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Research Article

Prevalence and Associated Factors of Low Birth Weight in Central Sudan: A Cross-sectional Study

Nagat B. Elhag[1*], Hager M. Alabass[1], Omaima A. Hamid[2], Khalid Albasheer[3], and Ishag Adam[4]

[1]Wad Medani College of Medical Sciences and Technology, Wad Medani, Sudan
[2]Department of Obstetrics and Gynecology, Faculty of Medicine, Northern Border University, Arar, Saudi Arabia
[3]Department of Obstetrics and Gynecology, College of Medicine, Prince Sattam bin Abdulaziz University, Saudi Arabia
[4]Department of Obstetrics and Gynecology, College of Medicine, Qassim University, Buraidah, Saudi Arabia

Abstract

Background: This study aims to assess the prevalence and associated factors of low birth weight (LBW) in central Sudan during the ongoing instability.

Methods: A hospital-based cross-sectional survey was conducted at Wad Madani, Central Sudan, from September to November 2023. Paired mothers and single live newborns were enrolled in this study. A questionnaire was used to collect medical and obstetric data. Multivariate binary regression was performed.

Results: Of the 384 neonates included, 148 (38.5%) were identified as LBW neonates. After adjusting for confounders, maternal age (adjusted odds ratio [AOR] = 0.95, 95% confidence interval [CI]: 0.91–0.98, P = 0.011) and gestational age (AOR = 0.62, 95% CI: 0.53–0.72, $P < 0.001$) were inversely associated with LBW. Lower maternal antenatal care (ANC) level (≤4 visits) was borderline associated with LBW (AOR = 1.69, 95% CI: 0.99–2.87, P = 0.051). Parity, maternal education level, maternal residence, maternal employment, history of miscarriage, maternal hemoglobin level, and the sex of the newborn were not associated with LBW.

Conclusion: LBW is a significant health issue in this region of Sudan, especially among younger mothers and those with fewer ANC visits. Increased efforts are necessary to reduce LBW deliveries, potentially by enhancing ANC services in conflict areas.

Keywords: low birth weight, age, hemoglobin, associated factors, Sudan

Corresponding Author: Nagat B. Elhag; email: ashmana552@gmail.com

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1. Introduction

The World Health Organization (WHO) defines low birth weight (LBW) as newborns weighing less than 2500 g at birth, regardless of gestational age [1]. LBW is one of the major global health issues, and research indicates there are 20.5 million newborns with LBW worldwide; the majority of these cases are in African countries, and the number of newborns with LBW is anticipated to rise [2, 3]. LBW can lead to several morbidities, including neonatal sepsis [4], birth asphyxia [5], admission to the neonatal intensive care unit [6], childhood stunting [7], childhood asthma [8], hypertension and chronic kidney disease in childhood and adulthood [9], impaired motor and cognitive functions [10], type 2 diabetes and insulin resistance [11], and increased perinatal [12] and neonatal mortality [13].

Despite ongoing efforts and various preventive measures, a high prevalence of LBW has recently been reported in several African countries [14–22]. Several factors, such as maternal education, maternal nutrition [23, 24], low levels of antenatal care (ANC) [25], maternal anthropometric measurements [26], and maternal anemia, [27] have been reported to be associated with LBW in newborns. Moreover, recent reports indicate that both post-traumatic stress disorder [28, 29] and exposure to armed conflict are linked to a reduction in birth weight [30] and LBW neonates [30, 31].

A high prevalence of LBW has been observed in various regions of Sudan [19, 32–37]; for example, 12.6% in central Sudan [35], 15.3% in Eastern Sudan [37], 14.9% in Darfur, Western Sudan [36], and 12.1% in Khartoum, Sudan [19, 32–37]. Several factors, including maternal anemia [38], maternal undernutrition [32], and inadequate antenatal care [39], have been reported to be associated with LBW in various hospitals in Sudan. LBW is the leading cause of neonatal mortality in Sudan [40]; however, there is a need to investigate the prevalence and associated factors of LBW during the ongoing armed conflict in Sudan. Moreover, reducing the incidence of LBW is a critical global public health priority, particularly in resource-constrained nations like Sudan. Reducing neonatal mortality to below 12 per 1000 live births by 2030 is one of the ongoing Sustainable Development Goals (SDG) 3.2 [41]. Therefore, we aim to evaluate the prevalence and associated maternal and neonatal factors of LBW in central Sudan.

2. Methods

A facility-based cross-sectional study was conducted at Wad Madani in Central Sudan from September to November 2023 to investigate the prevalence of LBW and its associated factors. Wad Madani is a tertiary hospital in Sudan's second-largest city, 184 km from the capital, Khartoum.

2.1. Inclusion and exclusion criteria

Paired mothers and single live newborns were included in the study. Newborns with a gestational age of <28 weeks; multiples/twins; those with congenital anomalies; newborns delivered to mothers aged <18 years or >40 years; mothers with antepartum hemorrhages, diabetes mellitus, hematological disorders, thyroid disease, and hypertensive diseases of pregnancy; and newborns with incomplete data were removed and deleted accordingly.

2.2. Sampling

A systematic random sampling technique was utilized to enroll the targeted sample size of mothers and newborns. During the three months leading up to the study, there were 1900 live newborns. Therefore, we divided the expected deliveries (1900) by the target sample size (1900/384 = 5). One in every five eligible mothers and their newborns were included in the study until we reached the required number of newborns (384).

2.3. Sample size

A sample size (*n*) of 384 mothers and newborns was estimated using the formula:

(n) = Z(sq) × P(1–P)/d(sq).

Z(sq) is a standard normal variate (at 5% type 1 error; $P < 0.05$) = 1.96. P represents the prevalence of the condition being studied and is obtained from a previous study, while d indicates the level of precision. This sample had 80% power and a difference of 5% at $\alpha = 0.05$.

2.4. Data collection

After obtaining informed consent, two female medical officers conducted face-to-face interviews with the mothers using a questionnaire. The collected information included maternal age, parity, maternal education level, maternal occupation, maternal residence, history of miscarriage(s), the number of ANC visits, and the interpregnancy interval. The last menstrual period and the ultrasound examinations were used to estimate the gestational age in weeks. The mother's BMI was calculated using her weight and height, measured by standard procedures. Under aseptic conditions, venipuncture (from the antecubital vein) was performed to withdraw 2 mL of venous blood from each mother, collected in a tube containing an anticoagulant (ethylenediaminetetraacetic acid). The sample was analyzed using an automated hematology analyzer (Sysmex KX-21, Japan) to determine hemoglobin levels. Maternal anemia was diagnosed when the hemoglobin level was <11 g/dl [42]. Blood smears for malaria, stained with Giemsa stain, were collected from the mothers, cords, and newborns, and analyzed by an expert microscopist.

Each newborn was weighed using the hospital's standard equipment (Seca, Hamburg, Germany), and the birth weight was promptly recorded. The newborn's sex was also noted as male or female.

2.5. Statistics

All data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 22.0 for Windows (IBM, Armonk, NY, USA). The median (interquartile range [IQR]) was used to express continuous data that were found to be not normally distributed based on the Shapiro-Wilk test. The frequency and percentage were used to represent the categorical variables. The proportions of continuous, maternal, and newborn data were compared between neonates with and without LBW using the Mann–Whitney U test and the Chi-square test, respectively. The univariate analyses were conducted with LBW (yes/no) as the dependent variable, while maternal factors—including maternal age (as both continuous and categorical), parity, education level (below and ≥ secondary level), history of miscarriage (yes/no), ANC level, BMI (continuous variable), and anemia/hemoglobin level—and newborn characteristics (sex of the infant [male/female]) served as independent variables. The independent variables with a *P*-value of <0.2 were adjusted to create a multivariable logistic regression model, accounting for covariates. This step has a better selection of covariates within the groups and can retain the essential confounding variables [43]. The adjusted odds ratios (AORs) and 95% CI were also calculated; a *P*-value of <0.05 was considered statistically significant.

3. Results

3.1. General characteristics

Initially, 554 mothers and their newborns were screened for this study. One hundred and seventy neonates were excluded from the study and its analysis because they did not meet the aforementioned inclusion criteria. Consequently, 384 newborns with complete data were enrolled. The median maternal age was 28.0 years (IQR: 23.0–34.0), and the median parity was 2 (IQR: 1–3), respectively. In total, 153 (39.8%) women had an education equivalent to or higher than a secondary level of education. Three hundred and thirty (85.9%) women were housewives. Fifty-four (21.3%) women had a history of miscarriage, and 85 (22.1%) women had received four or fewer ANC visits (Table **1**).

Of the 384 women, 235 (61.2%) reported a history of malaria during the index pregnancy. Seven placental samples and two pairs of maternal-umbilical cord blood samples tested positive for *Plasmodium falciparum*. The median maternal hemoglobin level was 10.9, with an IQR of 10.0–11.8 g/dL. Additionally, 149 (38.8%) women had hemoglobin <11 g/dL, which is the cutoff for anemia in this group.

The median (IQR) gestational age of the included neonates was 39.0 (38.0–39.0) weeks. Half of the 384 neonates were males, while the other half (192) were females. The mean ± standard deviation (SD) of birth weight was 2580 ± 521 g; the 10^{th} percentile was 2.000 g, and 36 (9.4%) neonates had weights below the 10^{th} percentile.

3.2. Factors associated with LBW

One hundred forty-eight neonates (38.5%) were identified as low birth weight (LBW). Therefore, the prevalence of LBW stood at 38.5%. Compared to women who delivered normal-weight neonates, the median (IQR) maternal age was significantly lower in women who delivered LBW (28.0 [22.0–32.7] years vs 29.0 [24.0–35.0] years, $P < 0.001$), as was the gestational age (38.0 [34.0–39.0] weeks vs 38.5 [38.0–39.0] weeks, $P < 0.001$). A significantly higher number of women who delivered LBW had lower ANC levels (41/148 [27.7%] vs 44/236 [18.6%], $P = 0.038$). The maternal, placental, and cord samples that tested positive for malaria were part of the LBW newborn group. However, the model was distorted when these malaria-positive samples were included in the univariate model.

In the univariate analysis, maternal and gestational age were associated with LBW. Conversely, parity, maternal education level, maternal residence, maternal employment, history of miscarriage, maternal BMI, maternal hemoglobin, maternal anemia, and newborn sex showed no association with LBW (Table **2**).

The multivariate analysis showed that age (AOR = 0.95, 95% CI: 0.91–0.98, $P = 0.011$), maternal age <29.0 years (AOR = 1.86, 95% CI: 1.11–3.13, $P = 0.019$), and gestational age (AOR = 0.62, 95.0% CI: 0.53–0.72, $P < 0.001$) were inversely associated with LBW. Age group <29.0 years (AOR = 1.86, 95% CI: 1.11–3.13, $P = 0.019$) was associated with increased odds of LBW. A lower maternal ANC level (≤4 visits) was borderline associated with LBW (AOR = 1.69, 95% CI: 0.99–2.87, $P = 0.051$; Table **3**).

Table 1: General characteristics of mothers of neonates enrolled in the study in central Sudan, 2023 (*n* = 384).

Variables		**Median**	**Interquartile range**
Age, yrs		28.0	23.0 –34.0
Parity		2	1–3
Body mass index, kg/m^2		31.5	26.4–34.7
Gestation age, wks		39.0	38.0–39.0
Maternal hemoglobin, g/dl		11.5	10.5–12.3
		Frequency	**Proportion**
Parity	Primipara	67	14.4
	Parous	317	82.6
Maternal residence	Urban	168	43.7
	Rural	216	56.3
Education level	≥Secondary	153	39.8
	<Secondary	231	60.2
Maternal occupation	Housewives	330	85.9
	Employed	54	14.1
History of miscarriage	No	330	78.8
	Yes	54	21.3
Antenatal care	>4 visits	299	77.9
	≤4 visits	85	22.1
Maternal anemia	No	247	64.3
	Yes	137	35.7
History of maternal malaria	No	149	38.8
	Yes	235	61.2
Sex of the newborn	Male	192	50.0
	Female	192	50.0

Table 2: Results from the univariate analysis of factors associated with low birth weight in neonates born in Central Sudan in 2023.

Variables		**Low birth weight (*n* = 148)**	**No low birth weight (*n* = 236)**	**OR (95% CI)**	***P*-value**
Median (interquartile range)					
Maternal age, yrs		28.0 (22.0–32.7)	29.0 (24.0–35.0)	0.95 (0.92–0.98)	0.003
Parity		2 (1–3)	2 (1–3)	0.94 (0.84–1.06)	0.371
Gestational age, wks		38.0 (34.0–39.0)	38.5 (38.0–39.0)	0.65 (0.57–0.74)	<0.001
Maternal body mass index, kg/m^2		31.1 (26.0–33.8)	31.8 (26.6–33.5)	0.96 (0.92–1.01)	0.090
Maternal hemoglobin level, g/dL		11.3 (10.2–12.1)	11.5 (10.6–12.3)	0.85 (0.74–1.01)	0.064
Frequency (proportion)					
Age groups	≥29.0 year	63 (42.6)	126 (53.4)	Reference	0.033
	<29.0 year	85 (57.4)	110 (46.6)	1.54 (1.02–2.33)	
Parity	Primipara	30 (20.3)	37 (15.7)	1.36 (0.80–2.32)	0.250
	Parous	118 (79.7)	199 (84.3)	Reference	

Table 2: Continued.

Variables		**Low birth weight (*n* = 148)**	**No low birth weight (*n* = 236)**	**OR (95% CI)**	***P*-value**
Maternal residence	Urban	61 (41.2)	107 (45.3)	Reference	0.428
	Rural	87 (58.2)	129 (54.7)	1.18 (0.78–1.79)	
Education level	≥Secondary	56 (37.8)	97 (41.1)	Reference	0.525
	<Secondary	92 (62.2)	139 (58.9)	1.14 (0.75–1.74)	
History of miscarriage	No	127 (85.8)	193 (81.8)	Reference	0.303
	Yes	21(14.2)	43 (18.2)	0.74 (0.42–1.30)	
Antenatal care	>4 visits	107 (72.3)	192 (81.4)	Reference	0.038
	≤4 visits	41 (27.7)	44 (18.6)	1.67 (1.02–2.72)	
Maternal anemia	No	92 (62.2)	155 (65.7)	Reference	0.484
	Yes	56 (37.8)	81 (34.3)	1.16 (0.76–1.78)	
Maternal malaria	No	55 (37.2)	94 (39.8)	Reference	0.602
	Yes	93 (62.8)	142 (60.2)	1.11(0.73–1.70)	
Newborn sex	Male	78 (52.7)	114 (48.3)	Reference	0.402
	Female	70 (47.3)	122 (51.7)	0.83 (0.55–1.26)	

Table 3: Multivariate analysis of the factors associated with low birth weight in central Sudan, 2023.

Variables		**AOR (95% CI)**	***P*-value**
Median (interquartile range)			
Maternal age, yrs*		0.95 (0.91–0.98)	0.011
Gestational age, wks		0.62 (0.53–0.72)	<0.001
Maternal body mass index, kg/m^2		1.01(0.96–1.07)	0.516
Maternal hemoglobin level, g/dL		0.91 (0.77–1.06)	0.246
Frequency (proportion)			
Antenatal care	>4 visits	Reference	0.051
	≤4 visits	1.69 (0.99–2.87)	
Age group, yrs	≥29.0	Reference	0.019
	<29.0	1.86 (1.11–3.13)	

*Entered one by one. OR, odds ratio; CI, confidence interval.

4. Discussion

The main findings of the current study indicate that the prevalence of LBW was 38.5%, and there was an inverse association between maternal age, gestational age, and LBW. Our findings suggest that the prevalence of LBW in this hospital in central Sudan is significantly higher than the previously reported prevalence of LBW in the same hospital (12.6%) [35] and in studies conducted in Eastern Sudan (15.3%) [37]; Darfur, Western Sudan (14.9%) [36]; Khartoum, Sudan (12.1%) [32]; South Sudan (11.4%) [22]; Addis Ababa, Ethiopia (13.06%) [16]; Ghana (13.5%) [20]; and Tanzania (21.0%) [21]. Moreover, the prevalence of LBW in our survey is significantly higher than the reported pooled prevalence of 5.7% for LBW, identified among 33,585 newborns during the Demographic and Health Survey (DHS) conducted in Saharan African countries [25]. The differences in the prevalence of LBW across various studies can be attributed to the distinct characteristics of different regions and the factors associated with LBW itself. It is reported that the prevalence of LBW is not evenly distributed within a country [47], and the risk factors for LBW vary across different countries and regions within the same country [44]. Perhaps different factors associated with LBW, such as HIV [46] and malaria [15], may have varying prevalences in other regions, and the prevalence of LBW differs among different populations. In the current study, the 10^{th} percentile of birth weight was 2000 g, and only 9.4% would be considered to have LBW if the 10^{th} percentile was used as a reference. We have previously shown that the 10^{th} percentile of birth weight in Khartoum was 2320 [45]. Therefore, the variation in birth weight among regions and populations must be considered.

Notably, the current study was conducted during the ongoing armed conflict in Sudan, and the city hosted approximately five times the number of displaced persons compared to its former population [46]. Sadly, two weeks after the study was completed, the town was attacked by armed forces and subsequently evacuated. It is estimated that nearly 16 million women were displaced in 2017. Armed conflict can lead to several adverse effects, such as malnutrition, physical injuries, infectious diseases, and poor reproductive health [47]. Previous reports have indicated that exposure to armed conflict is associated with an increased likelihood of LBW neonates, and this factor needs to be considered in ANC [31]. A previous study has shown that 7.3% of LBW and 5.0% of preterm infants were born in the post-conflict community of northern Uganda [15]. The war and internal displacement may lead to an increase in post-traumatic stress disorder, which has been reported to be associated with LBW [28]. Additionally, the war could severely damage Sudan's already fragile healthcare system [48]. Armed conflict can affect mothers' education, which in turn influences maternal and perinatal health [49, 50]. It may lead to acute maternal physical and psychological distress, resulting in poor birth and perinatal outcomes, such as LBW [51].

The current study showed that gestational age was inversely related to LBW (AOR = 0.62), which suggests that each additional week of gestation can reduce the likelihood of LBW by 38.0% (AOR = 0.62). This corresponds with the results of the studies conducted in the capital, Khartoum, Sudan [19, 35] and other African countries, including South Sudan [22], Zambia [49], and Ghana [20]. It appears challenging and complex to analyze the effect of gestational age per se on LBW without evaluating and taking into account the confounding influences of other detrimental maternal and perinatal factors, such as maternal anemia and preterm birth. Preterm birth is a significant health issue in sub-Saharan countries that requires the use of preventive measures to extend gestation and decrease the rate of preterm births and their related LBW deliveries [52].

Our findings indicate that maternal age was inversely associated with LBW (AOR = 0.95); this suggests that each year increase in age would result in a 5.0% decrease in LBW. A recent study in South Sudan has shown that maternal age <20 years and ≥35 years was associated with LBW [22]. Specifically, maternal age ≥35 years was associated with LBW in a post-conflict area of Northern Uganda [15].

In this study, a lower level of ANC showed a borderline association with LBW. This aligns with a previous meta-analysis that indicated women with <4 ANC visits were at higher risk of delivering LBW neonates [25].

Furthermore, this study did not associate maternal hemoglobin or anemia with LBW. This finding contradicts previous studies conducted in various regions of Sudan, which indicated that anemia was associated with LBW [35, 38].

One limitation of this study is that the sample came exclusively from a single tertiary hospital in Wad Madani, a city in central Sudan. Therefore, the findings may not generalize to a larger or different population. Another limitation is that the brief study duration (September–November 2023) is unlikely to reveal the true LBW prevalence and associated risk factors. Many potential confounders, such as maternal demographic factors, nutritional factors, anxiety, and depression, were not included. Moreover, we did not consider displacement as a single factor because we believed that including it might have risked the women's cooperation. LBW could be predicted in early pregnancy by measuring uterine artery blood flow [53], which may not be accessible in many settings in countries with low resources.

5. Conclusion

During the ongoing armed conflict, LBW is a significant health issue in this region of Sudan, particularly among younger mothers, regardless of their maternal parity, education level, or residence. Urgent action is required to reduce the high prevalence of LBW and enhance antenatal care in the conflict area. Antenatal care services in conflict zones must be improved.

Declarations

Acknowledgments

None.

Ethical Considerations

Ethical approval was obtained from the Wad Medani Obstetrics and Gynecology Hospital, Sudan (Ref. #2023, 05, date April 20, 2023). Informed written consent was obtained from the mother of the neonates. The questionnaire did not record personal identifying information, and the collected data were kept confidential. All the methods were conducted in accordance with appropriate guidelines and regulations.

Competing Interests

The authors have nothing to declare.

Availability of Data and Materials

The corresponding authors can provide the data upon a reasonable request.

Funding

None.

Abbreviations and Symbols

LBW: Low birth weight

AOR: Adjusted odds ratio

CI: Confidence interval

WHO: World Health Organization

ANC: Antenatal care

SDG: Sustainable Development Goals

SPSS: Statistical Package for the Social Sciences

IQR: Interquartile range

DHS: Demographic and Health Survey

References

[1] World Health Organization. (n.d.). *International statistical classification of diseases and related health problems*. https://apps.who.int/iris/handle/10665/246208

[2] ReliefWeb. (2022, November 15). *WHO recommendations for care of the preterm or low-birth-weight infant*. https://reliefweb.int/report/world/who-recommendations-care-preterm-or-low-birth-weight-infant

[3] Blencowe, H., Krasevec, J., de Onis, M., Black, R. E., An, X., Stevens, G. A., Borghi, E., Hayashi, C., Estevez, D., Cegolon, L., Shiekh, S., Ponce Hardy, V., Lawn, J. E., & Cousens, S. (2019). National, regional, and worldwide estimates of low birthweight in 2015, with trends from 2000: A systematic analysis. *The Lancet. Global Health, 7*, e849–e860. https://doi.org/10.1016/S2214-109X(18)30565-5

[4] Bech, C. M., Stensgaard, C. N., Lund, S., Holm-Hansen, C., Brok, J. S., Nygaard, U., & Poulsen, A. (2022). Risk factors for neonatal sepsis in Sub-Saharan Africa: A systematic review with meta-analysis. *BMJ Open, 12*(9), e054491. https://doi.org/10.1136/bmjopen-2021-054491

[5] Techane, M. A., Alemu, T. G., Wubneh, C. A., Belay, G. M., Tamir, T. T., Muhye, A. B., Kassie, D. G., Wondim, A., Terefe, B., Tarekegn, B. T., Ali, M. S., Fentie, B., Gonete, A. T., Tekeba, B., Kassa, S. F., Desta, B. K., Ayele, A. D., Dessie, M. T., Atalell, K. A., & Assimamaw, N. T. (2022). The effect of gestational age, low birth weight and parity on birth asphyxia among neonates in sub-Saharan Africa: Systematic review and meta-analysis: 2021. *Italian Journal of Pediatrics, 48*, 114. https://doi.org/10.1186/s13052-022-01307-5

[6] Rebelo, F., Carrilho, T. R. B., Canuto, R., Schlussel, M. M., Farias, D. R., Ohuma, E. O., & Kac, G. (2023). Estimated fetal weight standards of the INTERGROWTH-21st project for the prediction of adverse outcomes: A systematic review with meta-analysis. *The Journal of Maternal-Fetal & Neonatal Medicine, 36*(2), 2230510. https://doi.org/10.1080/14767058.2023.2230510

[7] Elmighrabi, N. F., Fleming, C. A. K., & Agho, K. E. (2024). Factors associated with childhood stunting in four North African countries: Evidence from multiple indicator cluster surveys, 2014-2019. *Nutrients, 16*(4), 473. https://doi.org/10.3390/nu16040473

[8] Ni, M., Li, B., Zhang, Q., Zhao, J., Li, W., Qi, S., Shen, Q., Yao, D., Chen, Z., Wang, T., Ding, X., Lin, Z., Cheng, C., Liu, Z., & Chen, H. (2023). Relationship between birth weight and asthma diagnosis: A cross-sectional survey study based on the National Survey of Children's Health in the U.S. *BMJ Open, 13*(12), e076884. https://doi.org/10.1136/bmjopen-2023-076884

[9] Grillo, M. A., Mariani, G., & Ferraris, J. R. (2022). Prematurity and low birth weight in neonates as a risk factor for obesity, hypertension, and chronic kidney disease in pediatric and adult age. *Frontiers in Medicine, 8*, 769734. https://doi.org/10.3389/fmed.2021.769734

[10] Radaelli, G., Leal-Conceiç ao, E., Kalil Neto, F., Taurisano, M. R. G., Majolo, F., Bruzzo, F. T. K., Booij, L., & Nunes, M. L. (2023). Motor and cognitive outcomes of neonates with low birth weight in Brazil: A systematic review and meta-analysis. *Arquivos de Neuro-Psiquiatria, 81*(02), 186–200. https://doi.org/10.1055/s-0042-1758866

[11] Martín-Calvo, N., Goni, L., Tur, J. A., & Martínez, J. A. (2022). Low birth weight and small for gestational age are associated with complications of childhood and adolescence obesity: Systematic review and meta-analysis. *Obesity Reviews, 23*(Suppl 1), e13380. https://doi.org/10.1111/obr.13380

[12] Kasa, G. A., Woldemariam, A. Y., Adella, A., & Alemu, B. (2023). The factors associated with stillbirths among sub-Saharan African deliveries: A systematic review and meta-analysis. *BMC Pregnancy and Childbirth, 23*, 835. https://doi.org/10.1186/s12884-023-06148-6

[13] Hazel, E. A., Erchick, D. J., Katz, J., Lee, A. C. C., Diaz, M., Wu, L. S. F., West, K. P., Jr., Shamim, A. A., Christian, P., Ali, H., Baqui, A. H., Saha, S. K., Ahmed, S., Roy, A. D., Silveira, M. F., Buffarini, R., Shapiro, R., Zash, R., Kolsteren, P.,... Black, R. E. (2024). Neonatal mortality risk of vulnerable newborns by fine stratum of gestational age and birthweight for 230 679 live births in nine low- and middle-income countries, 2000–2017. *BJOG*. Advance online publication. https://doi.org/10.1111/1471-0528.17743

[14] Barut, A., & Mohamud, D. O. (2023). The association of maternal anaemia with adverse maternal and foetal outcomes in Somali women: A prospective study. *BMC Womens Health*, *23*(1), 193. https://pubmed.ncbi.nlm.nih.gov/37098536/

[15] Odongkara, B., Nankabirwa, V., Ndeezi, G., Achora, V., Arach, A. A., Napyo, A., Musaba, M., Mukunya, D., Tumwine, J. K., & Thorkild, T. (2022). Incidence and risk factors for low birthweight and preterm birth in post-conflict Northern Uganda: A community-based cohort study. *International Journal of Environmental Research and Public Health, 19*(19), 12072. https://doi.org/10.3390/ijerph191912072

[16] Tadesse, T., Abebe, M., Molla, W., Ahmed Mahamed, A., & Mebratu, A. (2023). Magnitude and associated factors of low birth weight among term newborns delivered in Addis Ababa public hospitals, Ethiopia, 2021. *Journal of Obstetrics and Gynaecology, 43*(1), 2114332. https://doi.org/10.1080/01443615.2022.2114332

[17] Kargbo, D. K., Nyarko, K., Sackey, S., Addo-Lartey, A., Kenu, E., & Anto, F. (2021). Determinants of low birth weight deliveries at five referral hospitals in Western Area Urban district, Sierra Leone. *Italian Journal of Pediatrics, 47*, 212. https://doi.org/10.1186/s13052-021-01160-y

[18] Wondemagegn, A. T., Tsehay, B., Mebiratie, A. L., & Negesse, A. (2022). Effects of dietary diversification during pregnancy on birth outcomes in east Gojjam, Northwest Ethiopia: A prospective cohort study. *Frontiers in Public Health, 10*, 1037714. https://doi.org/10.3389/fpubh.2022.1037714

[19] Ahmed, A. B. A. (2022). Association between maternal undernutrition among Sudanese women and newborn birth weight. *Journal of Family Medicine and Primary Care, 11*(6), 2824–2827. https://doi.org/10.4103/jfmpc.jfmpc_1625_21

[20] Ahenkorah, B., Sakyi, S. A., Helegbe, G., Owiredu, E. W., Fondjo, L. A., Ofosu, W., Der, E. M., Amoani, B., Larbi, A. A., Cheetham, S., Arthur-Johnson, P., Kwablah, G. J., & Gyan, B. (2022). Foeto-maternal complications associated with low birth weight: A prospective multicenter study in northern Ghana. *PLoS One, 17*, e0266796. https://doi.org/10.1371/journal.pone.0266796

[21] Kamala, B. A., Mgaya, A. H., Ngarina, M. M., & Kidanto, H. L. (2018). Predictors of low birth weight and 24-hour perinatal outcomes at Muhimbili National Hospital in Dar es Salaam, Tanzania: A five-year retrospective analysis of obstetric records. *The Pan African Medical Journal, 29*, 220. https://doi.org/10.11604/pamj.2018.29.220.15247

[22] Lat, C., Murila, F., & Wamalwa, D. (2023). Prevalence and factors associated with low birth weight among newborns in South Sudan. *African Health Sciences, 23*(3), 149–158. https://doi.org/10.4314/ahs.v23i3.19

[23] Walle, B. M., Adekunle, A. O., Arowojolu, A. O., Dugul, T. T., & Mebiratie, A. L. (2022). Low birth weight and its associated factors in East Gojjam Zone, Amhara, Ethiopia. *BMC Nutrition, 8*, 124. https://doi.org/10.1186/s40795-022-00621-9

[24] Nkwabong, E., Djientcheu Deugoue, F., & Fouedjio, J. (2023). Pre-eclampsia in a Sub-Saharan African country and maternal-perinatal outcome. *Tropical Doctor, 53*(1), 61–65. https://doi.org/10.1177/00494755221113155

[25] Weyori, A. E., Seidu, A. A., Aboagye, R. G., Holmes, F. A., Okyere, J., & Ahinkorah, B. O. (2022). Antenatal care attendance and low birth weight of institutional births in sub-Saharan Africa. *BMC Pregnancy and Childbirth, 22*, 283. https://doi.org/10.1186/s12884-022-04576-4

[26] Goto, E. (2023). Dose-response relationships of maternal height and weight with risk of low birthweight neonates: A meta-analysis. *Minerva Pediatr, 75*(1), 110–116. https://doi.org/10.23736/S2724-5276.21.06672-6

[27] Dorsamy, V., Bagwandeen, C., & Moodley, J. (2022). The prevalence, risk factors and outcomes of anaemia in South African pregnant women: A systematic review and meta-analysis. *Systematic Reviews, 11*, 16. https://doi.org/10.1186/s13643-022-01884-w

[28] Rashid, H. U., Khan, M. N., Imtiaz, A., Ullah, N., Dherani, M., & Rahman, A. (2020). Post-traumatic stress disorder and association with low birth weight in displaced population following conflict in Malakand division, Pakistan: A case control study. *BMC Pregnancy and Childbirth, 20*, 166. https://doi.org/10.1186/s12884-020-2841-2

[29] Sanjuan, P. M., Fokas, K., Tonigan, J. S., Henry, M. C., Christian, K., Rodriguez, A., Larsen, J., Yonke, N., & Leeman, L. (2021). Prenatal maternal posttraumatic stress disorder as a risk factor for adverse birth weight and gestational age outcomes: A systematic review and meta-analysis. *Journal of Affective Disorders, 295*, 530–540. https://doi.org/10.1016/j.jad.2021.08.079

[30] Le, K., & Nguyen, M. (2020). Armed conflict and birth weight. *Economics and Human Biology, 39*, 100921. https://doi.org/10.1016/j.ehb.2020.100921

[31] Cabra-Bautista, G., Granados Rugeles, C. M., Grillo-Ardila, C. F., & Gil Laverde, F. A. (2022). Exposure to armed conflict as a factor associated with very low birth weight: Case-control population study. *International Journal of Gynaecology and Obstetrics, 158*(3), 619–625. https://doi.org/10.1002/ijgo.14082

[32] Bilal, J. A., Rayis, D. A., AlEed, A., Al-Nafeesah, A., & Adam, I. (2022). Maternal undernutrition and low birth weight in a tertiary hospital in Sudan: A cross-sectional study. *Frontiers in Pediatrics, 10*, 927518. https://doi.org/10.3389/fped.2022.927518

[33] Omer, S. A., Noureldein, A. N., Eisa, H., Abdelrahim, M., Idress, H. E., Abdelrazig, A. M., & Adam, I. (2019). Impact of submicroscopic *Plasmodium falciparum* parasitaemia on maternal anaemia and low birth weight in Blue Nile State, Sudan. *Journal of Tropical Medicine*. Epub ahead of print. https://doi.org/10.1155/2019/3162378

[34] Ali, A. A., Rayis, D. A., Abdallah, T. M., Elbashir, M. I. A. I., & Adam, I. (2011). Severe anaemia is associated with a higher risk for preeclampsia and poor perinatal outcomes in Kassala hospital, eastern Sudan. *BMC Research Notes, 4*, 311. https://doi.org/10.1186/1756-0500-4-311

[35] Elhassan, E. M., Abbaker, A. O., Haggaz, A. D., Abubaker, M. S., & Adam, I. (2010). Anaemia and low birth weight in Medani, Hospital Sudan. *BMC Research Notes, 3*, 181. https://doi.org/10.1186/1756-0500-3-181

[36] Haggaz, A. D., Radi, E. A., Adam, I. (2010). Anaemia and low birthweight in western Sudan. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, *104*(3), 234–236. https://doi.org/10.1016/j.trstmh.2009.07.013

[37] Adam, I., Babiker, S., Mohmmed, A. A., Salih, M. M., Prins, M. H., & Zaki, Z. M. (2008). Low body mass index, anaemia and poor perinatal outcome in a rural hospital in eastern Sudan. *Journal of Tropical Pediatrics, 54*(3), 202–204. https://doi.org/10.1093/tropej/fmm110

[38] Elmugabil, A., Al-Nafeesah, A., AlEed, A., AlHabardi, N., & Adam, I. (2023). Prevalence of low birth weight and its association with anemia in White Nile State, Sudan: A cross-sectional Study. *SAGE Open Nursing, 9*, 23779608231197590. https://doi.org/10.1177/23779608231197590

[39] Elhassan, E. M., Abbaker, A. O., Haggaz, A. D., Abubaker, M. S., & Adam, I. (2010). Anaemia and low birth weight in Medani, Hospital Sudan. *BMC Research Notes*, *3*, 181. https://doi.org/10.1186/1756-0500-3-181

[40] Ahmed, M. A. A., Mahgoub, H. M., Al-Nafeesah, A., Al-Wutayd, O., & Adam, I. (2022). Neonatal mortality and associated factors in the neonatal intensive care unit of Gadarif Hospital, Eastern Sudan. *Children (Basel, Switzerland), 9*(11), 1725. https://doi.org/10.3390/children9111725

[41] UNICEF. (2019). *UNICEF-WHO Low birthweight estimates: Levels and trends 2000–2015*. https://www.unicef.org/reports/UNICEF-WHO-low-birthweight-estimates-2019

[42] World Health Organization. (2015). *The global prevalence of anaemia in 2011*. https://apps.who.int/iris/bitstream/handle/10665/177094/9789241564960_eng.pdf

[43] Bursac, Z., Gauss, C. H., Williams, D. K., & Hosmer, D. W. (2008). Purposeful selection of variables in logistic regression. *Source Code for Biology and Medicine, 3*, 17. https://doi.org/10.1186/1751-0473-3-17

[44] Banerjee, A., Singh, A., & Chaurasia, H. (2020). An exploratory spatial analysis of low birth weight and its determinants in India. *Clinical Epidemiology and Global Health, 8*(3), 702–711. https://doi.org/10.1016/j.cegh.2020.01.006

[45] Abdelrahiem, S. K., Bilal, J. A., Al Nafeesah, A., Al-Wutayd, O., Rayis, D. A., & Adam, I. (2021). Low and high birth weight in a hospital population in Sudan: An analysis of clinical cut-off values. *International Journal of Gynaecology and Obstetrics, 154*(3), 427–430. https://doi.org/10.1002/ijgo.13543

[46] United Nations. (2023, July 18). *Sudan: Conflict displaces nearly 200,000 alone in the past week*. https://news.un.org/en/story/2023/07/1138837

[47] Bendavid, E., Boerma, T., Akseer, N., Langer, A., Malembaka, E. B., Okiro, E. A., Wise, P. H., Heft-Neal, S., Black, R. E., Bhutta, Z. A., Bhutta, Z., Black, R., Blanchet, K., Boerma, T., Gaffey, M., Langer, A., Spiegel, P., Waldman, R., Wise, P., & the BRANCH Consortium Steering Committee. (2021). The effects of armed conflict on the health of women and children. *Lancet, 397*(10273), 522–532. https://doi.org/10.1016/S0140-6736(21)00131-8

[48] Noorallah, T., Elgadi, A., & Altayeb, F. (2024). Child malnutrition is a devastating consequence of the conflict in Sudan. *BMJ (Clinical Research Ed.), 384*, q296. https://doi.org/10.1136/bmj.q296

[49] Le, K., & Nguyen, M. (2020). Shedding light on maternal education and child health in developing countries. *World Development, 133*, 105005. https://doi.org/10.1016/j.worlddev.2020.105005

[50] Brück, T., Di Maio, M., & Miaari, S. H. (2019). Learning the hard way: The effect of violent conflict on student academic achievement. *Journal of the European Economic Association, 17*(5), 1502–1537. https://doi.org/10.1093/jeea/jvy051

[51] Brück T, Justino P, Martin-Shields C. *Conflict and development: Recent research advances and future agendas* (WIDER Working Paper 2017/178). UNU-WIDER. https://doi.org/10.35188/UNU-WIDER/2017/404-9

[52] Young, M. F., Oaks, B. M., Rogers, H. P., Tandon, S., Martorell, R., Dewey, K. G., & Wendt, A. S. (2023). Maternal low and high hemoglobin concentrations and associations with adverse maternal and infant health outcomes: An updated global systematic review and meta-analysis. *BMC Pregnancy and Childbirth, 23*, 264. https://doi.org/10.1186/s12884-023-05489-6

[53] Prefumo, F., Güven, M., Ganapathy, R., & Thilaganathan, B. (2004). The longitudinal variation in uterine artery blood flow pattern in relation to birth weight. *Obstetrics and Gynecology, 103*(4), 764–768. https://doi.org/10.1097/01.AOG.0000118310.51730.2d