

Maternal Risk Factors for Low Birth Weight: A Case-Control Study

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ABSTRACT

Low birth weight (LBW) remains a leading cause of neonatal morbidity and mortality, with the burden concentrated almost entirely in low- and middle-income countries. National data from Indonesia show that LBW prevalence remains above the Sustainable Development Goals target, with considerable variation across regions. This study identified maternal risk factors associated with LBW in the service area of the Yosomulyo Community Health Center. We conducted an observational analytical study with a retrospective case-control design involving 78 mothers who had given birth (39 LBW cases and 39 non-LBW controls). The analysis included univariate analysis, bivariate tests (Chi-Square/Fisher's Exact and independent t-tests), and multiple logistic regression on 77 respondents with complete data after the iron tablet intake data were supplemented. Bivariate analysis showed that anemia, chronic energy deficiency (CED), hyperemesis gravidarum, and iron (Fe) tablet intake patterns were significantly associated with LBW ($p < 0.05$). Multivariate analysis showed that anemia (adjusted OR 47.14; 95% CI 6.72–330.62; $p < 0.001$), CED (adjusted OR 10.06; 95% CI 1.40–72.58; $p = 0.022$), and hyperemesis gravidarum (adjusted OR 6.61; 95% CI 1.03–42.63; $p = 0.047$) were independently associated with LBW, whereas regular iron tablet intake showed a protective association (adjusted OR 0.026; 95% CI 0.001–0.604; $p = 0.023$). The model had good fit (Hosmer-Lemeshow $p = 0.588$) and a classification accuracy of 90.9%. Anemia, CED, and hyperemesis gravidarum are the primary maternal factors associated with LBW in the study area, whereas adherence to iron tablet intake showed a protective association. Strengthening the early detection and management of anemia and CED in pregnant women, along with improving adherence to iron tablet intake through counseling and active monitoring by healthcare workers, should be prioritized to reduce the incidence of LBW.



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INTRODUCTION

Low birth weight (LBW), defined as a birth weight of less than 2,500 g regardless of gestational age, is one of the most important predictors of morbidity and mortality during the neonatal period and of long-term adverse effects on child growth and development. The latest global estimates indicate that the proportion of infants born with LBW remains far from the World Health Assembly target of a 30% reduction by 2030, with the burden disproportionately concentrated in low- and middle-income countries, including those in Asia (Okwaraji et al., 2024). The World Health Organization has long designated the reduction of LBW as a global nutrition target because of its contribution to neonatal mortality and the risk of noncommunicable diseases in adulthood (World Health Organization, 2014).

In Indonesia, the Indonesian Health Survey reported that nutritional and health problems among pregnant women, including anemia and chronic energy deficiency (CED), remain significant public health challenges and contribute to adverse pregnancy outcomes, including LBW (Kementerian Kesehatan RI, 2024). At the provincial level, a study of LBW determinants at

Demang Sepulau Raya Regional Hospital in Central Lampung also confirmed the important role of maternal factors in LBW in this region (Ningrum et al., 2021). Consequently, local-data studies conducted in the catchment areas of primary health care facilities are relevant for planning more targeted interventions.

Studies conducted in various regions of Indonesia have consistently identified maternal anemia as a risk factor for LBW, although the magnitude of the association varies across regions and research methods (Novianti & Aisyah, 2018; Anjani et al., 2024; Nurrahmaton, 2019; Rahmah & Karjadidjaja, 2020; Firdaus et al., n.d.; Koerniawati, 2022). Anemia is thought to impair placental oxygen and nutrient transfer, thereby restricting intrauterine fetal growth. Chronic energy deficiency (CED), indicated by a mid-upper arm circumference (MUAC) below 23.5 cm, has also been associated with an increased risk of LBW in case-control and cross-sectional studies in Indonesia, because maternal nutritional status before and during pregnancy determines the energy reserves available for fetal growth (Ermawan, 2016; Maifita, 2023; Andriani, 2023; Yulianti, 2025; Sumini, 2018; Fatimah, 2019).

Other factors, including hyperemesis gravidarum, advanced maternal age, and iron tablet consumption, may interact with nutritional status and anemia. Severe hyperemesis or hyperemesis requiring hospitalization has been associated with an increased risk of adverse birth outcomes, although findings have not been consistent across studies (Fiaschi et al., 2018; Jansen et al., 2023; Petry et al., 2018; Porgador et al., 2024). Advanced maternal age has been associated with LBW in several population studies, although part of this association may be explained by coexisting health conditions and family-related factors (Goisis et al., 2017; Kanmaz et al., 2019; Wu et al., 2019). Iron-folic acid supplementation benefits maternal hematologic status and may improve neonatal outcomes; however, its effect depends on adherence and the quality of antenatal care (Agegehu et al., 2019; Fatimatasari et al., 2013; Gebreamlak et al., 2017; Srivastava et al., 2025).

Evidence from different settings indicates that the patterns and magnitudes of associations between maternal factors and LBW may vary according to population characteristics and local health services (Abera et al., 2019; Adane & Dachew, 2018; Ahmed et al., 2018; Sebayang et al., 2012). Local evidence that examines multiple factors simultaneously is needed to establish service priorities and avoid conclusions based solely on bivariate associations. Therefore, this study aimed to analyze maternal factors associated with LBW in the catchment area of Yosomulyo Primary Health Care Center using a case-control approach and multivariable logistic regression.

METHOD

This observational analytic study used a retrospective case-control design and was conducted in the catchment area of Yosomulyo Primary Health Care Center, Metro City, Lampung, Indonesia. The study population comprised all 429 mothers of children aged 0–59 months who were registered at integrated health posts in the catchment area of Yosomulyo Primary Health Care Center; 65 mothers were included in the case population. The study sample consisted of 78 mothers: 39 cases, defined as mothers who delivered infants weighing <2,500 g, and 39 controls, defined as mothers who delivered infants weighing ≥2,500 g.

A two-stage sampling procedure was used to select participants. In the first stage, purposive sampling was applied based on inclusion and exclusion criteria. Inclusion criteria were: mothers and children willing to participate as respondents; children aged 0–59 months; children born at term (for both the LBW and non-LBW groups); mothers and children residing in the catchment area of Yosomulyo Primary Health Care Center; and mothers and children with complete Maternal and Child Health (KIA) handbook records. Exclusion criteria were: mothers or children with chronic illness or congenital anomalies, and mothers unable to communicate adequately (e.g., hearing impairment). In the second stage, eligible mothers were selected using simple random sampling (lottery) within each *kelurahan* (sub-district) in proportion to the eligible cases and controls available, yielding 39 cases and 39 controls (1:1 ratio) distributed across three *kelurahan*: Yosomulyo (14 cases, 14 controls), Hadimulyo Barat (11 cases, 11 controls), and

Hadimulyo Timur (14 cases, 14 controls). Respondents who did not attend the scheduled integrated health post (Posyandu) session were visited at home by the researcher to complete the interview and review the KIA handbook.

Primary data were obtained through respondent interviews, whereas secondary data were obtained from Maternal and Child Health handbooks and relevant health records. The dependent variable was LBW status. The principal candidate maternal factors were maternal age, anemia (hemoglobin [Hb] level <11 g/dL), chronic energy deficiency (CED; mid-upper arm circumference [MUAC] <23.5 cm), hyperemesis gravidarum, and adherence to iron tablet consumption; preeclampsia and antepartum hemorrhage were treated as additional candidates.

Adherence to iron tablet consumption was operationally defined as a mother's adherence to taking iron-folic acid (Fe) tablets during pregnancy as recommended by health workers, i.e., consuming at least 90 tablets at a rate of one tablet per day from the time pregnancy was identified until the postpartum period, as recorded in the KIA handbook or Fe-tablet distribution card. This variable was assessed through observation and interview and classified into three categories: regular (≥ 90 tablets, taken consistently according to the recommended dose and schedule), occasional (<90 tablets and/or taken inconsistently), and none (never consumed iron tablets during pregnancy).

Antenatal care (ANC) attendance, premature rupture of membranes (PROM), and congenital anomalies showed no variation across the sample; therefore, they were presented descriptively but were not included in the bivariate or multivariable analyses.

The analyses were conducted in stages. Univariate analysis summarized categorical variables as frequencies and percentages and numerical variables as means, standard deviations (SDs), medians, minima, and maxima. Bivariate analysis used the chi-square test to compare LBW proportions across maternal-factor categories, with Fisher's exact test used when a cell in a 2×2 table had an expected count <5 . Odds ratios (ORs) and 95% confidence intervals (CIs) were reported for each dichotomous variable; the Haldane–Anscombe correction was planned for zero-count cells. Independent-samples t-tests were used to compare mean maternal age, Hb level, and MUAC between the LBW and non-LBW groups. Variables with $p < 0.25$ in bivariate analysis and/or those considered theoretically important were considered for the multivariable model, taking into account the number of events per parameter and potential multicollinearity. Preeclampsia and antepartum hemorrhage were excluded from the main model because of their very low frequencies, three and six participants, respectively, which could produce unstable estimates.

Multivariable analysis was performed using multiple logistic regression with the enter method and the Newton–Raphson algorithm. LBW status was specified as the dependent variable, while at-risk maternal age, anemia, CED, hyperemesis gravidarum, and adherence to iron tablet consumption were entered as predictors; no iron tablet consumption was the reference category. Following verification and completion of the iron-consumption dataset against the original Fe-tablet distribution records, iron-consumption data became available for all 78 participants. One participant had missing data on hyperemesis gravidarum status and was excluded through complete-case analysis, leaving 77 participants in the multivariable model. Results are reported as adjusted odds ratios (aORs), 95% CIs, and p-values. Model fit was evaluated using the Hosmer–Lemeshow test and McFadden's pseudo- R^2 ; classification performance was summarized using sensitivity and specificity; and multicollinearity was assessed using the variance inflation factor (VIF). All analyses were reported in accordance with the STROBE principles for observational studies (von Elm et al., 2007). The $p < 0.25$ threshold followed the conventional purposeful-selection approach, chosen to reduce the risk of excluding variables that are confounders despite non-significant bivariate associations, although we acknowledge this threshold is a heuristic rather than a definitive statistical criterion. A p-value < 0.05 was considered statistically significant.

Ethical approval was obtained from the Health Research Ethics Committee of Tanjungkarang Health Polytechnic, Ministry of Health (No. 046/KEPK-TJK/III/2025; March 6, 2025). The confidentiality of participant data was maintained by anonymizing the secondary data before analysis.

RESULTS

A total of 78 mothers were analyzed, comprising 39 LBW cases and 39 non-LBW controls, as specified by the case-control design (1:1 ratio). Therefore, the 50% proportion in the sample does not represent the population prevalence of LBW. The numerical and categorical characteristics of the participants are presented in Tables 1 and 2.

Table 1. Distribution of Numerical Variables among Study Participants (n = 78)

Variable	Mean $\pm$ SD	Median	Min	Max
Maternal age (years)	31.04 $\pm$ 5.77	30.0	20	48
Birth weight (g)	2.604.23 $\pm$ 547.98	2.475.0	1.700	4,100
Hb level (g/dL)	11.39 $\pm$ 1.39	10.95	9.4	16.7
MUAC (cm)	26.02 $\pm$ 3.58	26.0	18.0	35.0

Table 2. Distribution of Categorical Variables among Study Participants (n = 78)

Variable	Category	n	%
LBW (outcome)	LBW (<2,500 g)	39	50
	Non-LBW ($\geq$ 2,500 g)	39	50
Maternal age group	At risk (>35 years)	17	21.8
	20–35 years	61	78.2
Anemia	Anemic (Hb <11 g/dL)	39	50.0
	Non-anemic	39	50.0
CED	CED (MUAC <23.5 cm)	24	30.8
	No CED	54	69.2
Hyperemesis gravidarum	Yes	28	35.9
	No	50	64.1
Preeclampsia	Yes	3	3.8
	No	75	96.2
Antepartum hemorrhage	Yes	6	7.7
	No	72	92.3
Iron tablet consumption	Regular	32	41.0
	None	7	9.0
	Occasional	39	50.0
ANC attendance	Yes (constant)	78	100.0
PROM	No (constant)	78	100.0
Congenital anomalies	No (constant)	78	100.0

Note: LBW = low birth weight; Hb = hemoglobin; CED = chronic energy deficiency; MUAC = mid-upper arm circumference; Fe = iron; ANC = antenatal care; PROM = premature rupture of membranes. ANC attendance, PROM, and congenital anomalies were constant across the sample; therefore, they are presented descriptively only and were not included in the bivariate or multivariable analyses.

Bivariate analysis showed that anemia, CED, hyperemesis gravidarum, and the pattern of iron tablet consumption were significantly associated with LBW ($p < 0.05$), whereas at-risk maternal age, preeclampsia, and antepartum hemorrhage were not significantly associated with LBW (Table 3).

Table 3. Bivariate Analysis of Dichotomous Risk Factors Associated with LBW

Risk factor	LBW (%)	Non-LBW (%)	OR (95% CI)	p	Test
At-risk maternal age (>35 years)	10 (58.8)	7 (41.2)	1.58 (0.53–4.68)	0.411	Chi-square

Risk factor	LBW (%)	Non-LBW (%)	OR (95% CI)	p	Test
Anemia	32 (82.1)	7 (17.9)	20.90 (6.57–66.44)	<0.001	Chi-square
CED	19 (79.2)	5 (20.8)	6.46 (2.09–19.99)	0.001	Chi-square
Hyperemesis gravidarum	21 (75.0)	7 (25.0)	5.33 (1.90–14.97)	0.001	Chi-square
Preeclampsia	1 (33.3)	2 (66.7)	0.49 (0.04–5.60)	1.000	Fisher's exact
Antepartum hemorrhage	4 (66.7)	2 (33.3)	2.11 (0.36–12.28)	0.675	Fisher's exact

Note: LBW = low birth weight; OR = odds ratio; CI = confidence interval; CED = chronic energy deficiency.

For iron tablet consumption, which had three categories, the analysis was performed using a 3×2 table with the full sample ($n = 78$). Mothers who regularly consumed iron tablets had a substantially lower proportion of LBW than those who did not consume iron tablets (Table 4). The overall chi-square test showed a highly significant association ($\chi^2 = 21.84$; $df = 2$; $p < 0.001$), which was confirmed by a Monte Carlo permutation test (20,000 iterations; $p < 0.001$).

Table 4. Iron Tablet Consumption and LBW ($n = 78$)

Iron consumption category	LBW	Non-LBW	OR vs None (reference)
None (reference)	6	1	1.00
Regular	6	26	0.04 (0.004–0.382)
Occasional	27	12	0.38 (0.04–3.47)

Note: Fe = iron; LBW = low birth weight; OR = odds ratio (95% CI). The analysis included the complete sample ($n = 78$) following finalization of the iron-consumption dataset.

Comparisons of mean numerical variables by LBW group are presented in Table 5. Mothers of infants with LBW had significantly lower Hb levels and MUAC than mothers of non-LBW infants, consistent with the categorical analyses of anemia and CED. The difference in mean maternal age between groups was not statistically significant.

Table 5. Comparison of Mean Numerical Variables by LBW Group

Variable	LBW group	Non-LBW group	t	P
Maternal age (years)	32.03 $\pm$ 5.57	30.05 $\pm$ 5.86	1.52	0.132
Hb level (g/dL)	10.59 $\pm$ 0.72	12.18 $\pm$ 1.44	-6.17	<0.001
MUAC (cm)	24.64 $\pm$ 3.16	27.39 $\pm$ 3.47	-3.66	0.001

Note: LBW = low birth weight; Hb = hemoglobin; MUAC = mid-upper arm circumference.

Based on the criterion of $p < 0.25$ in bivariate analysis and theoretical considerations, five variables were entered into the multiple logistic regression model: at-risk maternal age, anemia, CED, hyperemesis gravidarum, and iron tablet consumption (reference: no consumption). At-risk maternal age was retained in the model despite its bivariate p-value of 0.411 because of its theoretical and clinical importance as a maternal risk factor. The multivariable analysis results are presented in Table 6.

Table 6. Multiple Logistic Regression Analysis (n = 77)

Variable	Adjusted OR	95% CI	P
At-risk maternal age (>35 years)	1.98	0.26–15.17	0.511
Anemia	47.14	6.72–330.62	<0.001
CED	10.06	1.40–72.58	0.022
Hyperemesis gravidarum	6.61	1.03–42.63	0.047
Regular iron consumption (vs None)	0.026	0.001–0.604	0.023
Occasional iron consumption (vs None)	0.067	0.003–1.516	0.090

Note: OR = odds ratio; CI = confidence interval; CED = chronic energy deficiency; Fe = iron. The model included 77 participants with complete data (one participant with missing hyperemesis data was excluded).

The logistic regression model showed good fit, with a McFadden pseudo- R^2 of 0.591 and a significant likelihood-ratio test ($p < 0.001$), indicating that the overall model adequately explained variation in LBW. The Hosmer–Lemeshow test showed no significant difference between the observed and model-predicted values ($\chi^2 = 3.74$; $df = 5$; $p = 0.588$), indicating good calibration. The model achieved a classification accuracy of 90.9% (sensitivity, 94.7%; specificity, 87.2%). VIF values for all variables ranged from 1.02 to 3.53, below the threshold of 5, indicating no problematic multicollinearity among the predictors.

After adjustment for the other variables in the model, anemia, CED, and hyperemesis gravidarum were independently and significantly associated with LBW. Mothers with anemia had approximately 47 times the odds of LBW compared with mothers without anemia (adjusted OR, 47.14; 95% CI, 6.72–330.62; $p < 0.001$), mothers with CED had approximately 10 times the odds (adjusted OR, 10.06; 95% CI, 1.40–72.58; $p = 0.022$), and mothers with hyperemesis gravidarum had approximately 7 times the odds (adjusted OR, 6.61; 95% CI, 1.03–42.63; $p = 0.047$). Regular iron tablet consumption was associated with 97.4% lower odds of LBW compared with no iron consumption (adjusted OR, 0.026; 95% CI, 0.001–0.604; $p = 0.023$). Occasional iron consumption showed a similar direction of association but did not reach statistical significance (adjusted OR, 0.067; 95% CI, 0.003–1.516; $p = 0.090$). At-risk maternal age was not independently associated with LBW after adjustment for the other variables in the model (adjusted OR, 1.98; 95% CI, 0.26–15.17; $p = 0.511$).

DISCUSSION

The 50% proportion of LBW in this study sample was substantially higher than national and global prevalence estimates. This difference is attributable to the case-control design, which deliberately balanced the numbers of cases and controls (1:1 ratio). Thus, the 50% proportion in the sample cannot be interpreted as an estimate of LBW prevalence in the catchment area of Yosomulyo Primary Health Care Center; instead, it reflects the sampling structure of the case-control study.

The finding that anemia was the strongest independent risk factor for LBW in this study (adjusted OR, 47.14) is consistent with most national literature, which generally reports significant associations between maternal anemia and LBW, although the magnitude of the OR varies across regions and health care settings (Novianti & Aisyah, 2018; Anjani et al., 2024; Nurrahmaton, 2019; Rahmah & Karjadidjaja, 2020; Firdaus et al., n.d.; Koerniawati, 2022). Biologically, anemia during pregnancy, particularly iron-deficiency anemia, may impair oxygen transport to the fetoplacental unit, trigger placental dysfunction, and ultimately restrict intrauterine fetal growth. This consistency across studies strengthens the biological plausibility of anemia as a priority intervention target for reducing LBW in the study area and is supported by the markedly lower mean Hb level observed in the LBW group than in the non-LBW group.

Chronic Energy Deficiency was the second-strongest independent risk factor (adjusted OR, 10.06), consistent with studies from other regions of Indonesia showing that maternal

undernutrition, reflected by MUAC below the cutoff, is associated with an increased risk of LBW (Ermawan, 2016; Maifita, 2023; Andriani, 2023; Sumini, 2018; Fatimah, 2019). The Indonesian Ministry of Health has also long identified CED as an important determinant of LBW and perinatal mortality, because inadequate maternal energy reserves limit nutrient transfer to the fetus during pregnancy (Kementerian Kesehatan RI, n.d.). The significantly lower MUAC observed in the LBW group in this study further supports this association.

Hyperemesis gravidarum was significantly associated with LBW in both the bivariate analysis and, following completion of the iron-consumption dataset, the multivariable model (adjusted OR, 6.61; 95% CI, 1.03–42.63; $p = 0.047$), indicating an independent association with LBW even after adjustment for anemia, CED, maternal age, and iron consumption. This finding is consistent with literature reporting an association between hyperemesis gravidarum and low-birth-weight outcomes (Harahap et al., 2018; Rofi'ah, n.d.) and with cohort evidence suggesting that inadequate gestational weight gain among women with hyperemesis gravidarum may impair fetal growth independently of other nutritional markers (Morisaki et al., 2022). Biologically, mothers with severe hyperemesis are at risk of inadequate energy and micronutrient intake during a critical period of early fetal development, which may restrict fetal growth through pathways only partly captured by third-trimester anemia and CED status; given the relatively small number of hyperemesis cases in this study, however, this finding should be confirmed in larger samples. Similarly, at-risk maternal age (>35 years) was not independently associated with LBW after adjustment for nutritional and clinical factors (adjusted OR, 1.98; 95% CI, 0.26–15.17; $p = 0.511$). This finding is consistent with studies that did not identify an independent association between maternal age and LBW after adjustment for other confounders (Limbong, n.d.; Putri et al., 2019; Pertiwi et al., 2022; Rahfiluddin et al., 2017), although it differs from several bivariate studies that reported a significant association between at-risk maternal age and LBW (Sari, 2021; Dary et al., 2022). This discrepancy may indicate that at-risk maternal age operates through, or overlaps with, nutritional status and anemia rather than acting as an independent risk factor for LBW.

The finding that regular iron tablet consumption was associated with approximately 97.4% lower odds of LBW (adjusted OR, 0.026; 95% CI, 0.001–0.604; $p = 0.023$) has important policy implications. This result is consistent with a case-control study in Bantul Regency that reported a significant association between adherence to iron tablet consumption and LBW (Fatimatasari et al., 2013), as well as evidence that adherence to iron tablet consumption is closely related to a reduction in anemia among pregnant women (Bangun, 2018), and is further supported by recent regional evidence that iron-folic acid supplementation, particularly when combined with adequate antenatal care attendance, is synergistically associated with lower odds of LBW in South Asian populations (Khanal et al., 2024). Occasional iron consumption showed a similarly protective direction of association (adjusted OR, 0.067; 95% CI, 0.003–1.516) but did not reach statistical significance ($p = 0.090$). This suggests that the benefit of iron supplementation may be dose-dependent: inconsistent consumption may be insufficient to optimally correct maternal iron status. These findings underscore the importance of programs that focus not only on distributing iron tablets but also on strategies to support complete adherence throughout pregnancy.

A methodological consideration in interpreting the multivariable model concerns the simultaneous inclusion of anemia and iron tablet consumption as predictors. Biologically, these two variables are plausibly linked along a causal pathway (iron tablet consumption $\rightarrow$ maternal hemoglobin/iron status $\rightarrow$ pregnancy outcome), such that anemia may act as a mediator of the effect of iron consumption on LBW rather than purely as an independent confounder. Variance inflation factor (VIF) values for both variables were low (anemia VIF ≈ 1.47 ; regular-Fe VIF ≈ 3.53 ; occasional-Fe VIF ≈ 3.46), indicating the absence of problematic collinearity; however, a low VIF does not resolve questions of causal pathway, since mediation and collinearity are distinct statistical phenomena. A simplified directed acyclic graph (DAG) summarizing the hypothesized pathway can be expressed as: Iron tablet consumption $\rightarrow$ Maternal hemoglobin (anemia status) $\rightarrow$ Low birth weight, with chronic energy deficiency acting as a parallel nutritional pathway toward the same outcome. Under this framework, the adjusted OR for iron consumption reported in Table 6 should be interpreted as the direct effect of adherence that is not explained by its influence on hemoglobin status, whereas the total effect of iron consumption on LBW (unadjusted for anemia) is better reflected in the bivariate analysis (Table 4). We therefore present both the bivariate (total

effect) and multivariable (direct effect, adjusted for the hypothesized mediator) estimates, and we encourage future studies to apply formal mediation analysis (e.g., the Baron and Kenny approach or structural equation modeling) to more precisely quantify the proportion of the iron-consumption effect on LBW that operates through anemia.

Practical Implications and Study Limitations

Overall, the findings indicate that strengthening the early detection and management of anemia and CED among pregnant women, together with improving adherence to iron tablet consumption through counseling and active monitoring by health workers, could be a priority strategy for reducing LBW in the catchment area of Yosomulyo Primary Health Care Center. The logistic regression model developed in this study showed good fit and high classification accuracy, supporting its use to explain associations between maternal risk factors and LBW in similar populations.

This study has several limitations that should be considered when interpreting the results. First, although the iron-consumption dataset was completed for all 78 participants (resolving the missing-data concern present in our earlier analysis), the overall sample size (39 cases and 39 controls; $n = 77$ in the final multivariable model after excluding one participant with missing hyperemesis data) remains relatively small. Several candidate predictors therefore had a low number of events per variable, which produced wide and unstable confidence intervals for some estimates, particularly for anemia and the iron-consumption categories; preeclampsia and antepartum hemorrhage were excluded from the main model for the same reason. These findings should therefore be interpreted cautiously and ideally confirmed in studies with larger samples. Second, the sample size (39 cases and 39 controls) was determined pragmatically based on the number of eligible LBW cases identified in the catchment area during the study period rather than from an a priori power calculation, and internal validation procedures such as bootstrap resampling were not performed; both limit the precision and external robustness of the adjusted estimates, and we recommend that future studies incorporate formal sample-size planning and internal validation. Third, ANC attendance, PROM, and congenital anomalies could not be analyzed because they showed no variation in this sample; consequently, their potential contributions to LBW could not be evaluated. Fourth, the retrospective design, which relied partly on secondary data from the KIA handbook and on maternal recall of exposures and behaviors (including iron tablet consumption) during pregnancy, may be susceptible to recall and information bias; this concern is accentuated because children in this study were aged up to 59 months, meaning some mothers were asked to recall pregnancy-related behaviors that occurred up to five years earlier. Although data quality-control checks were conducted before analysis, recall bias cannot be fully excluded and should be considered when interpreting the strength of the associations reported, particularly for iron tablet consumption and hyperemesis gravidarum. Fifth, hemoglobin and MUAC values were obtained from measurements routinely recorded in the KIA handbook rather than being independently re-measured or calibrated by the research team; although these measurements are taken as part of standard antenatal care procedures, the absence of independent calibration checks is a limitation. Sixth, this study was conducted in a single primary health care catchment area with a relatively small source population, which limits the generalizability of the findings to other settings with different demographic, nutritional, or health service characteristics. Future prospective, multi-site studies with larger samples, a priori power calculations, and internal validation are needed to confirm these findings and to evaluate additional risk factors, including interpregnancy interval, socioeconomic status, and exposure to tobacco smoke.

CONCLUSION

Anemia, chronic energy deficiency (CED), and hyperemesis gravidarum were independently and significantly associated with LBW in the catchment area of Yosomulyo Primary Health Care Center, with adjusted ORs of 47.14, 10.06, and 6.61, respectively. Regular iron tablet consumption was associated with lower odds of LBW (adjusted OR, 0.026). At-risk maternal age was not independently associated with LBW after adjustment for nutritional and clinical factors. The logistic regression model showed good fit and a classification accuracy of 90.9%.

AUTHOR'S DECLARATION

Authors' contributions and responsibilities

Septi Widiyanti contributed to the conceptualization, methodology, data collection and analysis, drafting, and review of the manuscript.

Islamiyati: Formal Analysis.

Sri Lestariningsih: Supporting Draft, Review and Editing.

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Availability of data and materials

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable ethical, privacy, and confidentiality requirements.

Competing interests

The author declares no conflict of interest.

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