Maternal preventive and sociodmographic determinants of birth weight: Evidence from a nationally representative survey in Indonesia

Rudi Saputra[1], Irfansyah B. Pakki*[2]

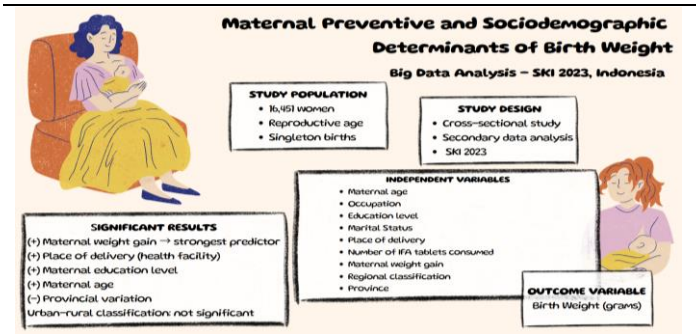
[1] Master of Public Health Program, Faculty of Public Health, Mulawarman University, Samarinda, Indonesia
[2] Department of Epidemiology, Faculty of Public Health, Mulawarman University, Samarinda, Indonesia

DOI: 10.24252/al-sihah.v18i2.63995
Received: 23 December 2025 / In Reviewed: 6 February 2026 / Accepted: 22 June 2026 / Available online: 30 June 2026
©The Authors 2026. This is an open access article under the CC BY-NC-SA 4.0 license

ABSTRACT
Birth weight is a key indicator of neonatal health and intergenerational health inequality, yet few studies have simultaneously integrated maternal characteristics, health service utilization, and regional context using nationally representative data within a public health framework. This study examined maternal preventive practices and sociodemographic determinants of birth weight using nationally representative data from the 2023 Indonesian Health Survey. A cross-sectional analysis was conducted on 16,451 women with complete childbirth information. Birth weight was analyzed as a continuous outcome using Spearman's rank correlation and multivariable linear regression. Maternal age, education level, place of delivery, maternal weight gain, and provincial variation were included as independent variables. Maternal age, education level, place of delivery, and maternal weight gain were positively associated with birth weight, whereas provincial variation showed a significant inverse association. Maternal weight gain was the strongest predictor after adjustment for confounders. These findings demonstrate that birth weight is associated with the combined influence of maternal, healthcare, and regional factors. The results support public health interventions focused on routine monitoring of gestational weight gain, nutritional counseling during antenatal care, strengthening maternal health services in underserved areas, and region-specific policies to reduce inequalities in birth outcomes across

ABSTRAK
Berat lahir merupakan indikator utama kesehatan neonatal dan ketimpangan kesehatan antargenerasi. Namun, hanya sedikit studi yang secara bersamaan mengintegrasikan karakteristik ibu, pemanfaatan layanan kesehatan, dan konteks regional menggunakan data yang representatif secara nasional dalam kerangka kesehatan masyarakat. Studi ini meneliti praktik pencegahan maternal dan determinan sosiodemografis terhadap berat lahir menggunakan data representatif nasional dari Survei Kesehatan Indonesia 2023. Analisis potong lintang dilakukan terhadap 16.451 perempuan dengan informasi persalinan yang lengkap. Berat lahir dianalisis sebagai luaran kontinu menggunakan korelasi peringkat Spearman dan regresi linear multivariat. Usia ibu, tingkat pendidikan, tempat persalinan, kenaikan berat badan ibu, dan variasi provinsi dimasukkan sebagai variabel independen. Usia ibu, tingkat pendidikan, tempat persalinan, dan kenaikan berat badan ibu berhubungan positif dengan berat lahir, sedangkan variasi provinsi menunjukkan hubungan terbalik yang signifikan. Kenaikan berat badan ibu merupakan prediktor terkuat setelah penyesuaian terhadap faktor perancu. Temuan ini menunjukkan bahwa berat lahir dipengaruhi oleh kombinasi faktor maternal, layanan kesehatan, dan regional. Hasil ini mendukung intervensi kesehatan masyarakat yang berfokus pada pemantauan rutin kenaikan berat badan selama kehamilan, konseling gizi selama perawatan antenatal, penguatan layanan kesehatan ibu di wilayah kurang terlayani, serta kebijakan spesifik wilayah untuk mengurangi ketimpangan luaran kelahiran di berbagai daerah.

GRAPHICAL ABSTRACT



Keyword
birth weight
educational status
female
gestational weight gain
maternal age

*** Correspondence**
Sambaliung Street, Samarinda, East Kalimantan, 75119, Indonesia
irfanchango@gmail.com

ISSN-P : 2086-2040
ISSN-E : 2548-5334

INTRODUCTION

Birth weight is a critical indicator of neonatal health and a reflection of maternal well-being during pregnancy. Adequate intrauterine growth is essential for immediate survival and long-term health outcomes, whereas low birth weight (LBW) is strongly associated with increased risks of neonatal morbidity and mortality, impaired cognitive development, and susceptibility to chronic diseases later in life (Adanikin et al., 2025; Busreea et al., 2025). Despite substantial progress in maternal and child health services worldwide, LBW continues to pose a significant public health challenge, particularly in low- and middle-income countries (Dhungana et al., 2025). The multifactorial nature of birth weight, influenced by biological, behavioral, and social determinants, makes its study crucial for developing effective preventive strategies and evidence-based interventions that enhance neonatal outcomes and inform public health planning (Herwanto et al., 2024; Hossain et al., 2025).

Globally, the World Health Organization (2025) estimates that approximately 20 million infants are born with LBW each year, representing roughly 15% of all live births. The burden of LBW is disproportionately concentrated in Southeast Asia, where maternal undernutrition, limited access to quality antenatal care, and socioeconomic inequalities remain prevalent (Rahmadani & Santik, 2024). In Indonesia, national health surveys have consistently reported LBW as a significant contributor to neonatal mortality and long-term developmental challenges. Data from the 2023 Indonesia Health Survey (Survei Kesehatan Indonesia/SKI) indicate substantial variations in birth weight across provinces, urban-rural areas, and population subgroups, highlighting that birth outcomes are shaped not only by individual clinical factors but also by broader sociodemographic, environmental, and contextual determinants (Kementerian Kesehatan Republik Indonesia, 2023). These disparities underline the importance of understanding both maternal and environmental influences on neonatal health, which is essential for designing effective, context-specific interventions.

Previous studies have identified multiple factors associated with birth weight, including maternal age, educational attainment, employment status, parity, nutritional status, and utilization of maternal health services (Kassie et al., 2025; Salam et al., 2025). Adequate prenatal care provides opportunities for early detection of risks, nutritional counseling, and timely medical interventions, while maternal nutritional status, commonly measured through gestational weight gain, remains a key determinant of fetal growth and development (Alemu et al., 2025; da Silva et al., 2025; Dewidar et al., 2024). Although these findings are well established, many studies focus narrowly on specific clinical or service-related factors, often examining them in isolation. Limited attention has been paid to the combined effects of maternal sociodemographic characteristics, nutritional status, and regional context on birth outcomes. In a country like Indonesia, which exhibits substantial geographic, cultural, and socioeconomic diversity, overlooking these interactions may conceal important structural determinants of LBW, hinder effective resource allocation, and impede the design of targeted public health strategies.

This study is also aligned with the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being), which aims to reduce neonatal mortality and improve maternal health outcomes and SDG 2 (Zero Hunger), which emphasizes the importance of adequate maternal nutrition (United Nations, 2025). Understanding the determinants of birth weight is essential for supporting evidence-based interventions that contribute to healthier pregnancies, improved neonatal survival, and the reduction of health inequalities across populations.

Although previous studies in Indonesia have identified determinants of LBW, most have focused primarily on LBW as a dichotomous outcome and have paid limited attention to geographic disparities across rural-urban and provincial settings. Consequently, the broader influence of maternal and contextual factors on birth weight remains insufficiently understood. This research aims to address these gaps by analyzing the maternal and sociodemographic determinants of birth weight using nationally representative survey data from Indonesia collected in 2023.

We hypothesize that maternal age, educational level, nutritional status, and regional context are significantly associated with birth weight. By integrating these factors, this study seeks to provide robust empirical evidence to guide public health policies and interventions, support maternal and child health programs, and address regional inequalities in neonatal outcomes. The findings are expected to contribute to the formulation of comprehensive, evidence-based strategies that not only reduce the prevalence of LBW but also strengthen health system planning, improve neonatal

survival, and enhance overall child health and development across diverse populations in Indonesia.

METHODS

This study employed an analytical observational design with a cross-sectional approach to examine maternal preventive practices and sociodemographic determinants of birth weight. The analysis utilized secondary data from the 2023 Indonesian Health Survey, a large-scale national health survey conducted by the Indonesian Ministry of Health. The 2023 Indonesian Health Survey employed a complex multistage sampling design involving stratification and cluster selection based on census blocks, developed in collaboration with Statistics Indonesia (Badan Pusat Statistik/BPS) to ensure broad population coverage across provinces and districts/cities in Indonesia.

Data were collected nationwide throughout 2023 and included diverse geographic, demographic, and socioeconomic populations. The present study analyzed eligible respondents with complete information on birth weight and study variables. Because the analysis was conducted using the available secondary dataset and did not incorporate survey weights or complex survey procedures, the findings should be interpreted as reflecting associations within a large national sample rather than population-level estimates fully adjusted for the survey design. The use of secondary data eliminated direct interaction with participants and enabled analysis of a large population-based dataset.

The study subjects were women of reproductive age who had complete information related to childbirth outcomes. A total sampling technique was applied, whereby all valid observations were included to maximize statistical power and ensure representativeness. From an initial dataset of approximately 306,642 records, a systematic data cleaning process was conducted to remove duplicate, inconsistent, and implausible records. After applying predefined eligibility criteria, a final analytical sample of 16,451 respondents was obtained. The inclusion criteria consisted of women aged 10-54 years years with complete data on birth weight, maternal preventive practices, and key sociodemographic variables. This age range was adopted according to the reproductive-age population framework used in the 2023 Indonesian Health Survey dataset and was retained to maximize the representativeness of all reported births captured in the survey. Exclusion criteria included multiple pregnancies (e.g., twin or higher-order births), biologically implausible birth weight values, and records with logical inconsistencies that could not be verified.

The dependent variable was birth weight, analyzed as a continuous variable measured in grams. Independent variables included maternal preventive practices and sociodemographic characteristics such as maternal age, education level, marital status, employment status, regional classification, place of delivery, maternal weight gain, and provincial variation. All variables were derived from standardized 2023 Indonesian Health Survey instruments. Data analysis was performed using IBM SPSS Statistics version 25. Univariate analysis was conducted to describe the distribution of each variable. Bivariate analysis using Spearman's rank correlation test was applied to assess associations between independent variables and birth weight. Variables with a p-value < 0.25 in the bivariate analysis were included in the multivariable analysis.

Prior to multivariable linear regression, the assumptions of linear regression were assessed. Normality of residuals was evaluated using histograms and normal probability (P-P) plots, homoscedasticity and linearity were examined through scatterplots of standardized residuals against predicted values, multicollinearity was assessed using tolerance and variance inflation factor (VIF) statistics, and influential observations were evaluated using Cook's distance. The diagnostic assessment indicated that the assumptions of normality, linearity, homoscedasticity, and absence of multicollinearity were adequately met. Tolerance values ranged from 0.951 to 0.996, VIF values ranged from 1.004 to 1.051, and the maximum Cook's distance was 0.004, indicating no evidence of problematic multicollinearity or influential outliers.

Multivariable linear regression was used to identify independent determinants of birth weight while controlling for potential confounding factors. Results were reported as regression coefficients (B), standardized coefficients (β), 95% confidence intervals (95% CI), and p-values. Model fit was assessed using the coefficient of determination (R^2), adjusted R^2, F-statistics, and standard error of the estimate (SEE).

RESULTS

As presented in Table 1, the study population was dominated by women in their early thirties, with a mean maternal age of 31.78 ± 6.17 years. Most participants were not formally employed (59.00%) and

Table 1
Sociodemographic, maternal, and birth characteristics of study participants

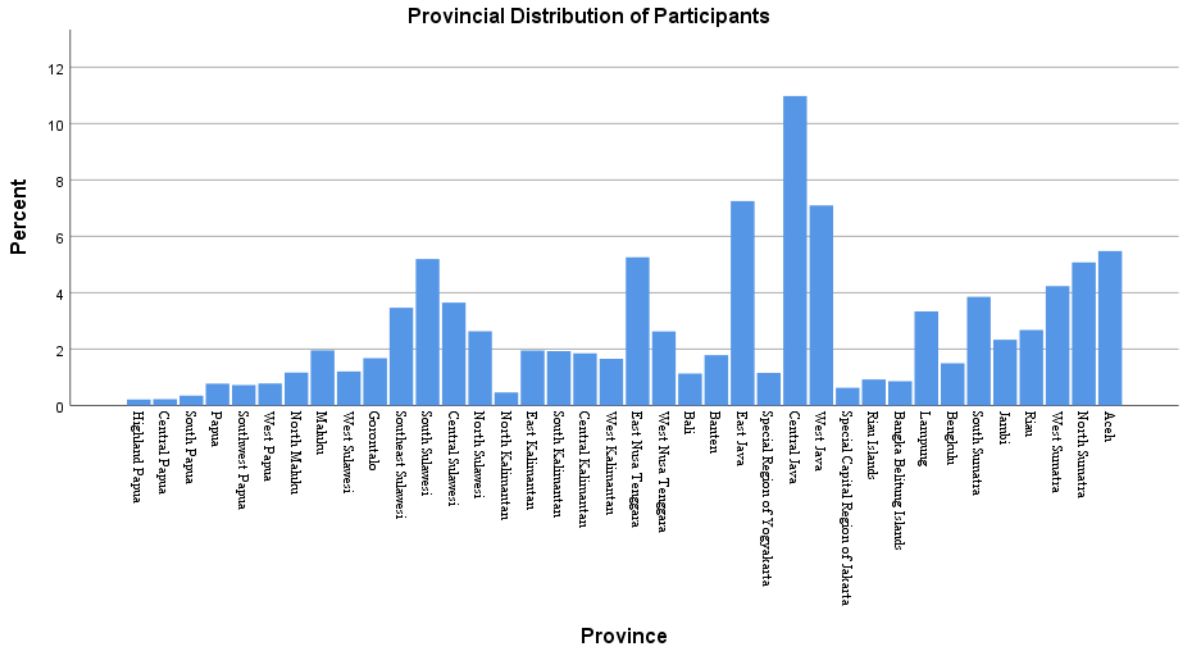
Characteristics	Number (n = 16,451)	Percentage (%)
Age (Years)	31.78 ± 6.17	
Occupation		
Not employed	9700	59
Student	89	0.5
Government employee / Military / Police / State-owned enterprise	531	3.2
Private-sector employee	1094	6.7
Self-employed	1300	7.9
Farmer	1227	7.5
Fisherman	15	0.1
Manual laborer / Driver / Domestic worker	266	1.6
Others	2229	13.5
Education Level		
No formal education	290	1.8
Did not complete primary school	610	3.7
Completed primary school	2720	16.4
Completed junior secondary school	3660	22.2
Completed senior secondary school	6480	39.4
Completed diploma	1194	7.3
Completed higher education	1515	9.2
Marital Status		
Married	16196	98.4
Widowed	82	0.5
Divorced	173	1.1
Regional Classification		
Urban	7493	45.5
Rural	8958	54.5
Place of Delivery		
Government hospital	3332	20.3
Private hospital	3248	19.7
Clinic	843	5.1
Community health center (Puskesmas / sub-centers / mobile units)	4078	24.8
Private physician practice	102	0.6
Private midwife practice	2940	17.9
Village health post (Poskesdes / Polindes)	629	3.8
Home	1246	7.6
Others	33	0.2
Number of IFA Tablets Consumed	62.56 ± 40.9	
Maternal Weight Gain		
Yes	1019	6.2
No	15432	93.8
Birth Weight (grams)	3090.01 ± 440.54	

had attained at least senior secondary education (39.40%). Nearly all respondents were married (98.40%) and a slightly higher proportion resided in rural areas (54.50%) than in urban settings (45.50%). Delivery predominantly occurred at formal health facilities, particularly community health centers (24.80%) and hospitals (40.00%), indicating substantial utilization of institutional delivery services. On average, women consumed 62.56 iron-folic acid (IFA) tablets during pregnancy, although intake varied widely among participants (SD = 40.90). The mean birth weight was 3,090.01 ± 440.54 grams, indicating that the majority of infants were born with normal birth weight; nevertheless, adequate maternal weight gain during pregnancy remained relatively uncommon.

Figure 1 illustrates the provincial distribution of study participants across Indonesia. The largest proportion of respondents originated from Central Java, accounting for approximately 11% of the total sample, highlighting the substantial contribution of this province to the national dataset. In contrast, the smallest proportions were observed in Central Papua and Highland Papua, each contributing approximately 0.2% of participants. This uneven distribution reflects population size and regional representation within the national survey framework, while still ensuring coverage across all provinces for comparative analysis.

Correlation analysis using Spearman's rank test (see Table 2) showed that several maternal and contextual factors were significantly associated with

Figure 1
Provincial distribution of participants



birth weight. Maternal age (ρ = 0.061; p < 0.001), education level (ρ = 0.040; p < 0.001), place of delivery (ρ = 0.087; p < 0.001), and maternal weight gain during pregnancy (ρ = 0.058; p < 0.001) were positively correlated with birth weight, indicating that infants born to older and more educated mothers, those delivered in health facilities, and those whose mothers achieved adequate gestational weight gain tended to have higher birth weights.

In contrast, regional classification (ρ = −0.022; p = 0.005) and provincial variation (ρ = −0.084; p < 0.001) demonstrated significant negative correlations with birth weight, suggesting the presence of geographic and contextual disparities in birth outcomes. Other sociodemographic variables, including occupation, marital status, and the number of IFA tablets consumed, showed weak and statistically non-significant associations with birth weight (p > 0.05) and were therefore not emphasized further in the analysis.

Multivariable linear regression analysis (see Table 3) confirmed maternal weight gain as the most dominant predictor of birth weight after adjustment for confounding variables. Place of delivery and maternal education level remained significant positive predictors, underscoring the combined importance of maternal nutritional status and access to quality healthcare services. Maternal age retained a modest but statistically significant association with birth weight. Provincial variation persisted as a significant inverse predictor, indicating the influence of broader contextual and regional factors beyond individual characteristics. Urban-rural classification did not remain statistically significant after adjustment. Overall, the regression model was statistically significant (p < 0.001), although the adjusted R^2 suggested that the included variables explained only a limited proportion of birth weight variability, implying the presence of additional unmeasured determinants influencing birth outcomes at the population level.

DISCUSSION

This study examined the maternal preventive and sociodemographic determinants of birth weight using nationally representative survey data from Indonesia. The present study identified several key determinants of birth weight in Indonesia. Place of delivery, maternal weight gain, maternal education, maternal age, and provincial variation were consistently associated with birth weight in the multivariable model. Among these factors, maternal weight gain showed the strongest positive association, highlighting the importance of adequate maternal nutrition during pregnancy. These findings suggest that both individual maternal characteristics and broader contextual factors contribute to variations in birth weight across Indonesia.

Table 2
Spearman's rank correlation between birth weight and sociodemographic and maternal factors

Variable	Spearman's ρ	p-value
Age	0.061	<0.001*
Occupation	-0.005	0.524
Education level	0.04	<0.001*
Marital status	-0.005	0.529
Regional classification	-0.022	0.005*
Place of delivery	0.087	<0.001*
Number of IFA tablets consumed	0.003	0.664
Maternal weight gain	0.058	<0.001*
Province	-0.084	<0.001*

Note: * indicates statistical significance at $p < 0.05$.

Maternal age emerged as an important factor associated with birth weight, highlighting the intersection between biological readiness and social maturity. From a developmental perspective, women within an optimal reproductive age range tend to have more stable physiological conditions, greater autonomy in health-related decision-making, and stronger engagement with healthcare services (Idris et al., 2023; Vizheh et al., 2021). Previous research has shown that younger maternal age, particularly adolescence, is associated with compromised fetal growth due to biological immaturity and limited access to resources (Huang et al., 2025; Putri & Herdiman, 2023). The present findings support this body of evidence and emphasize the need for targeted reproductive health education and support for younger women to mitigate risks related to suboptimal birth outcomes.

Education played a pivotal role in shaping birth weight, underscoring its function as a fundamental social determinant of health. Education not only enhances knowledge but also empowers women to navigate healthcare systems, adopt healthier behaviors, and respond effectively to medical advice (Rizvi, 2022). The association between higher educational attainment and improved birth outcomes has been widely documented in both high-income and low- and middle-income settings (Liu et al., 2022; Raru et al., 2022). The findings of this study reaffirm that maternal education remains a critical upstream factor influencing neonatal health, suggesting that investments in female education yield long-term benefits extending into the next generation.

The significance of place of delivery reflects the broader continuum of maternal healthcare utilization rather than the delivery setting alone. Facility-based delivery often represents sustained contact with healthcare services throughout pregnancy, including antenatal care, nutritional counseling, and risk screening (Mlotshwa & Sibiya, 2023; Mordal et al., 2021). This aligns with Andersen's behavioral model of health service use, which posits that health outcomes are shaped by predisposing, enabling, and need-related factors that influence service utilization (Alkhawaldeh et al., 2023). The association observed in this study highlights the importance of strengthening primary healthcare systems and ensuring continuity of care from pregnancy through childbirth.

Among all examined factors, maternal weight gain during pregnancy emerged as the most influential determinant of birth weight. This finding strongly supports nutritional and developmental theories that emphasize the role of maternal energy reserves and nutrient transfer in fetal growth (Parrettini et al., 2020). Adequate gestational weight gain reflects not only sufficient caloric intake but also overall maternal well-being and metabolic adaptation to pregnancy. Previous studies consistently identify inadequate gestational weight gain as a major risk factor for LBW and intrauterine growth restriction (Kurniasari et al., 2024; Kusuma et al., 2024; Minami et al., 2022). These findings are consistent with broader evidence demonstrating that gestational weight gain is a modifiable determinant of fetal growth and adverse pregnancy outcomes.

The prominence of maternal weight gain in the present analysis has important public health implications. As maternal weight gain can be routinely monitored during antenatal care, it may serve as a practical early warning indicator for identifying pregnancies at increased risk of adverse birth outcomes. Routine assessment of gestational weight gain, combined with individualized nutritional counseling and timely nutritional interventions, may facilitate early detection of nutritional inadequacy before fetal growth is compromised. These findings underscore the need to strengthen maternal nutrition

Table 3
Multivariable linear regression analysis of factors associated with birth weight

Variable	B	Std. Error	β	95% CI	p-value
Constant	2710.68	38.03	-	2636.13-2785.23	<0.001*
Age (years)	3.94	0.55	0.055	2.86-5.02	<0.001*
Education level	15.97	2.66	0.047	10.76-21.18	<0.001*
Regional classification	−10.46	7	−0.012	−24.17-3.26	0.135
Place of delivery	18.34	1.57	0.092	15.28-21.41	<0.001*
Maternal weight gain	92.49	14.13	0.051	64.79-120.19	<0.001*
Province	−1.18	0.14	−0.066	−1.46-−0.91	<0.001*

Note: Model fit: R = 0.144; R^2 = 0.021; Adjusted R^2 = 0.021; F(6, 16,444) = 58.41; p < 0.001; SEE = 435.99 g. B = unstandardized regression coefficient; β = standardized regression coefficient; CI = confidence interval; SEE = standard error of the estimate. * indicates statistical significance at p < 0.05.

programs by integrating systematic gestational weight monitoring into routine antenatal services, particularly in underserved regions where nutritional vulnerability and adverse birth outcomes remain disproportionately high. Such an approach may contribute to improving birth outcomes while reducing regional inequalities in maternal and neonatal health.

An important finding of this study is the significant association between provincial variation and birth weight, suggesting that birth outcomes are influenced not only by individual maternal characteristics but also by broader contextual conditions. Indonesia continues to experience substantial disparities in maternal and child health indicators across provinces, reflecting differences in healthcare infrastructure, availability of skilled health personnel, transportation networks, socioeconomic development, and access to essential maternal services. Previous studies have shown considerable geographic disparities in maternal and newborn healthcare utilization, with access to healthcare facilities and maternal services strongly influenced by contextual characteristics and geographic accessibility (Marthias et al., 2025; Tripathi et al., 2024). Provinces with limited healthcare resources, higher poverty rates, lower food security, and more challenging geographic conditions often face greater barriers to accessing antenatal care, skilled birth attendance, and timely referral services, all of which may contribute to suboptimal birth outcomes. These disparities are particularly evident between more developed western regions and several eastern provinces, where maternal and child health indicators remain less favorable.

The persistence of provincial variation after adjustment for individual-level characteristics highlights the influence of contextual and structural determinants. Differences in regional development, healthcare infrastructure, food availability, and social support systems likely contribute to unequal birth outcomes across provinces. This finding resonates with ecological models of health, which emphasize that individual health is shaped by multilayered environmental contexts. Recent evidence further suggests that neighborhood deprivation, structural conditions, and area-level inequalities contribute substantially to disparities in birth outcomes (Gangopadhyaya et al., 2024; Marthias et al., 2025). Importantly, it suggests that addressing birth weight disparities requires policy responses that extend beyond individual behavior change to include regional equity in health and social development. The findings further underscore the importance of strengthening primary healthcare infrastructure, improving the distribution of health workers, expanding geographic access to maternal services, and enhancing referral systems in underserved regions (Marthias et al., 2025; Tripathi et al., 2024).

The absence of a significant association between urban-rural classification and birth weight after adjustment for potential confounders provides an important insight. This finding should not be interpreted as evidence that disparities in maternal healthcare access have been eliminated. Rather, it suggests that the observed urban-rural differences may be explained, at least in part, by other factors included in the model, particularly provincial variation, maternal education, and place of delivery. These findings indicate that regional and socioeconomic characteristics may play a more prominent role than urban-rural residence alone in shaping birth weight outcomes. Nevertheless, substantial inequalities in healthcare infrastructure, geographic accessibility, and the availability of maternal health services continue to exist across provinces in Indonesia, particularly in remote and underserved areas, underscoring the need for geographically targeted maternal and neonatal health interventions. The lack of an independent urban-rural association after adjustment may also suggest that provincial-level indicators better capture meaningful contextual differences than a simple

urban-rural classification. This finding contributes to ongoing discussions regarding the most appropriate geographic measures for monitoring maternal and neonatal health inequalities.

Although maternal IFA supplementation was included as an indicator of preventive maternal health practices, it was not significantly associated with birth weight in the adjusted analysis. Several explanations may account for this finding. First, the 2023 Indonesian Health Survey dataset did not capture adherence to supplementation, including the timing of initiation, duration of use, or completion of the recommended dosage, all of which are important determinants of IFA effectiveness (Smith et al., 2025). Higher adherence and earlier initiation of antenatal micronutrient supplementation have been associated with improved birth weight and reduced risk of LBW. Second, information on IFA consumption was based on maternal self-report and may therefore be subject to recall bias or misclassification, potentially reducing the ability to detect a true association (Keats et al., 2021). Third, although IFA supplementation is well established in preventing and treating maternal anemia, its direct effect on birth weight is generally modest and is likely mediated through improvements in maternal nutritional and hematological status rather than acting as an independent determinant of fetal growth. Consequently, the absence of a significant association in this study should not be interpreted as evidence that IFA supplementation is ineffective. Rather, it highlights the importance of ensuring adequate adherence, timely initiation, and sufficient dosage throughout pregnancy to achieve optimal maternal and neonatal outcomes (Engidaw et al., 2024; Smith et al., 2025).

From a public health perspective, this study offers several key contributions. First, it demonstrates the value of integrating nutritional, educational, and contextual factors into analyses of birth outcomes using large-scale national data. Second, it identifies maternal weight gain as a critical intervention point, reinforcing the need for effective nutritional monitoring and counseling during pregnancy. Third, it highlights regional disparities that warrant tailored, context-specific policy responses rather than uniform national approaches. The study also possesses notable strengths. The use of a nationally representative dataset enhances generalizability, while the large sample size ensures robust statistical analysis. The application of multivariable modeling allows for the simultaneous consideration of multiple determinants, reducing confounding and strengthening inference. Furthermore, the inclusion of provincial variation provides nuanced insights into geographic disparities often overlooked in national analyses.

This study advances the understanding of birth weight determinants in Indonesia by demonstrating how maternal characteristics, health system engagement, and regional context interact to shape fetal growth outcomes. Rather than viewing birth weight as the product of isolated biological processes, the findings reinforce the perspective that birth outcomes are embedded within broader social, nutritional, and structural environments, consistent with life-course and social determinants of health theories.

Nevertheless, several limitations should be acknowledged. The cross-sectional design limits causal interpretation and the reliance on secondary data restricts the availability of detailed biological and behavioral variables, such as dietary quality and pre-pregnancy nutritional status. Reporting bias may also be present due to self-reported measures. Additionally, the modest explanatory power of the regression model suggests that birth weight is influenced by complex factors beyond those captured in the dataset. Future research should employ longitudinal or prospective cohort designs to better clarify causal pathways underlying birth weight variation. In addition, studies should incorporate a broader range of determinants, including pre-pregnancy nutritional status, maternal anemia, parity, birth spacing, maternal health conditions, quality of antenatal care, and environmental factors, which may substantially influence fetal growth and birth outcomes but were not available in the current dataset. Further exploration of regional disparities is essential to inform targeted interventions, and mixed-method approaches may provide deeper insights into maternal health behaviors and decision-making processes.

CONCLUSIONS

This study demonstrates that birth weight in Indonesia is associated with the interplay of maternal characteristics, health service utilization, and regional context. Maternal age, education level, place of delivery, maternal weight gain during pregnancy, and provincial variation were identified as significant determinants of birth weight, with maternal weight gain showing the strongest association. These findings suggest that optimal fetal growth is closely linked to maternal nutritional status, educational attainment, access to healthcare services, and broader regional disparities.

A major contribution of this study is the use of nationally representative data from the 2023 Indonesian Health Survey to provide comprehensive evidence that integrates maternal, healthcare, and contextual determinants of birth weight within a public health framework. The findings are particularly relevant for strengthening maternal and child health policies, supporting rural public health planning, and reducing regional inequalities in birth outcomes across Indonesia. The persistence of provincial disparities underscores the need for region-specific interventions rather than uniform national strategies. Accordingly, policies should prioritize routine monitoring of maternal weight gain during antenatal care, strengthen maternal nutrition programs, improve the quality and continuity of antenatal and delivery services, and expand equitable access to maternal healthcare, particularly in underserved and remote areas. Because this study employed a cross-sectional design, the findings should be interpreted as associations rather than evidence of causal relationships.

ACKNOWLEDGEMENT
The authors would like to express their sincere gratitude to the Faculty of Public Health, Mulawarman University for the invaluable support and facilitation provided throughout the implementation of this study.

FUNDING
The authors received no specific funding for this study.

AUTHORS' CONTRIBUTIONS
Rudi Saputra contributed to the study design, conceptualisation of the study, manuscript writing, participant enrolment, data collection, data acquisition, data analysis, fieldwork, manuscript review, and manuscript revision. Irfansyah B. Pakki contributed to the study design, conceptualisation of the study, manuscript writing, fieldwork, manuscript review, and manuscript revision. Both authors read and approved the final version of the manuscript.

AUTHORS' INFORMATION
dr. Rudi Saputra, S.Ked. is a researcher and student affiliated with the Master of Public Health Program, Faculty of Public Health, Mulawarman University, Samarinda, Indonesia. Dr. Irfansyah Baharuddin Pakki, S.KM., M.Kes. is a researcher and lecturer affiliated with the Department of Epidemiology, Faculty of Public Health, Mulawarman University, Samarinda, Indonesia.

COMPETING INTERESTS
The authors confirm that all of the text, figures, and tables in the submitted manuscript work are original work created by the authors and that there are no competing professional, financial, or personal interests from other parties.

REFERENCES
Adanikin, A., Lavin, T., Ogunkunle, T., Eleje, G. U., Osoti, A., Abdurrahman, A., & Ohuma, E. (2025). Mortality risks of infants with unmeasured birth weight in 33 Saharan African countries: An observational analysis. *BMJ Global Health*, *10*, 1–7. https://doi.org/10.1136/bmjgh-2024-018213

Alemu, M., Alemayehu, T., Messelu, M. A., Alemu, T., Mekonen, H., Alamneh, A. A., Agedew, E., & Endalifer, M. L. (2025). Gestational weight gain and its determinant factors among women attending at public health facilities, Northwest Ethiopia, 2023. *Maternal Health, Neonatology and Perinatology*, *11*, 1–7. https://doi.org/10.1186/s40748-025-00220-z

Alkhawaldeh, A., ALBashtawy, M., Rayan, A., Abdalrahim, A., Musa, A., Eshah, N., Khait, A. A., Qaddumi, J., Khraisat, O., & ALBashtawy, S. (2023). Application and Use of Andersen's Behavioral Model as Theoretical Framework: A Systematic Literature Review from 2012–2021. *Iran J Public Health*, *52*(7), 1346–1354. https://doi.org/10.18502/ijph.v52i7.13236

Busreea, R. A., Sen, S., Jahan, A., Begum, F., Siddika, M., & Mou, M. M. (2025). Relationship between birth weight of the neonate with weight of placenta and cord length in a tertiary care hospital. *International Journal of Reproduction. Contraception. Obstetrics and Gynecology*, *14*(4), 1023–1028. https://doi.org/10.18203/2320-1770.ijrcog20250837

da Silva, A. M., Stadler, C., Gustavo, L., Camargo, G. De, Silva, P. R., Marçallo, N., Souza, P., Lopes, M. S., Gomes, F., Rego, D. M., Bonini, J. S., Fabbri, R., Brand, J., Ferreira, L. M., Henrique, M., & Sari, M. (2025). The role of prenatal care in fetal and infant development in Brazil: A narrative review. *Healthcareare*, *13*, 1–25. https://doi.org/10.3390/healthcare13192414

Dewidar, O., John, J., Baqar, A., Madani, M. T., Saad, A., Riddle, A., Ota, E., Kung'u, J. K., Arabi, M., Raut, M. K., Klobodu, S. S., Rowe, S., Hatchard, J., Busch-Hallen, J., Jalal, C., Wuehler, S., & Welch, V. (2024). Effectiveness of nutrition counseling for pregnant women in low- and middle-income countries to improve maternal and infant behavioral, nutritional, and health outcomes: A systematic review. *Campbell Systematic Reviews*, *19*, 1–89. https://doi.org/10.1002/cl2.1361

Dhungana, R., Dhungana, A., Fassl, B., Judkins, A., Tomlin, B., Shakya, D. V., & Chalise, M. (2025). Determinants of low birth weight in newborns at a referral hospital in the Western Nepal: An unmatched case-control study. *BMC Pediatrics*, *25*, 1–11. https://doi.org/10.1186/s12887-025-06158-7

Engidaw, M. T., Lee, P., Fekadu, G., Mondal, P., & Ahmed, F. (2024). Effect of nutrition education during pregnancy on iron–folic acid supplementation compliance and anemia in low- and middle-income countries: A systematic review and meta-analysis. *Nutrition Reviews*, *83*(7), 1472–1487. https://doi.org/10.1093/nutrit/nuae170

Gangopadhyaya, A., Dubay, L., Johnston, E., & Pancini, V. (2024). How structural racism, neighborhood deprivation, and maternal characteristics contribute to inequities in birth outcomes. *Health Affairs Scholar*, *2*(8), 1–7. https://doi.org/10.1093/haschl/qxae092

Herwanto, E. S., Hudiyanto, P. S., & Muhammad, I. (2024). Factors of maternal influence on low birth weight. *Asian Journal of Health Research*, *3*(1), 5–10. https://doi.org/10.55561/ajhr.v3i1.144

Hossain, R., Begum, S., Neyma, M. al, Hossain, K., Faruk, M. O., Hossain, S., & Afnan, H. (2025). Parental socioeconomic, demographic, and neonatal factors influencing infants' low birth weight: A cross-sectional study in Bangladesh. *Health Science Reports*, *8*, 1–11. https://doi.org/10.1002/hsr2.71146

Huang, Z., Zhang, Y., Wang, J., Tan, X., & Zhang, A. (2025). Impact of maternal age on birth weight- related adverse

outcomes in newborns: A retrospective study in South-Central China. *BMC Pregnancy and Childbirth*, *25*, 1–8. https://doi.org/10.1186/s12884-025-07199-7

Idris, I. B., Hamis, A. A., Bukhori, A. B., Chan, D., Hoong, C., Yusop, H., Al, M., Shaharuddin, A., Adline, N., & Fauzi, F. A. (2023). Women's autonomy in healthcare decision making: A systematic review. *BMC Women's Health*, *23*, 1–10. https://doi.org/10.1186/s12905-023-02792-4

Kassie, G. A., Gebrekidan, A. Y., Adella, G. A., Woldegeorgis, B. Z., Haile, K. E., Workineh, A., & Asgedom, Y. S. (2025). Socioeconomic inequality and determinants of low birth weight in Kenya: A multilevel analysis using 2022 demographic and health survey. *Italian Journal of Pediatrics*, *51*, 1–10. https://doi.org/10.1186/s13052-025-02074-9

Keats, E. C., Oh, C., Chau, T., Khalifa, D. S., Imdad, A., & Bhutta, Z. A. (2021). Effects of vitamin and mineral supplementation during pregnancy on maternal, birth, child health and development outcomes in low- and middle- income countries: A systematic review. *Campbell Systematic Reviews*, *17*, 1–246. https://doi.org/10.1002/cl2.1127

Kementerian Kesehatan Republik Indonesia. (2023). Survei Kesehatan Indonesia. In *Kementerian Kesehatan RI*.

Kurniasari, L., Kartasurya, M. I., Nugraheni, S. A., & Agushybana, F. (2024). Determinants for low birth weight in mothers giving birth during the Covid-19 pandemic. *Amerta Nutrition*, *8*(1), 27–36. https://doi.org/10.20473/amnt.v8i1SP.2024.27

Kusuma, F. N., Riana, S., Agustina, T., & Herawati, E. (2024). The relationship between maternal weight gain during pregnancy and compliance with antenatal care and baby's weight at birth. *Eduvest*, *4*(6), 5377–5387. https://doi.org/10.59188/eduvest.v4i6.1463

Liu, Y., Jin, C., Ni, L., Zheng, T., & Liu, X. (2022). Educational attainment and offspring birth weight: A bidirectional Mendelian randomization study. *Frontiers in Genetics*, *13*, 1–12. https://doi.org/10.3389/fgene.2022.922382

Marthias, T., Anindya, K., Saputri, N. S., Putri, L. P., Atun, R., & Lee, J. T. (2025). Effective coverage for reproductive, maternal, neonatal and newborn health: An analysis of geographical and socioeconomic inequalities in 39 low-income countries. *BMJ Global Health*, *10*, 1–12. https://doi.org/10.1136/bmjgh-2024-016549

Minami, M., P, N. A. J., Noguchi, S., Eitoku, M., Marie, S., Muchanga, J., Mitsuda, N., Komori, K., Lovell, K. Y., Maeda, N., Fujieda, M., & Suganuma, N. (2022). Gestational weight gain mediates the effects of energy intake on birth weight among singleton pregnancies in the Japan Environment and Children's Study. *BMC Pregnancy and Childbirth*, *22*, 1–12. https://doi.org/10.1186/s12884-022-04898-3

Mlotshwa, P. R., & Sibiya, M. N. (2023). Pregnant women's views regarding maternity facility-based delivery at primary health care facilities in the Province of KwaZulu-Natal in South Africa. *International Journal of Environmental Research and Public Health*, *20*, 1–12. https://doi.org/10.3390/ijerph20156535

Mordal, E., Hanssen, I., Kassa, A., & Vatne, S. (2021). Mothers' experiences and perceptions of facility-based delivery care in Rural Ethiopia. *Health Services Insights*, *14*, 1–7. https://doi.org/10.1177/11786329211017684

Parrettini, S., Caroli, A., & Torlone, E. (2020). Nutrition and metabolic adaptations in physiological and complicated pregnancy: Focus on obesity and gestational diabetes. *Frontiers in Endocrinology*, *11*, 1–19. https://doi.org/10.3389/fendo.2020.611929

Putri, S. A., & Herdiman, J. (2023). The relationship between maternal age and the incidence of low birth weight babies. *Jurnal Eduhealt*, *14*(3), 1358–1362. https://doi.org/10.54209/jurnaleduhealth.v14i3.2592

Rahmadani, H. D. M., & Santik, Y. D. P. (2024). Factors of low birth weight in Indonesia: An analysis of the 2017 Indonesia Demographic and Health Survey (IDHS 2017). *Unnes Journal of Public Health*, *13*(1), 1–10. https://doi.org/10.15294/ujph.v13i1.68487

Raru, T. B., Ayana, G. M., Zakaria, H. F., & Merga, B. T. (2022). Association of higher educational attainment on antenatal care utilization among pregnant women in East Africa using Demographic and Health Surveys (DHS) from 2010 to 2018: A multilevel analysis. *International Journal OfWomen's Health*, *14*, 67–77. https://doi.org/10.2147/IJWH.S350510

Rizvi, D. S. (2022). Health education and global health: Practices, applications, and future research. *Journal of Education and Health Promotion*, *11*, 1–7. https://doi.org/10.4103/jehp.jehp

Salam, A., Islam, M., & Karim, R. (2025). Risk factors and co-occurring patterns of low birth weight in Bangladesh: Insights from logistic regression and association rule mining. *PLOS Global Public Health*, *20*, 1–15. https://doi.org/10.1371/journal.pgph.0005177

Smith, E. R., Gomes, F., Adu-afarwuah, S., Aguayo, V. M., Arifeen, S. El, Bhutta, A., Caniglia, E. C., Christian, P., Devakumar, D., Dewey, K. G., Fawzi, W. W., Friis, H., Gomo, E., Guindo, O., Hallamaa, L., Isanaka, S., Kæstel, P., Lachat, C., Maleta, K., Sudfeld, C. R. (2025). Contribution of maternal adherence to the effect of multiple micronutrient supplementation during pregnancy: A systematic review and individual participant data meta-analysis. *Advances in Nutrition*, *16*, 1–11. https://doi.org/10.1016/j.advnut.2025.100455

Tripathi, P., Chakrabarty, M., Singh, A., & Let, S. (2024). Geographic disparities and determinants of full utilization of the continuum of maternal and newborn healthcare services in rural India. *BMC Public Health*, *24*, 1–14. https://doi.org/10.1186/s12889-024-20714-3

United Nations. (2025). *The 17 Goals*. United Nations. https://sdgs.un.org/goals

Vizheh, M., Muhidin, S., Moghadam, Z. B., & Zareiyan, A. (2021). Women empowerment in reproductive health: A systematic review of measurement properties. *BMC Women's Health*, *21*, 1–13. https://doi.org/10.1186/s12905-021-01566-0

World Health Organization. (2025). *Preterm and low birth weight infants*. WHO. https://www.who.int/teams/maternal-newborn-child-adolescent-health-and-ageing/newborn-health/preterm-and-low-birth-weight