DOI: https://dx.doi.org/10.4314/ejpch.v19i2.3

Ethiopian Journal of Pediatrics and Child Health, 2024, 19(2)
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ISSN 2413-2640 *eISSN* 2519-0334

OPEN ACCESS

Original Article

Associations of maternal age and body mass index with birth weight: a generalized additive model

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Abstract

Background: *Abnormal birth weight is a major factor in infant mortality, birth defects, and increased risk of various adult diseases. Epidemiological studies on how maternal age and body mass index affect newborn birth weight are still limited. Our study aimed to explore these relationships to better understand their impact on birth weight.*

Methods*: A community-based cross-sectional study was conducted using data from the Ethiopian Demographic and Health Survey 2019. The study included a total of 2,110 participants. Data were collected using a multistage sampling technique to select the study participants. Inclusion criteria required complete and valid data on maternal age, maternal body mass index, and newborn birth weight. Linear regression and generalized additive models were employed for the analysis. A p-value < 0.05 was considered statistically significant. All statistical analyses were conducted using SPSS and R software. .*

Results: *The average birth weight, low birth weight, and macrosomia were 3,280 g, 1,920 g, and 4,880 g, respectively. In the adjusted models, a one-year increase in maternal age was associated with a 6.375 g increase in newborn birth weight. Maternal body mass index was positively associated with birth weight (β=0.323, P < 0.001) and negatively associated with macrosomia (β=-0.041, P < 0.05). The generalized additive model also revealed an approximately linear relationship between maternal age and body mass index, as well as between maternal age and birth weight.*

Conclusion*: These findings confirm that maternal age and body mass index are positively and linearly related to newborn birth weight. Additionally, maternal body mass index directly influences the likelihood of macrosomia. This study recommends closely monitoring maternal age and BMI during pregnancy to reduce adverse outcomes and improve maternal health.*

Key words: *Maternal age; Body mass index; Birth weight; Macrosomia; Generalized additive model*

Citation : Charkos T. G., Associations of maternal age and body mass index with birth weight: a generalized additive model. *Ethiop J Pediatr Child Health*. 2024;19 (2):105-114 ***Submission date:*** *11 April 2024* ***Accepted****: 5 November 2024* ***Published****: 31 December 2024*

Background

Abnormal birth weight (BW) is the most important factor for infant mortality, birth defects, and the risk of various diseases in adulthood [1, 2]. An abnormal BW should include a low birth weight (LBW) of less than 2500 g and macrosomia greater than 4000 g, which leads to adverse effects on the intrauterine growth and development of newborns and is a marker of age-related disease risk [3, 4]. Studies have suggested that low birth weight infants have a 20-fold greater likelihood of dying than infants with normal birth weight [5, 6]. Birth weight may serve as a convenient surrogate for other factors causally associated with mortality, hypertension, diabetes, and other metabolic diseases [7]. The incidence of abnormal BW is generally high worldwide; it is estimated that 5-7% of LBW cases occur in developed countries, and approximately 19% occur in developing countries [8]. A recent study reported that the average incidence of LBW in Ethiopia was 17.1% [9], which is the highest reported incidence.

Recently, the relationship between maternal age and newborn birth weight has received increasing attention. Some studies have suggested that advancing maternal age (≥35 years) is associated with increasing stillbirths, preterm births, intrauterine growth restriction, young maternal age, and chromosomal abnormalities [10-13]. Gibbs et al. suggested that teenage mothers have a greater risk of preterm birth, low birth weight, low Apgar score, and postnatal mortality [14]. Maternal body weight may have an independent adverse effect on birth weight and newborn growth. In low-income countries such as Ethiopia, no studies have been conducted to assess the effects of age, extreme childbearing years, and maternal body mass index on birth weight. Therefore, we aimed to investigate the relationships of maternal age and body mass index with birth weight using a generalized additive model.

Methods and Materials

Study population

The 2019 Ethiopian Demographic and Health Survey (EDHS) is a cross-sectional, population-based survey designed to provide a comprehensive overview of key population, maternal, and child health indicators [15]. The survey was conducted by the Central Statistical Agency (CSA) at the request of the Federal Ministry of Health (FMoH). The country was divided into nine regions and two administrative cities. Each region was further stratified into urban and rural areas, resulting in a total of 21 sampling strata. The sampling frame consisted of a list of all enumerator area (EA) strata. In the first stage of sampling, 645 EAs were selected with probability proportional to their size (based on the 2007 Population and Housing Census), with independent selection within each stratum. In the second stage, 28 households per cluster were selected using equal probability systematic sampling from newly created household listings. This study is based on publicly available data from the

EDHS website: https://dhsprogram.com/data/availabledatasets.cfm. The study proposal was submitted online to access all available parameters from the DHS database.

Inclusion and exclusion criteria

All mothers who gave birth within one year prior to data collection were included in this analysis. However, mothers were excluded if they had missing or incomplete maternal information, birth weights under 1,000 grams due to twin births, or missing maternal age data.

Study variables and measurements

In all of the selected households, each woman interviewed in the survey was asked to provide a detailed age at recent birth, history of all her live births in chronological order, sex of the child, height, and weight measurements were collected from women aged 15-49 years, anemia, place of delivery, place of residence, higher education level, wealth index and birth weight of the newborn child. Anemia testing was performed on consenting women. Body mass index (BMI) was calculated as body weight (kg) divided by body height squared (m2). In this study, we investigated the relationships between maternal age and body mass index with birth weight (BW), low birth weight, and macrosomia. LBW was defined as a BW less than 2500 g [16]. Macrosomia was defined as a birth weight greater than or equal to 4000 g, which is above the standard for birth weight [17].

Statistical analysis

In the descriptive analysis, continuous variables with a normal distribution are presented as means (± SDs), while categorical variables are shown as absolute frequencies and percentages. We used multivariate linear regression models to examine the relationships between maternal age, BMI, and birth outcomes, including birth weight, low birth weight, and macrosomia. All models were adjusted for factors such as place of residence, maternal anemia status, child's sex, place of delivery, highest education level, family wealth index, and antenatal care follow-up. Additionally, generalized additive models (GAMs) were employed to explore potential nonlinear relationships between maternal age, BMI, and the birth outcomes, adjusting for the same covariates as the linear regression models.All the statistical analyses were performed using SPSS software (version 25.0; SPSS, Chicago, IL), R software (version 3.4.3; R Foundation for Statistical Computing, Vienna, Austria), and the Statistical Analysis System (SAS) (version 9.1, SAS Institute Inc., Cary, NC).

Results

Characteristics of the participants

After applying the exclusion criteria, 2,110 newborns from the 2019 Ethiopian Demographic and Health Survey were included in the study. The exclusion criteria were as follows: missing birth weight data (N = 7,253), incomplete maternal information (N = 1,260), birth weight less than 1,000 g due to twin births (N = 13), and absence of maternal age information (N = 5). The selection process is illustrated in Figure 1.

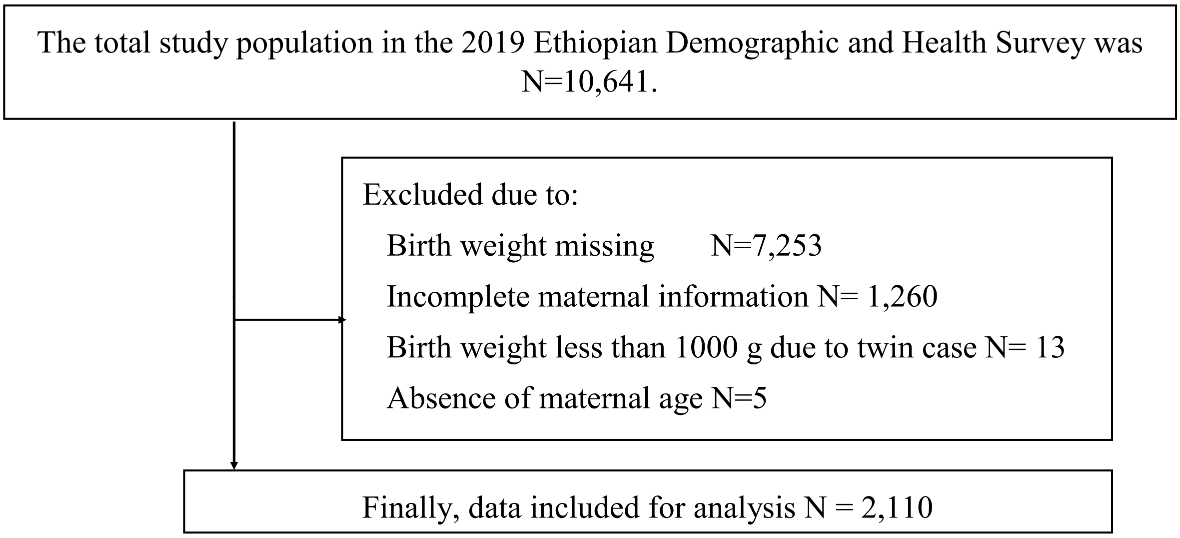

Figure 1: Flow diagram for the selection of new-borns in the study

The average age of the participants was 28.49 years. Overall, 60.47% of the participants were urban residents, while 39.53% were rural residents. Majority of the mothers (75.69%) were from a poor wealth index category. About 96% of the mothers have delivered at a health center. Among the neonates, the averages for BMI, BW, LBW, and macrosomia were 26.70 kg/m², 3,277.04 g, 1,919.59 g, and 4,880 g, respectively (Table 1). The majority of the mothers were free of anemia (69.05%). Only 0.38%, 5.12%, and 17.73% of the mothers had severe, moderate, and mild anemia, respectively.

Table 1: Characteristics of mothers and newborns included from the Ethiopian Demographic and Health Survey 2019 (EDHS).

Variables	Value
Age of mothers (years) †	28.49 (± 6.08)
Place of residence, n (%)	
Urban	1276 (60.47)
Rural	834 (39.53)
Mothers anemia status, n (%)	
Severe	8 (0.38)
Moderate	108 (5.12)
Mild	374 (17.73)
Not anemic	1457 (69.05)
Child of sex, n (%)	
Male	1078 (51.09)
Female	1032 (48.91)
Place of delivery, n (%)	
Home	76 (3.60)
Health center	2023 (95.88)
Education level, n (%)	
No education	564 (26.73)
Primary school	787 (37.30)
Secondary school	429 (20.33)
Higher	330 (25.64)
Wealth index of the family, n (%)	
Poor	1597 (75.69)
Mild	389 (18.44)
Rich	124 (5.88)
Body mass index (kg/m^2)†	26.70 (± 18.03)
Birth weight (in grams)†	3277.04 (± 829.92)
Low birth weight (in grams)†	1919.59 (± 827.82)
Macrosomia (in gram)†	4880.14 (± 820.20)

Mean ± standard deviation (SD)

Table 2 presents the results of the multivariate linear regression models for the predictors of birth weight, low birth weight, and macrosomia. After adjusting for place of residence, maternal anemia status, child's sex, place of delivery, highest education level, family wealth index, and antenatal care follow-up, we found that maternal age (β=6.375; P=0.032) was significantly associated with newborn birth weight. A one-year increase in maternal age was associated with a 6.375 g increase in newborn birth weight. Additionally, BMI was significantly associated with both birth weight (β=0.323) and macrosomia (β=-0.041) (Table 2; all $P < 0.05$). In this study, maternal age and BMI did not have a significant impact on low birth weight.

Table 2: The univariate and multivariable linear regression models on the associations of maternal age and body mass index (BMI) with birth weight, low birth weight, and macrosomia

Independent variable	Dependent variable	Univariate linear β (p)	Multivariable linear β (p)*
Maternal age	Birth weight	5.231 (0.001)	6.375 (**0.032**)
	Low birth weight	4.351 (0.372)	5.135 (0.210)
	Macrosomia	-0.291 (0.873)	-0.157 (0.977)
BMI	Birth weight	0.493 (0.001)	0.323 (**<.001**)
	Low birth weight	-0.007 (0.865)	-0.002 (0.901)
	Macrosomia	-0.039 (0.021)	-0.041 (**0.016**)

*β : cofficent of the regressors, p: p-value *Values were adjusted for place of residence, number of visits for antenatal care, education level of the mother, wealth index, smoking status, occupation of the mother, and place of birth.*

According to the generalized additive model, both maternal age and body mass index were positively and approximately linearly related to newborn birth weight (Figure 2). The relationship between body mass index and the birth weight of newborns seemed more linear than that between body mass index and maternal age.

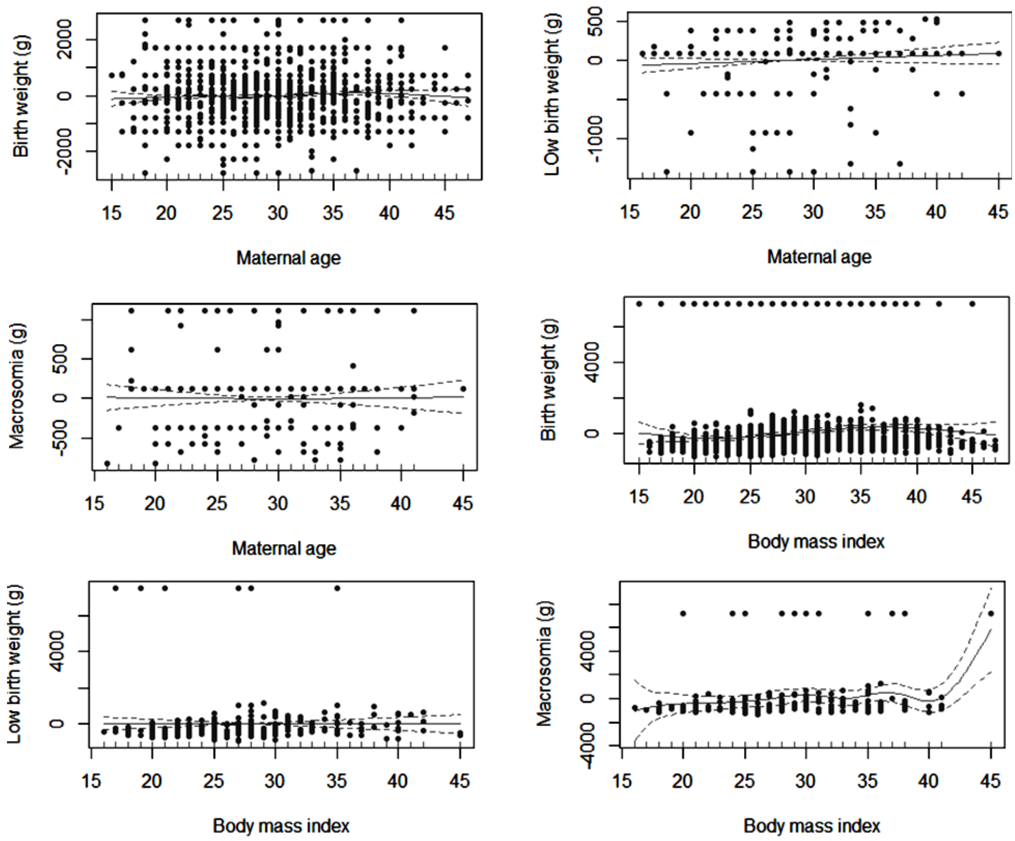

Figure 2: Plot from a generalized additive model on the relationship between maternal age and body mass index with birth weight, low birth weight, and macrosomia. The associations were adjusted for place of residence, mother's anemia status, child sex, place of delivery, education level of the mother, wealth index of the family, and antenatal care follow-up.

Discussion

In this population-based cross-sectional study, we found that advancing maternal age was linked to increased birth weight. Additionally, body mass index (BMI) was linearly related to both birth weight and macrosomia. These results enhance our understanding of how maternal age and BMI influence newborn birth weight.

Numerous studies have demonstrated that maternal age is linked to newborn birth weight. Research across various racial and ethnic groups in the U.S. indicates that mothers over the age of 30 are at higher risk of delivering babies with low birth weight [18, 19]. Similarly, teenagers (15-19 years) are at a significantly higher risk of delivering low birth weight babies compared to those of optimal childbearing age (25-29 years). Additionally, research indicates that advanced maternal age is an independent factor linked to both low birth weight and preterm birth outcomes [20]. Risk estimates for low birth weight associated with maternal age of 35 years were 5.3% (95% CI, 4.7-6.0) among African Americans, 4.3% (95% CI, 1.7-6.9) among Puerto Ricans, and 3.7% (95% CI, 2.8-4.5) among Mexican Americans, compared to 2.6% (95% CI, 2.4-2.7) in non-Hispanic whites [21].

Consistently, several studies have shown that preterm birth is a major cause of low birth weight. Elena et al. conducted a cross-sectional study involving more than 42,000 newborns and found that both maternal height and body mass index were significantly associated with newborn birth weight [22]. However, a previous report indicated that maternal age is an independent risk factor for preterm delivery [20, 23, 24]. A prospective cohort study of healthy women with a single pregnancy reported increasing adjusted odds ratios for preterm delivery with advancing maternal age, even after adjusting for demographic characteristics, smoking status, history of infertility, and other medical conditions [25]. In addition, a Swedish study involving 2,009,068 births revealed that advanced maternal age is associated with an increased risk of preterm birth, especially very preterm birth, regardless of parity. The adjusted odds ratios (ORs) were 1.18 to 1.28 for ages 30–34 years, 1.59 to 1.70 for ages 35–39 years, and 1.97 to 2.40 for ages 40 years and older [26]. Taken together, these findings indicate that preterm delivery is an independent factor affecting birth weight.

To the best of our knowledge, this is the first study to investigate both linear and potentially nonlinear relationships between maternal age and body mass index with birth weight, low birth weight, and macrosomia using linear regression and a generalized additive model, respectively. Our study yielded important findings: the relationships between maternal age and body mass index, as well as between birth weight and macrosomia, appeared to be linear.

The biological mechanisms underlying the relationship between BMI and birth weight remain unclear. However, some studies suggest that maternal BMI may directly influence fetal growth by affecting nutrient supply and hormone profiles [27, 28]. Obese women face adverse outcomes during pregnancy [29-31], and their fetuses have an increased risk of still-birth and birth defects. [32-35]. Fetal over-growth is common in pregnancies of women with an increased body mass index (BMI) and results in the birth of a large-for-gestational-age infant (typically defined as a birth weight greater than the 90th percentile). However, birth weight is also influenced by a combination of intrauterine, genetic, and environmental factors. In our study, we found that BMI was related to newborn birth weight, consistent with the findings of previous studies [22].

Some limitations should be noted. First, due to the cross-sectional design, we cannot determine the causation of low birth weight; we only assessed the associations between maternal age and BMI with birth weight. Second, although the Ethiopian Demographic and Health Survey data are nationally representative, the number of households with a history of birth is relatively small, which may partly affect our findings.

Conclusion

This study identified a linear relationship between maternal age and birth weight. Additionally, body mass index (BMI) showed a positive linear association with both birth weight and macrosomia. Specifically, each 1 kg/m^2 increase in BMI was linked to a 0.323 g increase in birth weight and a 0.509 g increase in macrosomia. This study recommends close monitoring of maternal age and BMI during pregnancy. Health care providers should focus on maintaining a healthy BMI to reduce risks of low birth weight and macrosomia and offer targeted support to older mothers to improve birth outcomes

Acknowledgments

I would like to thank the Demographic and Health Surveys (DHS) Program for providing the data.

Authors' contributions

Conceptualization of the study, analysis of the data, writing of the first draft, writing of a review, and editing were performed solely by TGC.

Funding: Not available

Competing interest: The authors declare no competing interests.

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