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Determinants of Low Birth Weight at Dr. Moewardi Hospital, Surakarta, Central Java, Indonesia

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ABSTRACT

Background: Low birth weight (LBW) is a major cause of infant and neonatal mortality in Indonesia. Data from the 2022 Nutritional Status Survey and the 2023 Indonesia Health Survey reported an increase in the prevalence of LBW from 5.9% to 6.1%. Records from Dr. Moewardi General Hospital, Indonesia, also show a rise in the number of LBW cases, from 392 cases in 2023 to 412 cases in 2024. This study examines the effects of maternal education, household income, antenatal care (ANC), anemia during pregnancy, preeclampsia, and chronic energy deficiency (CED) on the incidence of LBW at Dr. Moewardi hospital.

Subjects and Method: This quantitative study employed a case–control design. The research was conducted at Dr. Moewardi hospital and included 100 infants with low birth weight and 100 infants with normal birth weight, selected using fixed-disease and random sampling methods. The dependent variable was LBW. The independent variables were maternal education, household income, ANC, anemia during pregnancy, preeclampsia, and CED. Data were collected through questionnaires and medical records, and analyzed using simple logistic regression and path analysis.

Results: LBW was directly associated with maternal CED (b= 0.79; 95% CI= 0.08 to 1.51; p= 0.028), maternal anemia (b= 0.91; 95% CI= 0.17 to 1.65; p= 0.015), and preeclampsia (b= 1.45; 95% CI= 0.77 to 2.13; p < 0.001). LBW was indirectly influenced by ANC visits, family income, and maternal education. The path model demonstrated good fit indices (AIC= 1221.24; BIC= 1283.91).

Conclusion: LBW directly increases with maternal CED, maternal anemia, and preeclampsia. LBW indirectly affects by ANC visit, family income, and maternal education.

Keywords: low birthweight, antenatal care, anemia, preeclampsia, chronic energy deficiency

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BACKGROUND

Low birth weight (LBW) is defined as a birth weight of less than 2,500 grams measured within the first hour after delivery (Girotra et al., 2023). In 2020, the global prevalence of LBW was 14.7%, with regional estimates of 13.9% in Africa, 7.0% in Europe, 11.8% in Oceania, 17.2% in Asia, and 12.5% in Southeast Asia (UNICEF, 2023). According to the 2022 Indonesia Nutrition Status

Survey, the proportion of LBW in Indonesia was 5.9% (Ministry of Health of the Republic of Indonesia, 2022b). However, findings from the 2023 Indonesia Health Survey indicate that this proportion increased to 6.1% (Health Development Policy Agency, 2023).

Low birth weight (LBW) leads to various adverse physiological outcomes due to the instability of the infant's condition (Suwaibah et al., 2023). LBW is the leading cause of neonatal mortality (0–28 days), accounting for 5,154 deaths (Ministry of Health of the Republic of Indonesia, 2022a). In addition, LBW was the second leading cause of infant mortality in 2024, contributing to 24.4% of cases (DGKIA, 2023). Infants with LBW are highly susceptible to hypothermia, which may progress to hypoxia and tachycardia (Rohmah et al., 2020). LBW also results in impaired growth, increased susceptibility to infections, long-term physical and cognitive disorders, and a heightened risk of chronic diseases (Zaveri et al., 2020).

LBW commonly occurs in developing countries with low socioeconomic conditions. Each year, more than 20 million infants are born with LBW, and over 96.5% of these cases occur in low-income countries (Bekela et al., 2020). Families with lower economic status often have limited access to health care and adequate nutrition, both of which are essential for optimal fetal growth (Syahrir et al., 2024). Mothers with low income are more likely to deliver infants with LBW compared to those with higher income. Conversely, higher socioeconomic status facilitates financial ability to access antenatal care services more easily (Sundani, 2020).

Socioeconomic status also influences the ability to purchase adequate food to meet the nutritional needs of pregnant women and their fetuses (Handayani et al., 2024). Pregnant women experiencing chronic energy deficiency (CED) are at risk of impaired fetal development, which increases the likelihood of delivering an infant with low birth weight (LBW) (Rahayu & Sagita, 2019). Adequate nutritional intake, particularly iron, is essential during pregnancy. Insufficient iron consumption can lead to anemia (Wagiyo & Putrono, 2016), which may result in intrauterine growth restriction and ultimately LBW (Abu-Ouf & Jan, 2015). Mothers with anemia have a higher likelihood of giving birth to LBW infants compared to non-anemic mothers (Rahmawati et al., 2020). In Surakarta, the leading causes of obstetric complications in 2023 were anemia (46%) and CED (31%) (Surakarta City Health Office, 2023).

LBW is also affected by pregnancy complications such as preeclampsia, characterized by hypertension and proteinuria (Zainiyah & Harahap, 2023). Mothers with preeclampsia have a higher probability of delivering LBW infants compared to those without the condition (Aulia & Aisyah, 2019). In Central Java, the three most common causes of obstetric complications in 2023 were CED (54,947 cases), anemia (46,634 cases), and preeclampsia (13,991 cases) (Central Java Provincial Health Office, 2023). Additionally, preeclampsia ranked fifth as a cause of obstetric complications in Surakarta, accounting for 2% of cases (Surakarta City Health Office, 2023).

One of the Ministry of Health's key programs for preventing pregnancy complications is antenatal care (ANC). According to Regulation of the Minister of Health No. 21 of 2021, ANC should be conducted at least six times (K6), with a minimum of one visit to a physician during both the first and third trimesters (Ministry of Health of the Republic of Indonesia, 2021). Irregular ANC attendance, particularly failure to meet the 4th ANC visit standard, is associated with a

higher risk of delivering infants with low birth weight (Yuwana et al., 2022). However, research examining compliance with the 6th-visit of ANC standard remains limited.

The national target in 2023 was for 80% of pregnant women to receive ANC six times. Nevertheless, the reported achievement in 2023 reached only 73.57%, falling short of the target (Maternal and Child Health Movement, 2023).

Antenatal care (ANC) utilization can be influenced by maternal education. Low maternal education may lead to limited understanding of the availability, accessibility, and importance of ANC services. Conversely, women with higher education levels tend to possess better knowledge of reproductive health, pregnancy maintenance, and prenatal care, enabling them to more readily access and utilize health services (Barman et al., 2020). In addition, mothers with low education levels may show less concern for fetal health and are more likely to attend ANC irregularly, increasing the risk of pregnancy complications and the likelihood of delivering infants with low birth weight (LBW) (Handayani et al., 2024). According to national education statistics, the majority of Indonesians aged 15 years and older have not completed the 12-year compulsory education program (58.95%) (Directorate of Social Welfare Statistics, 2024b).

According to the 2022 Nutrition Survey, the proportion of LBW in Central Java was 6.6% (Ministry of Health, 2022). Meanwhile, data from the 2023 Indonesia Health Survey indicated an LBW proportion of 6.1% in Central Java (Health Development Policy Agency, 2023). An increase in LBW cases was also observed in Surakarta, rising from 213 cases in 2021 to 302 cases in 2023 (Directorate of Social Welfare Statistics, 2024a).

Dr. Moewardi Hospital, located in Surakarta, serves as a referral hospital for patients from Central Java and the western region of East Java. Medical records from Dr. Moewardi Hospital show that the number of LBW cases increased from 392 cases in 2023 to 412 cases in 2024. Based on this evidence, the researchers were motivated to conduct a study titled "Determinants of Low Birth Weight at Dr. Moewardi Hospital".

SUBJECTS AND METHOD

1. Study Design

This was a case control study carried out at Dr. Moewardi Hospital, Surakarta, Central Java, Indonesia, on April to May 2025.

2. Population and Sample

The population in this study consisted of all infants born at Dr. Moewardi Hospital between January 2023 and March 2025. The study sample included 200 infants, comprising 100 infants with LBW and 100 infants with normal birth weight. The sampling technique employed was fixed disease sampling, with samples for both case and control groups selected using random sampling.

3. Study Variables

The dependent variable was low birth weight (LBW). The independent variables included maternal education, family income, ANC, anemia during pregnancy, preeclampsia, and chronic energy deficiency.

4. Operational Definition of Variables

Maternal Education: The mother's highest level of education based on her most recent diploma or certificate.

Family Income: Total monthly income received by the family, measured in monetary terms.

Antenatal Care: Pregnancy monitoring program conducted from conception until before delivery.

Anemia During Pregnancy: A condition in which maternal hemoglobin (Hb) levels fall below 11 g/dL in the first and third trimesters, and below 10.5 g/dL in the second trimester.

Preeclampsia: A pregnancy disorder occurring at ≥20 weeks of gestation, characterized by systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg, and proteinuria of 1+ on a dipstick test.

Chronic Energy Deficiency: Long-term deficiency of macro- and micronutrients, assessed using mid-upper arm circumference (MUAC <23.5 cm).

Low Birth Weight: Weight of a newborn measured within 1 hour after birth, with a weight of less than 2,500 grams.

5. Study Instruments

Data on maternal education, family income, and antenatal care (ANC) were collected using questionnaires. Data on anemia, preeclampsia, chronic energy deficiency (CED), and low birth weight (LBW) were obtained from the medical records of Dr. Moewardi Hospital.

6. Data analysis

Univariate analysis was used to describe the frequency distribution of sample characteristics. Bivariate analysis was conducted using simple logistic regression to examine the relationship between independent and dependent variables. Multivariate analysis was performed using path analysis to assess both the direct and indirect relationships between independent and dependent variables.

7. Research Ethics

Research ethics considerations, including informed consent, anonymity, and confidentiality, were carefully addressed throughout the study process. Ethical approval for this research was obtained from the Research Ethics Committee of Dr. Moewardi Hospital, Surakarta, Indonesia (No. 626/III/HREC/2025), dated April 8, 2025.

RESULTS

1. Sample Characteristics

Table 1 presents numerical data showing that the 200 respondents had a mean age of 30 years, ranging from 18 to 45 years. The mean MUAC was 26.32 cm, with a minimum of 18.9 cm and a maximum of 45 cm. The mean hemoglobin (Hb) level was 11.04 g/dL, ranging from 6 g/dL to 14.7 g/dL. The average number of ANC visits was eight, with a minimum of three and a maximum of fifteen visits. The mean birth weight of infants was 2,500.3 grams, ranging from 985 grams to 3,900 grams.

Table 1. Sample characteristics (continous data)

Variables	Mean	SD	Min.	Max.
Maternal age (years old)	30.23	5.42	18	45
Maternal MUAC (cm)	26.32	4.66	18.9	45
Maternal hemoglobin level (g/dL)	11.04	1.36	6	14.7
ANC visit	8.18	2.37	3	15
Infants birthweight (g)	2,500.3	644.49	985	3,900

Table 2 presents categorical data showing that the majority of samples were from Central Java (89.5%). Most mothers worked as employees (37%), and most husbands were employed as workers (58%). The majority of mothers received ANC during the first trimester (1st ANC visit) from both midwives and doctors (41%), during the second trimester (2nd ANC visit) from both midwives and doctors (42%), and during the third trimester (3rd ANC visit) from both midwives and doctors (86%).

Table 2. Sample characteristics (categorical data)

Variable	Category	Frequency (n)	Percentage (%)
Province of residence	Central Java	179	89.5
	East Java	13	6.5
	Yogyakarta	2	1
	West Java	3	1.5
	Jakarta	1	0.5
	South Sulawesi	1	0.5
	Central Papua	1	0.5
Maternal employment	Housewives	73	36.5
	Entrepreneurs	38	19
	Laborers	5	2.5
	Farmers	1	0.5
	Civil servant	74	37
	Health workers	9	4.5
Paternal employment	Entrepreneurs	57	28.5
	Laborers	18	9
	Farmers	5	2.5
	Civil servant	116	58
	Health workers	4	2
1st ANC visit	No ANC visit	37	18.5
	Midwife	74	37
	Medical doctor	7	3.5
	Midwife and medical doctor	82	41
2nd ANC visit	No ANC visit	9	4.5
	Midwife	80	40
	Medical doctor	27	13.5
	Midwife and medical doctor	84	42
3rd ANC visit	Medical doctor	28	14
	Midwife and medical doctor	172	86

2. Univariate Analysis

Descriptive analysis of the independent and dependent variables was conducted using categorical data, presented as frequencies and percentages. Table 3 shows that the majority of mothers had a high level of education (60%), high family income (50.5%), inadequate antenatal care (ANC) visits (56%), experienced anemia during pregnancy (51%), did not experience preeclampsia (51.5%), and did not suffer from chronic energy deficiency (CED) (56%).

Table 3. Univariate Analysis

Variables	Category	Frequency (n)	Percentage (%)
Maternal education	Low (<Senior high school)	80	40
	High (≥Senior high school)	120	60
Family income	Low (<Rp. 3,300,000)	99	49.5
	High (≥Rp. 3,300,000)	101	50.5
Antenatal care	Irregular	112	56
	Regular	88	44
Anemia in pregnancy	No	98	49
	Yes	102	51
Preeclampsia in pregnancy	No	103	51.5
	Yes	97	48.5

Variables	Category	Frequency (n)	Percentage (%)
CED	Normal (MUAC ≥23.5 cm)	112	56
	CED (MUAC <23.5 cm)	88	44
LBW	Normal weight (2,500-4,000 g)	100	50
	LBW (<2,500 g)	100	50

3. Bivariate Analysis

Table 4 shows that the risk of LBW in infants decreased with higher maternal education (OR= 0.29; 95% CI= 0.16 to 0.54; p <0.001), higher family income (OR= 0.33; 95% CI= 0.18 to 0.58; p <0.001), and regular ANC visits (OR= 0.31; 95% CI= 0.17 to 0.55; p <0.001).

Conversely, the risk of LBW in infants increased with maternal anemia during pregnancy (OR= 5.99; 95% CI= 3.25 to 11.05; p <0.001), maternal preeclampsia during pregnancy (OR= 6.96; 95% CI= 3.58 to 12.97; p <0.001), and maternal CED (OR= 4.22; 95% CI= 2.32 to 7.68; p <0.001).

Table 4. Bivariate Analysis of Factors Associated with Low Birth Weight

Independent variables	Normal birthweight		Low birth-weight		OR	95% CI		p
	N	%	N	%		Lower Limit	Upper Limit	
Maternal education								
Low	26	32.5	54	67.5	0.29	0.16	0.54	<0.001
High	74	61.5	46	38.3				
Family income								
Low	36	36.3	63	63.4	0.33	0.18	0.58	<0.001
High	64	63.3	37	36.6				
ANC visit								
Irregular	42	37.5	70	62.5	0.31	0.17	0.55	<0.001
Regular	58	65.9	30	34				
Anemia in pregnancy								
No	70	71.4	28	28.5	5.99	3.25	11.05	<0.001
Yes	30	29.4	72	70.5				
Preeclampsia								
No	74	71.8	29	28.1	6.96	3.58	12.97	<0.001
Yes	26	26.8	71	73.2				
CED								
No	73	65.1	39	34.8	4.22	2.32	7.68	<0.001
Yes	27	30.6	61	69.3				

4. Multivariate Analysis

Figure 1 illustrates the path analysis model, depicting both the direct and indirect effects among variables. The exogenous variable is maternal education, while the endogenous variables include family income, antenatal care (ANC), anemia during pregnancy, pre-eclampsia, chronic energy deficiency (CED), and low birth weight (LBW). The path diagram indicates a good model fit (AIC= 1221.24; BIC= 1283.91).

Table 5 shows that LBW is directly influenced by anemia during pregnancy, preeclampsia, and CED. In addition, LBW is indirectly affected by maternal education, family income, ANC, anemia during pregnancy, and CED.

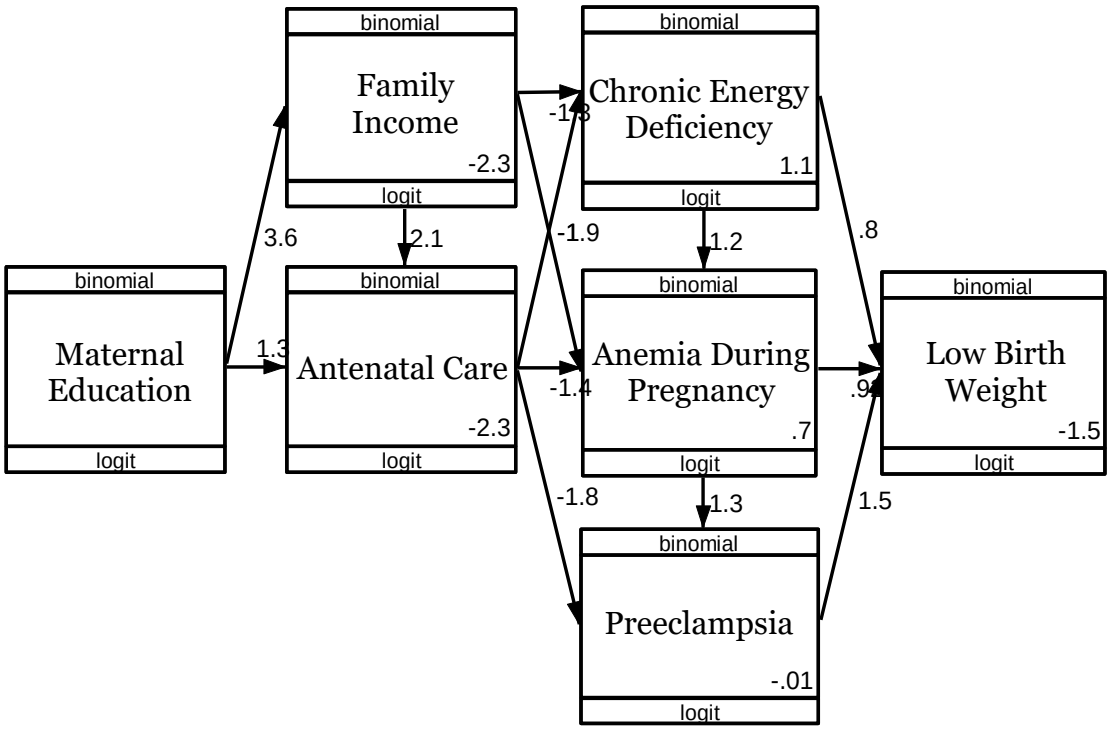

Figure 1. Path analysis model estimating the effects of maternal education, family income, ANC, anemia during pregnancy, preeclampsia, and CED on LBW

Table 5 shows that the risk of low birth weight (LBW) in infants increases directly among mothers with anemia during pregnancy (b= 0.91; 95% CI= 0.17 to 1.65; p= 0.015), chronic energy deficiency (CED) during pregnancy (b= 0.79; 95% CI= 0.08 to 1.51; p= 0.028), and a history of preeclampsia (b= 1.45; 95% CI= 0.77 to 2.13; p < 0.001).

The risk of low birth weight (LBW) in infants was indirectly associated with maternal education, family income, and antenatal care (ANC). Preeclampsia in mothers during pregnancy increased with anemia (b= 1.31; 95% CI= 0.60 to 1.95; p = 0.003) but decreased with regular ANC visits (b= -1.77; 95% CI = -2.50 to -1.03; p < 0.001).

Anemia in mothers during pregnancy was negatively associated with regular ANC visits (b= -1.42; 95% CI= -2.23 to -0.62; p <0.001) and higher family income (b= -1.03; 95% CI= -1.81 to -0.25; p= 0.010).

Maternal chronic energy deficiency was reduced by regular ANC visits (b= -1.94; 95% CI= -2.75 to -1.13; p < 0.001) and higher family income (b= -1.29; 95% CI= -2.04 to -0.54; p= 0.001).

ANC visits were positively associated with higher family income (OR= 2.08; 95% CI= 1.23 to 2.92; p < 0.001) and higher maternal education (OR= 1.30; 95% CI= 0.37 to 2.23; p= 0.006). Family income increased with higher maternal education (b= 3.62; 95% CI = 2.74 to 4.51; p < 0.001)

Tabel 5. Path analysis of the effects of maternal education, family income, antenatal care, pregnancy anemia, preeclampsia, and chronic energy deficiency on low birth weight

Dependent Variable	Independent Variable	b	95% CI		p
			Lower Limit	Upper Limit	
Direct Effect					
Low birthweight	← Anemia in pregnancy	0.91	0.17	1.65	0.015
	← Preeclampsia	1.45	0.77	2.13	<0.001
	← CED	0.79	0.08	1.51	0.028
Indirect Effect					
Preeclampsia	← Anemia in pregnancy	1.31	0.6	2.02	<0.001
	← ANC	-1.77	-2.5	-1.03	<0.001
Anemia in pregnancy	← CED	1.18	0.41	1.95	0.003
	← ANC	-1.42	-2.23	-0.62	<0.001
	← Family income	-1.03	-1.81	-0.25	0.010
CED	← ANC	-1.94	-2.75	-1.13	<0.001
	← Family income	-1.29	-2.04	-0.54	0.001
ANC	← Family income	2.08	1.23	2.92	<0.001
	← Maternal education	1.30	0.37	2.23	0.006
Family income	← Maternal education	3.62	2.74	4.51	<0.001

DISCUSSION

Education serves as a foundation for imparting knowledge that shapes individuals' attitude and positive character, including health-related behaviors (Zainiyah and Harahap, 2023). Maternal education influences a mother's perceptions and behaviors in planning childbirth optimally (Septikasari, 2020). Behaviors developed through long-term education affect healthy lifestyle patterns during pregnancy preparation and childbirth (Handayani et al., 2024). Therefore, maternal education acts as a protective factor against LBW in infants (Diabelková et al., 2022). Kuswandari et al. (2020) also reported that mothers with low education have a 1.5-fold higher risk of delivering an infant with LBW compared to mothers with higher education.

Higher education increases the likelihood of obtaining employment and thereby raising family income (Christiani, 2023). Low income reduces purchasing power, which can compromise maternal nutrition during pregnancy and increase the risk of delivering a LBW infant (Handayani et al., 2024). Mothers with lower education may perceive pregnancy as a natural process, leading them to neglect ANC and other pregnancy-related health services (Khayati et al., 2016). Conversely, higher education enables mothers to better understand their pregnancy conditions, encouraging regular ANC visits to minimize complications that could affect the risk of LBW (Agustini et al., 2023). Thus, higher maternal education can reduce the risk of delivering an LBW infant through its positive effects on family income and ANC quality.

Family income determines the quality and quantity of maternal nutrition during pregnancy (Sundani, 2020). Low family income makes it difficult to provide nutritious food (Akbarini and Siswina, 2022). Inadequate maternal nutrition can impair fetal growth and development (Supriyatun, 2020). Conversely, higher family income allows for sufficient intake of calories and protein, helping to prevent CED (Akbarini and Siswina, 2022). CED can hinder fetal

development and affect birth weight (Nuraeni et al., 2024). Low family income also increases the likelihood of consuming iron-poor foods, raising the risk of maternal anemia (Bansal et al., 2020). Anemia reduces placental function, increasing the risk of delivering a LBW infant (Irgi et al., 2025). Therefore, higher family income supports adequate maternal nutrition, preventing CED and anemia, which in turn reduces the risk of LBW (Rahayu and Sagita, 2019).

Low family income increases barriers to prioritizing health needs, often leading to neglected utilization of ANC services (Lumempouw et al., 2016). In contrast, higher family income enables mothers to afford healthcare services and transportation costs to access these services (Kahasse and Alemayehu, 2017). Adequate ANC aims for early detection and management of pregnancy complications that may increase the risk of delivering a LBW infant (Sadarang, 2022). ANC visits are typically conducted six times, with at least one visit to a physician during the first and third trimesters. Physician visits, including ultrasound examinations, are used to screen for pregnancy risk factors, plan delivery, and provide referrals when necessary. Midwife visits focus on early detection of risk factors, obstetric complications, and nutritional issues (Ministry of Health of the Republic of Indonesia, 2021). The more frequently a mother attends ANC, the greater the range of 10T services she receives, enhancing maternal and fetal health outcomes (Astuti and Dhesi, 2025).

The 10T ANC services, including blood pressure and proteinuria checks, aim to prevent preeclampsia (Ministry of Health of the Republic of Indonesia, 2021). During ANC visits, midwives can monitor adequate folic acid intake, which helps reduce the risk of preeclampsia (Liu et al., 2021). Preeclampsia screening during ANC also serves as a basis for referring at-risk mothers to hospitals (Ministry of Health of the Republic of Indonesia, 2024). Consequently, mothers can promptly receive secondary prevention measures, such as aspirin administration, calcium supplementation, vitamins C and E, and dietary monitoring with salt restriction (Indonesian Society of Obstetricians and Gynecologists, 2016). Thus, adequate ANC can prevent preeclampsia and reduce the risk of delivering a LBW infant (Oktarina et al., 2019).

In addition, hemoglobin (Hb) testing and iron supplementation are conducted during ANC visits to monitor and prevent anemia (Nurmasari and Sumarmi, 2019). Mothers who attend ANC receive iron tablets according to their needs, thereby increasing iron intake and improving Hb levels (Rohani et al., 2023). Low Hb levels or anemia increase the risk of delivering a LBW infant (Abu-Ouf & Jan, 2015). The 10T ANC examination also includes measuring MUAC to identify nutritional problems such as CED. The ANC program helps pregnant women understand the importance of consuming a diverse and balanced diet to support optimal fetal growth and development (Ministry of Health of the Republic of Indonesia, 2021). Nutritional interventions are also provided in the form of supplementary feeding made from local food sources. Pregnant women with CED who attend ANC become eligible for the supplementary feeding program, which improves nutritional status and reduces the risk of delivering an LBW infant (Ministry of Health of the Republic of Indonesia, 2023).

Chronic energy deficiency (CED) is a condition characterized by a prolonged lack of energy intake from macronutrients such as carbohydrates, proteins, and fats, as well as micronutrients including vitamin A,

vitamin D, iron, calcium, folic acid, zinc, and iodine (Norviatin et al., 2022). The primary parameter for detecting CED is a mid-upper arm circumference (MUAC) measurement of less than 23.5 cm (Wandini et al., 2024). Pregnancy increases maternal energy requirements to support both the mother and the developing fetus (Mijayanti et al., 2020). During the second trimester, energy is needed for blood volume expansion, uterine development, and fat storage (Nuraeni et al., 2024). In the third trimester, additional energy is required for placental development and fetal growth. Nutritional deficiencies beginning in early pregnancy or the first trimester can adversely affect fetal growth and development (Mulianisaa et al., 2021).

The energy requirement for non-pregnant women is approximately 2,500 kcal per day. However, during pregnancy, additional energy intake is needed—about 180 kcal per day in the first trimester, and 300 kcal per day in the second and third trimesters. This increased energy should come from macronutrients such as carbohydrates, fats, and proteins (Nisar et al., 2016). In addition to macronutrients, micronutrient intake is also essential during pregnancy, including vitamins and minerals such as folic acid, vitamin D, calcium, iodine, zinc, and iron. Therefore, consuming a variety of foods that meet both macronutrient and micronutrient needs is crucial to support optimal fetal growth and development (Nasriyah and Ediyono, 2023).

Chronic energy deficiency (CED) leads to a reduction in blood volume and cardiac output, accompanied by decreased quantity and quality of nutrient transfer through the placenta. Consequently, the placenta becomes smaller in size, limiting the mother's ability to supply adequate nutrients to the fetus. These placental changes cause hypoxia, which reduces blood circulation to the fetus. As a result, fetal growth and development are impaired, leading to a higher risk of low birth weight (Nuraeni et al., 2024). Infants born to mothers with CED during pregnancy are also more susceptible to infections due to immature immune function and are at risk of delayed motor development (Sumiati et al., 2021).

Food intake is a key factor contributing to chronic energy deficiency (CED). The typical Indonesian diet tends to be high in fiber, which can inhibit iron absorption (Nasriyah and Ediyono, 2023). Deficiencies in protein, energy, and micronutrients—particularly iron and folic acid—are major nutritional problems that lead to iron-deficiency anemia due to the increased iron requirements during pregnancy (Getaneh et al., 2021). Pregnant women with CED often have poor dietary patterns, resulting in insufficient intake of protein and vitamins. This imbalance disrupts metabolism and inhibits hemoglobin synthesis, ultimately causing anemia (Nur et al., 2020). If left untreated, anemia can impair fetal growth and development and increase the risk of low birth weight (Abu-Ouf and Jan, 2015). Women with anemia are three times more likely to deliver low-birth-weight infants compared to those without anemia (Susanti et al., 2021).

Anemia, defined as a decrease in maternal hemoglobin (Hb) levels to below 11 g/dL during the first and third trimesters and below 10.5 g/dL during the second trimester (Sepduwiana and Sutrianingsih, 2017), often occurs due to inadequate intake of iron-rich foods, insufficient supplementation, or impaired iron absorption (Wagiyo and Putrono, 2016). Anemia leads to fetal hypoxia, which stimulates the release of corticotrophin hormone, thereby reducing placental blood flow and impairing placental function. Repeated episodes of reduced placental function can restrict fetal growth, increasing the risk of low birth weight

(Amiruddin et al., 2022). Fetal hypoxia also decreases fat and glycogen stores, leading to hypoglycemia. Consequently, levels of Insulin-like Growth Factor-1 (IGF-1), which supports protein and glycogen synthesis as well as brain and neuronal development, decline. Reduced IGF-1 concentrations slow fetal growth rates and heighten the likelihood of low birth weight (Syafiqoh et al., 2021).

A decrease in hemoglobin levels leads to placental hypoxia, which restricts trophoblast invasion to the proximal decidua and results in incomplete spiral artery remodeling. This condition causes vasoconstriction of the spiral artery lumen, leading to increased blood pressure. Therefore, low hemoglobin levels are considered one of the key factors contributing to preeclampsia (Correa et al., 2016). Preeclampsia is characterized by systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg, and proteinuria of ≥1+ on dipstick testing (Pratiwi et al., 2024). It arises from abnormal placentation and reduced placental blood flow, which trigger the release of pro-inflammatory and anti-angiogenic proteins. These processes lead to endothelial dysfunction, resulting in the clinical manifestations of preeclampsia, including hypertension and proteinuria (Bisson et al., 2023).

High blood pressure can damage the glomerular capillaries and impair kidney function, leading to elevated protein levels in the urine. This occurs due to increased vascular resistance (Mutiara et al., 2018). In addition, constriction of the afferent arterioles causes damage to the glomerular membrane, increasing its permeability to proteins and resulting in proteinuria during pregnancy (Santoso et al., 2020). Preeclampsia also reduces uteroplacental blood flow, leading to placental hypoxia and ischemia. These conditions can cause fetal complications such as oligohydramnios (reduced amniotic fluid), IUGR, and an increased risk of LBW (Bisson et al., 2023).

AUTHOR CONTRIBUTION

All authors have made significant contributions to the data analysis and preparation of the final manuscript.

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CONFLICT OF INTEREST

There are no conflicts of interest.

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