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Birth spacing, health insurance, source of drinking water, and low birth weight in Indonesia

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Abstract

Purpose: Low birth weight (LBW) in Indonesia is a major concern and must be addressed immediately, as it affects human resource quality. The study aimed to determine the proximate, intermediate, and distal factors associated with LBW in Indonesia. **Methods:** The study used a cross-sectional design to estimate the association between risk factors and LBW in Indonesia using data sources from the 2012 IDHS and 2017 IDHS. We identified women who gave birth in the past five years and had only a singleton baby as eligible respondents. **Results:** Infants living in Sumatera (aOR = 0.57; 95% CI = 0.32-0.99) and rural areas (aOR = 0.69; 95% CI = 0.50-0.97) were more protective of LBW than those living in Papua and Maluku and their urban counterparts. Meanwhile, households with an improved source of drinking water had a higher risk of LBW than households with an unimproved source (aOR = 1.45; 95% CI = 1.06-1.97). The odds of LBW were four times higher among mothers who never married than among others (aOR= 3.57; 95% CI = 1.08-11.81). The risk of LBW was also higher for mothers who delivered by cesarean section than for those who had no cesarean section/vaginal delivery (aOR = 1.75; 95% CI = 1.21-2.52). Further-more, female infants were approximately 1.35 times more likely to have LBW than male infants (aOR = 1.35; 95% CI = 1.00-1.83). Although health insurance ownership was not associated with LBW, the data show differences in the number of respondents with and without health insurance. **Conclusion:** Residence area, marital status, cesarean section, and infant sex were significant determinants of LBW. A public health strategy should implement targeted antenatal counseling for vulnerable groups such as rural mothers and unmarried mothers by establishing standard protocols for monitoring fetal growth within routine antenatal care services.

Keywords: cesarean section; IDHS; low birth weight; maternal factors; social factors

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INTRODUCTION

The World Health Organization (WHO) defines low birth weight (LBW) as a birth weight of less than 2500 grams regardless of gestational age [1]. LBW is a major public health problem in many developing countries [2–6]. LBW is also considered a global indicator of nutrition and maternal health and an important predictor of mortality and morbidity of neonates and children under five [7,8]. Globally, the estimated LBW rate is still 15–20% of births worldwide, or about 20 million births per year [1]. The percentage of LBW in low- and middle-income countries (LMICs) is estimated at >90% [4]. Data from the Indonesia Demographic and Health Survey (IDHS) show that the percentage of LBW was 7.3% in 2012 and 7.1% in 2017 [9]. Although the percentage of LBW in Indonesia has decreased

compared with the previous period, it is still far from the Global Nutrition Targets 2025, which calls for a 30% reduction in LBW, or 3% per year [1]. The problem of LBW in Indonesia is an important concern and must be addressed immediately because it will affect the quality of human resources [10].

Various studies reported that socio-demographic factors, maternal and obstetric characteristics, and pregnancy complications were significant determinants of LBW [11]. A study conducted in India has shown that socio-demographics, maternal characteristics, infant characteristics, and antenatal care are associated with LBW [12]. Studies conducted in Indonesia using IDHS reported that prenatal care, biological, obstetrical, socio-demographic characteristics, and maternal factors were associated with LBW. However, those studies had limited generalizability because those studies only used the 2017 IDHS [10,13].

Although many similar studies exist, research on factors associated with LBW remains essential to reduce its prevalence in Indonesia. Existing studies have mostly used data from a single survey wave, which limits the ability to track changes over time and restricts how broadly the results can be applied. In contrast, this study identified that female infant sex, cesarean section, never-married status, maternal illiteracy, and improved drinking water sources were associated with higher LBW risk, whereas rural residence and living in Sumatra served as protective factors. To address the evidence gap of multi-wave analyses, this study pooled data from the 2012 and 2017 IDHS surveys using a structured hierarchical framework, aiming to determine the distal, intermediate, and proximate factors contributing to low birth weight in Indonesia.

METHODS

Study design, data source, study population, and sample selection

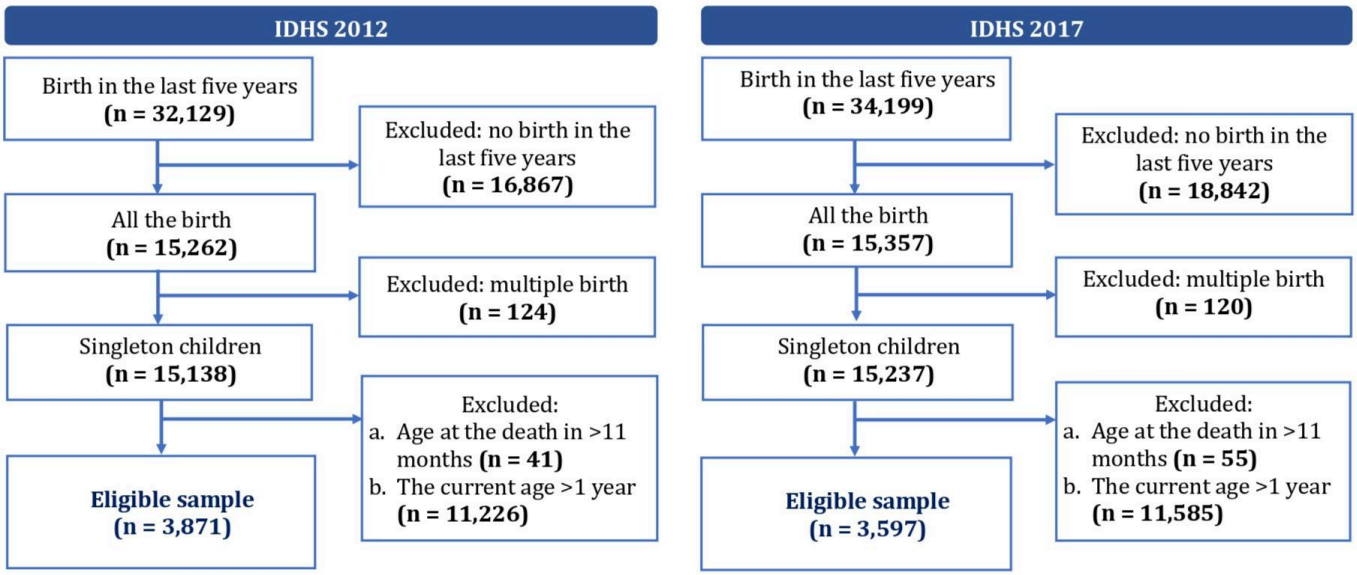
This cross-sectional study estimates the association between risk factors and LBW in Indonesia using data from the 2012 and 2017 IDHS. The IDHS sampling design used a two-stage stratified cluster sampling method that reflects national, provincial, and urban/rural levels. In the first stage, researchers selected urban and rural census blocks as the main sampling units across all provinces using Probability Proportional to Size (PPS). Stage 2 (Households): A fixed number of households, usually 25 per block, were selected systematically from the most recent household records within each selected census block. We identified women who gave birth in the last five years and had only a singleton baby as eligible respondents. A total of 3,871 live-born infants from the 2012 IDHS and 3,597 from the 2017 IDHS met the initial eligibility criteria. The sampling flow chart was presented in Figure 1. Data were weighted using DHS sampling weights. To account for the complex survey design, all models incorporated individual sampling weights (v005/1,000,000), cluster IDs as primary sampling units (v001/v021), and regional urban–rural stratification variables (v022/v023). In the descriptive analysis, the sample has not undergone weighting, whereas in the bivariate analysis, the sample size reflects the application of weighting.

Variables and operational definitions

The dependent variable was birth weight, dichotomized into two groups: low (<2,500 grams) and normal (≥2,500 grams). The independent variables were proximate factors, including wealth index, area of residence, region type, and source of drinking water. Before pooling, drinking water sources from the 2012 and 2017 IDHS were standardized into improved and unimproved categories based on WHO/UNICEF JMP guidelines to ensure comparability. Intermediate factors include maternal age, mother's education, mother's literacy, marital status, and parity status. Henceforth, the mother's desire, prenatal assistance, place of delivery, delivery assistance, cesarean section, history of abortion, and health insurance were considered. Furthermore, the distal variables were the sex of the infant and birth interval.

Statistical analysis

To formally assess differences in sample distribution across survey years, we conducted design-adjusted Rao-Scott chi-square tests. We addressed missing data using an available-case approach for descriptive statistics, resulting in varying numbers of observations across variables. We retained variables with missing values, such as birth interval, where missingness was primarily structural because primiparous births lack a preceding birth interval, rather than excluding them. Retaining these variables prevents omitted variable bias and preserves the hierarchical framework's theoretical integrity.



Note: Sample counts presented in the flowchart were weighted frequencies based on the complex survey design.

Figure 1. Sample flowchart IDHS 2012 and 2017

For multivariable logistic regression modeling (SAS PROC GENMOD), a complete-case analysis (listwise deletion) was applied, retaining only observations with complete data for all variables included in each respective model. Characteristics did not differ significantly between complete and missing cases. A separate multivariable logistic regression analysis was performed for the 2012 IDHS and 2017 IDHS datasets, with stratified analysis carried out using SAS PROC GENMOD.

Multivariate analysis was conducted separately for each survey year (IDHS 2012 and IDHS 2017) (stratified multivariable logistic regression analysis). We did not use a pooled multivariable model in Table 3 to examine the determinants of LBW for each era. We used a hierarchical modeling approach, entering distal factors first in Model 1, intermediate factors in Model 2, and proximate factors in Model 3. Potential interactions between the independent variables within each year of the survey were examined, but no statistically significant interaction effects were found ($p>0.05$). As a result, the final multivariable models were developed without including interaction terms in order to keep the model as simple and efficient as possible. All models included individual sampling weights, cluster identifiers, and strata to address the complex survey design. The level of statistical significance was set at $p< 0.05$. Respondents provided informed consent, participated voluntarily, and their privacy and confidentiality were protected throughout the study. The Ethics Committee of Universitas Ahmad Dahlan approved this study (Approval No. 022104018). Informed consent was obtained from all participants.

RESULTS

Table 1 lists the characteristics of infants with LBW. Of 3,871 samples, 11.79% (2012 IDHS) were LBW infants. In the 2017 IDHS, 6.92% of 3,597 infants were LBW. The percentage of LBW decreased significantly from 12% to 7%.

Determinants of LBW

The highest percentages were among infants living in Sumatera (2012 IDHS) and Java and Bali (2017 IDHS). About 51-55% of infants live in rural areas, and 90-95% of mothers are able to read the whole sentence. In contrast, the percentage of an un-improved source of drinking water in 2012 IDHS (84%) and an un-improved drinking water source in 2017 IDHS (49%). Around 96% of mothers were married. Regarding the mode of delivery, the proportion of mothers who delivered via cesarean section was 14.0% in 2012 and increased to 19.0% in 2017. The vast majority of mothers delivered non-surgically (vaginally), accounting for 86.0% of births in 2012 and 81.0% in 2017. Further, the higher percentage was among male infants (52%).

Table 2 shows the bivariate analysis: mothers in the middle-income (cOR = 1.43; 95% CI = 1.23–1.82) and richest wealth quantile (cOR = 1.88; 95% CI = 1.35–2.62) groups showed higher risks of LBW. Maternal age of 25–34 years consistently served as a protective factor against LBW (cOR = 0.31 95% CI = 0.22–0.46) compared to the younger age group of 15–24 years. Delivery in non-health facilities (cOR = 2.04; 95% CI = 1.30–2.73) and delivery assisted by non-professional health workers (cOR = 1.83; 95% CI = 1.30–2.58) increased the risk of LBW.

Table 1. Distribution of LBW by selected factors in IDHS 2012 and 2017

Variables	IDHS 2012 (N=3,871)	IDHS 2017 (N=3,597)
	n (%)	n (%)
Low birth weight (LBW) (2012: n= 3,291; 2017: n=3,287)		
Yes	388 (11.79)	366 (6.92)
No	2,903 (88.21)	2,921 (93.08)
DISTAL FACTORS		
Wealth index		
Poorest or poor	1,934 (49.96)	1,714 (47.65)
Middle	688 (17.77)	644 (17.90)
Richest or rich	1,249 (32.27)	1,239 (34.45)
Region		
Papua and Maluku	469 (12.12)	369 (10.26)
Sumatera	1,126 (29.09)	966 (26.86)
Java and Bali	1,023 (26.43)	1,068 (29.69)
Nusa Tenggara	225 (5.81)	303 (8.42)
Kalimantan	398 (10.28)	318 (8.84)
Sulawesi	630 (16.27)	573 (15.93)
Residence type		
Urban	1,737 (44.87)	1,740 (48.37)
Rural	2,134 (55.13)	1,857 (51.63)
Source of drinking water (2012: n=3,869; 2017: n=3,420)		
Unimproved source	3,247 (83.92)	1,688 (49.36)
Improved source	622 (16.08)	1,732 (50.64)
INTERMEDIATE FACTORS		
Maternal age (years)		
15-24	1,252 (32.34)	922 (25.63)
25-34	1,891 (48.85)	1,887 (52.46)
35-49	728 (18.81)	788 (21.91)
Mother education		
No education	137 (3.54)	53 (1.47)
Primary	1,095 (28.29)	811 (22.55)
Secondary and higher	2,639 (68.17)	2,733 (75.98)
Mother's literacy (2012: n=3,478; 2017: n=3,408)		
Cannot read at all	373 (9.69)	180 (5.02)
Able to read the whole sentence	3,478 (90.31)	3,408 (94.98)
Marital status		
Married	3,726 (96.25)	3,440 (95.64)
Never married	81 (2.09)	87 (2.42)
Widowed or divorced	64 (1.65)	70 (1.95)
Parity		
1-3	3,205 (82.80)	2,974 (82.68)
≥4	666 (17.20)	623 (17.32)
Mother desired the pregnancy (2012: n=3,523; 2017: n=2,930)		
Then	3,257 (84.71)	2,930 (82.19)
Later	322 (8.37)	356 (9.99)
No more	266 (6.92)	279 (7.83)
Prenatal assistance (2012: n=3,669; 2017: n=3,408)		
Health professional	3,669 (95.52)	3,408 (95.65)
Non-health professional	172 (4.48)	155 (4.35)
Place of delivery (2012: n= 3,845; 2017: n=2,625)		
Health facility	1,495 (38.88)	2,625 (77.50)
Non-health facility	2,350 (61.12)	762 (22.50)
Delivery assistance (2012: n=3,061; 2017: n=3,122)		
Health professional	3,061 (79.65)	3,122 (87.43)
Non-health professional	782 (20.35)	449 (12.57)
Cesarean section (2012: n=3,298; 2017: n=2,902)		
No	3,298 (85.93)	2,902 (81.43)
Yes	540 (14.07)	662 (18.57)
History of an abortion		
No	3,341 (86.31)	3,063 (85.15)
Yes	530 (13.69)	534 (14.85)
Health insurance (2012: n=3,868)		
No	2,381 (61.56)	1,216 (33.81)
Yes	1,487 (38.44)	2,381 (66.19)
PROXIMATE FACTORS		
Sex of the child		
Male	2,028 (52.39)	1,881 (52.29)
Female	1,843 (47.61)	1,716 (47.71)
Birth interval (2012: n= 2,442; 2017: n=2,448)		
<24 months	314 (12.86)	267 (10.91)
≥24 months	2,128 (87.14)	2,181 (89.09)

Note: Sample sizes (*n*) are reported as unweighted counts, whereas percentages (%) were calculated using complex survey design sample weights. Total valid sample sizes (*N*) per variable varies due to missing data or subgroup restrictions. Initial eligible samples were N = 3,871 (2012) and N = 3,597 (2017).

Table 2. Bivariate analysis of factors associated with LBW IDHS 2012 and 2017

Variables	IDHS 2012 (N=3,871)			IDHS 2017 (N=3,597)		
	LBW	Non LBW	COR (95%CI)	LBW	Non LBW	COR (95%CI)
DISTAL FACTORS						
Wealth index						
Poorest or poor	213	1,212	Ref	198	1,258	Ref
Middle	70	575	1.87 (1.46–2.39)***	48	573	1.43 (1.23–1.82)**
Richest or rich	105	1,116	1.44 (1.08–1.92)*	120	1,090	1.88 (1.35–2.62)**
Region						
Papua and Maluku	38	225	Ref	37	234	Ref
Sumatera	92	927	1.70 (1.14–2.55)*	90	818	1.44 (0.95–2.16)
Java and Bali	114	857	1.27 (0.86–1.89)	104	925	1.41 (0.94–2.10)
Nusa Tenggara	31	152	0.83 (0.49–1.39)	42	219	0.83 (0.51–1.33)
Kalimantan	40	319	1.35 (0.84–2.17)	30	200	1.42 (0.85–2.37)
Sulawesi	73	423	0.98 (0.64–1.50)	63	456	1.45 (0.74–1.77)
Residence type						
Urban	180	1,479	Ref	152	1,501	Ref
Rural	208	1,424	0.83 (0.67–1.03)	191	1,420	0.78 (0.62–0.98)*
Source of drinking water (2012: n=3,291; 2017: n=3,124)						
Un-improved source	334	2,416	Ref	152	1,404	Ref
Improved source	54	487	1.25 (0.92–1.69)	191	1,377	1.00 (0.77–1.30)
INTERMEDIATE FACTORS						
Maternal age (years)						
15-24	155	890	Ref	107	723	Ref
25-34	156	1,489	0.33 (0.24–0.46)***	181	1,571	0.31 (0.22–0.46)***
35-49	77	524	0.76 (0.56–1.04)	78	627	0.78 (0.54–1.13)
Mother education						
No education	7	40	Ref	4	19	Ref
Primary	130	687	1.52 (0.67–3.43)	89	593	2.46 (1.10–5.54)
Secondary and higher	251	2,176	0.93 (0.41–2.11)	273	2,309	1.34 (0.58–3.05)
Mother's literacy (2012: n=3,274; 2017: n=3,279)						
Cannot read at all	31	158	Ref	22	89	Ref
Able to read the whole sentence	355	2,730	1.51 (1.01–2.25)*	342	2,826	2.29 (1.47–3.57)**
Marital status						
Married	369	2,831	Ref	340	2,825	Ref
Never married	9	34	0.50 (0.25–1.00)	13	51	0.50 (0.25–1.02)
Widowed or divorced	10	38	0.49 (0.23–1.04)	13	45	2.07 (0.66–6.60)
Parity						
1-3	328	2,499	Ref	311	2,464	Ref
≥4	60	404	0.88 (0.66–1.17)	55	457	0.41 (0.31–0.54)***
Mother desired the pregnancy (2012: n=3,290; 2017: n=3,287)						
Then	336	2,446	Ref	305	2,400	Ref
Later	24	250	0.99 (0.66–1.49)	35	288	0.90 (0.55–1.46)
No more	28	206	0.70 (0.45–1.08)	26	233	1.16 (0.71–1.87)
Prenatal assistance (2012: n=3,286; 2017: n=3,286)						
Health professional	367	2,798	Ref	351	2,810	Ref
Non-health professional	20	101	0.66 (0.41–1.08)	15	110	1.58 (0.89–2.78)
Place of delivery (2012: n=3,290; 2017: n=3,109)						
Health facility	116	854	Ref	65	446	Ref
Non-health facility	271	2,049	1.03 (0.82–1.30)	278	2,320	2.04 (1.30–2.73)***
Delivery assistance (2012: n=3,289; 2017: n=3,286)						
Health professional	326	2,480	Ref	333	2,653	Ref
Non-health professional	61	422	0.91 (0.67–1.22)	33	267	1.83 (1.30–2.58)**
Cesarean section (2012: n=3,283; 2017: n=3,284)						
No	326	2,425	Ref	286	2,343	Ref
Yes	60	472	1.06 (0.79–1.42)	80	575	0.95 (0.66–1.35)
History of an abortion (2012: n=3,291; 2017: n=3,287)						
No	337	2,494	Ref	311	2,476	Ref
Yes	51	409	1.08 (0.79–1.48)	55	445	1.25 (0.89–1.76)
Health insurance (2012: n=3,289; 2017: n=3,287)						
No	233	1,731	Ref	109	978	Ref
Yes	154	1,171	1.02 (0.82–1.27)	257	1,943	0.97 (0.74–1.27)
PROXIMATE FACTORS						
Sex of child (2012: n=3,291; 2017: n=3,287)						
Male	191	1,523	Ref	184	1,528	Ref
Female	197	1,380	0.88 (0.71–1.09)	182	1,393	0.92 (0.74–1.15)
Birth interval (2012: n=2,013; 2017: n=2,214)						
<24 months	28	192	Ref	27	194	Ref
≥24 months	173	1,620	1.37 (0.89–2.09)	203	1,790	1.23 (0.80–1.88)

Note: * p<0.05; ** p<0.01; *** p<0.001. The sum of the subcategories for the variables is affected by missing data. COR (Crude Odds Ratio); CI (Confidence Interval)

Table 3. Factors associated with LBW IDHS 2012 and 2017

Variables	IDHS 2012			IDHS 2017		
	Model 1 aOR (95% CI)	Model 2 aOR(95% CI)	Model 3 aOR(95% CI)	Model 1 aOR(95% CI)	Model 2 aOR(95% CI)	Model 3 aOR(95% CI)
DISTAL FACTORS						
Wealth index						
Poorest or poor	Ref	Ref	Ref	Ref	Ref	Ref
Middle	0.70(0.52–0.94)***	0.77(0.57–1.05)	1.02(0.67–1.56)	0.54(0.38–0.77)**	0.56(0.39–0.82)*	0.64(0.40–1.01)
Richest or rich	0.53(0.40–0.70)*	0.61(0.45–0.82)**	0.73 (0.47–1.13)	0.72(0.54–0.96)**	0.73(0.53–1.00)	0.79(0.53–1.19)
Region						
Papua and Maluku	Ref	Ref	Ref	Ref	Ref	Ref
Sumatera	0.61(0.40–0.91)**	0.61(0.40–0.94)***	0.56(0.31–1.02)	0.79(0.52–1.21)	0.74(0.47–1.18)	0.57(0.32–0.99)*
Java and Bali	0.93(0.62–1.41)	0.89(0.57–1.38)	0.90(0.49–1.67)	0.76(0.50–1.16)	0.81(0.51–1.28)	0.67(0.38–1.18)
Nusa Tenggara	1.11(0.66–1.87)	1.00(0.64–1.89)	1.22(0.58–2.56)	1.10(0.67–1.80)	1.23(0.72–2.10)	0.91(0.47–1.78)
Kalimantan	0.74(0.46–1.20)	0.72(0.44–1.18)	0.74(0.36–1.52)	0.70(0.41–1.21)	0.74(0.42–1.30)	0.64(0.32–1.28)
Sulawesi	1.00(0.65–1.53)	1.02(0.66–1.60)	1.29(0.71–2.34)	0.83(0.53–1.31)	0.84(0.52–1.37)	0.86(0.48–1.53)
Residence type						
Urban	Ref	Ref	Ref	Ref	Ref	Ref
Rural	0.98(0.77–1.24)	0.98(0.76–1.25)	0.92(0.66–1.31)	0.87(0.67–1.12)	0.78(0.59–1.03)	0.69(0.50–0.97)*
Source of drinking water						
Un-improved source	Ref	Ref	Ref	Ref	Ref	Ref
Improved source	0.78(0.57–1.06)	0.79(0.58–1.08)	0.70(0.45–1.10)	1.21(0.95–1.53)	1.24(0.97–1.58)	1.45(1.06–1.97)*
INTERMEDIATE FACTORS						
Maternal age (years)						
15-24	—	Ref	Ref	—	Ref	Ref
25-34	—	0.66(0.52–0.85)***	0.70(0.43–1.13)	—	0.87(0.65–1.16)	1.02(0.60–1.72)
35-49	—	0.82(0.52–1.19)	0.91(0.52–1.60)	—	0.97(0.66–1.43)	1.06(0.58–1.92)
Mother education						
No education	—	Ref	Ref		Ref	Ref
Primary	—	1.60(0.62–4.10)	1.62(0.53–4.99)	—	1.13(0.33–3.96)	1.50(0.37–6.11)
Secondary and higher	—	1.12(0.42–2.94)	0.85(0.26–2.74)	—	1.08(0.30–3.97)	1.38(0.32–5.96)
Mother's literacy						
Cannot read at all	—	Ref	Ref	—	Ref	Ref
Able to read the whole sentence	—	0.93(0.57–1.49)	1.00(0.56–1.78)	—	0.48(0.26–0.90)*	0.37(0.19–0.73)**
Marital status						
Married	—	Ref	Ref	—	Ref	Ref
Never married	—	1.26(0.58–2.75)	3.57(1.08–11.81)*	—	1.60(0.77–3.32)	2.05(0.70–6.01)
Widowed or divorced	—	1.63(0.79–3.37)	1.96(0.96–6.22)	—	1.73(0.84–3.55)	1.49(0.49–4.55)
Parity						
1-3	—	Ref	Ref	—	Ref	Ref
≥4	—	1.03(0.71–1.49)	1.17(0.78–1.74)	—	0.86(0.59–1.25)	0.89(0.61–2.32)
Mother's desire for pregnancy						
Then	—	Ref	Ref	—	Ref	Ref
Later	—	0.68(0.43–1.06)	0.87(0.51–1.48)	—	1.05(0.71–1.57)	1.05(0.65–1.69)
No more	—	0.97(0.62–1.52)	1.08(0.67–1.73)	—	0.94(0.59–1.49)	0.92(0.56–1.50)
Prenatal assistance						
Health professional	—	Ref	Ref	—	Ref	Ref
Non-health Professional	—	1.43(0.85–2.39)	1.57(0.76–3.26)	—	128(0.71–2.33)	1.14(0.54–2.41)
Place of delivery						
Health facility	—	Ref	Ref	—	Ref	Ref
Non-health facility	—	1.14(0.84–1.54)	1.08(0.69–1.61)	—	0.76(0.52–1.12)	0.79(0.49–1.27)
Delivery assistance						
Health professional	—	Ref	Ref	—	Ref	Ref
Non-health professional	—	0.85(0.59–1.23)	1.05(0.64–1.72)	—	0.85(0.53–1.36)	0.99(0.56–1.73)
Cesarean section						
No	—	Ref	Ref	—	Ref	Ref
Yes	—	1.08(0.78–1.48)	1.51(0.97–2.34)	—	1.32(0.98–1.78)	1.75(1.21–2.52)**
History of an abortion						
No	—	Ref	Ref	—	Ref	Ref
Yes	—	0.96(0.69–1.33)	0.89(0.59–1.34)	—	0.98(0.70–1.36)	0.84(0.56–1.26)
Health insurance						
No	—	Ref	Ref	—	Ref	Ref
Yes	—	1.00(0.80–1.26)	0.94(0.68–1.29)	—	1.34(1.02–1.75)*	1.36(0.97–1.92)
PROXIMATE FACTORS						
Sex of the child						
Male	—	—	Ref	—	—	Ref
Female	—	—	1.35(1.00–1.83)*	—	—	1.08(0.52–1.32)
Birth interval						
<24 months	—	—	Ref	—	—	Ref
≥24 months	—	—	0.77(0.47–1.23)	—	—	0.82(0.52–1.32)

Note: * $p<0.05$; ** $p<0.01$; *** $p<0.001$. aOR (adjusted odds ratio); CI (confidence interval)

Multivariate analysis

Preliminary evaluation of potential interaction terms among independent variables within the 2012 and 2017 models revealed no statistically significant interactions (p>0.05). The difference in the effective sample size (N) between the models for that year is due to the removal of missing data. Table 3 shows the multivariate logistic regression analysis and adjusted ORs. In Model 1, being in the middle (aOR = 0.70; 95% CI = 0.52-0.94) wealth group was a strong predictor of LBW. Additionally, being in the richest or rich wealth group was a strong predictor (aOR = 0.53; 95% CI = 0.40-0.70) in Model 1. When Model 2 included additional factors related to maternal and health services, the impact of wealth became more significant (aOR = 0.61; 95% CI = 0.45-0.82). Additionally, the effect

of living in Sumatra was significant, with an aOR of 0.61 (95% CI: 0.40–0.94). Health insurance ownership was significantly associated with LBW risk. This result indicates that the effect of socio-economic disadvantage on LBW is mainly influenced by maternal health behaviors, including insufficient antenatal care visits and the mother's age.

Adding proximate clinical variables in Model 3 further refined the distal and intermediate associations. An increased risk of LBW was significantly associated with an improved source of drinking water (aOR = 1.45; 95% CI: 1.06–1.97), mothers who had never been married (aOR = 3.57; 95% CI: 1.08–11.81), utilizing and delivery by cesarean section (aOR = 1.75; 95% CI: 1.21–2.52), and female infant sex (aOR = 1.35; 95% CI: 1.00–1.83). On the other hand, several protective factors against LBW include residing in the Sumatera region compared to Papua and Maluku (aOR = 0.57; 95% CI: 0.32–0.99), rural residence (aOR = 0.69; 95% CI: 0.50–0.97), and maternal literacy (aOR = 0.37; 95% CI: 0.19–0.73)

DISCUSSION

The most common cause of neonatal morbidity and mortality is low birth weight (LBW). Understanding the causes of LBW is needed to achieve the Sustainable Development Goals (SDGs) targets. This study found that LBW was associated with residence area, marital status, cesarean section (CS), and infant sex. Health insurance was unrelated to LBW. More respondents had access to health insurance in 2012 than in 2017. Comparing 2012 and 2017 results shows major, large-scale changes in Indonesia's maternal healthcare system. The 2012 survey represents the baseline period of fragmented health financing under the Jamkesmas and Jampersal programs, while the 2017 survey marks the beginning of the expansion phase of the National Health Insurance Scheme (Jaminan Kesehatan Nasional/JKN), introduced in January 2014.

The significant nationwide rise in facility-based and institutional deliveries during these 5 years aligns with JKN's elimination of financial obstacles to accessing skilled birth attendance. Although the JKN program has increased access to childbirth services in healthcare facilities, reducing LBW requires a change in approach. Instead of focusing only on access to delivery services, attention should shift to the quality of care provided from the first trimester. The Ministry of Health should require all Community Health Centers (*Puskesmas*) to follow standard screening procedures, regularly monitor fetal growth, and provide necessary nutritional support to pregnant women. In addition, BPJS Kesehatan should tie the reimbursement rates for service providers to their adherence to the complete standard of six antenatal care (ANC) visits.

The odds of LBW were significantly lower for infants residing in rural areas than in urban areas. A study conducted in Morocco reported a similar result [14]. Unlike previous beliefs that living in rural areas always increases newborn risk, our study shows that rural residence can offer protection when accounting for factors such as wealth and education. In Indonesia's decentralized health system, the growth of Community Health Centers (Puskesmas) and Integrated Community Health Service (Posyandu) in rural areas has effectively enhanced basic maternal outreach and social support networks. When we consider household wealth and access to healthcare, rural areas may offer stronger community support systems and less exposure to the stressful conditions often found in urban environments.

Meanwhile, other studies reported discrepant findings, with rural residents having a higher likelihood of LBW [15–18]. It could be that the problems experienced by pregnant women living in rural areas were quite complex. These include differences in income, education, and workload [11]. Pregnant women do not access ANC services, do not use health facility services, and are more susceptible to poor nutrition due to women not having sufficient income to afford it [11,16]. Another reason is poor infrastructure and less access to basic health services in rural areas [15,19,20]. Women in rural areas do hard physical work, both outdoors and at home, so they bear a double burden [15].

This study revealed that the risk of LBW was four times higher among mothers who had never married. Our findings are similar to several studies [3,21–23]. Social environment, such as living arrangements and marital status, is a risk factor for gynecological and neonatal health indicators. Mothers who live without a partner have been shown to have significantly affected pregnant women's mental and physical health, as do their babies [22]. Unmarried women may experience higher stress than married mothers due to less stable relationships. In addition, they live under pressure and lack social support from their families, the baby's father, and general functional support during pregnancy, affecting fetal growth and resulting in LBW [21].

Given the elevated risk among single, unmarried, and socio-economically disadvantaged mothers, existing social protection programs (such as *Program Keluarga Harapan* / PKH) should explicitly incorporate conditional cash transfers tied to early ANC attendance and maternal nutritional compliance for high-risk pregnant women. Leverage rural community health

networks to maintain the positive outcomes seen in rural areas; regional health offices should increase financial support and provide structured training for integrated community health workers (*Kader Posyandu*). Enhancing home-visiting programs for mothers in rural areas helps identify pregnancy issues early and addresses the challenge of limited access to medical services in remote locations. Standardizing early-warning referral systems between Community Health Centers (Puskesmas) and the Regional Public Hospital (RSUD) ensures timely management of high-risk pregnancies and low-birth-weight infants.

Cesarean Section is also a predictor of LBW. This finding aligns with several studies [24–26]. Many studies do not explain the underlying mechanisms of cesarean section and LBW. Pregnant women may need an emergency lower segment cesarean section (LSCS) due to threatened maternal conditions, such as premature gestation, eclampsia, bleeding, Placenta Previa, and an infant with LBW [27]. The positive link found between delivering a baby by cesarean section and LBW should be understood by considering that the cause might be the other way around, such as when medical reasons for the cesarean section were actually related to the baby's LBW. In clinical practice, pregnancies that were considered high risk, such as those where there was a suspicion of fetal growth restriction, low amniotic fluid, or signs of fetal distress, were more likely to be managed with surgical delivery or early labor induction. Therefore, a cesarean delivery serves as an indicator of underlying obstetric issues that affect the baby's birth weight, rather than being the direct physiological reason for a LBW.

In contrast, studies conducted in Bangladesh and Turkey found that the LBW infant born by vaginal delivery was significantly higher than infants born by cesarean Section. Regarding infant sex, previous studies reported that female infants were more likely to have LBW than male infants [12,18,19,28,29]. Globally, boys' birth weight is higher than girls' in the general population. Female babies were more likely to have a LBW than male babies. This difference reflects biological differences between males and females, not societal or cultural attitudes toward gender. Cell division in male embryos occurs more rapidly than in female embryos, which may contribute to gender differences in birth weight [30]. This difference starts after 28 weeks of gestation. Although the exact mechanism that influences the difference in body weight is unknown, it may be due to androgens or the Y chromosome, which carries the genetic material for fetal growth. As a result, male infants may have higher intrauterine growth and birth weight than their female counterparts. Another explanation for why mothers have a female infant with LBW may be due to sexual preference. Many couples prefer a male and provide adequate care during conception for a male rather than a female.

The current study has strengths, such as the IDHSs using a validated and standardized survey tool to interview survey participants. However, our study has some limitations. First, recall bias may have occurred during data collection. The infant's birth weight was obtained from written records on the hospital card or the mother's memory. In addition, a low number of LBW infants were recorded in health facilities, as most births were carried out at home. Infants born at home may not have been weighed or may have been weighed inappropriately, which may have reduced the observed prevalence of LBW in this study. Second, the survey team did not calibrate or validate the instruments used to measure birth weight, which could lead to misclassification.

To build on these findings, future studies should use prospective longitudinal cohort studies to identify clear cause-and-effect relationships and overcome the limitations of cross-sectional data found in secondary surveys. Future research should also include primary clinical measurements, such as exact gestational age, pre-pregnancy body mass index (BMI), maternal weight gain, blood pressure, and specific reasons for cesarean delivery, which standard DHS questionnaires typically do not include. It will be important to review more recent national health data to understand better the long-term effects of established JKN coverage and post-pandemic changes in healthcare on trends in LBW in Indonesia. It is also recommended to conduct qualitative implementation research to examine community-level support systems in rural primary healthcare settings and develop scalable maternal health interventions focused on promoting equity.

CONCLUSION

This study utilized pooled cross-sectional data from the 2012 and 2017 Indonesia Demographic and Health Surveys to examine the main socioeconomic, maternal, and clinical factors linked to LBW in Indonesia. In a combined analysis of multiple variables, not being married, undergoing a cesarean delivery, and the sex of the infant being female were linked to a higher likelihood of LBW. Rural residence and living in the Sumatera region were identified as protective factors against LBW. However, models specific to each survey showed changes over time. Marital status and infant sex were statistically significant in 2012 but not in 2017, showing that demographic patterns changed between the different survey periods. Furthermore, the link

between cesarean section and LBW should be viewed with caution, as it may mainly result from reverse causation, where pregnancies at higher risk or with fetal growth problems are more often planned for surgical delivery. To tackle these identified risks, national health strategies under JKN should go beyond increasing coverage and focus on implementing early first-trimester ANC screening, maintaining integrated community health services (*Posyandu*) in rural areas, and creating consistent referral systems between Community Health Centers (Puskesmas) and Regional Public Hospitals (RSUD) for complicated pregnancy cases.

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Authors' contributions
Y.W.: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing; L.S., R., and E.G.: Methodology, Writing – original draft, Writing – review & editing; B.Q.H. and K.V.F.: Writing – original draft, Writing – review & editing; A.W.O.: Data curation, Writing – original draft, Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

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Data availability
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics statement
The Ethics Committee of Universitas Ahmad Dahlan approved this study (Approval No. 022104018). Informed consent was obtained from all participants.

Conflicts of interest
The authors reported no potential conflict of interest.

Use of artificial intelligence (AI)
The Grammarly application has been used to enhance clarity and language.

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