicity				9.9 (3; .02)
Basotho	6233 (97.2)	4462 (71.6, 70.5-72.7)	1772 (28.4, 27.3-29.5)	
Maxhosa	65 (1.0)	41 (63.1, 51.4-74.8)	24 (36.9, 25.2-48.6)	
Bathepu	86 (1.3)	49 (57.0, 46.5-67.5)	37 (43.0, 32.5-53.5)	
Other	29 (0.5)	23 (79.3, 64.6-94.0	6 (20.7, 6.0-35.4)	
Sex of household head				3.6 (1; .06)
Male	3653 (57.0)	2584 (70.7, 69.2-72.2)	1069 (29.3, 27.8-30.8)	
Female	2760 (43.0)	1991 (72.1, 70.4-73.8)	770 (27.9, 26.2-29.6)	
Literacy				25.2 (2; <.001)
Cannot read at all	110 (1.7)	60 (55.0, 45.7-64.3)	49 (45.0, 35.7-54.3)	

Background characteristics and categories	Total, n (%)	Women's age at first birth		Log-rank test
		No early first birth by the age of 20 years, n (%, 95% CI)	Early first birth (<20 y), n (%, 95% CI)	χ^2 (*df*; *P* value)
Able to read only parts of sentence	436 (6.8)	275 (63.1, 58.6-67.6)	161 (36.9, 32.4-41.4)	
Able to read whole sentence	5867 (91.5)	4239 (72.3, 71.2-73.4)	1628 (27.7, 26.6-28.8)	
Self-reported health status				4.1 (2; .13)
Good	3609 (56.3)	2661 (73.7, 72.3-75.1)	949 (26.3, 24.9-27.7)	
Moderate	2236 (34.9)	1543 (69.0, 67.1-70.9)	693 (31.0, 29.1-32.9)	
Bad	568 (8.9)	371 (65.3, 61.4-69.2)	197 (34.7, 30.8-38.6)	
Wealth index				205.6 (2; <.001)
Poor	1949 (30.4)	1143 (58.6, 56.4-60.8)	806 (41.4, 39.2-43.6)	
Middle	1253 (19.5)	880 (70.2, 67.7-72.7)	374 (29.8, 27.3-32.3)	
Rich	3211 (50.1)	2552 (79.5, 78.1-80.9)	659 (20.5, 19.1-21.9)	
Smokes cigarettes				2.9 (1; .09)
No	6261 (97.6)	4470 (71.4, 70.3-72.5)	1791 (28.6, 27.5-29.7)	
Yes	152 (2.4)	105 (68.6, 61.2-76.0)	48 (31.4, 24.0-38.8)	
Marital status				35.1 (5; <.001)
Single	2304 (35.9)	2046 (88.8, 87.5-90.1)	258 (11.2, 9.9-12.5)	
Married	3058 (47.7)	1937 (63.3, 61.6-65.0)	1122 (36.7, 35.0-38.4)	
Living with partner	126 (2.0)	63 (50.0, 41.3-58.7)	63 (50.0, 41.3-58.7)	
Widowed	323 (5.0)	184 (57.0, 51.6-62.4)	139 (43.0, 37.6-48.4)	
Divorced	99 (1.5)	69 (69.7, 60.6-78.8)	30 (30.3, 21.2-39.4)	
No longer living together/separated	503 (7.8)	276 (54.9, 50.6-59.2)	227 (45.1, 40.8-49.4)	
Currently working				95.8 (1; <.001)
No	3848 (60)	2696 (70.1, 68.7-71.5)	1152 (29.9, 28.5-31.3)	
Yes	2565 (40)	1878 (73.2, 71.5-74.9)	687 (26.8, 25.1-28.5)	
Media exposure				70.4 (1; <.001)
Exposed	5092 (79.4)	3771 (74.1, 72.9-75.3)	1320 (25.9, 24.7-27.1)	
Not exposed	1321 (20.6)	803 (60.8, 58.2-63.4)	518 (39.2, 36.6-41.8)	
Heard of family planning at community meetings or events				2.7 (1; .10)
No	5461 (85.2)	3951 (72.3, 71.1-73.5)	1510 (27.7, 26.5-28.9)	
Yes	952 (14.8)	623 (65.4, 62.4-68.4)	329 (34.6, 31.6-37.6)	

Regarding self-reported health status, more than half (n=3609, 56.3%) of the women described their health as good, 34.9% (n=2236) as moderate, and 8.9% (n=568) as poor. In terms of wealth index, 30.4% (n=1949) of the women were from poor households, 19.5% (n=1253) from middle-income households, and 50.1% (n=3211) from rich households. Most participants (n=6261, 97.6%) were nonsmokers, and nearly half (n=3058, 47.7%) were married. Additionally, 60% (n=3848) of the women reported being unemployed, while 40% (n=2565) were employed. The findings further showed that most (n=5092, 79.4%) women had media exposure, and a large proportion (n=5461, 85.2%) had not heard about family planning during community meetings (Table 2).

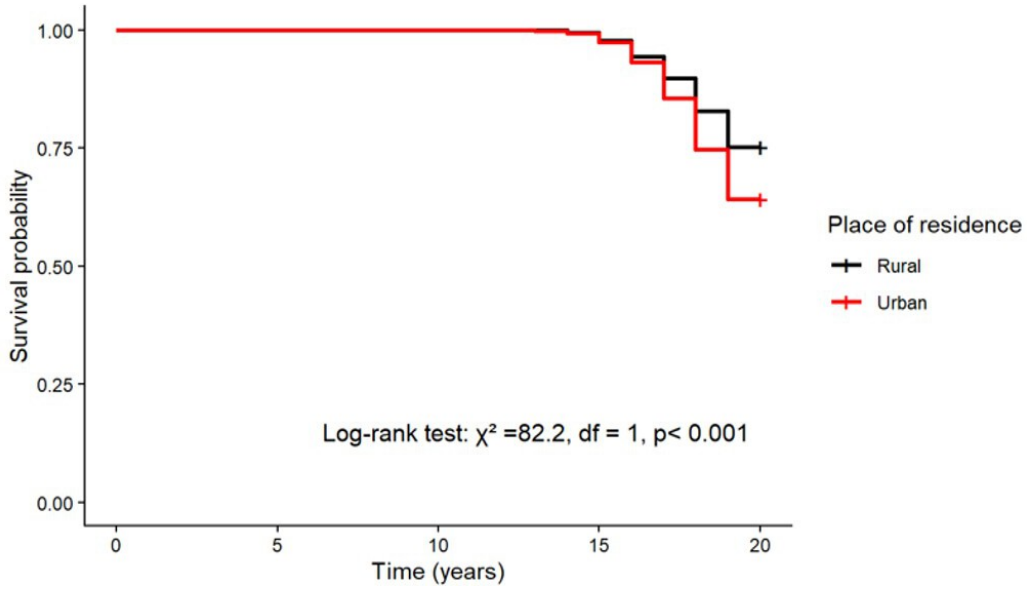
Age at First Birth Among Study Participants

Among women who experienced early first birth, defined as first birth before the age of 20 years, the median age at first birth was 18 (IQR 17-19) years. Higher proportions of early childbirth were observed among women residing in rural areas (32.1%, 95% CI 30.6%-33.6%) and among women with a primary level of education (49.6%, 95% CI 47.1%-52.1%). Higher proportions were also observed among Bathepu women (43.0%, 95% CI 32.5%-53.5%), women unable to read (45.0%, 95% CI 35.7%-54.3%), women from poor households (41.4%, 95% CI 39.2%-43.6%), and those not working (29.9%, 95% CI 28.5%-31.3%). Furthermore, the highest proportion of early childbirth was observed among women who were not exposed to media (39.2%, 95% CI 36.6%-41.8%; (Table 2).

Comparison of Survival Functions Across Categorical Variables

We used the KM survival curve and the log-rank test to estimate and compare survival functions across different participant characteristics. The KM curve stratified by place of residence indicated that women residing in rural areas had a lower probability of remaining free from early first birth up to the age of 20 years compared to those living in urban areas (χ^2_1=56.6; P <.001). The KM curve and log-rank test showed a statistically significant difference in the probability of delaying first birth beyond the age of 20 years between women who were exposed and not exposed to media (χ^2_1=70.4; P<.001), with media-exposed women showing a higher probability of delaying first birth beyond the age of 20 years. Furthermore, the KM curves indicated that women from wealthier households and those with higher levels of education had a higher probability of remaining free from early first birth up to the age of 20 years compared to their counterparts (Figure 1 and Figure 2). The results from the log-rank test further revealed significant differences in survival distributions by place of residence (χ^2_1=56.6; P<.001; Figure 2), ethnicity (χ^2_3=9.9; P=.02), literacy (χ^2_2=25.2; P<.001), marital status (χ^2_5=35.1; P<.001), and employment status (χ^2_1=95.8; P<.001; Table 2).

Figure 2. Kaplan-Meier survival curves showing the probability of remaining free from early first birth up to age 20 years, stratified by place of residence.



The PH assumption was assessed using Schoenfeld residuals in the standard multivariable Cox PH model [34,35]. The global test provided evidence of a violation of the PH assumption (χ^2_{23}=78.0; P<.001). At the individual-variable level, significant evidence of nonproportionality was observed for sex of household head (P=.02), literacy (P=.049), and marital status (P <.001). The use of an extended Cox model with time-dependent covariates was not pursued because allowing covariate effects to vary over time would result in time-specific hazard ratios that are less straightforward to interpret than constant hazard ratios [36]. Instead, stratified Cox models were fitted, with variables showing evidence of nonproportionality specified as stratification variables. Literacy and marital status were specified as stratification variables in the subsequent survival models. Following stratification, the global Schoenfeld residuals test was no longer statistically significant (χ^2_{16}=22.9; P=.12), indicating no evidence of a remaining global violation of the PH assumption. After incorporating the selected stratification variables, there was no longer evidence of nonproportionality for sex of household head (P=.49; Table 3).

Table 3. Assessment of the proportional hazards (PH) assumption using Schoenfeld residuals before and after stratification.

	Standard Cox PH assumption		Stratified Cox PH assumption	
Variables	χ^2 (*df*)	*P* value	χ^2 (*df*)	*P* value
Place of residence	1.7 (1)	.19	0.4 (1)	.52
Education level	5.0 (3)	.17	0.3 (3)	.20
Ethnicity	3.0 (3)	.40	3.2 (3)	.37
Sex of household head	5.4 (1)	.02	0.5 (1)	.49
Literacy	6.0 (2)	.049	—[a]	—
Self-reported health status	6.0 (2)	.051	3.2 (2)	.21

Variables	Standard Cox PH assumption		Stratified Cox PH assumption	
	χ^2 (*df*)	*P* value	χ^2 (*df*)	*P* value
Wealth index	2.5 (2)	.28	2.6 (2)	.27
Smokes cigarettes	0.5 (1)	.48	0.7 (1)	.40
Marital status	48.3 (5)	<.001	—	—
Currently working	1.0 (1)	.32	0.1 (1)	.80
Media exposure	0.7 (1)	.41	0.8 (1)	.38
Heard of family planning at community meetings or events	1.7 (1)	.19	0.6 (1)	.46
Global test	78.0 (23)	<.001	22.9 (16)	.12

[a]Not available.

Bivariable and Multivariable Analyses of Predictors of Age at First Birth Under a Gamma Shared Frailty Model

The results presented in Table 3 compare the estimates from the initial multivariable Cox PH model with those from the shared gamma frailty model. The estimates for most covariates were broadly similar between the 2 models, suggesting that accounting for cluster-level heterogeneity had limited influence on the estimated associations for most observed characteristics. For example, the hazard ratio for rural compared with urban residence remained essentially unchanged after the incorporation of the frailty term (adjusted hazard ratio [AHR]=0.95, 95% CI 0.84-1.07 in the standard Cox model vs AHR=0.95, 95% CI 0.84-1.08 in the shared frailty model). Similarly, the association between higher education and the timing of early first birth was consistent across models, with women with higher education having a substantially lower hazard of early first birth than those with no education (AHR=0.18, 95% CI 0.11-0.29 in the standard Cox model vs AHR=0.18, 95% CI 0.10-0.29 in the shared frailty model). Comparable patterns were also observed for wealth index, smoking, current employment status, media exposure, and exposure to family-planning information.

The estimated frailty variance decreased from 0.1503 in the null frailty model to 0.0424 in the fully adjusted shared gamma frailty model, with the latter remaining statistically significant (*P*=.007; Table 4). This reduction suggests that the observed covariates explained a substantial proportion of the heterogeneity between clusters captured by the frailty term. Nevertheless, the statistically significant residual frailty variance indicates that a small amount of unobserved cluster-level heterogeneity remained after adjustment. Thus, the findings do not suggest strong clustering of early first birth but rather indicate modest residual dependence between women within the same sampling clusters that was not fully explained by the measured covariates. Model fit was further evaluated by comparing the standard Cox PH model with the adjusted shared gamma frailty model. The adjusted shared gamma frailty model demonstrated lower AIC (31194.68) and BIC (31252.37) values than the standard Cox model (AIC=33874.92; BIC=34004.12), indicating better relative model fit based on these information criteria. In addition, the inclusion of the shared frailty component resulted in a statistically significant residual frailty variance of 0.0424 (*P* value =.007) after adjustment for the measured covariates.

Table 4. Comparison of Cox proportional hazards (PH) and shared gamma frailty models for factors associated with the timing of early first birth.[a]

Background characteristics and categories	Standard Cox PH model[b]	Shared gamma frailty model[c,d]	
	AHR[e] (95% CI)	CHR[f] (95% CI)	AHR (95% CI)
Place of residence			
Urban	1	1	1
Rural	0.95 (0.84-1.07)	1.60 (1.42-1.80)	0.95 (0.84-1.08)
Education level			
No education	1	1	1
Primary	1.16 (0.76-1.78)	1.25 (0.84-1.85)	1.19 (0.77-1.85)
Secondary	0.71 (0.46-1.09)	0.56 (0.38-0.82)	0.71 (0.46-1.11)
Higher	0.18 (0.11-0.29)	0.13 (0.08-0.20)	0.18 (0.10-0.29)
Ethnicity			
Basotho	1	1	1
Maxhosa	0.94 (0.69-1.26)	1.01 (0.74-1.37)	0.92 (0.68-1.25)
Bathepu	0.99 (0.78-1.26)	1.33 (1.03-1.71)	0.98 (0.76-1.25)
Other	1.34 (0.55-3.23)	0.83 (0.34-2.02)	1.36 (0.56-3.32)
Sex of household head			
Male	1	1	1

Background characteristics and categories	Standard Cox PH model[b] AHR[e] (95% CI)	Shared gamma frailty model[c,d] CHR[f] (95% CI)	AHR (95% CI)
Female	1.10 (1.00-1.21)	0.93 (0.85-1.02)	1.10 (1.00-1.22)
Literacy			
Cannot read at all	1	1	—[k]
Able to read only parts of sentence	1.11 (0.83-1.49)	1.10 (0.83-1.46)	—
Able to read whole sentence	1.15 (0.88-1.50)	0.75 (0.59-0.96)	—
Self-reported health status			
Good	1	1	1
Moderate	0.97 (0.88-1.07)	1.14 (1.03-1.25)	0.97 (0.89-1.07)
Bad	1.02 (0.88-1.18)	1.45 (1.25-1.67)	1.02 (0.88-1.18)
Wealth index			
Poor	1	1	1
Middle	0.86 (0.76-0.97)	0.70 (0.62-0.79)	0.85 (0.75-0.97)
Rich	0.71 (0.61-0.82)	0.44 (0.39-0.49)	0.70 (0.60-0.81)
Smokes cigarettes			
No	1	1	1
Yes	1.18 (0.90-1.54)	1.35 (1.02-1.78)	1.19 (0.91-1.57)
Marital status			
Single	1	1	—
Married	3.05 (2.67-3.47)	3.47 (3.06-3.94)	—
Living with partner	4.34 (3.20-5.87)	5.34 (3.92-7.26)	—
Widowed	2.94 (2.39-3.61)	4.11 (3.36-5.02)	—
Divorced	3.57 (2.46-5.19)	3.05 (2.09-4.44)	—
No longer living together/separated	3.67 (3.08-4.37)	4.45 (3.75-5.30)	—
Currently working			
No	1	1	1
Yes	0.94 (0.85-1.04)	0.94 (0.85-1.04)	0.94 (0.85-1.04)
Media exposure			
Not exposed	1	1	1
Exposed	0.97 (0.88-1.04)	0.67 (0.60-0.74)	0.97 (0.87-1.07)
Heard of family planning at community meetings or events			
No	1	1	1
Yes	0.87 (0.80-0.98)	0.70 (0.61-0.83)	0.85 (0.76-0.96)

[a]Literacy and marital status were included as stratification variables in the shared gamma frailty model because they violated the proportional hazards assumption; therefore, hazard ratios are not reported for these variables in the final model.
[b]Akaike information criterion (AIC)=33,874.92; Bayesian information criterion (BIC)=34,004.12; Log-likelihood=–16,914.46.
[c]Null frailty: AIC=33,277.64; BIC=33,277.64; Log-likelihood=–16,638.82; frailty variance of random effect (frailty variance), θ=0.1503; P <.001.
[d]AHR: AIC=31,194.68; BIC=31,252.37; Log-likelihood=–15,587.34; Frailty variance of random effect (frailty variance), θ=0.0424; P=.007.
[e]AHR: adjusted hazard ratio.
[f]CHR: crude hazard ratio.
[g]Not available.

Although the magnitude of the frailty variance was small, the statistically significant estimate indicates that residual cluster-level heterogeneity remained after accounting for the observed characteristics. The lower information criteria and the presence of statistically detectable residual heterogeneity therefore provide complementary evidence supporting the use of the shared gamma frailty model over the standard Cox specification. The findings suggest that most of the between-cluster heterogeneity was explained by the measured covariates, leaving only modest residual heterogeneity at the cluster level. This is reflected in the reduction in frailty variance from 0.1503 in the null frailty model to 0.0424 in the adjusted model. Thus, the purpose of retaining the shared frailty component was not to imply substantial clustering, but to account for the remaining unobserved cluster-level heterogeneity within the hierarchical sampling structure. The final model therefore provides a more flexible specification that simultaneously accommodates the nonproportionality identified in the initial Cox analysis through stratification and

accounts for residual dependence among individuals sampled within the same clusters.

The adjusted shared gamma frailty model showed that several sociodemographic and reproductive-related characteristics were associated with the hazard of experiencing early first birth, after accounting for observed covariates and residual cluster-level heterogeneity. Compared with women with no formal education, those with higher education had a lower hazard of experiencing early first birth (AHR=0.18, 95% CI 0.10-0.29), corresponding to an 82% lower hazard. Although the point estimate for women with secondary education also suggested a lower hazard (AHR=0.71, 95% CI 0.46-1.11), the association was not statistically significant. Sex of the household head was also significantly associated with the hazard of experiencing early first birth. Women residing in female-headed households had a 10% higher hazard of early first birth compared with those in male-headed households (AHR=1.10, 95% CI 1.00-1.22). Compared with women from poor households, those from middle-income households had a 15% lower hazard of early first birth (AHR=0.85, 95% CI 0.75-0.97), while women from rich households had a 30% lower hazard (AHR=0.70, 95% CI 0.60-0.81). Women who had heard about family planning through community meetings or events had a 15% lower hazard of early first birth than those who had not (AHR=0.85, 95% CI 0.76-0.96). The remaining covariates did not show statistically significant associations with the hazard of experiencing early first birth in the adjusted shared gamma frailty model (Table 4).

Discussion

Principal Findings

This study used a shared gamma frailty model with an unspecified baseline hazard distribution to identify factors associated with the timing of early first birth, defined as having a first live birth before the age of 20 years among women aged 15 to 49 years in Lesotho, using data from the 2023-2024 LDHS. A shared gamma frailty term was included at the cluster level to account for potential unobserved heterogeneity and within-cluster dependence among women residing in the same sampling cluster. The estimated frailty variance from the adjusted shared gamma frailty model was small (θ=0.0424), with a corresponding Kendall τ of approximately 0.0208, suggesting minimal residual dependence among women within the same cluster after accounting for the covariates included in the model. Thus, residual clustering appeared to have limited practical impact on the timing of early first birth in the present study. Nevertheless, the frailty model was retained to formally account for potential cluster-level heterogeneity and the hierarchical structure of the survey data. The estimates from the shared frailty model were also comparable with those from a Cox PH model without a frailty term, indicating that the main findings were robust to the inclusion of the cluster-level frailty term.

The findings of this study showed that among the 6413 women included in the analysis, 28.7% (n=1838) experienced an early first live birth before the age of 20 years. Among these women, the median age at first birth was 18 (IQR 17-19) years, which is consistent with the findings from previous studies [37,38]. This median age was lower than those reported in some other regions, including Nigeria, where the median age at first birth was 20 years [39]; Uganda, where it was 19.2 years [40]; and Kenya, where it was 20.3 years [41]. The relatively young age at early first birth observed in Lesotho may be partly related to the prevalence of early sexual activity, limited educational opportunities for girls, and the predominantly rural population [42]. Previous studies have also identified several factors associated with the timing of first birth, including maternal education, age at first marriage, knowledge of contraceptive methods, age at first sexual experience, and media exposure, particularly television [37,43,44].

The adjusted shared gamma frailty model identified educational attainment, sex of household head, wealth index, and exposure to family planning information at community meetings or events as key factors associated with the timing of early first birth among participants. After adjusting for frailty and other covariates, women with higher levels of education had a lower hazard of experiencing an early first birth than those with no formal education. This finding agrees with previous studies that reported that greater educational attainment is associated with delayed childbearing and increased awareness of reproductive health [45]. One possible explanation is that girls who remain in school may tend to postpone early sexual activity, acquire greater knowledge about reproductive health, and use contraceptive methods, which may collectively delay the timing of first birth. The results indicate that women from female-headed households had a significantly higher hazard of experiencing an early first birth compared with those from male-headed households. This finding suggests that household headship may reflect broader socioeconomic and family circumstances that shape the timing of first birth. Female-headed households may, in some contexts, face greater economic constraints, reduced access to social and material resources, or changes in parental supervision and support, which could influence reproductive behaviors and the timing of first birth. However, the relationship between household headship and early childbearing may vary across settings and according to other household characteristics. For example, recent evidence from SSA reported higher odds of early adolescent childbearing among women from male-headed households compared with those from female-headed households [46], while another study found that the association between household headship and adolescent pregnancy in Nigeria varied according to the age of the household head [15]. These differences highlight the importance of considering the broader social and household context when interpreting the association between household headship and early first birth.

Our findings indicated that women from middle- and rich-wealth households had a lower hazard of experiencing early first birth compared with those from poorer households. This finding may reflect the socioeconomic advantages associated with greater household resources. Families with

greater financial resources may be better able to support girls' continued education and provide access to health information and reproductive health services, which may contribute to delaying the timing of first birth. Consistent with this interpretation, previous research reported substantial inequalities in adolescent childbearing across SSA according to household wealth, education, and place of residence, with adolescent childbearing being more prevalent among girls from poorer households, those with lower levels of education, and those living in rural areas [47]. Cultural and structural factors may also shape the timing of early first birth. Social norms that facilitate early unions and childbearing, together with limited parental support or supervision, may contribute to earlier childbirth. Additionally, structural barriers, including rural residence, limited access to health facilities, and gaps in adolescent-friendly reproductive health services, may further limit opportunities for young women to delay their first birth.

Moreover, our findings revealed a significant association between exposure to family planning information at community meetings or events and the timing of early first birth. Women who had heard about family planning at community meetings or events had a lower hazard of experiencing an early first birth before the age of 20 years compared with those who had not heard about family planning at such meetings or events. This finding is consistent with previous research showing that access to family planning information and contraceptive use are important factors in shaping adolescent fertility and the timing of childbearing [48]. These findings suggest that exposure to family planning information at community meetings or events, together with improved access to reproductive health information and contraceptive services, may play an important role in delaying early first birth.

Implications for Public Health and Policy

This study highlights the need for strengthened public health interventions to delay early first birth in Lesotho, particularly among women with lower levels of education and those from poorer households. Policies should focus on providing young women with accessible sexual and reproductive health services that offer clear, accurate information and facilitate access to modern contraceptive methods. Strengthening educational opportunities for girls, particularly among those from socioeconomically disadvantaged households, may help delay early first birth by supporting continued schooling and improving access to reproductive health information. Reducing socioeconomic inequalities and strengthening social protection programs may also indirectly contribute to delaying early childbearing by supporting continued education and improving access to health services. Community-based interventions should further expand the provision of family planning information through community meetings and events, particularly in settings where access to formal health services may be limited. Such interventions should also address social norms related to early marriage and childbearing and promote informed decision-making regarding reproductive health. Strengthening policies and programs that empower young women to make informed decisions about their reproductive health may contribute to delaying early first childbirth and reducing early childbearing in Lesotho.

Limitations

Limitations should be considered. First, the study relied on self-reported data, which may be subject to recall bias. The cross-sectional nature of the data also limits causal inference. In addition, the use of secondary data meant that potentially important contextual factors, including cultural practices, partner characteristics, and community-level influences, were not available for analysis. The sample was also restricted to women aged 15 to 49 years. An important consideration concerns the operationalization of early first birth in the time-to-event analysis. The event was defined as a first birth before age 20 years; therefore, women whose first birth occurred at age 20 years or later were classified as nonevents for the early-first-birth outcome. Consequently, the estimated hazard ratios should be interpreted specifically as associations with the occurrence of early first birth before age 20 years and not as determinants of the timing of first birth across the entire reproductive life course. The age-20 threshold may also result in interpretations that differ from conventional survival models examining time to first birth at any age.

The timing of measurement of certain variables also warrants consideration. Marital status may have changed after the occurrence of first birth, and therefore, given the cross-sectional nature of the data, it should not be interpreted as a causal predictor of early first birth. Similarly, self-reported health status was measured at the time of the survey and may not reflect participants' health status at the time of their first birth, particularly among women whose first birth occurred several years earlier. Thus, the temporal relationship between health status and early first birth cannot be established. Finally, although sampling weights were applied to the descriptive analyses, the shared gamma frailty model did not simultaneously incorporate DHS sampling weights, clustering, and stratification within a fully design-based survey survival framework. Therefore, the model-based hazard ratios should be interpreted as associations estimated after accounting for cluster-level unobserved heterogeneity rather than as fully design-adjusted population estimates.

Conclusions

Early childbearing remains common in Lesotho. This study highlights the critical influence of education, household wealth, and exposure to family planning information at community meetings or events on the timing of early first birth. Women with higher levels of education and greater economic resources had a lower hazard of experiencing early first birth, while women with limited schooling and those from poorer households had a higher hazard. These findings underscore the persistent role of social, economic, and cultural factors in shaping reproductive behavior. Addressing early childbearing requires multisectoral interventions that expand access to education, strengthen adolescent reproductive health programs, and support vulnerable households. Policies that delay marriage and promote informed reproductive decision-making may further contribute to delaying early

first birth. Future longitudinal and qualitative research is needed to clarify unexpected patterns, such as the association between literacy and earlier first birth. Overall, the study provides actionable evidence to guide targeted strategies aimed at improving reproductive health outcomes among young women in Lesotho.

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Data Availability

The dataset used in this study is available from the DHS Program website. Access to the data files can be obtained after registration at the following link: [49].

Authors' Contributions

Conceptualization: SVM, RC
Formal analysis: SVM
Investigation: SV, WBZ
Methodology: SVM
Software: RC
Validation: RC
Writing – original draft: SVM
Writing – review & editing: SV, WBZ, RC

Conflicts of Interest

None declared.

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Abbreviations

AHR: adjusted hazard ratio
AIC: Akaike information criterion
AOR: adjusted odds ratio
BIC: Bayesian information criterion
DHS: Demographic and Health Surveys
EA: enumeration area
ICF: informed consent form
KM: Kaplan-Meier
LDHS: Lesotho Demographic and Health Survey
PH: proportional hazards
PSU: primary sampling unit
SSA: sub-Saharan Africa
VIF: variance inflation factor

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