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Early neonatal mortality in Ethiopia from 2000 to 2019: an analysis of trends and a multivariate decomposition analysis of Ethiopian demographic and health survey

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Abstract

Background Early neonatal deaths, occurring within the first six days of life, remain a critical public health challenge. Understanding the trends and factors associated with this issue is crucial for designing effective interventions and achieving global health goals. This study aims to examine the trends in early neonatal mortality in Ethiopia and identify the key factors associated with changes in early neonatal mortality over time.

Methods This study utilized five consecutive Ethiopian Demographic and Health Survey datasets from 2000 to 2019. To investigate the trends and identify factors influencing changes in early neonatal mortality over time, conducted a trend analysis and a logit-based multivariate decomposition analysis. Data management and analyses were performed using STATA version 17/MP software. All analyses were weighted to account for sampling probabilities and non-response. Statistical significance was determined at a two-sided *p*-value threshold of less than 0.05.

Result The analysis included a total of 12,260 weighted women from the 2000 survey and 5,527 weighted women from the 2019 survey. Over the study period, there was an overall downward trend in early neonatal mortality, decreasing from 34 deaths per 1000 live births in 2000 to 27 deaths per 1000 live births in 2019. The annual rate of reduction was estimated to be 1.03%. Approximately 45% of the observed decline in early neonatal mortality rate can be attributed to changes in population characteristics or endowments (E) during the study period. Factors such as the mother's age, maternal education, marital status, preceding birth interval, types of pregnancy, and the sex of the child significantly contributed to the compositional change in the early neonatal mortality rate.

Conclusion Over the past two decades, Ethiopia has seen a modest decline in early neonatal mortality, but this progress falls short of the Sustainable Development Goal (SDGs) targets. To achieve the SDGs, the Ministry of Health and its partners should intensify efforts to reduce early neonatal mortality. Strategies like preventing early/late pregnancies, promoting appropriate marriage timing, and prioritizing education could help further reduce early neonatal deaths. Further research is also needed to explore the factors driving this issue.

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Keywords Decomposition analysis, Early neonatal mortality, Ethiopia, Trend

Introduction

Neonatal mortality, defined as the number of deaths among live-born infants before 28 completed days, is a critical indicator of a country's socioeconomic development and quality of life [1]. Within the neonatal period, early neonatal mortality specifically refers to the probability of dying during the first six days of life per 1000 live births [2].

Unfortunately, global estimates indicate that over 5.0 million children under the age of five and 2.4 million infants died in 2020, with newborns accounting for half of these deaths [1]. Alarming, nearly 3 million children worldwide die within the neonatal period, with a staggering 99% of these deaths occurring in low and middle-income countries [3]. Moreover, within the neonatal period, the majority of deaths (75%) occur within the first week of life, with a substantial proportion (25–45%) occurring within the first 24 h after birth [2].

While Ethiopia has made overall progress in reducing under-five and infant mortality rates, the country has experienced an unfortunate increase in neonatal deaths, with the neonatal mortality rate rising from 29 deaths per 1,000 live births in 2016 to 33 deaths per 1,000 live births in 2019. This reversal in the trend is a significant public health concern that requires urgent attention. However, the factors contributing to the rising neonatal mortality rates in Ethiopia are not well-understood [4].

The Sustainable Development Goals (SDGs) prioritize the reduction of under-five child mortality rates globally. To achieve this goal, it is crucial to address neonatal mortality rates, particularly in high-risk nations, where 98% of neonatal deaths occur (<https://ethiopia.un.org/en/sdgs/3>). The SDGs have set targets to lower newborn mortality to 25 and under-five mortality to 12 per 1,000 live births by 2030 [5]. Achieving these objectives necessitates a concerted effort to decrease early neonatal mortality rates, especially in developing nations.

Fortunately, evidence suggests that up to 50% of neonatal deaths can be prevented through cost-effective interventions that can be implemented before, during, and after delivery [6]. These interventions play a crucial role in reducing early neonatal mortality rates and improving the survival chances of newborns. However, the lack of understanding of the specific drivers of neonatal mortality in Ethiopia hampers the development of targeted policies and interventions.

Therefore, this study aims to investigate the trends and factors associated with neonatal mortality in Ethiopia. By identifying the contributing factors and understanding the underlying causes, policymakers and healthcare professionals can develop targeted interventions and

strategies to effectively reduce early neonatal mortality rates and achieve the SDG targets. The findings of this study will fill an important research gap and provide critical insights to guide the efforts towards improving neonatal health and survival in Ethiopia.

Methods and materials

Study area, period, and design

Ethiopia is located in the horn of Africa, with its geographical coordinates ranging between latitude 3° and 14°N and longitude 33° and 48°E. The country spans a total area of 1,100,000 square kilometers (<https://ethiopianembassy.org/overview-about-ethiopia/>) and is divided into nine regional states, namely Tigray, Afar, Amhara, Gambela, Benishangul-Gumuz, Harari, Oromia, Somali, and Southern Nations Nationalities and Peoples of Region, along with two city administrations (Addis Ababa and Dire Dawa). The analysis utilized data from the Ethiopian Demographic and Health Surveys (EDHS) conducted in 2000, 2005, 2011, 2016, and 2019. The study employed a community-based cross-sectional study design.

Source and study population

The source population for this study consisted of all women of reproductive age who had given birth within five years before each survey. The study population included reproductive-age women who had given birth within five years preceding each survey in the selected enumeration areas (EAs). The surveys utilized nationally representative samples drawn from birth records, with the following weighted numbers of women participating: 12,260 in 2000, 11,163 in 2005, 11,872 in 2011, 11,022 in 2016, and 5,527 in 2019.

Data collection tools and procedures

The data collection process for each survey year involved two stages. Stratification was carried out based on urban and rural areas within each region of the country. In the first stage, a specific number of enumeration areas (EAs) were selected: 539 EAs in 2000, 535 EAs in 2005, 596 EAs in 2011, 643 EAs in 2016, and 305 EAs in 2019 for the EDHS. In the second stage, a fixed number of households were selected within each EA using systematic sampling. For the detailed sampling procedure, can refer to the EDHS reports available on the Measure DHS website (<https://dhsprogram.com/Data/terms-of-use.cfm>) for each specific survey.

Outcome variable

Dependent variables: Early neonatal mortality (Yes, No).

Early neonatal mortality refers to the mortality of newborn babies within the first six days of life. For regression analysis, newborn babies who experienced mortality within the first six days were coded as '1', while newborn babies who survived beyond six days were coded as '0'.

Independent variables: Socio-demographic characteristics (age of the women, maternal educational status, marital status, place of residency and region), Maternal and Neonatal characteristics (high-risk fertility, antenatal care, place of delivery, mode of delivery, postnatal care, birth interval, birth order, types of pregnancy and sex of the baby).

Decomposing variable: Survey year was used to decompose (2000 labeled as "0" and 2019 labeled as "1").

Operational definition

Early neonatal mortality refers to the deaths of newborn babies that occur within the first six days of their postnatal age, as recorded in the dataset.

Risk fertility behavior refers to the characteristics of mothers who exhibit behaviors associated with higher risks in terms of fertility. These behaviors include being too young (under the age of 18) or too old (over the age of 34), having short birth intervals (less than 24 months between the preceding birth and the current pregnancy), and having a high parity (having more than three children).

Data management and analysis

The data were extracted, edited, coded, and verified by using STATA version 17/MP software. Descriptive statistics were conducted to understand the variables. The trends were analyzed separately for each survey period. Before conducting statistical tests, the data was weighted using sampling weight, primary sampling unit, and strata to ensure the survey's representativeness. The trend in early neonatal mortality rate was estimated by calculating the rate difference and annual rate of reduction. The annual rate of reduction (ARR) was used to describe the decrease in mortality rate per year. In this study, ARR was calculated as follows:

$$ARR = \frac{(r1 - r2) * 100}{r1 * t}$$

- r1=mortality rate for the year of the survey used as a baseline
- r2=mortality rate in the year of the final survey
- t=number of years between the first and second survey

A recently developed statistical technique called multivariate decomposition was employed in this study to analyze the differences in a distribution statistic between two groups or its change over time. This approach allows for the decomposition of the components of a group

difference or change into various explanatory factors. The technique utilizes regression models to separate the factors contributing to the differences in a statistic, such as a mean or proportion, between groups. These factors include compositional differences between groups, differences in characteristics (endowments), and differences in the effects of characteristics (differences in coefficients). This analysis technique is also useful for examining changes over time, as it can partition the components of change into those attributable to changing composition and changing effects [7]. In this particular study, a non-linear multivariate logit decomposition model was used to assess the contribution of changes in proportion to the early neonatal mortality rate over the past two decades.

The proportion difference in early neonatal mortality rate between 2000 and 2019 EDHS surveys can be decomposed as:

$$Y_A - Y_B = F(X_A\beta_A) - F(X_B\beta_B)$$

For the log odds of early neonatal mortality rate, the proportion of the model is written as.

$$\text{Logit}(Y_A) - \text{logit}(Y_B) = F(X_A\beta_A) - F(X_B\beta_B) = \frac{F(X_A\beta_A) - F(X_B\beta_A)}{(E)} + \frac{F(X_B\beta_A) - F(X_B\beta_B)}{(C)}$$

The component 'E' is the difference attributable to endowment change, usually called the explained component. The 'C' component is the difference attributable to coefficients (behavioral) change, usually called the unexplained component.

Result

Background characteristics of the study population

Table 1 provides information on the distribution of individual characteristics of women who gave birth in the five years preceding each survey conducted between 2000 and 2019. The average age of respondents was 29.5 years (+6.9) in 2000 and 28.6 years (+6.5) in 2019, indicating a slight decrease over the study period. In terms of maternal education, the percentage of uneducated mothers decreased from 82.07% in 2000 to 53.58% in 2019, showing a significant decline. This suggests an improvement in educational attainment among women over time.

These findings highlight several positive changes in individual characteristics and healthcare utilization among women giving birth in Ethiopia between 2000 and 2019. In both survey years, the proportion of males among the newborns was approximately 51%, indicating a relatively balanced sex ratio. Furthermore, there was a notable increase in the utilization of antenatal care services and institutional delivery. The proportion of women receiving the recommended fourth or more antenatal care visits increased by 4.2 times, indicating

Table 1 Percentage distribution of socio-demographic characteristics of respondents from 2000–2019 EDHS

Characteristics	Category	Weighted percentage				
		2000 N= 12,260	2005 N= 11,163	2011 N= 11,872	2016 N= 11,022	2019 N= 5,527
Age of the women	15–19	4.55	5.15	4.14	3.43	4.76
	20–34	69.16	69.12	71.61	71.76	72.02
	35–49	26.29	25.73	24.25	24.81	23.22
Maternal educational status	Non-educated	82.07	79.17	69.3	66.08	53.58
	Primary education	13.02	16.62	27.05	26.77	35.4
	Secondary or higher	4.9	4.21	3.66	7.15	11.02
Marital status	In Union	91.22	93.19	87.41	93.79	93.88
	Not in Union	8.78	6.81	12.59	6.21	6.12
Place of residency	Urban	10.41	7.3	12.87	11.03	24.73
	rural	89.59	92.7	87.13	88.97	75.27
Region	Addis Ababa	1.49	1.37	1.87	2.21	2.83
	Dire Dawa	0.33	0.33	0.33	0.43	0.54
	Tigray	6.42	6.25	6.34	6.49	6.72
	Afar	1.03	0.96	1.02	1.04	1.55
	Amhara	26.12	23.48	22.37	18.8	19
	Oromiya	40.78	39.51	42.23	44.01	40
	Somali	1.16	4.28	3.07	4.61	7.39
	Benishangul-Gumuz	1.01	0.94	1.18	1.1	1.22
	SNNPR	21.22	22.39	21.01	20.83	20.01
	Gambella	0.24	0.28	0.34	0.24	0.45
Harari	0.21	0.2	0.24	0.23	0.3	

an improvement in access to prenatal care. Similarly, the percentage of women giving birth in a healthcare facility (institutional delivery) increased by nearly 10 times, reflecting an enhanced utilization of healthcare facilities during childbirth. The increase in educational attainment, antenatal care visits, institutional deliveries, and Cesarean section deliveries signifies progress in maternal and newborn health services (Table 2).

Trends of early neonatal mortality in the five survey years

The early neonatal mortality rate in Ethiopia showed a significant decrease from 2000 to 2019. During Phase I (2000 to 2016) and Phase III (2000 to 2019), there was an overall decline in the early neonatal mortality rate, decreasing from 34 per 1000 live births in 2000 to 27 per 1000 live births in 2019 (Fig. 1), with an annual rate of reduction of 1.03%. However, in Phase II (2016 to 2019), there was a slight increase in the early neonatal mortality rate, rising from 22 to 27 per 1000 live births (Table 3).

The rate of decline in early neonatal mortality varied among different background characteristics of the study participants. Among the eleven regions included in the analysis, only four regions (Tigray, Amhara, Oromia, and Southern nation nationality) showed a significant reduction in early neonatal mortality rates. The Southern nation nationality region exhibited the largest annual rate of reduction (ARR) in early neonatal mortality rates with the total reductions of 67 deaths per 1000 live births, respectively, from 2000 to 2019.

The rate of reduction was highest among participants who had home deliveries (2.4 per annum), received no antenatal care visits (2.29 per annum), had twin pregnancies (2.05 per annum), were uneducated (2.03 per annum), and were currently not married (1.93 per annum). Conversely, the lowest average annual rate of reduction was observed in the Somali region (-85.71% per annum), Dire Dawa (-12.5% per annum), and among mothers who gave birth in a healthcare institution and through cesarean section delivery (-49.6 and -38.6 per annum, respectively) (Table 3).

Across all surveys, the early neonatal mortality rate showed a decline for mothers living in rural areas, uneducated women, those with a single high-risk fertility factor, women who delivered at home, and women with twin pregnancies. However, the Somali region recorded an increase of 119 deaths per 1000 live births in early neonatal mortality throughout 2000 to 2019.

These findings underscore the varying trends in early neonatal mortality rates across different regions and population groups in Ethiopia. It highlights the need to target interventions and resources to regions and populations where early neonatal mortality rates remain high or have experienced an increase. By addressing the factors contributing to these trends, further progress can be made in reducing early neonatal mortality and improving overall neonatal health in Ethiopia.

Table 2 Percentage distribution of maternal and neonatal characteristics of respondents from 2000–2019 EDHS

Characteristics	Category	Weighted percentage				
		2000 N= 12,260	2005 N= 11,163	2011 N= 11,872	2016 N= 11,022	2019 N= 5,527
High-risk fertility category	No any high-risk	39.97	38.08	41	40.45	43.37
	single high-risk	29.58	30.47	30.23	29.23	28.82
	Multiple high-risk	30.45	31.45	28.76	30.33	27.81
Antenatal care (ANC)	No ANC	73.17	71.92	57.51	37.34	25.81
	1 to three times	16.42	15.95	23.5	30.87	31.19
	Four and above	10.41	12.13	19	31.79	43
Place of delivery	Home delivery	95.07	94.3	90.05	72.55	51.42
	Institutional delivery	4.84	5.29	9.52	26.24	47.54
Mode of delivery	Caesarian-section (C/S)	0.7	0.99	1.48	1.93	5.44
	Other than C/S	99.3	98.99	98.52	98.07	94.56
Postnatal care *	Yes	5.68	6.25	9.3	25.67	37.56
	No	94.32	93.71	90.52	74.33	62.44
Birth interval	Less than 24 months	19.69	17.67	16.53	17.62	17.75
	24 months and above	80.31	82.33	83.47	82.38	82.25
Birth order	First baby	19.03	17.31	19.05	18.67	21.79
	Second & third	30.09	30.02	31.12	30.47	31.93
	Fourth and above	50.89	52.67	49.83	50.85	46.28
Types of pregnancy	Singleton	97.83	98.21	97.68	97.35	97.35
	Multiple	2.17	1.79	2.32	2.65	2.65
Sex of the baby	Male	51.29	51.27	51.95	51.94	51.42
	Female	48.71	48.73	48.05	48.06	48.58

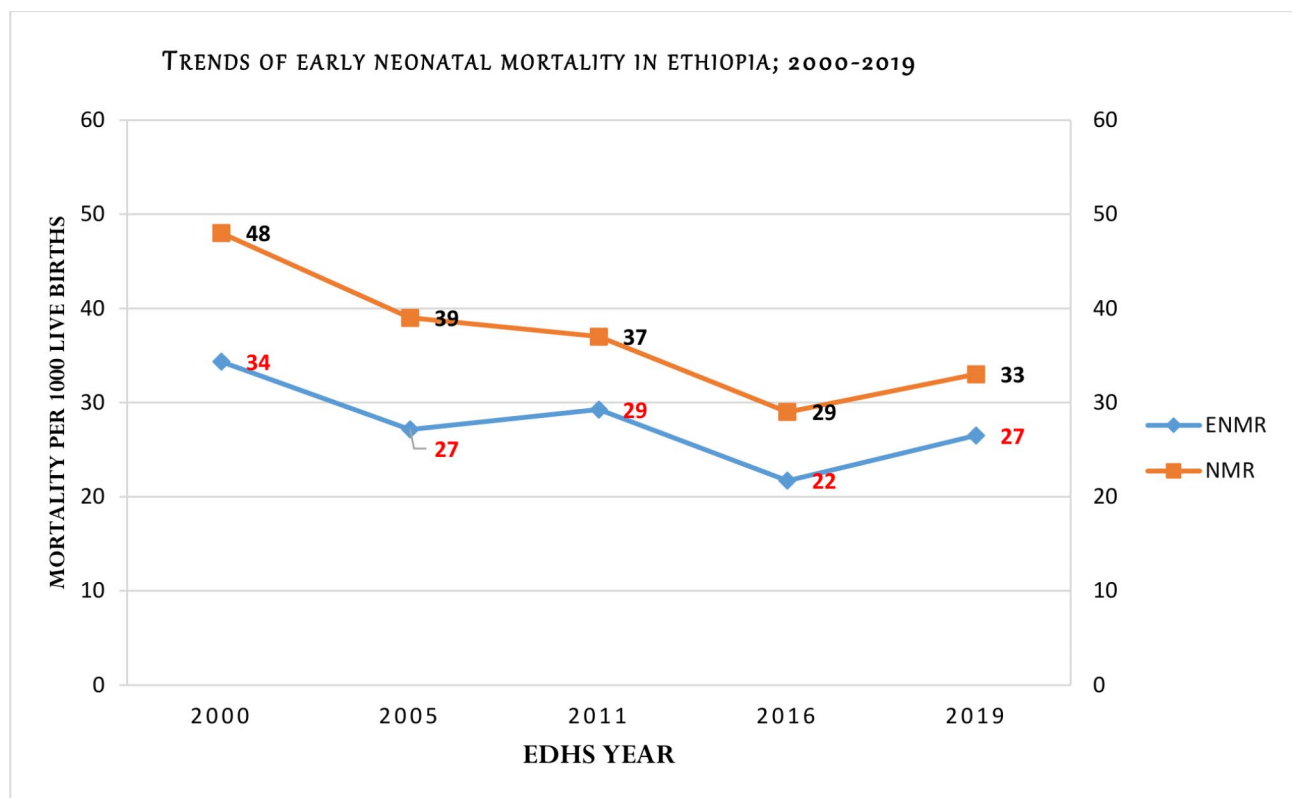


Fig. 1 Trends of early neonatal mortality in Ethiopia; 2000–2019

Table 3 Trends of early neonatal mortality from 2000 to 2019 EDHS

		ENMR/ 1000 live birth			Phase I	Phase II	Phase III	Annual rate of reduction
		2000	2016	2019	2000/2016	2016/2019	2000/2019	
Total early neonatal mortality		34	22	27	-13	5	-8	1.03
Maternal Education	No Education	853	666	506	-187	-160	-347	2.03
	Primary And above	147	334	494	187	160	347	-11.80
Marital Status	Married	863	949	916	86	-33	53	-0.31
	Unmarried	137	51	84	-86	33	-53	1.93
Region	Addis Ababa	11	21	14	11	-7	4	-1.36
	Dira Dawa	2	5	7	3	2	5	-12.50
	Tigray	60	64	52	3	-11	-8	0.67
	Afar	8	8	14	0	6	6	-3.75
	Amhara	227	178	197	-48	19	-29	0.66
	Oromiya	465	457	424	-8	-33	-41	0.44
	Somali	7	79	127	72	47	119	-85.71
	Benishangul-Gumuz	16	12	24	-5	12	7	-2.50
	SNNPR	200	171	133	-29	-38	-67	1.68
	Gambella	2	2	5	0	3	3	-7.50
	Harari	1	3	3	2	0	2	-10.00
Residency	Urban	96	170	181	73	11	85	-4.43
	Rural	904	830	819	-73	-11	-85	0.47
Sex	Male	568	682	561	114	-121	-7	0.06
	Female	432	318	439	-114	121	7	-0.08
High-Risk Pregnancy	No Any	403	349	401	-54	53	-2	0.02
	High-Risk Fertility	597	651	599	54	-53	2	-0.02
ANC Visit	No ANC visit	816	432	442	-384	10	-374	2.29
	One to three times	141	279	228	138	-51	87	-3.09
	Fourth & above	43	289	330	246	41	287	-33.37
Place Of Delivery	Home	954	623	497	-331	-126	-457	2.40
	Health Facility	44	353	480	309	127	436	-49.55
Mode Of Delivery	Other Than C/S	993	926	939	-67	13	-54	0.27
	Caesarian Section	7	74	61	67	-13	54	-38.57
Birth Interval	Less Than 24 Months	311	308	331	-2	23	20	-0.32
	24 Months & Above	689	692	669	2	-23	-20	0.15
Birth Order	Less than three	523	465	515	-58	51	-7	0.08
	Fourth and above	477	535	485	58	-51	7	-0.08
Types Of Pregnancy	Single	844	871	908	27	37	63	-0.38
	Twin	156	129	92	-27	-37	-63	2.05

N.B: ANC, Antenatal care; SNNPR- Southern nation's nationalities and peoples

Decomposition analysis

The early neonatal mortality rate in Ethiopia has seen a significant reduction of 8 per 1000 live births from 2000 to 2019. A multivariate decomposition logistic regression analysis reveals that approximately 45% of the observed mortality difference can be attributed to the characteristics of the surveyed women, known as compositional factors (Table 4).

Several compositional factors were found to have a notable impact on the change in early neonatal mortality. These factors include the age of the mother, maternal education, marital status, preceding birth interval, types of pregnancy, and the sex of the child. The analysis indicates that certain changes in these factors positively

or negatively contributed to the decline in early neonatal mortality rates.

The reduction in early neonatal mortality rates was significantly influenced by an increase in the proportion of women aged 20 to 34 years, married women, and those with primary or higher education. Conversely, compositional factors that remained relatively stable or unchanged exhibited a negative correlation with the decline in early neonatal mortality rates. These factors include birth intervals of 24 months or more, singleton pregnancies, and male infants.

After accounting for the effect of compositional factors, it was found that 55% of the change in early neonatal mortality between 2000 and 2019 in Ethiopia can be attributed to behavioral change factors or the effects of

Table 4 Decomposition analysis in early neonatal mortality in EDHS 2000–2019

Covariates	Early neonatal mortality	Difference due to characteristics (E)			Due to Difference in Coefficients (C)		
		Coef.	P-value	Pct.	Coef.	P-value	Pct.
	TOTAL	0.00362	0.025 *	44.8	0.00446	0.144	55.2
Age of the mother	15–19 years	1			1		
	20–34 years	0.00038	0.027 *	4.72	-0.00032	0.968	-3.97
	35–49 years	-0.00035	0.101	-4.35	-0.00228	0.478	-28.26
Maternal Education	Non-Educated	1			1		
	Primary Education and above	0.00277	0.027 *	34.22	-0.00914	0.025	-113.16
Marital Status	Not in union	1			1		
	In Union	0.00041	0.001 **	5.1	-0.0056	0.543	-69.26
Residency	Rural	1			1		
	Urban	0.00013	0.863	1.67	0.00285	0.171	35.22
Region	Somali	1			1		
	Addis Ababa	-0.00014	0.620	-1.75	0.00097	0.270	11.98
	Dira Dawa	-0.00001	0.874	-0.14	0.00006	0.801	0.72
	Tigray	-0.00004	0.358	-0.54	0.00212	0.183	26.26
	Afar	-0.00004	0.706	-0.55	0.00039	0.422	4.81
	Amhara	0.0009	0.430	11.14	0.00397	0.302	49.18
	Oromiya	0.00016	0.186	2.01	0.01337	0.126	165.5
	Benishangul-Gumuz	-0.00009	0.094	-1.17	0.00031	0.360	3.89
	SNNPR	0.0002	0.309	2.46	0.00817	0.078	101.07
	Gambella	-0.00002	0.764	-0.28	0.00009	0.688	1.06
	Harari	-0.00001	0.890	-0.06	0.00005	0.767	0.63
High-risk fertility	Multiple high-risk	1			1		
	No any high-risk	-0.00023	0.251	-2.86	-0.00614	0.194	-76.03
Birth Order	Fourth and above	1			1		
	less than three	-0.00006	0.810	-0.74	0.00597	0.269	73.83
Preceding Birth Interval	less than 24 months	1			1		
	24 months and above	-0.00028	0.001 **	-3.44	0.01601	0.005	198.09
Types of Pregnancy	twin	1			1		
	single	-0.00033	0.000 **	-4.04	-0.02431	0.103	-300.84
Sex of the child	male	1			1		
	female	-0.00001	0.004 **	-0.15	-0.0019	0.495	-23.53
Mode of delivery	Caesarian section	1			1		
	Other than C/S	0.00029	0.735	3.54	0.0072	0.697	89.09

N.B: *significant at 0.05, ** - at 0.01, *** - at <0.001; Pct. - percentage contribution; Coef. – Coefficient

specific characteristics, rather than the structural composition of the two cohorts. However, this difference was not statistically significant (Table 4). These findings underscore the importance of considering various compositional factors (endowments) rather than coefficients when analyzing changes in early neonatal mortality rates. Understanding the specific contributions of these factors can provide valuable insights for designing effective interventions and policies to further reduce neonatal mortality rates in Ethiopia.

Discussion

Early neonatal mortality is a crucial measure of newborn health and has a strong association with neonatal and under-five mortality rates. It poses a significant challenge, especially in low-income countries such as Ethiopia,

where efforts to reduce early neonatal mortality are of utmost importance. Therefore, this study aims to examine the pattern and multivariate decomposition of early neonatal mortality in Ethiopia over the past two decades.

The early neonatal mortality rate in Ethiopia has shown a significant decrease from 34 per 1000 live births in 2000 to 27 per 1000 live births in 2019. This decline is in line with Ethiopia's commitment to achieving the Sustainable Development Goals (SDGs) and its efforts to reduce neonatal mortality (<https://www.scribd.com/document/518384802/Annual-Performance-Report-2012-2019-2020>). The Ethiopian government, along with development partners and organizations, has implemented several initiatives aimed at improving access to healthcare, enhancing maternal and child health services, and increasing community awareness of

newborn care. These interventions have played a crucial role in addressing the factors contributing to early neonatal mortality [8]. However, despite the decline, the early neonatal mortality rate in Ethiopia remains high compared to global standards. To achieve the SDG targets for neonatal survival, further interventions are necessary. These include strengthening health systems, enhancing the capacity of healthcare professionals, promoting evidence-based practices, and addressing socio-cultural barriers [9].

Multivariate decomposition logistic regression analysis revealed that 45% of the observed early neonatal mortality difference is attributed to maternal characteristics (compositional factors) between the surveys. This highlights the importance of considering women's characteristics when examining changes in early neonatal mortality rates. Specifically, the compositional change in maternal age, marital status, and education level have made important contributions to the decrease in early neonatal mortality rates in Ethiopia over the last twenty years.

Compositional change in maternal age makes an important contribution to the decrease in early neonatal mortality rate in Ethiopia over the last twenty years. Previous studies have shown that both younger and older maternal ages are associated with an increased risk of early neonatal mortality [10–12].

The compositional change in marital status has also been identified as a contributing factor for decrement in early neonatal mortality rate in Ethiopia. This finding highlights the protective role of marriage in early neonatal health outcomes. This might be because married women often have access to emotional and financial support from their spouses, which can contribute to improved health-seeking behavior and better utilization of healthcare services during pregnancy and childbirth. This supportive and stable environment reduces maternal stress which can lead to adverse pregnancy outcomes [13, 14]. Kebede et al. (2021) also found that married women had lower early neonatal mortality rates compared to unmarried or single women [15].

Additionally, the compositional change in the education level of mothers has significantly contributed to the decrease in early neonatal mortality. Educated individuals are more likely to adhere to healthcare recommendations, adopt healthier habits, have better access to media, and have greater decision-making power within their households, all of which contribute to improved neonatal health [16, 17]. Their enhanced financial capacity also plays a crucial role in ensuring adequate care for their newborn babies [18].

However, the data also revealed minimal changes in the composition of women's birth intervals, which had a substantial negative effect on the rate of early neonatal

mortality decline. Longer birth intervals may be associated with factors like delayed access to prenatal care, increased maternal age, or other underlying health conditions that increase the risk of early neonatal mortality [19]. Further research is needed to explore the underlying causes and mechanisms behind this negative impact.

Furthermore, slight decrements in the composition of women with singleton pregnancies and being female were also negatively associated with the change in early neonatal mortality rate. This may be due to women with singleton pregnancies and being female having a higher chance of survival compared to their counterparts [20, 21], potentially due to improved access to healthcare services, better prenatal care, or biological factors that confer a survival advantage [22].

Strengths and limitations

This study utilized a nationally representative dataset with a large sample size, providing robust statistical power to analyze the characteristics of the study population. The findings have implications for healthcare professionals and policymakers in identifying influential factors and designing interventions to reduce early neonatal mortality in Ethiopia. However, it is important to note that certain variables, such as gestational age, comorbidities, NICU admission history, treatment-related characteristics, and details about antenatal and postnatal care, were not included in the analysis due to limited availability or a high number of missing values in the data collected through the EDHS. This limitation restricts the comprehensive examination of these factors' impact on early neonatal mortality. Moreover, the data collected through the DHS surveys rely on self-reported information, which may be subject to recall bias or social desirability bias. This potential for bias should be considered when interpreting the findings of the study.

Conclusion and recommendations

Over the past two decades, there has been a modest decline in early neonatal mortality in Ethiopia, but the rate remains unacceptably high. Approximately 45% of the overall reduction in early neonatal mortality can be attributed to changes in the characteristics of women during this period. Factors such as the age of the mother, maternal education, marital status, preceding birth interval, type of pregnancy, and the sex of the child have played a role, either positively or negatively, in influencing the change in early neonatal mortality in Ethiopia. To further reduce the early neonatal mortality rate, it is beneficial to encourage pregnancies among women between the ages of 20 and 34, promote marriage, and continue to prioritize education among the population. Additionally, interventions are needed to address the issue of short birth intervals, which has been identified as a significant

barrier to delayed initiation of breastfeeding in Ethiopia over the past decade. Lastly, to achieve the Sustainable Development Goals, the Ministry of Health and other stakeholders should continue their efforts to decrease early neonatal mortality. Furthermore, further research is necessary to gain deeper insights into the underlying factors and mechanisms driving early neonatal mortality in Ethiopia.

Abbreviations

ARR	Annual rate of reduction
ANC	Antenatal care
C/S	Cesarean section
DHS	Demographic health survey
EAs	Enumeration areas
EDHS	Ethiopian demographic and health survey
ENMR	Early neonatal mortality rate
NICUs	Neonatal intensive care units
SDG	Sustainable Development Goals
SNNPR	Southern nation's nationalities and peoples
UNICEF	United Nations international children's fund
WHO	World health organization

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Author contributions

FSB, LA, AA, and AE were involved in this study from the inception to design, acquisition of data, data cleaning, and data analysis. AG, DM, AMH, and AM were involved in data analysis, interpretation, drafting, and revising of the manuscript. ET and FD were involved in supervising the final manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets used during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

Under the ethical principles outlined in the Declaration of Helsinki, the authors took all necessary steps to adhere to guidelines for medical research. Due to the authors' limited direct contact with neonates and their families, obtaining informed consent was not feasible. The data sets utilized in this study are accessible through the Ethiopian Statistical Agency and the Ministry of Health. The authors submitted the proposed title and study aim to the online DHS website to download and utilize the data. The EDHS program granted authorization for data access, which was then used in the current study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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