BMJ Open

Low birth weight and its association with adverse maternal situations in Bangladesh: a nationwide population-based study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-036162
Article Type:	Original research
Date Submitted by the Author:	04-Dec-2019
Complete List of Authors:	Khan, Md. Mostaured; University of Rajshahi, Population Science and Human Resource Development Mustagir, Md. Golam; University of Rajshahi, Population Science and Human Resource Development Kaikobad, Md. Sharif; University of Rajshahi, Population Science and Human Resource Development Khan, Hafiz; University of West London, College of Nursing, Midwifery and Healthcare Islam, Md; University of Rajshahi, Population Science and Human Resource Development
Keywords:	NEONATOLOGY, Community child health < PAEDIATRICS, Nutrition < TROPICAL MEDICINE

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Low birth weight and its association with adverse maternal situations in Bangladesh: *a nationwide population-based study*

Authors: Md. Mostaured Ali Khan[1, 2], Md. Golam Mustagir[1], Md. Sharif Kaikobad[1], Hafiz T.A. Khan[3], and Md. Rafiqul Islam[1*]

Affiliations:

[1] Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh.

[2] Global Public Health Research Foundation, Road-12, Sector-10, Uttara, Dhaka-1230, Bangladesh.

[3] Professor of Public Health & Statistics, The Graduate School, University of West London St Mary's Road, Ealing, London W5 5RF, United Kingdom.

Corresponding Author:

Md. Rafiqul Islam, PhD
Professor, Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh.
E-mail: rafique_pops@yahoo.com
Mobile: +8801775715126
Phone: +880721-711524

Low birth weight and its association with adverse maternal situations in Bangladesh: *a nationwide population-based study*

Abstract

Objectives: To achieve the goal of improving newborn health, identifying the maternal risk factors associated with giving birth to low birth weight (LBW) baby is very urgent. In this regard, this study aimed at exploring the prevalence of LBW and its association with various adverse maternal characteristics in Bangladesh.

Designs and settings: The study utilised data extracted from a national representative Bangladesh Demographic and Health Survey (BDHS), 2014. Chi-square test was performed to measure the association between LBW and several adverse maternal characteristics. Further, important determinants of maternal characteristics on LBW were identified using logistic regression analysis.

Participants: The study selected 4728 women who had given at least one birth within 5 years prior to the survey.

Results: The prevalence of LBW was around 20% in Bangladesh with the highest in Sylhet region. The findings indicated that the LBW rate was higher in the rural territory and illiterate households. Several adverse maternal characteristics such as, maternal underweightness (Adjusted odds ratio (AOR): 1.26), unwanted birth (AOR: 1.22), previous terminated pregnancy (AOR: 1.28), victim of intimate partner violence (AOR: 1.23) and taking ANC <4 times (AOR: 1.23) were found as significant influencing factors of giving birth to LBW baby. Maternal high-risk fertility behaviors like age at birth <18 years (AOR: 1.42), birth interval <24 months (AOR: 1.25) were revealed as vital risk factors of LBW in newborns, and the risk was also significantly increased when we consider multiple high-risk fertility behaviours together, i.e. maternal age at birth <18 years with interval <24 months (AOR: 1.26) and birth order >3 with interval <24 months (AOR: 1.68).

Conclusion: We may conclude that various socio-demographic and adverse maternal characteristics including high-risk fertility behaviours have a significant influence on LBW in neonates and that can impede the progress towards achieving the sustainable development goal (SDG) target towards newborn health care in Bangladesh.

Keywords: Low birth weight (LBW), high-risk fertility behaviours, adverse maternal characteristics, Bangladesh, BDHS

Limitations and Strengths of the study

- The strengths comprise the use of nationally representative data and a large sample size that give the study more reliable results with greater exactness and power. Furthermore, the BDHS has used a globally standardized method which permits this study results to compare with other nations adopting a similar methodology.
- This study analysis was done by taking into account the simplex survey design and sample weight which also gives vital strength. However, secondary data used in this study was collected referring to last birth that occurred within five years prior to the survey dates.
- As the study outcomes were based on self-report, recall bias is common for such type of data collection as well as non-response problem.
- Moreover, the use of secondary data limits the analyses in terms of variable selection. However, enhancing the available information, this research will contribute to developing suitable interventions for reducing LBW and improving newborn health in Bangladesh.

Funding

This research did not receive any specific grant either from the university or from any funding agencies in the public, commercial, or not-for-profit sectors.

Competing interests

The authors have declared that there are no competing interests exist.

Ethics Statement

The ethical approval for all BDHS surveys was taken from the ICF Macro Institutional Review Board, Maryland, USA, and the National Research Ethics Committee of the Bangladesh Medical Research Council (BMRC), Dhaka, Bangladesh. The National Institute of Population Research and Training conducted these surveys with the support of the United States Agency for International Development (USAID). Informed consent was obtained from all participants. The BDHS is part of the worldwide Demography and Health Surveys (DHS) program and is available in the public domain for research purposes.

Patient and public involvement

This study analyzed a secondary data to accomplish the study objectives. This country representative survey was conducted in seven administrative division of Bangladesh. The main respondents in this study was the individuals (women) who had given at least one birth within 5 year prior to the survey. Their child's birth weight information was collected according to mother's perception. Results was not disseminated to study participants further but they clearly know about the purpose of the study

Introduction

Globally, low birth weight (LBW) remains to be a critical child health concern, particularly in low- and middle-income country (LMIC) settings [1 2]. A newborn who born with a weight of fewer than 2.5 kilograms (5.5 pounds) is termed as LBW baby [3]. It is one of the key underlying contributors of increasing the infant mortality risk, susceptibility of severe childhood illness [1 4], malnutrition [5], and impedes future cognitive development [6]. Unfortunately, worldwide, around 20 million (15.5%) babies are born with LBW each year, approximately 96% of them are born in developing countries [7] like Bangladesh. Regional statistics illustrate that the global burden of LBW is severely skewed towards South Asia with the highest prevalence (28%) followed by Sub-Sahara African countries (13%), the Caribbean and Latin America (9%), and the Pacific and Eastern Asia (6%) [3]. In Bangladesh, National Low Birth Weight Survey reports showed that the LBW prevalence in newborns was 22.6% in 2015, which was around 36% in 2004 [1 8], that means the rate of LBW is progressively decreasing day by day.

Previous statistics confirm that the LBW have a high contribution to neonatal and infant mortality [7]. Worldwide, 60%-80% of neonatal death (within 28 days of life) occurred due to the LBW [7]. Moreover, the very LBW (<1500 g) infants are around 20 times more likely to die in infancy than the infants born with normal weight [9]. Due to congenital malformation and perinatal factors, LBW is also accelerating the risk of mortality in later childhood and adolescence [9]. Researchers have also discovered many adverse health and growth aspects of children and adolescents born with LBW. For instance, chronic disease such as childhood asthma [10], attention-deficit or hyperactivity disorder [11], post-natal growth failure [12], stunting, wasting, underweight [13] etc. These negative health aspects can be extended into adulthood and increase the risk of developing chronic diseases such as cardiovascular disease [14 15], respiratory diseases [15 16] etc. Therefore, the significance of preventing LBW is inevitable to prevent mortality and morbidity risk in childhood and even adulthood.

Worldwide, a wide range of robust endeavours has been expanded to reveal the etiology and to identify the risk factors LBW, though it's very complicated, and vary among regions. Prior findings from different regions (both developed and developing), suggest that various potential risk factors such as history of premature delivery [17], maternal younger age (<18 years) and advanced age (>34 years) at childbirth [17 18], insufficient prenatal care [1 18 19], underweight mother [18 20], shorter birth interval [20], hard work and low nutritious food consumption during pregnancy [17], antepartum hemorrhage and anemia [19], hypertension disorder and diabetes during pregnancy [21] etc. are significantly enhancing the LBW risk. In addition, various socio-demographic factors of mothers such as live in rural territories [1], illiteracy [1 18], poor economic status [1 20], a victim of any kind of intimate partner violence (IPV) (physical or sexual or mental) [22], etc. are also significantly associated with the risk for infant to born with LBW. Understanding the etiology of LBW as well as affecting factors of newborn's health is very urgent for developing effective prevention programs to reduce the burden.

The world health organization (WHO) has set a goal to achieve a 30% reduction in the rate of infant's LBW by the year 2025 worldwide, due to its unavoidable significance to meet up the sustainable development goals (SDGs) [3]. Though the prevalence of LBW was noticeably decreased in Bangladesh, the rate remains much higher compared to the global prevalence [1 7 8]. However, similar to other countries of South Asia, there is a lack of monitoring and surveillance system, well-developed birth registry system, and quality data on birth weight in Bangladesh, which poses a key challenge for the country. To achieve the goal on reducing LBW in newborns, the urgency of research work is indispensable to identify potentially modifiable protective factors for LBW with nationwide survey data along with to define the epidemiology of LBW in Bangladesh. Though researchers have focused on this vital health concern, our country is far behind in this context. Only a limited extent of study has been conducted regarding LBW to determine its risk factors, particularly no such research has been shown the impact of various

adverse maternal characteristics like maternal high-risk fertility behaviours on LBW of the infants. Thus, to address these gaps, utilising a nationwide population survey, this study is designed to explore the prevalence of low birth weight and its association with various adverse maternal characteristics including high-risk fertility behaviours in Bangladesh.

Methodology

Data sources and sampling procedure

This study utilized data extracted from a nationally representative household survey conducted in 2014 called "Bangladesh Demographic and Health Survey (BDHS)". An elaborate explanation of the survey was published elsewhere [23]. Briefly, this cross-sectional survey based on a two-stage stratified sampling procedure. Bangladesh Bureau of Statistics (BBS) divided the country into several primary sampling units through which data were collected [23]. In each of the seven administrative divisions of Bangladesh, the survey was conducted to collect nationally representative data. In the first sampling stage, 600 of enumeration areas (EA) (as primary sampling unit) were selected based on a probability proportional to their size (207 EAs in urban areas and 393 EAs in rural areas) and in the second phase, 30 households were selected in each primary sampling unit by systematic random sampling procedure [23]. Within this sample design, BDHS identified 18245 reproductive-aged (15-49 years) ever-married women from 18000 households. With an overall response rate of around 98%, this BDHS interviewed 17863 women and collected a wide range of data concerning women and their children monitoring a range of indicators including health and nutrition. In this study, our analysis was restricted to women who had experienced at least one birth within 5 years prior to the survey, and we identified 7886 eligible respondents. Further, we excluded 3158 individuals because of unavailability of data regarding birth weight or size and finally, the eligible sample size for the analysis was n = 4728.

Outcome variable

Low birth weight of the newborn was considered as the main outcome variable of this current analysis, dichotomised as Yes=1 (the baby born with LBW) and No=0 (otherwise). A greater number of deliveries in LMICs, including Bangladesh occur at home without appropriate measurement of birth weight [24]. Therefore, as a useful proxy of birth weight, the BDHS retrospectively gathered the data on baby's birth size according to mother's perception by questioning all women who had given birth within 5 years prior to the survey, "was the baby very large, larger than average, average, smaller than average or very small at the time of birth?" (Those babies who were born within 5 years prior to the survey). The mothers' report about baby's size at birth was "very small" or "smaller than average" was considered as a useful proxy of LBW and, the variable was selected and categorized according to the guideline of BDHS and previous literature [23 24]. Mother's report was 90% correct in terms of the baby who was born with LBW [23 24].

Explanatory variables

Individuals' socio-demographic characteristics and several adverse maternal characteristics such as underweight or overweight mother, unwanted birth, IPV, previous pregnancy termination, maternal high-risk fertility behaviours, etc. were considered as the main explanatory variables of occurrence and non-occurrence of LBW in newborns. A complete list of explanatory variables is presented in Table 1. The selection procedure of these variables followed international guidelines and was chosen by reviewing the previous literature [23 25].

"Insert Table 1"

Statistical analysis

For the entire study population, the prevalence of LBW of the child was measured. The association between LBW and different socio-demographic, adverse maternal characteristics including high-risk fertility behaviours were assessed by Chi-square tests (set at $p<0.05$ level of significance). Afterwards, a binary logistic regression model was fitted owing to the outcome variable had binary categories, and odds ratios (ORs) (both unadjusted and adjusted) were estimated to measure the effect size of explanatory variables on the outcome variable. For each of ORs, 95% confidence intervals (CIs) were also assessed to inspect the level of significance. In the dataset, few explanatory variables for the study had more than 5% of missing values. Therefore, multiple imputation techniques using linear regression was applied for the estimation of the missing values of those variables by considering the known values [26]. This analysis was done to protect representativeness and to prevent misinterpretation or any bias [26]. In the imputation, residence, education, economic status and employment status were used as covariates. All the analysis in this study was done by taking into account the complex survey design and sample weights and was performed using the computer program Stata in windows version 13.0 (Stata Corporation, College Station, TX, USA).

Results

Prevalence and distribution of LBW

The prevalence of LBW and its association with several adverse maternal characteristics are presented in Table 2. This study revealed that the prevalence of LBW in newborns was 19.9% in Bangladesh. In Fig. 1, the geographical prevalence of LBW across seven administrative regions of Bangladesh using most recent BDHS 2014 data are presented and the highest prevalence of LBW was found in Sylhet region (26.2%) while the lowest prevalence was

observed in Rangpur region (13.5%). Besides, the prevalence was also noticeably higher in Dhaka (20.9%) and Chittagong (21.8%) regions of Bangladesh.

"Insert Fig 1."

The rate of LBW was observed significantly higher in the rural territory (20.8%), in poor households (22.3%), and among uneducated mothers (26.6%). We also found that several adverse maternal characteristics were significantly related to the highest prevalence of LBW in infants, such as underweight mother (24.9% vs 18.4%), for women who were not taken ANC at least 4 times (21.6%) during pregnancy, for unwanted birth (24.6% vs 19.0%) and for mothers who were the victim of IPV (21.0%). Similarly, the LBW rate in newborns was also observed remarkably higher for individuals with high-risk fertility behaviours like mothers aged <18 years at the time of childbirth (29.2% vs 18.5%), and for the individuals whose birth interval was <24 months (26.6% vs 17.9%). Moreover, in newborns, LBW prevalence was noticeably increased if we took into account multiple characteristics of high-risk fertility behaviours together. For instance, around 22.4%, 27.1% and 24.5% of LBW in newborns was found among the mothers who aged <18 years at the times of childbirth with birth interval <24 months, for maternal age at birth >34 years with birth interval <24 and birth order >3 with birth interval <24 months, respectively.

"Insert Table 2"

Influence of adverse maternal characteristics on LBW

Table 3 illustrates the effect size of several adverse maternal characteristics on children's low birth weight in Bangladesh and were assessed by logistic regression analysis. The result found that the risk of LBW was higher in the rural territories (AOR: 1.22, CI: 1.02-1.46) compared to the urban. On the other hand, maternal education was found protective in the occurrence of LBW in infants. The likelihood of giving birth an infant with LBW was decreased

for Primary (AOR: 0.72, CI: 0.57-0.90), and secondary and above (AOR: 0.57, CI: 0.45-0.73) educated mothers than the uneducated mothers. The chance of children born with LBW was significantly increased for underweight mother (AOR: 1.26, CI: 1.06-1.49), and for mothers who had not taken ANC at least 4 times (AOR: 1.23, CI: 1.03-1.48) compared to their counterparts. The risk of LBW in newborns was also advanced for unwanted birth (AOR: 1.22, CI: 1.03-1.44), for women who had a history of previous pregnancy termination record (AOR: 1.28, CI: 1.05-1.57), and for mothers who were a victim of IPV (AOR: 1.23, CI: 1.05-1.45) than their counterparts. Maternal single high-risk fertility behaviours were appeared to strongly associated with newborns' LBW. Maternal younger age at childbirth (<18 years), and birth interval <24 months had a 42% (AOR: 1.42, CI: 1.11-1.83), and 26% (AOR:1.26, CI: 1.02-1.57), respectively, increased the risk of LBW in newborns. This was also the case for mothers with multiple high-risk fertility behaviors such as, maternal age at birth <18 years with birth interval <24 months (AOR: 1.26, CI: 1.02-1.57), and birth order >3 with interval <24 months (AOR: 1.68, CI: 1.18-2.37) compared with the mother who had no such risky behaviors.

"Insert Table 3"

Discussion

This study result supports our hypothesis that various types of socio-demographic and adverse maternal factors, including high-risk fertility behaviours are significantly enhancing the likelihood of giving birth to an LBW child. Using nationally representative data, we observed that the prevalence of LBW is about 20% in Bangladesh. The burden is significantly varying according to regional variation with a very high prevalence in the Sylhet region and comparatively low prevalence in Rangpur region. Though a significant deterioration of LBW rate is observed in Bangladesh, still the rate is much higher than the global average [1 7 8]. It admits no doubt that continued effort is very urgent to lessen the LBW rate in Bangladesh. According

to our study, the burden is comparatively higher in rural areas and in the illiterate community of Bangladesh. A study regarding developing country has also identified that illiterate and poor women are in a significantly higher risk of giving birth to an LBW baby [27], which supports our findings. On the contrary, several previous works have observed the significant association of LBW with the household economic condition, but this study result was failed to corroborate with previous findings in this regard [18 28].

Maternal underweightness is a well-established risk factor of giving birth to an LBW baby [29 30]. Our study corroborates earlier endeavours because according to this study findings, underweight mothers were at a higher risk of giving birth to an LBW baby than their counterparts [29 31 32]. In underweight mothers, there occurs a deficiency of micronutrients and caloric supplementation which resist proper growth of the fetus and leads baby towards born with LBW [33]. So, to reduce the risk of giving birth to an LBW baby, the urgency of maternal proper nutrition comes to the 1st in terms of its importance. However, taking ANC >4 times can mitigate the incidence of LBW in newborns. Our findings regarding higher chances of giving birth to an LBW baby among mother who has taken ANC <4 times is consistent with recent study results [18 34]. In general, ANC provides the precise care required for both mother and newborn babies by addressing all forms of maternal and newborn health complications. In Ethiopia, Assefa and colleagues [28] have significantly noticed that the women who were not taken any ANC had a 1.6 times higher risk to give birth an LBW baby. A key challenge to reduce the risk is to reach those women and newborns who are in the greatest need.

In this study, the risk of LBW in the newborn is also higher for unwanted births. The previous findings of Wado *et al.* [35] and Shah *et al.* [36] support our study. Unwanted pregnancy profoundly enhancing the risk of antenatal depression, which is an essential predictor of LBW [35 37]. Pregnancy intention is a very complicated process. Pregnancy arouses many feelings on a woman like anxiety, fear, excitement, happiness, etc. and may fluctuate in pregnancy period, which may

cause variation in birth outcomes [36 38]. Our findings regarding the higher likelihood of giving birth to a baby with LBW among mothers whoever had a terminated pregnancy is showing uniformity with some earlier endeavours [39 40]. On the other hand, contrary to our findings, among Southern Chinese women, Li Ke and colleagues [41] observed no significant association between induced abortion and LBW for first-time mothers. These study findings regarding the higher likelihood of giving birth to an LBW baby among mothers who experienced any sorts of IPV, either physical or sexual, is supported by earlier study results [22 28 42 43]. The burden is much higher for women who experienced both physical and sexual IPV [22]. IPV may affect LBW in diverse pathways. For instance, IPV during pregnancy increases the risk of unintended pregnancy and also responsible for pregnancy complications, both of which directly advance the risk of giving birth to an LBW baby [36 44 45]. All these factors, i.e. unintended pregnancy or IPV have a direct connection with chronic psychosocial stress in women, and that's why the risk of giving birth to LBW neonates is much higher for this women [46].

In this study, our analysis observed that several forms of maternal high-risk fertility behaviours i.e. younger maternal age at birth (<18 years), birth interval <24 months are significantly enhancing the risk of LBW in newborns [47]. Supporting our findings, earlier endeavours have also found that younger maternal age at birth (<18 years) is strongly associated with an increased likelihood of giving birth an LBW baby [17 48 49]. Childbirth in adolescence is detrimental for child health due to maternal socio-economic factors, immature behaviour, biological factors like comparatively immature reproductive system, etc. [48] Consequently, a woman of this age cluster is often unable to handle complexities of pregnancy and the fetus remain deficient according to its nutritional needs that are required for proper growth and development [48]. However, our study findings regarding giving another birth within a short interval (<24 months) are remarkably increasing the risk of giving birth to an LBW baby, is showing consistency with previous findings [20 50 51]. In northern Tanzania, a retrospective cohort study concluded that shorter interpregnancy

intervals (<24 months) was 1.61 times highly enhancing the risk of giving birth to an LBW infant compared to the interpregnancy interval of 24–36 months [50]. Among women with shorter interpregnancy interval, the depletion of iron and folic acid is observed, which is related to increased risks of growth restriction of the fetus [52]. Moreover, the risk of giving birth to an LBW baby is also increased if we consider multiple high-risk behaviors together. If a woman give birth at adolescent age (<18 years) with shorter birth interval (<24 months), than it is clearly perilous for the newborn and has a higher likelihood to born with LBW due to aforementioned reasons. A similar risk was also observed for maternal higher birth order (>3) with lower birth interval. Therefore, we can conclude that maternal high-risk fertility behaviors have a significant influence on giving birth to a baby with LBW.

Conclusion

The high prevalence of LBW in newborns indicates a serious newborn health hazard in Bangladesh. To understand the influencing risk factors of LBW in newborns, this study is inevitable and this can be used as a basis for developing prevention strategies. This study reveals that several socio-demographic and adverse maternal characteristics including several individuals and multiple high-risk fertility behaviors appear to impact on newborns birth weight and increases the risk of giving birth to an LBW baby. These findings highlight the essentiality of early screening and interventions targeted to all women. This endeavor suggests that policymakers and public health authorities need to address these adverse maternal factors while designing prevention interventions to reduce LBW in newborns. In this regard, reproductive health promotion programs among targeted individuals could be introduced to assist them to reduce these adverse factors as well as LBW. Finally, we may conclude that these adverse maternal characteristics can impede the progress towards achieving the SDG target regarding newborn health care.

Abbreviations

LBW, Low Birth Weight; LMIC, Low- and Middle-Income Country; SDG, Sustainable Development Goal; BDHS, Bangladesh Demographic and Health Survey; ANC, Antenatal Care; CI, Confidence Interval; OR, Odds Ratio.

Authors Contribution

MMAK, MGM, MSK, HTAK and MRI are the authors of this manuscript and all authors have read and approved the final manuscript.

1. MMAK conceptualize and designed the research
2. MMAK, MGM and MSK ran the formal data analysis and responsible for all analysis
3. MRI supervise the study
4. MMAK and MGM wrote the manuscript
5. MRI and HTAK critically revised the manuscript

References

1. Khan JR, Islam MM, Awan N, et al. Analysis of low birth weight and its co-variants in Bangladesh based on a sub-sample from nationally representative survey. *BMC pediatrics* 2018;18(1):100. doi: 10.1186/s12887-018-1068-0
2. Katz J, Lee AC, Kozuki N, et al. Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. *The Lancet* 2013;382(9890):417-25.
3. WHO. Global nutrition targets 2025: low birth weight policy brief (WHO/NMH/NHD/14.5). *World Health Organization, Geneva, Switzerland* 2014:8.
4. Wilcox AJ. On the importance—and the unimportance—of birthweight. *International journal of epidemiology* 2001;30(6):1233-41.
5. Saville NM, Shrestha BP, Style S, et al. Impact on birth weight and child growth of Participatory Learning and Action women's groups with and without transfers of food or cash during pregnancy: Findings of the low birth weight South Asia cluster-randomised controlled trial (LBWSAT) in Nepal. *PLOS ONE* 2018;13(5):e0194064. doi: 10.1371/journal.pone.0194064
6. Veena SR, Krishnaveni GV, Wills AK, et al. Association of birthweight and head circumference at birth to cognitive performance in 9-to 10-year-old children in South India: prospective birth cohort study. *Pediatric research* 2010;67(4):424.
7. WHO. WHO | Care of the preterm and low-birth-weight newborn: World Health Organization, Geneva, Switzerland; 2018 [updated 2018-11-14 15:51:42. Available from: https://www.who.int/maternal_child_adolescent/newborns/prematurity/en/.
8. NNS. National Low Birth Weight Survey (NLBWS) Bangladesh, 2015. *National Nutrition Services, Institute of public health nutrition, Directorate general of health services, Ministry of Health & Family Welfare, Dhaka, Bangladesh* 2017

9. Watkins WJ, Kotecha SJ, Kotecha S. All-Cause Mortality of Low Birthweight Infants in Infancy, Childhood, and Adolescence: Population Study of England and Wales. *PLOS Medicine* 2016;13(5):e1002018. doi: 10.1371/journal.pmed.1002018
10. Brooks A-M, Byrd RS, Weitzman M, et al. Impact of Low Birth Weight on Early Childhood Asthma in the United States. *Archives of Pediatrics & Adolescent Medicine* 2001;155(3):401-06. doi: 10.1001/archpedi.155.3.401
11. Franz AP, Bolat GU, Bolat H, et al. Attention-Deficit/Hyperactivity Disorder and Very Preterm/Very Low Birth Weight: A Meta-analysis. *Pediatrics* 2018;141(1):e20171645. doi: 10.1542/peds.2017-1645
12. Lee SM, Kim N, Namgung R, et al. Prediction of Postnatal Growth Failure among Very Low Birth Weight Infants. *Scientific Reports* 2018;8(1):3729. doi: 10.1038/s41598-018-21647-9
13. Sania A, Fall CH, Victora CG, et al. Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. *International Journal of Epidemiology* 2013;42(5):1340-55. doi: 10.1093/ije/dyt109
14. Tian J, Qiu M, Li Y, et al. Contribution of birth weight and adult waist circumference to cardiovascular disease risk in a longitudinal study. *Scientific reports* 2017;7(1):9768-68. doi: 10.1038/s41598-017-10176-6
15. Belbasis L, Savvidou MD, Kanu C, et al. Birth weight in relation to health and disease in later life: an umbrella review of systematic reviews and meta-analyses. *BMC Medicine* 2016;14(1):147. doi: 10.1186/s12916-016-0692-5
16. Mebrahtu TF, Feltbower RG, Greenwood DC, et al. Birth weight and childhood wheezing disorders: a systematic review and meta-analysis. *J Epidemiol Community Health* 2015;69(5):500-08.
17. Sharma SR, Giri S, Timalsina U, et al. Low Birth Weight at Term and Its Determinants in a Tertiary Hospital of Nepal: A Case-Control Study. *PLOS ONE* 2015;10(4):e0123962. doi: 10.1371/journal.pone.0123962
18. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. *Journal of preventive medicine and public health = Yebang Uihakhoe chi* 2017;50(1):18-28. doi: 10.3961/jpmph.16.087 [published Online First: 12/27]
19. Feresu SA, Harlow SD, Woelk GB. Risk Factors for Low Birthweight in Zimbabwean Women: A Secondary Data Analysis. *PLOS ONE* 2015;10(6):e0129705. doi: 10.1371/journal.pone.0129705
20. Silveira MF, Victora CG, Horta BL, et al. Low birthweight and preterm birth: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015. *International Journal of Epidemiology* 2018:dyy106-dyy06. doi: 10.1093/ije/dyy106
21. Rao J, Fan D, Wu S, et al. Trend and risk factors of low birth weight and macrosomia in south China, 2005–2017: a retrospective observational study. *Scientific Reports* 2018;8(1):3393. doi: 10.1038/s41598-018-21771-6
22. Ferdos J, Rahman MM. Maternal experience of intimate partner violence and low birth weight of children: A hospital-based study in Bangladesh. *PLOS ONE* 2017;12(10):e0187138. doi: 10.1371/journal.pone.0187138
23. NIPORT. Bangladesh Demographic and Health Survey 2014. *National Institute of Population Research and Training (NIPROT), Mitra and Associates & Macro International, Dhaka, Bangladesh and Calverton, Maryland, USA* 2016
24. Rahman MS, Howlader T, Masud MS, et al. Association of Low-Birth Weight with Malnutrition in Children under Five Years in Bangladesh: Do Mother's Education, Socio-Economic Status, and Birth Interval Matter? *PLOS ONE* 2016;11(6):e0157814. doi: 10.1371/journal.pone.0157814
25. Rahman M, Islam MJ, Haque SE, et al. Association between high-risk fertility behaviours and the likelihood of chronic undernutrition and anaemia among married Bangladeshi women of reproductive age. *Public health nutrition* 2017;20(2):305-14. doi: 10.1017/s136898001600224x [published Online First: 2016/09/10]
26. Sterne JA, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *Bmj* 2009;338:b2393.

27. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. *J Prev Med Public Health* 2017;50(1):18-28. doi: 10.3961/jpmph.16.087
28. Assefa N, Berhane Y, Worku A. Wealth Status, Mid Upper Arm Circumference (MUAC) and Antenatal Care (ANC) Are Determinants for Low Birth Weight in Kersa, Ethiopia. *PLOS ONE* 2012;7(6):e39957. doi: 10.1371/journal.pone.0039957
29. He Z, Bishwajit G, Yaya S, et al. Prevalence of low birth weight and its association with maternal body weight status in selected countries in Africa: a cross-sectional study. *BMJ open* 2018;8(8):e020410.
30. Britto RPdA, Florêncio TMT, Benedito Silva AA, et al. Influence of Maternal Height and Weight on Low Birth Weight: A Cross-Sectional Study in Poor Communities of Northeastern Brazil. *PLOS ONE* 2013;8(11):e80159. doi: 10.1371/journal.pone.0080159
31. Patel A, Prakash AA, Das PK, et al. Maternal anemia and underweight as determinants of pregnancy outcomes: cohort study in eastern rural Maharashtra, India. *BMJ Open* 2018;8(8):e021623. doi: 10.1136/bmjopen-2018-021623
32. Karim MR, Mondal MNI, Rana MM, et al. Maternal Factors are Important Predictors of Low Birth Weight: Evidence from Bangladesh Demographic & Health Survey-2011. *Malaysian Journal of Nutrition* 2016;22(2)
33. Razak F, Finlay JE, Subramanian SV. Maternal underweight and child growth and development. *The Lancet* 2013;381(9867):626-27. doi: 10.1016/S0140-6736(13)60344-X
34. Pinzón-Rondón ÁM, Gutiérrez-Pinzon V, Madriñan-Navia H, et al. Low birth weight and prenatal care in Colombia: a cross-sectional study. *BMC pregnancy and childbirth* 2015;15(1):118.
35. Wado YD, Afework MF, Hindin MJ. Effects of Maternal Pregnancy Intention, Depressive Symptoms and Social Support on Risk of Low Birth Weight: A Prospective Study from Southwestern Ethiopia. *PLOS ONE* 2014;9(5):e96304. doi: 10.1371/journal.pone.0096304
36. Shah PS, Balkhair T, Ohlsson A, et al. Intention to become pregnant and low birth weight and preterm birth: a systematic review. *Matern Child Health J* 2011;15(2):205-16. doi: 10.1007/s10995-009-0546-2 [published Online First: 2009/12/17]
37. Niemi M, Falkenberg T, Petzold M, et al. Symptoms of antenatal common mental disorders, preterm birth and low birthweight: a prospective cohort study in a semi-rural district of V ietnam. *Tropical medicine & international health* 2013;18(6):687-95.
38. Sable MR, Spencer JC, Stockbauer JW, et al. Pregnancy wantedness and adverse pregnancy outcomes: differences by race and Medicaid status. *Family planning perspectives* 1997;29:76-81.
39. Brown JS, Jr., Adera T, Masho SW. Previous abortion and the risk of low birth weight and preterm births. *J Epidemiol Community Health* 2008;62(1):16-22. doi: 10.1136/jech.2006.050369 [published Online First: 2007/12/15]
40. Kc S, Hemminki E, Gissler M, et al. Perinatal outcomes after induced termination of pregnancy by methods: A nationwide register-based study of first births in Finland 1996–2013. *PLOS ONE* 2017;12(9):e0184078. doi: 10.1371/journal.pone.0184078
41. Ke L, Lin W, Liu Y, et al. Association of induced abortion with preterm birth risk in first-time mothers. *Scientific Reports* 2018;8(1):5353. doi: 10.1038/s41598-018-23695-7
42. Henriksen L, Schei B, Vangen S, et al. Sexual violence and neonatal outcomes: a Norwegian population-based cohort study. *BMJ Open* 2014;4(10):e005935. doi: 10.1136/bmjopen-2014-005935
43. Chambliss LR. Intimate partner violence and its implication for pregnancy. *Clinical obstetrics and gynecology* 2008;51(2):385-97.
44. Rahman M, Sasagawa T, Fujii R, et al. Intimate Partner Violence and Unintended Pregnancy Among Bangladeshi Women. *Journal of Interpersonal Violence* 2012;27(15):2999-3015. doi: 10.1177/0886260512441072
45. Ferdos J, Rahman MM, Jesmin SS, et al. Association between intimate partner violence during pregnancy and maternal pregnancy complications among recently delivered women in Bangladesh. *Aggressive behavior* 2018;44(3):294-305. doi: 10.1002/ab.21752

46. Borders AE, Grobman WA, Amsden LB, et al. Chronic stress and low birth weight neonates in a low-income population of women. *Obstet Gynecol* 2007;109(2 Pt 1):331-8. doi: 10.1097/01.AOG.0000250535.97920.b5 [published Online First: 2007/02/03]
47. Rahman M, Hosen A, Khan MA. Association between Maternal High-Risk Fertility Behavior and Childhood Morbidity in Bangladesh: A Nationally Representative Cross-Sectional Survey. *The American journal of tropical medicine and hygiene* 2019 doi: 10.4269/ajtmh.19-0221 [published Online First: 2019/07/25]
48. Fall CHD, Sachdev HS, Osmond C, et al. Association between maternal age at childbirth and child and adult outcomes in the offspring: a prospective study in five low-income and middle-income countries (COHORTS collaboration). *The Lancet Global Health* 2015;3(7):e366-e77. doi: 10.1016/S2214-109X(15)00038-8
49. Dennis JA, Mollborn S. Young maternal age and low birth weight risk: An exploration of racial/ethnic disparities in the birth outcomes of mothers in the United States. *The Social science journal* 2013;50(4):625-34. doi: 10.1016/j.soscij.2013.09.008
50. Mahande MJ, Obure J. Effect of interpregnancy interval on adverse pregnancy outcomes in northern Tanzania: a registry-based retrospective cohort study. *BMC Pregnancy and Childbirth* 2016;16(1):140. doi: 10.1186/s12884-016-0929-5
51. Veloso HJF, da Silva AAM, Bettiol H, et al. Low birth weight in São Luís, northeastern Brazil: trends and associated factors. *BMC Pregnancy and Childbirth* 2014;14(1):155. doi: 10.1186/1471-2393-14-155
52. Winkvist A, Rasmussen KM, Habicht J-P. A new definition of maternal depletion syndrome. *American journal of public health* 1992;82(5):691-94.

Table 1. A complete list and details of explanatory variables.

Variables	Collected data	Answer category
Socio-demographic variables		
Maternal education[1]	Maternal highest level of education	1 = No education; 2 = Primary; 3 = Secondary & above
Residence	Place of residence	1 = Urban; 2 = Rural
Economic status[2]	Wealth index of the family	1 = Poor; 2 = Middle; 3 = Rich
Employment status[2]	Employment status of the individuals	1 = Unemployed; 2 = Employed
Adverse maternal characteristics		
Underweight mother	The nutritional status (BMI) of mother was measured and if BMI was less than 18.5 kg/m^2 then she was underweighted.	0 = No; 1 = Yes
Overweight/obese mother	The nutritional status (BMI) of mother was measured and if BMI was higher than 25.0 kg/m^2 then she was overweight and BMI was higher than 30.0 kg/m^2 then she was obese.	0 = No; 1 = Yes
Unwanted birth	The birth was not wanted at that time	0 = No; 1 = Yes
Ever had a terminated pregnancy	The mother had a previous pregnancy termination history (abortion, miscarriage etc.)	0 = No; 1 = Yes
Victim of intimate partner violence (IPV)	The mother who were a victim of IPV such as beaten in front of child, beaten by husband when refuse to intercourse or burn food etc.	0 = No; 1 = Yes
ANC <4 times	The mother who had taken ANC less than 4 times during pregnancy	0 = No; 1 = Yes
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years	The mother whose age at the time of the birth was less than 18 years	0 = No; 1 = Yes
Maternal age at birth >34 years	The mother whose age at the time of the birth was greater than 34 years	0 = No; 1 = Yes
Birth interval <24 months	The mother who gave birth with a birth interval of less than 24 months	0 = No; 1 = Yes
Birth order >3	The mother whose birth order was higher than 3	0 = No; 1 = Yes
Maternal age at birth <18 years and Birth interval <24 months[3]	The mother whose age at the time of the birth was less than 18 years with an interval of less than 24 months	0 = No; 1 = Yes
Maternal age at birth >34 years and Birth interval <24 months[4]	The mother whose age at the time of the birth was greater than 34 years with an interval of less than 24 months	0 = No; 1 = Yes
Birth interval <24 months and birth order >3	The mother whose birth order was higher than 3 with interval of less than 24 months	0 = No; 1 = Yes

Note: The analysis was restricted to mother who gave a least one birth within 5 years prior to the survey. High-risk fertility behavior variables categorization followed BDHS standard measure. [1] Primary and secondary education is defined as completing grade 5 and 10, respectively**.** [2] followed standard BDHS measure. [3] includes the categories "age at birth <18 years with birth order >3" and "age at birth <18 years with interval <24 months and birth order >3". [4] includes the categories "age at birth <34 years with interval <24 months" and "age at birth <34 years with interval <24 months and birth order >3". [5] includes obesity (BMI > 30.0 kg/m^2)

Table 2. The prevalence of low birth weight and its association with socio demographic risk factors adverse maternal characteristics including maternal high-risk fertility behaviors in Bangladesh, BDHS 2014.

Background characteristics	Low birth weight (%, 95% CI)	p-value
Overall	19.9 (18.5-21.5)	
Socio-demographic variables:		
Residence		<0.001
Urban	17.5 (15.1-20.2)	
Rural	20.8 (18.9-22.8)	
Maternal education		<0.001
No education	26.6 (22.2-31.5)	
Primary	21.1 (18.2-24.3)	
Secondary and above	17.7 (16.0-19.7)	
Economic status		<0.001
Poor	22.3 (19.8-24.9)	
Middle	19.7 (15.8-24.3)	
Rich	17.7 (15.5-20.1)	
Employment status		0.683
Unemployed	19.6 (17.7-21.6)	
Employed	21.1 (18.1-24.4)	
Adverse maternal characteristics		
Underweight mother		<0.001
No	18.4 (16.6-20.2)	
Yes	24.9 (21.9-28.1)	
Overweight/obese mother		0.004
No	20.8 (19.1-22.5)	
Yes	15.9 (12.9-19.3)	
Taken ANC <4 times		<0.001
No	16.3 (14.4-18.4)	
Yes	21.6 (19.6-23.7)	
Unwanted birth		0.002
No	19.0 (17.4-20.7)	
Yes	24.6 (20.9-26.6)	
Ever had a terminated pregnancy		0.096
No	19.5 (17.9-21.2)	
Yes	22.8 (18.8-27.2)	
Victim of intimate partner violence		0.014
No	19.5 (17.8-21.4)	
Yes	21.0 (18.6-23.6)	
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years		<0.001
No	18.5 (17.0-20.2)	
Yes	29.2 (25.1-33.7)	
Maternal age at birth >34 years		0.204
No	19.5 (18.1-21.2)	
Yes	23.0 (19.9-30.9)	
Birth interval <24 months		<0.001
No	17.9 (16.7-19.7)	
Yes	26.6 (23.5-29.8)	
Birth order >3		0.008
No	19.3 (17.7-21.0)	
Yes	24.0 (20.2-28.3)	
Maternal age at birth <18 years and birth interval <24 months		<0.001
No	18.8 (17.3-20.5)	
Yes	22.4 (19.6-25.5)	
Maternal age at birth <34 years and birth interval <24 months		0.003
No	18.8 (17.2-20.5)	
Yes	27.1 (23.1-31.5)	

Birth order >3 and birth interval <24 months		0.011
No	19.7 (18.3-21.4)	
Yes	24.5 (18.0-32.5)	

Note: The sample was weighted. "No" values for low birth weight was omitted from the table and calculated for row percentage.

Table 3. Unadjusted and adjusted odds ratio to measure the effect size of adverse maternal characteristics on newborn's low birth weight in Bangladesh, BDHS 2014.

Background characteristics	Low birth weight (LBW)	
	UOR (95% CI)	AOR (95% CI)
Socio-demographic variables:		
Residence		
Urban (RC)	1.00	1.00
Rural	1.34 (1.16-1.61) ***	1.22 (1.02-1.46) *
Maternal education		
No education (RC)	1.00	1.00
Primary	0.73 (0.59-0.90) **	0.72 (0.57-0.90) **
Secondary and above	0.54 (0.44-0.66) ***	0.57 (0.45-0.73) ***
Economic status		
Poor (RC)	1.00	1.00
Middle	0.87 (0.71-1.06)	1.03 (0.84-1.26)
Rich	0.68 (0.58-0.80) ***	0.97 (0.79-1.18)
Employment status		
Unemployed (RC)	1.00	1.00
Employed	1.04 (0.88-1.23)	1.02 (0.86-1.21)
Adverse maternal characteristics		
Underweight mother		
No (RC)	1.00	1.00
Yes	1.48 (1.25-1.72) ***	1.26 (1.06-1.49) **
Overweight/obese mother		
No (RC)	1.00	1.00
Yes	0.74 (0.61-0.91) **	0.98 (0.78-1.23)
Taken ANC <4 times		
No (RC)	1.00	1.00
Yes	1.44 (1.23-1.70) ***	1.23 (1.03-1.48) *
Unwanted birth		
No (RC)	1.00	1.00
Yes	1.29 (1.10-1.51) **	1.22 (1.03-1.44) *
Ever had a terminated pregnancy		
No (RC)	1.00	1.00
Yes	1.18 (0.97-1.43)	1.28 (1.05-1.57) **
Victim of intimate partner violence		
No (RC)	1.00	1.00
Yes	1.22 (1.04-1.42) **	1.23 (1.05-1.45) *
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years		
No (RC)	1.00	1.00
Yes	1.81 (1.50-2.19) ***	1.42 (1.11-1.83) **
Maternal age at birth >34 years		
No (RC)	1.00	1.00
Yes	1.23 (0.89-1.71)	0.93 (0.63-1.39)
Birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.54 (1.32-1.80) ***	1.25 (1.01-1.55) *
Birth order >3		
No (RC)	1.00	1.00
Yes	1.30 (1.07-1.59) **	1.04 (0.83-1.33)
Maternal age at birth <18 years and birth interval <24 months		

No (RC)	1.00	1.00
Yes	1.31 (1.12-1.53) ***	1.26 (1.02-1.57) **
Maternal age at birth <34 years and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.34 (1.11-1.64) **	1.22 (0.97-1.54)
Birth order >3 and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.50 (1.09-2.06) *	1.68 (1.18-2.37) **

Note: Model was adjusted for all the predictors included in this table. Values with superscript asterisks *, **, and *** indicate $p<0.05$, $p<0.01$, and $p<0.001$, respectively. UOR: unadjusted odds ratio; AOR: adjusted odds ratio; CI: confidence interval; ANC: antenatal care.

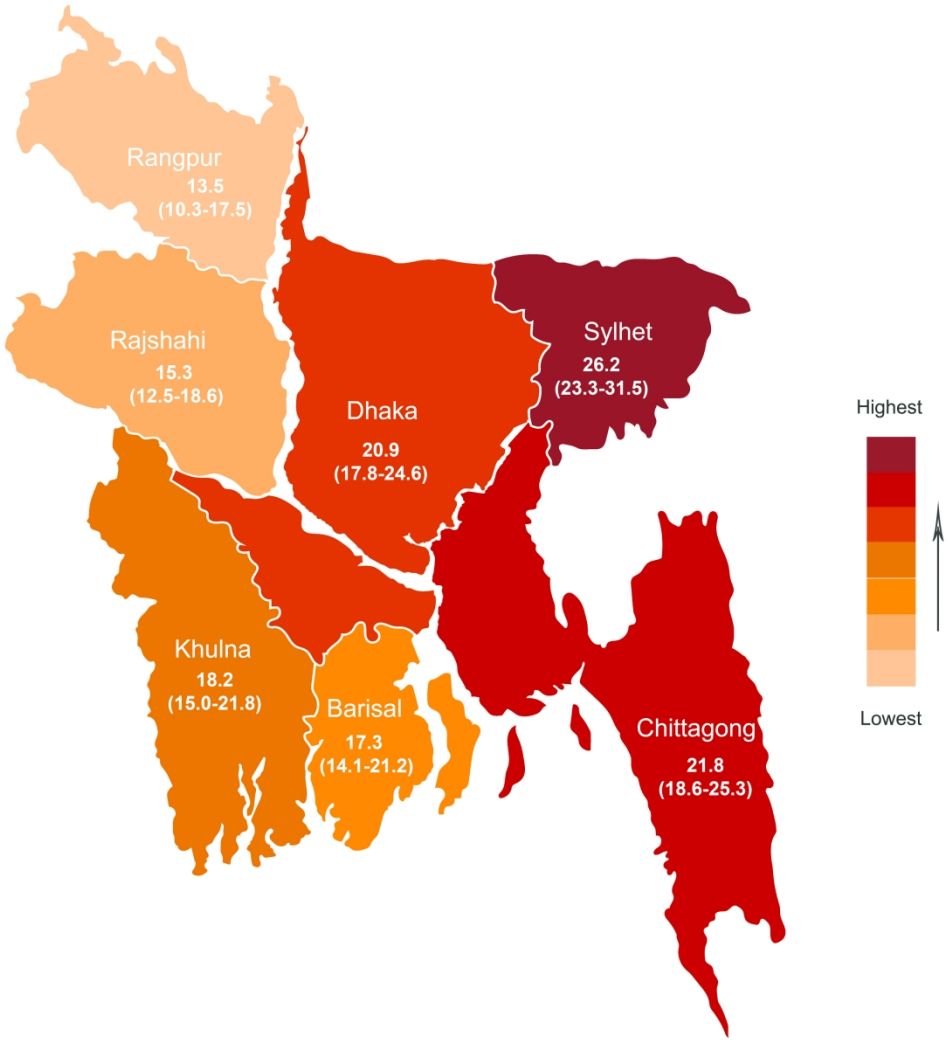

Fig 1. Geographical prevalence (%, 95% CI) of low birth weight according to seven administrative divisions in Bangladesh (using data BDHS 2014).

254x275mm (300 x 300 DPI)

BMJ Open

Exploring the impact of adverse maternal situations on low birth weight in Bangladesh: a nationwide population-based study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-036162.R1
Article Type:	Original research
Date Submitted by the Author:	23-Jun-2020
Complete List of Authors:	Khan, Md. Mostaured; University of Rajshahi, Population Science and Human Resource Development Mustagir, Md. Golam; University of Rajshahi, Population Science and Human Resource Development Islam, Md; University of Rajshahi, Population Science and Human Resource Development Kaikobad, Md. Sharif; University of Rajshahi, Population Science and Human Resource Development Khan, Hafiz; University of West London, College of Nursing, Midwifery and Healthcare
Primary Subject Heading:	Paediatrics
Secondary Subject Heading:	Paediatrics, Nutrition and metabolism
Keywords:	NEONATOLOGY, Community child health < PAEDIATRICS, Nutrition < TROPICAL MEDICINE

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Exploring the impact of adverse maternal situations on low birth weight in Bangladesh: *a nationwide population-based study*

Authors: Md. Mostaured Ali Khan[1], Md. Golam Mustagir[1], Md. Rafiqul Islam[1*], Md. Sharif Kaikobad[1], and Hafiz T.A. Khan[2]

Affiliations:

[1] Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh.

[2] Professor of Public Health & Statistics, College of Nursing, Midwifery and Healthcare, University of West London, Paragon House, Boston Manor Road, Brentford, Middlesex TW8 9GB, United Kingdom

Corresponding Author:

Md. Rafiqul Islam, PhD
Professor, Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh.
E-mail: rafique_pops@yahoo.com
Mobile: +8801775715126
Phone: +880721-711524

Exploring the impact of adverse maternal situations on low birth weight in Bangladesh: *a nationwide population-based study*

Abstract

Objectives: In order to improve the healthcare of newborn babies, it is essential to know if adverse maternal situations are contributing towards low birth weight (LBW). This study is concerned with examining the impact of adverse maternal situations on LBW in Bangladesh.

Study designs and settings: Data taken from the "Bangladesh Demographic and Health Survey (BDHS), 2014" was analysed and the association between LBW and adverse maternal characteristics were assessed using a Chi-square test. The effects of selected adverse situations on LBW were identified using logistic regression analysis.

Participants: The study is based on 4,728 children aged below 5 years born to women of selected households.

Results: The prevalence of LBW was around 19.9% (199 per 1000 live birth) in Bangladesh with the highest in the Sylhet region (26.2%). The prevalence was even higher in rural areas (20.8%) and among illiterate mothers (26.6%). Several adverse maternal characteristics, such as, being underweight (Adjusted Odds Ratio (AOR): 1.26 and 95% Confidence Interval (CI): 1.06-1.49); unwanted birth (AOR: 1.22, 95% CI: 1.03-1.44); previous terminated pregnancy (AOR: 1.28, 95% CI: 1.05-1.57); victim of intimate partner violence (AOR: 1.23, 95% CI: 1.05-1.45) and taking ANC <4 times (AOR: 1.23, 95% CI: 1.03-1.48) were found to be significant factors influencing the likelihood of giving birth to a LBW baby. High-risk fertility behaviors such as age at birth <18 years (AOR: 1.42, 95% CI: 1.11-1.83) and birth interval <24 months (AOR: 1.25, 95% CI: 1.01-1.55) were revealed as important risk factors. The risk was significantly increased when looking at multiple high-risk fertility behaviours together, that is, maternal age at birth <18 years with interval <24 months (AOR: 1.26, 95% CI: 1.02-1.57), and birth order >3 with interval <24 months (AOR: 1.68, 95% CI: 1.18-2.37).

Conclusion: It can be concluded that high-risk fertility behaviours have a significant influence on LBW in neonates. These behaviours can impede progress towards achieving the sustainable development goal (SDG) in Bangladesh concerned with the healthcare of newborns.

Keywords: Low birth weight (LBW), high-risk fertility behaviours, adverse maternal characteristics, Bangladesh, BDHS

Strengths and limitations of the study

- Analyzing a nationally representative data set helps to provide a wider picture of society and also provide more reliable results.
- However, LBW was based on the mother's perception of the size of the child at birth instead of the actual birth weight due to unavailability of the data.
- The study outcome and predictor were based on self-reporting, recall bias is commonly found in this type of data collection.
- The use of secondary data limited the analysis in variable selection and model adjustment.

Funding: This study did not receive any specific grant either from the university or any funding agencies in the public, commercial, or not-for-profit sectors.

Competing interests: None declared.

Acknowledgement: We gratefully acknowledge the Demographic and Health Survey programme for granting permission to use the data.

Ethical Statement

Ethical approval for all BDHS surveys was taken from the ICF Macro Institutional Review Board, Maryland, USA, and the National Research Ethics Committee of the Bangladesh Medical

Research Council (BMRC), Dhaka, Bangladesh. The National Institute of Population Research and Training conducted these surveys with the support of the United States Agency for International Development (USAID). Informed consent was obtained from all participants. The BDHS is part of the worldwide Demography and Health Surveys (DHS) programme and is available in the public domain for research purposes.

Patient consent: Not required.

Data sharing statement: The data sets used for the current study are publicly available upon request at http://dhsprogram.com/data/available-datasets.cfm.

Introduction

Low birth weight (LBW) is a critical concern of child health on a global scale, particularly in low- and middle-income countries (LMICs) [1 2]. A newborn weighing less than 2.5 kilograms (5.5 pounds) is classed as a LBW baby [3]. It is one of the key underlying contributors for potentially increasing the risk of infant mortality, susceptibility to severe childhood illness [1 4] and malnutrition [5], and can impede the future cognitive development of the baby [6]. Unfortunately, around 20 million (15.5%) babies worldwide are born each year with LBW with around 96% of these in developing countries [7] like Bangladesh. Regional statistics illustrate that the global burden of LBW is severely skewed towards South Asia that has the highest prevalence (28%) followed by Sub-Saharan African countries (13%), then the Caribbean and Latin America (9%), and the Pacific and Eastern Asia (6%) [3]. The National Low Birth Weight Survey of Bangladesh reported that the prevalence of LBW decreased from around 36% in 2004 to 22.6% in 2015 [1 8] providing an indication of progressive improvement.

Previous statistics confirm that LBW contributes significantly to neonatal and infant mortality [7] with 60%-80% of neonatal deaths worldwide (within 28 days of life) occurring because of it [7]. Infants with a significant LBW (<1500 g) are around 20 times more likely to die in infancy than those born within normal weight limits [9]. LBW is accelerating the risk of mortality in later childhood and adolescence due to congenital malformation and perinatal factors, [9]. Researchers have also discovered other adverse health and growth problems associated with LBW including chronic disease such as childhood asthma [10], attention-deficit or hyperactivity disorder [11], post-natal growth failure [12], stunting, wasting and being underweight [13] . These negative health aspects can extend into adulthood and increase the risk of developing chronic diseases such as cardiovascular disease [14 15] and respiratory diseases [15 16] . The importance of preventing LBW therefore is vital for reducing the mortality and morbidity risk in childhood and in adulthood.

Efforts have been expanded worldwide to reveal the etiology and to identify the risk factors of LBW even though it can be complex and varies amongst regions. Previous research findings gathered from developed and developing regions suggest that potential risk factors for LBW include a history of premature delivery [17], maternal younger age (<18 years) and advanced age (>34 years) at childbirth [17 18], insufficient prenatal care [1 18 19], underweight mother [18 20], shorter birth interval [20], hard work and low nutritious food consumption during pregnancy [17], antepartum hemorrhage and anemia [19], hypertension disorder and diabetes during pregnancy [21]. Various socio-demographic factors affecting mothers such as living in rural territories [1], illiteracy [1 18], poor economic status [1 20] and victims of any kind of intimate partner violence (IPV) either physical, sexual or mental [22] are also significantly associated with the risk factors for LBW. Therefore, an understanding of the etiology of LBW and various other factors affecting the health of newborns is vital for the development of effective prevention programmes to help reduce the burden.

The World Health Organization (WHO) has set a worldwide goal for a 30% reduction in the rate of LBW to be achieved by 2025 in order to meet the sustainable development goals (SDGs) [3] regarding newborn healthcare. The prevalence of LBW has noticeably decreased in Bangladesh but the rate remains much higher compared to global prevalence [1 7 8]. In common with other countries in South Asia, a lack of a monitoring and surveillance system, a well-developed birth registry system, and quality data on birth weight in Bangladesh pose key challenges for the country. Research is urgently needed in Bangladesh to help identify potentially modifiable risk factors of LBW nationwide as well as help define its epidemiology. There has been research on this topic but not nearly enough has been conducted in Bangladesh and there has been a limited focus generally on the risk factors [1 22-24] particularly adverse maternal characteristics like specific and multiple maternal high-risk fertility behaviours. In order to address these gaps, this study analyses a nationwide population survey to help explore the

prevalence of LBW and also assess the impact of various adverse maternal situation on LBW in Bangladesh.

Methodology

Data sources and sampling procedure

This study analysed data extracted from the 2014 "Bangladesh Demographic and Health Survey (BDHS)". A detailed explanation of the survey has been published elsewhere [25] but briefly, it is based on a two-stage stratified sampling procedure where the Bangladesh Bureau of Statistics (BBS) divided the country into several primary sampling units [25] and the survey then carried out in each of the seven administrative divisions of Bangladesh. In the first sampling stage, 600 enumeration areas (EA) were selected as the primary sampling unit (PSU) based on a probability proportional to their size (207 EAs in urban areas and 393 EAs in rural areas). In the second stage, 30 households were selected in each PSU by systematic random sampling [25]. Following this process, the BDHS identified 18,245 ever-married women of reproductive-age (15-49 years) from 18,000 households. There was an overall response rate of around 98% with 17,863 women interviewed and a wide range of data collected on women and their children covering a range of indicators including health and nutrition. The survey also collected data on 7,886 children that were born within five years prior to the survey from respondents (women) that were interviewed. This study excluded 3,158 individuals because of unavailability of data regarding birth weight or size and the eligible sample size for the analysis was n = 4728.

Outcome variable

Low birth weight was considered as the main outcome variable for this analysis, dichotomised as Yes=1 (baby born with LBW) and No=0 (otherwise). A great number of deliveries in LMICs, including Bangladesh, occur at home without appropriate measurement of

birth weight [26]. The BDHS, therefore, retrospectively gathered data on the birth size of babies according to the mother's perception by questioning all women who had given birth within five years prior to the survey and asking "was the baby very large, larger than average, average, smaller than average or very small at the time of birth? Those reporting baby size at birth as "very small" or "smaller than average" was considered a useful proxy of LBW, and the variable was selected and categorized according to BDHS guidelines and previous literature [25 26]. According to studies conducted using other demographic and health survey data, reports from mothers were around 75% correct in terms of babies born with LBW [23 26].

Explanatory variables

The socio-demographic and adverse maternal characteristics of mothers such as being under or overweight, unwanted births, IPV, previous pregnancy terminations and maternal high-risk fertility behaviours were considered as explanatory variables of occurrence and non-occurrence of LBW in newborns. A complete list of explanatory variables is presented in Table 1. The selection process for these variables followed BDHS guidelines and also by reviewing previous literature [1 17 24 25 27-31].

"Insert Table 1"

Statistical analysis

The prevalence of LBW was measured for the entire study population. The association between LBW and different socio-demographic and adverse maternal characteristics including high-risk fertility behaviours were assessed by Chi-square tests (set at $p<0.05$ level of significance). A binary logistic regression model was then fitted as the outcome variable had binary categories, and odds ratios (ORs), both unadjusted and adjusted, were estimated in order to measure the effect of explanatory variables on the outcome variable. Each of the ORs were also assessed for 95% confidence intervals (CIs) to inspect the level of significance. In the

dataset, few explanatory variables for the study had more than 5% of missing values. Therefore, multiple imputation techniques using linear regression were applied to provide an estimation of the missing values of those variables by considering the known values [32]. This analysis was carried out to ensure representativeness and to prevent misinterpretation or any bias [32]. In the imputation, residence, education, economic status and employment status were used as covariates. All the analysis in this study took into account the complex survey design and sample weights (used *svy:* command in Stata) and was performed using the computer programme Stata in Windows version 13.0 (Stata Corporation, College Station, TX, USA).

Patient and public involvement

This study analysed secondary data of BDHS. The BDHS questionnaires were based on the MEASURE DHS model questionnaires. Patients were not directly involved in the study. The country representative survey was conducted in seven administrative divisions of Bangladesh among women of reproductive age. Information collected about the birth weight of the children was based on the perceptions of the mothers. We were unable to disseminate the study results to the survey participants. The results will be used by health researchers and policy makers of the country.

Results

Prevalence and distribution of LBW

The prevalence of LBW and its association with several adverse maternal characteristics are presented in Table 2. This study revealed that the prevalence of LBW in newborns in Bangladesh was 19.9%. In Figure 1, the geographical prevalence of LBW across seven administrative regions of Bangladesh using the most recent 2014 BDHS data are presented. The highest prevalence of LBW was found in Sylhet region (26.2%) while the lowest prevalence was

observed in Rangpur region (13.5%). The prevalence was also noticeably higher in the Dhaka (20.9%) and Chittagong (21.8%) regions.

"Insert Figure 1."

The prevalence of LBW was observed to be significantly higher in rural territories (20.8%), in poor households (22.3%), and among uneducated mothers (26.6%). Several adverse maternal characteristics were significantly related to the higher prevalence of LBW such as underweight mothers (24.9%), women who did not have ANC at least four times (21.6%) during pregnancy, unwanted births (24.6%) and mothers who were victims of IPV (21.0%). Similarly, the LBW prevalence was also observed to be remarkably higher for women with high-risk fertility behaviours such as aged <18 years at the time of birth (29.2%), and for women whose birth interval was <24 months (26.6%). The prevalence of LBW in newborns was noticeably increased if multiple characteristics of high-risk fertility behaviours were taken together. For instance, LBW in newborns was found among mothers aged <18 years at the time of childbirth with birth intervals <24 months (22.4%); maternal age at birth >34 years with birth interval <24 (27.1%) and birth order >3 with birth interval <24 months (24.5%).

"Insert Table 2"

Influence of adverse maternal situations on LBW

Table 3 illustrates a logistic regression analysis that assessed the effect that several adverse maternal characteristics can have on LBW in Bangladesh. The risk of LBW was higher in rural territories (adjusted odds ratio (AOR): 1.22, 95% CI: 1.02-1.46) compared to urban areas. Maternal education, however, was found to offer protection against LBW in infants. The likelihood of giving birth to a baby with LBW was decreased for Primary (AOR: 0.72, 95% CI: 0.57-0.90), and secondary and above (AOR: 0.57, 95% CI: 0.45-0.73) educated mothers than for uneducated mothers. The odds of having an LBW baby were significantly increased for

underweight mothers (AOR: 1.26, 95% CI: 1.06-1.49), and for mothers who did not utilize ANC at least four times (AOR: 1.23, 95% CI: 1.03-1.48) during pregnancy compared to their counterparts. The risk of LBW also increased in the case of unwanted births (AOR: 1.22, 95% CI: 1.03-1.44), a history of previous pregnancy terminations (AOR: 1.28, 95% CI: 1.05-1.57), and victims of IPV (AOR: 1.23, 95% CI: 1.05-1.45) compared to their counterparts. Maternal single high-risk fertility behaviours also appeared to be associated with the LBW of newborns. Maternal younger age at childbirth (<18 years), and birth interval <24 months had a 1.42 times (95% CI: 1.11-1.83), and a 1.26 times (95% CI: 1.02-1.57) increased risk of LBW in newborns respectively, compared to women that did not have such risky fertility behaviors. This was also the case for mothers with multiple high-risk fertility behaviours such as, maternal age at birth <18 years with birth interval <24 months (AOR: 1.26, 95% CI: 1.02-1.57), and birth order >3 with interval <24 months (AOR: 1.68, 95% CI: 1.18-2.37) compared with mothers that had no such risky behaviours.

"Insert Table 3"

Discussion

This study analysed a country representative sample size of 4,728 and found that various types of socio-demographic and adverse maternal factors, including high-risk fertility behaviours, are significantly increasing the likelihood of giving birth to a LBW child. Using nationally representative data, the prevalence of LBW was observed to be around 20% in Bangladesh. The burden varies significantly on a regional basis with a very high prevalence in the Sylhet region and comparatively low prevalence in the Rangpur region. Though a significant reduction of the LBW rate is observed in Bangladesh, it is still much higher than the global average [1 7 8]. According to this study, the burden is comparatively higher in rural areas and within the illiterate community. Another study in a developing country also identified that illiterate and

poor women had a significantly higher risk of giving birth to a LBW baby [33] that supports our findings. Several other research projects have found a significant association of LBW with a household's economic situation, but this study did not discover any corroborative evidence for this finding. [18 34].

A well-established risk factor for giving birth to a LBW baby is for mothers to be underweight [30 35]. This study corroborates earlier research findings where underweight mothers were at a higher risk of giving birth to a LBW baby than their counterparts [24 30 36]. In underweight mothers, a deficiency of micronutrients and calorific supplementation can impede the proper growth of the foetus leading to a LBW newborn [37]. In order to reduce this risk, the urgency of proper maternal nutrition comes to the fore and taking ANC ≥4 times can help mitigate the incidence of LBW. The findings of this study regarding the higher chance of giving birth to an LBW baby among mother who utilized ANC <4 times is consistent with recent study results [18 38]. In general, ANC provides the precise care required for both mother and newborn babies by addressing all forms of maternal and newborn health complications [23 34 38]. In Ethiopia, Assefa et al (2012) have significantly noticed that women who did not utilize at least one ANC during pregnancy had a 1.6 times higher risk of giving birth to a LBW baby [34]. A key challenge to reduce the risk is to reach those women and newborns in the greatest need.

The risk of LBW in newborns is also higher for unwanted births with the findings of Wado et al (2014) [39] and Shah et al (2009) [31] supporting the findings in this study. Unwanted pregnancy profoundly increases the risk of antenatal depression that is a crucial predictor of LBW [39 40]. An unwanted pregnancy can cause a woman to feel anxiety, fear, excitement and happiness that may all fluctuate over the course of the pregnancy period and may cause variation in birth outcomes [31 41]. The findings of this study regarding the higher likelihood of giving birth to a baby with LBW among mothers who ever had a pregnancy terminated resonates with other research projects [28 42]. Contrary to the findings of this study, however, Li Ke et al (2018) observed

no significant association between induced abortion and LBW for first-time mothers among southern Chinese women [43]. This study's findings regarding the higher likelihood of giving birth to a LBW baby among mothers who experienced any sorts of IPV, either physical or sexual, is supported by earlier study results [22 34 44 45]. The burden is much higher for women that experienced both physical and sexual IPV [22]. There are diverse pathways for LBW to be affected by IPV, for example, it increases the risk of unintended pregnancy and can also be responsible for pregnancy complications that can both advance the risk of giving birth to a LBW baby [31 46 47]. Unintended pregnancy or IPV have a direct connection with chronic psychosocial stress in women, and that's why the risk of giving birth to LBW babies is much higher for these women [48].

The analysis in this study observed that several forms of maternal high-risk fertility behaviours, that is, younger maternal age at birth (<18 years) and birth interval <24 months, are significantly increasing the risk of LBW in newborns [49]. Other research projects also found that a younger maternal age at birth (<18 years) was strongly associated with an increased likelihood of giving birth a LBW baby [17 29 50]. Childbirth in adolescence is detrimental for child health due to maternal socio-economic factors, immature behaviour and biological factors as adolescent females have comparatively underdeveloped reproductive systems. [50] Consequently, a woman of this age cluster is often unable to handle the complexities of pregnancy and the foetus can be deficient in the nutrition required for proper growth and development [50]. However, the findings in this study regarding giving birth again within a short interval (<24 months), markedly increase the risk of giving birth to a LBW baby and shows consistency with previous findings [20 51 52]. In northern Tanzania, a retrospective cohort study concluded that a shorter interpregnancy interval (<24 months) was 1.61 times more likely to increase the risk of giving birth to a LBW infant compared to an interpregnancy interval of 24–36 months [51]. Among those women with a shorter interpregnancy interval, the depletion of iron and folic acid is observed that is related to an

increased risk of foetal growth restriction [53]. The risks of giving birth to a LBW baby is further increased if multiple high-risk behaviors are considered together. If a woman gives birth during adolescence (<18 years) with a shorter birth interval (<24 months), than it is clearly perilous with a higher likelihood of the newborn having a LBW. A similar risk was also observed for maternal higher birth order (>3) with lower birth interval. Therefore, it can be concluded that maternal high-risk fertility behaviours have significant influence for giving birth to a baby with LBW.

Strengths and limitations of the study

The strengths comprise the use of nationally representative data and a large sample size that gave the study more reliable results with greater precision and strength. In addition, the 2014 BDHS used a globally standardized method that enables the results of this study to be compared with research in other countries that used a similar methodology. The study analysis took into account the complex survey design and sample weights that helped to provide greater accuracy in representing the country. However, some important limitations of this study should be mentioned. The measurement of LBW was defined by using a mother's perception of the size of their child at birth instead of the actual birth weight due to the unavailability of the data. This therefore meant that underreporting was likely as many mothers could only remember if LBW was a factor if the newborn was very small in size. In addition, the study outcome and predictors were based on self-reporting and past events were related through the recall method. Data collected through these methods mean that recall bias is common. The cross-sectional nature of the 2014 BDHS data did not allow for any causal inferences to be drawn between outcome variables and predictors and the use of secondary data limits the analysis in variable selection. For example, pre-term birth is responsible for a large no of LBW babies, but the dataset had no information about gestational age.

Conclusion

The high prevalence of LBW indicates a serious health hazard for newborn babies in Bangladesh. This study has explored the risk factors that influence the prevalence of LBW in newborns and can be used as a basis for developing prevention strategies. This study also reveals that several socio-demographic and adverse maternal characteristics along with multiple high-risk fertility behaviours appear to impact on a newborn baby's birth weight thereby increasing the risk of LBW. These findings highlight the vital importance of early screening and interventions targeted at all women. This study recommends that policymakers and public health authorities address these adverse maternal factors when designing prevention interventions to reduce LBW in newborns. In this regard, reproductive health promotion programmes among targeted individuals could be introduced to help in limiting adverse factors as well as LBW. In conclusion, adverse maternal characteristics can impede progress towards achieving the SDG target regarding newborn health care. There is no doubt that a continued effort for reducing the LBW prevalence in Bangladesh is of paramount importance.

Abbreviations

LBW, Low Birth Weight; LMIC, Low- and Middle-Income Country; SDG, Sustainable Development Goal; BDHS, Bangladesh Demographic and Health Survey; ANC, Antenatal Care; CI, Confidence Interval; OR, Odds Ratio.

Authors Contribution: MMAK conceptualized the study and designed the analytical approach. MMAK, MGM, and MSK performed the data analyses and interpreted the findings. MMAK, and MGM drafted the manuscript. MRI, and HTAK helped in variable selection, revised the manuscript critically for important intellectual content, and helped in the final approval of the version to be submitted. All authors helped to write the manuscript. All authors read and approved the final manuscript.

References

1. Khan JR, Islam MM, Awan N, et al. Analysis of low birth weight and its co-variants in Bangladesh based on a sub-sample from nationally representative survey. *BMC pediatrics* 2018;18(1):100. doi: 10.1186/s12887-018-1068-0
2. Katz J, Lee AC, Kozuki N, et al. Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. *The Lancet* 2013;382(9890):417-25.
3. WHO. Global nutrition targets 2025: low birth weight policy brief (WHO/NMH/NHD/14.5). *World Health Organization, Geneva, Switzerland* 2014:8.
4. Wilcox AJ. On the importance—and the unimportance—of birthweight. *International journal of epidemiology* 2001;30(6):1233-41.
5. Saville NM, Shrestha BP, Style S, et al. Impact on birth weight and child growth of Participatory Learning and Action women's groups with and without transfers of food or cash during pregnancy: Findings of the low birth weight South Asia cluster-randomised controlled trial (LBWSAT) in Nepal. *PLOS ONE* 2018;13(5):e0194064. doi: 10.1371/journal.pone.0194064
6. Veena SR, Krishnaveni GV, Wills AK, et al. Association of birthweight and head circumference at birth to cognitive performance in 9-to 10-year-old children in South India: prospective birth cohort study. *Pediatric research* 2010;67(4):424.
7. WHO. WHO | Care of the preterm and low-birth-weight newborn: World Health Organization, Geneva, Switzerland; 2018 [updated 2018-11-14 15:51:42. Available from: https://www.who.int/maternal_child_adolescent/newborns/prematurity/en/.
8. NNS. National Low Birth Weight Survey (NLBWS) Bangladesh, 2015. *National Nutrition Services, Institute of public health nutrition, Directorate general of health services, Ministry of Health & Family Welfare, Dhaka, Bangladesh* 2017
9. Watkins WJ, Kotecha SJ, Kotecha S. All-Cause Mortality of Low Birthweight Infants in Infancy, Childhood, and Adolescence: Population Study of England and Wales. *PLOS Medicine* 2016;13(5):e1002018. doi: 10.1371/journal.pmed.1002018
10. Brooks A-M, Byrd RS, Weitzman M, et al. Impact of Low Birth Weight on Early Childhood Asthma in the United States. *Archives of Pediatrics & Adolescent Medicine* 2001;155(3):401-06. doi: 10.1001/archpedi.155.3.401
11. Franz AP, Bolat GU, Bolat H, et al. Attention-Deficit/Hyperactivity Disorder and Very Preterm/Very Low Birth Weight: A Meta-analysis. *Pediatrics* 2018;141(1):e20171645. doi: 10.1542/peds.2017-1645
12. Lee SM, Kim N, Namgung R, et al. Prediction of Postnatal Growth Failure among Very Low Birth Weight Infants. *Scientific Reports* 2018;8(1):3729. doi: 10.1038/s41598-018-21647-9
13. Sania A, Fall CH, Victora CG, et al. Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. *International Journal of Epidemiology* 2013;42(5):1340-55. doi: 10.1093/ije/dyt109
14. Tian J, Qiu M, Li Y, et al. Contribution of birth weight and adult waist circumference to cardiovascular disease risk in a longitudinal study. *Scientific reports* 2017;7(1):9768-68. doi: 10.1038/s41598-017-10176-6
15. Belbasis L, Savvidou MD, Kanu C, et al. Birth weight in relation to health and disease in later life: an umbrella review of systematic reviews and meta-analyses. *BMC Medicine* 2016;14(1):147. doi: 10.1186/s12916-016-0692-5
16. Mebrahtu TF, Feltbower RG, Greenwood DC, et al. Birth weight and childhood wheezing disorders: a systematic review and meta-analysis. *J Epidemiol Community Health* 2015;69(5):500-08.
17. Sharma SR, Giri S, Timalsina U, et al. Low Birth Weight at Term and Its Determinants in a Tertiary Hospital of Nepal: A Case-Control Study. *PLOS ONE* 2015;10(4):e0123962. doi: 10.1371/journal.pone.0123962
18. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. *Journal of preventive medicine and public health = Yebang Uihakhoe chi* 2017;50(1):18-28. doi: 10.3961/jpmph.16.087 [published Online First: 12/27]

19. Feresu SA, Harlow SD, Woelk GB. Risk Factors for Low Birthweight in Zimbabwean Women: A Secondary Data Analysis. *PLOS ONE* 2015;10(6):e0129705. doi: 10.1371/journal.pone.0129705
20. Silveira MF, Victora CG, Horta BL, et al. Low birthweight and preterm birth: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015. *International Journal of Epidemiology* 2018;48 doi: 10.1093/ije/dyy106
21. Rao J, Fan D, Wu S, et al. Trend and risk factors of low birth weight and macrosomia in south China, 2005–2017: a retrospective observational study. *Scientific Reports* 2018;8(1):3393. doi: 10.1038/s41598-018-21771-6
22. Ferdos J, Rahman MM. Maternal experience of intimate partner violence and low birth weight of children: A hospital-based study in Bangladesh. *PLOS ONE* 2017;12(10):e0187138. doi: 10.1371/journal.pone.0187138
23. Haque SR, Tisha S, Huq NJB. Poor birth size a badge of low birth weight accompanying less antenatal care in Bangladesh with substantial divisional variation: evidence from BDHS-2011. 2015;1(2476):33.8.
24. Karim MR, Mondal MNI, Rana MM, et al. Maternal Factors are Important Predictors of Low Birth Weight: Evidence from Bangladesh Demographic & Health Survey-2011. *Malaysian Journal of Nutrition* 2016;22(2)
25. NIPORT. Bangladesh Demographic and Health Survey 2014. *National Institute of Population Research and Training (NIPROT), Mitra and Associates & Macro International, Dhaka, Bangladesh and Calverton, Maryland, USA* 2016
26. Rahman MS, Howlader T, Masud MS, et al. Association of Low-Birth Weight with Malnutrition in Children under Five Years in Bangladesh: Do Mother's Education, Socio-Economic Status, and Birth Interval Matter? *PLOS ONE* 2016;11(6):e0157814. doi: 10.1371/journal.pone.0157814
27. Rahman M, Islam MJ, Haque SE, et al. Association between high-risk fertility behaviours and the likelihood of chronic undernutrition and anaemia among married Bangladeshi women of reproductive age. *Public health nutrition* 2017;20(2):305-14. doi: 10.1017/s136898001600224x [published Online First: 2016/09/10]
28. Brown JS, Jr., Adera T, Masho SW. Previous abortion and the risk of low birth weight and preterm births. *J Epidemiol Community Health* 2008;62(1):16-22. doi: 10.1136/jech.2006.050369 [published Online First: 2007/12/15]
29. Dennis JA, Mollborn S. Young maternal age and low birth weight risk: An exploration of racial/ethnic disparities in the birth outcomes of mothers in the United States. *The Social science journal* 2013;50(4):625-34. doi: 10.1016/j.soscij.2013.09.008
30. He Z, Bishwajit G, Yaya S, et al. Prevalence of low birth weight and its association with maternal body weight status in selected countries in Africa: a cross-sectional study. *BMJ open* 2018;8(8):e020410.
31. Shah PS, Balkhair T, Ohlsson A, et al. Intention to become pregnant and low birth weight and preterm birth: a systematic review. *Matern Child Health J* 2011;15(2):205-16. doi: 10.1007/s10995-009-0546-2 [published Online First: 2009/12/17]
32. Sterne JA, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *Bmj* 2009;338:b2393.
33. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. *J Prev Med Public Health* 2017;50(1):18-28. doi: 10.3961/jpmph.16.087
34. Assefa N, Berhane Y, Worku A. Wealth Status, Mid Upper Arm Circumference (MUAC) and Antenatal Care (ANC) Are Determinants for Low Birth Weight in Kersa, Ethiopia. *PLOS ONE* 2012;7(6):e39957. doi: 10.1371/journal.pone.0039957
35. Britto RPdA, Florêncio TMT, Benedito Silva AA, et al. Influence of Maternal Height and Weight on Low Birth Weight: A Cross-Sectional Study in Poor Communities of Northeastern Brazil. *PLOS ONE* 2013;8(11):e80159. doi: 10.1371/journal.pone.0080159
36. Patel A, Prakash AA, Das PK, et al. Maternal anemia and underweight as determinants of pregnancy outcomes: cohort study in eastern rural Maharashtra, India. *BMJ Open* 2018;8(8):e021623. doi: 10.1136/bmjopen-2018-021623
37. Razak F, Finlay JE, Subramanian SV. Maternal underweight and child growth and development. *The Lancet* 2013;381(9867):626-27. doi: 10.1016/S0140-6736(13)60344-X

38. Pinzón-Rondón ÁM, Gutiérrez-Pinzon V, Madriñan-Navia H, et al. Low birth weight and prenatal care in Colombia: a cross-sectional study. *BMC pregnancy and childbirth* 2015;15(1):118.
39. Wado YD, Afework MF, Hindin MJ. Effects of Maternal Pregnancy Intention, Depressive Symptoms and Social Support on Risk of Low Birth Weight: A Prospective Study from Southwestern Ethiopia. *PLOS ONE* 2014;9(5):e96304. doi: 10.1371/journal.pone.0096304
40. Niemi M, Falkenberg T, Petzold M, et al. Symptoms of antenatal common mental disorders, preterm birth and low birthweight: a prospective cohort study in a semi-rural district of V ietnam. *Tropical medicine & international health* 2013;18(6):687-95.
41. Sable MR, Spencer JC, Stockbauer JW, et al. Pregnancy wantedness and adverse pregnancy outcomes: differences by race and Medicaid status. *Family planning perspectives* 1997;29:76-81.
42. Kc S, Hemminki E, Gissler M, et al. Perinatal outcomes after induced termination of pregnancy by methods: A nationwide register-based study of first births in Finland 1996–2013. *PLOS ONE* 2017;12(9):e0184078. doi: 10.1371/journal.pone.0184078
43. Ke L, Lin W, Liu Y, et al. Association of induced abortion with preterm birth risk in first-time mothers. *Scientific Reports* 2018;8(1):5353. doi: 10.1038/s41598-018-23695-7
44. Henriksen L, Schei B, Vangen S, et al. Sexual violence and neonatal outcomes: a Norwegian population-based cohort study. *BMJ Open* 2014;4(10):e005935. doi: 10.1136/bmjopen-2014-005935
45. Chambliss LR. Intimate partner violence and its implication for pregnancy. *Clinical obstetrics and gynecology* 2008;51(2):385-97.
46. Rahman M, Sasagawa T, Fujii R, et al. Intimate Partner Violence and Unintended Pregnancy Among Bangladeshi Women. *Journal of Interpersonal Violence* 2012;27(15):2999-3015. doi: 10.1177/0886260512441072
47. Ferdos J, Rahman MM, Jesmin SS, et al. Association between intimate partner violence during pregnancy and maternal pregnancy complications among recently delivered women in Bangladesh. *Aggressive behavior* 2018;44(3):294-305. doi: 10.1002/ab.21752
48. Borders AE, Grobman WA, Amsden LB, et al. Chronic stress and low birth weight neonates in a low-income population of women. *Obstet Gynecol* 2007;109(2 Pt 1):331-8. doi: 10.1097/01.AOG.0000250535.97920.b5 [published Online First: 2007/02/03]
49. Rahman M, Hosen A, Khan MA. Association between Maternal High-Risk Fertility Behavior and Childhood Morbidity in Bangladesh: A Nationally Representative Cross-Sectional Survey. *The American journal of tropical medicine and hygiene* 2019 doi: 10.4269/ajtmh.19-0221 [published Online First: 2019/07/25]
50. Fall CHD, Sachdev HS, Osmond C, et al. Association between maternal age at childbirth and child and adult outcomes in the offspring: a prospective study in five low-income and middle-income countries (COHORTS collaboration). *The Lancet Global Health* 2015;3(7):e366-e77. doi: 10.1016/S2214-109X(15)00038-8
51. Mahande MJ, Obure J. Effect of interpregnancy interval on adverse pregnancy outcomes in northern Tanzania: a registry-based retrospective cohort study. *BMC Pregnancy and Childbirth* 2016;16(1):140. doi: 10.1186/s12884-016-0929-5
52. Veloso HJF, da Silva AAM, Bettiol H, et al. Low birth weight in São Luís, northeastern Brazil: trends and associated factors. *BMC Pregnancy and Childbirth* 2014;14(1):155. doi: 10.1186/1471-2393-14-155
53. Winkvist A, Rasmussen KM, Habicht J-P. A new definition of maternal depletion syndrome. *American journal of public health* 1992;82(5):691-94.

Table 1. A complete list and details of explanatory variables.

Variables	Collected data	Answer category
Socio-demographic variables		
Maternal education[1]	Maternal highest level of education	1 = No education; 2 = Primary; 3 = Secondary & above
Residence	Place of residence	1 = Urban; 2 = Rural
Economic status[2]	Wealth index of the family	1 = Poor; 2 = Middle; 3 = Rich
Employment status[2]	Employment status of the individuals	1 = Unemployed; 2 = Employed
Adverse maternal characteristics		
Underweight mother	The nutritional status (BMI) of mother was measured and if BMI was less than 18.5 kg/m^2 then she was underweight.	0 = No; 1 = Yes
Overweight/obese mother	The nutritional status (BMI) of mother was measured and if BMI was higher than 25.0 kg/m^2 then she was overweight and BMI was higher than 30.0 kg/m^2 then she was obese.	0 = No; 1 = Yes
Unwanted birth	The child birth was not wanted at that time	0 = No; 1 = Yes
Ever had a terminated pregnancy	The mother had a previous pregnancy termination history (abortion, miscarriage etc.)	0 = No; 1 = Yes
Victim of intimate partner violence (IPV)	The mother who were a victim of IPV such as beaten in front of child, beaten by husband when refuse to intercourse or burn food etc.	0 = No; 1 = Yes
ANC <4 times	The mother who had utilized ANC less than 4 times during pregnancy	0 = No; 1 = Yes
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years	The mother whose age at the time of the birth was less than 18 years	0 = No; 1 = Yes
Maternal age at birth >34 years	The mother whose age at the time of the birth was greater than 34 years	0 = No; 1 = Yes
Birth interval <24 months	The mother who gave birth with a birth interval of less than 24 months	0 = No; 1 = Yes
Birth order >3	The mother whose birth order was higher than 3	0 = No; 1 = Yes
Maternal age at birth <18 years and Birth interval <24 months[3]	The mother whose age at the time of the birth was less than 18 years with an interval of less than 24 months	0 = No; 1 = Yes
Maternal age at birth >34 years and Birth interval <24 months[4]	The mother whose age at the time of the birth was greater than 34 years with an interval of less than 24 months	0 = No; 1 = Yes
Birth interval <24 months and birth order >3	The mother whose birth order was higher than 3 with interval of less than 24 months	0 = No; 1 = Yes

Note: The analysis was restricted for children who were born within 5 years prior to the survey. High-risk fertility behavior variables categorization followed BDHS standard measure. [1] Primary and secondary education is defined as completing grade 5 and 10, respectively**.** [2] followed standard BDHS measure. [3] includes the categories "age at birth <18 years with birth order >3" and "age at birth <18 years with interval <24 months and birth order >3". [4] includes the categories "age at birth <34 years with interval <24 months" and "age at birth <34 years with interval <24 months and birth order >3". [5] includes obesity (BMI > 30.0 kg/m^2)

Table 2. The prevalence of low birth weight and its association with socio demographic risk factors, adverse maternal characteristics including maternal high-risk fertility behaviors in Bangladesh, BDHS 2014.

Background characteristics	Low birth weight (%, 95% CI)	p-value
Overall	19.9 (18.5-21.5)	
Socio-demographic variables:		
Residence		<0.001
Urban	17.5 (15.1-20.2)	
Rural	20.8 (18.9-22.8)	
Maternal education		<0.001
No education	26.6 (22.2-31.5)	
Primary	21.1 (18.2-24.3)	
Secondary and above	17.7 (16.0-19.7)	
Economic status		<0.001
Poor	22.3 (19.8-24.9)	
Middle	19.7 (15.8-24.3)	
Rich	17.7 (15.5-20.1)	
Employment status		0.683
Unemployed	19.6 (17.7-21.6)	
Employed	21.1 (18.1-24.4)	
Adverse maternal characteristics		
Underweight mother		<0.001
No	18.4 (16.6-20.2)	
Yes	24.9 (21.9-28.1)	
Overweight/obese mother		0.004
No	20.8 (19.1-22.5)	
Yes	15.9 (12.9-19.3)	
Taken ANC <4 times		<0.001
No	16.3 (14.4-18.4)	
Yes	21.6 (19.6-23.7)	
Unwanted birth		0.002
No	19.0 (17.4-20.7)	
Yes	24.6 (20.9-26.6)	
Ever had a terminated pregnancy		0.096
No	19.5 (17.9-21.2)	
Yes	22.8 (18.8-27.2)	
Victim of intimate partner violence		0.014
No	19.5 (17.8-21.4)	
Yes	21.0 (18.6-23.6)	
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years		<0.001
No	18.5 (17.0-20.2)	
Yes	29.2 (25.1-33.7)	
Maternal age at birth >34 years		0.204
No	19.5 (18.1-21.2)	
Yes	23.0 (19.9-30.9)	
Birth interval <24 months		<0.001
No	17.9 (16.7-19.7)	
Yes	26.6 (23.5-29.8)	
Birth order >3		0.008
No	19.3 (17.7-21.0)	
Yes	24.0 (20.2-28.3)	
Maternal age at birth <18 years and birth interval <24 months		<0.001
No	18.8 (17.3-20.5)	
Yes	22.4 (19.6-25.5)	
Maternal age at birth >34 years and birth interval <24 months		0.003
No	18.8 (17.2-20.5)	
Yes	27.1 (23.1-31.5)	

Birth order >3 and birth interval <24 months		0.011
No	19.7 (18.3-21.4)	
Yes	24.5 (18.0-32.5)	

Note: The sample was weighted. "No" values for low birth weight was omitted from the table and calculated for row percentage.

Table 3. Unadjusted and adjusted odds ratio to measure the effect size of adverse maternal characteristics on newborn's low birth weight in Bangladesh, BDHS 2014.

Background characteristics	Low birth weight (LBW)	
	UOR (95% CI)	AOR (95% CI)
Socio-demographic variables:		
Residence		
Urban (RC)	1.00	1.00
Rural	1.34 (1.16-1.61) ***	1.22 (1.02-1.46) *
Maternal education		
No education (RC)	1.00	1.00
Primary	0.73 (0.59-0.90) **	0.72 (0.57-0.90) **
Secondary and above	0.54 (0.44-0.66) ***	0.57 (0.45-0.73) ***
Economic status		
Poor (RC)	1.00	1.00
Middle	0.87 (0.71-1.06)	1.03 (0.84-1.26)
Rich	0.68 (0.58-0.80) ***	0.97 (0.79-1.18)
Employment status		
Unemployed (RC)	1.00	1.00
Employed	1.04 (0.88-1.23)	1.02 (0.86-1.21)
Adverse maternal characteristics		
Underweight mother		
No (RC)	1.00	1.00
Yes	1.48 (1.25-1.72) ***	1.26 (1.06-1.49) **
Overweight/obese mother		
No (RC)	1.00	1.00
Yes	0.74 (0.61-0.91) **	0.98 (0.78-1.23)
Taken ANC <4 times		
No (RC)	1.00	1.00
Yes	1.44 (1.23-1.70) ***	1.23 (1.03-1.48) *
Unwanted birth		
No (RC)	1.00	1.00
Yes	1.29 (1.10-1.51) **	1.22 (1.03-1.44) *
Ever had a terminated pregnancy		
No (RC)	1.00	1.00
Yes	1.18 (0.97-1.43)	1.28 (1.05-1.57) **
Victim of intimate partner violence		
No (RC)	1.00	1.00
Yes	1.22 (1.04-1.42) **	1.23 (1.05-1.45) *
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years		
No (RC)	1.00	1.00
Yes	1.81 (1.50-2.19) ***	1.42 (1.11-1.83) **
Maternal age at birth >34 years		
No (RC)	1.00	1.00
Yes	1.23 (0.89-1.71)	0.93 (0.63-1.39)
Birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.54 (1.32-1.80) ***	1.25 (1.01-1.55) *
Birth order >3		
No (RC)	1.00	1.00
Yes	1.30 (1.07-1.59) **	1.04 (0.83-1.33)
Maternal age at birth <18 years and birth interval <24 months		

No (RC)	1.00	1.00
Yes	1.31 (1.12-1.53) ***	1.26 (1.02-1.57) **
Maternal age at birth >34 years and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.34 (1.11-1.64) **	1.22 (0.97-1.54)
Birth order >3 and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.50 (1.09-2.06) *	1.68 (1.18-2.37) **

Note: Model was adjusted for all the predictors included in this table. Values with superscript asterisks *, **, and *** indicate $p<0.05$, $p<0.01$, and $p<0.001$, respectively. UOR: unadjusted odds ratio; AOR: adjusted odds ratio; CI: confidence interval; ANC: antenatal care.

Figure legend

Figure 01. Geographical prevalence (%, 95% CI) of low birth weight according to seven administrative divisions in Bangladesh (using data BDHS 2014).

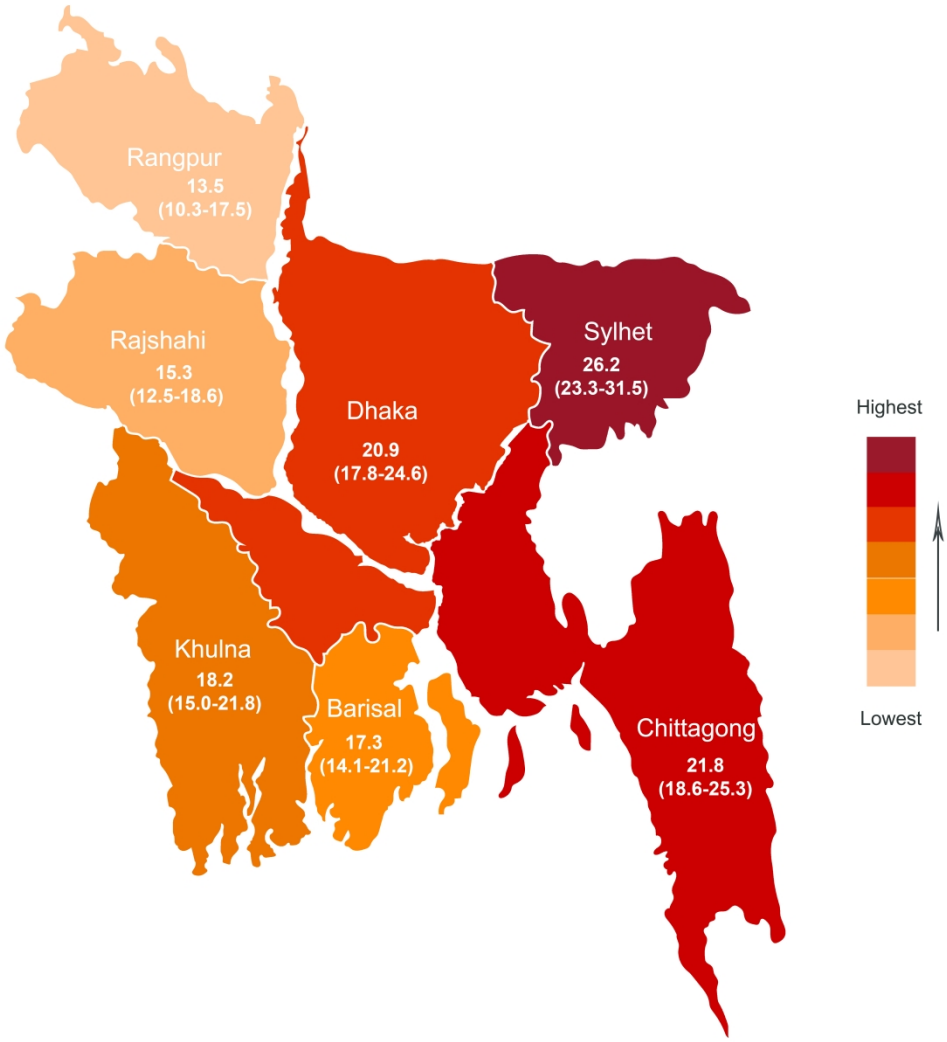

Fig 1. Geographical prevalence (%, 95% CI) of low birth weight according to seven administrative divisions in Bangladesh (using data BDHS 2014).

BMJ Open

Exploring the association between adverse maternal circumstances and low birth weight in neonates: a nationwide population-based study in Bangladesh

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-036162.R2
Article Type:	Original research
Date Submitted by the Author:	22-Aug-2020
Complete List of Authors:	Khan, Md. Mostaured; University of Rajshahi, Population Science and Human Resource Development Mustagir, Md. Golam; University of Rajshahi, Population Science and Human Resource Development Islam, Md; University of Rajshahi, Population Science and Human Resource Development Kaikobad, Md. Sharif; University of Rajshahi, Population Science and Human Resource Development Khan, Hafiz; University of West London, College of Nursing, Midwifery and Healthcare
Primary Subject Heading:	Paediatrics
Secondary Subject Heading:	Paediatrics, Nutrition and metabolism
Keywords:	NEONATOLOGY, Community child health < PAEDIATRICS, Nutrition < TROPICAL MEDICINE

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Exploring the association between adverse maternal circumstances and low birth weight in neonates: *a nationwide population-based study in Bangladesh*

Authors: Md. Mostaured Ali Khan[1,2], Md. Golam Mustagir[1], Md. Rafiqul Islam[1*], Md. Sharif Kaikobad[1], and Hafiz T.A. Khan[3]

Affiliations:

[1] Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh.

[2]MEL and Research, Practical Action, House no. 28/A, Road no. 5, Dhanmondi, Dhaka-1205, Bangladesh

[3]Professor of Public Health & Statistics, College of Nursing, Midwifery and Healthcare, University of West London, Paragon House, Boston Manor Road, Brentford TW8 9GB, United Kingdom

Corresponding Author:

Md. Rafiqul Islam, PhD
Professor, Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh.
E-mail: rafique_pops@yahoo.com

Exploring the association between adverse maternal circumstances and low birth weight in neonates: *a nationwide population-based study in Bangladesh*

Abstract

Objective: This study is concerned with helping to improve the health and care of newborn babies in Bangladesh by exploring adverse maternal circumstances and assessing whether these are contributing towards low birth weight (LBW) in neonates.

Study designs and settings: Data was drawn and analysed from the "Bangladesh Demographic and Health Survey (BDHS), 2014." Any association between LBW and adverse maternal circumstances were assessed using a Chi-square test with determinants of LBW identified by multivariate logistic regression analysis.

Participants: The study is based on 4,728 children aged below 5 years and born to women from selected households.

Results: The rate of LBW was around 19.9% (199 per 1000 live births) with the highest level found in the Sylhet region (26.2%). The rate was even higher in rural areas (20.8%) and among illiterate mothers (26.6%). Several adverse maternal circumstances of the women included in the survey were found to be significant for increasing the likelihood of giving birth to LBW babies. These circumstances included the women being underweight (Adjusted Odds Ratio (AOR) 1.26, 95% Confidence Interval (CI) 1.06-1.49); having unwanted births (AOR 1.22, 95% CI 1.03-1.44); had previous pregnancies terminated (AOR 1.28, 95% CI 1.05-1.57); were victims of intimate partner violence (AOR 1.23, 95% CI 1.05-1.45) and taking ANC <4 times (AOR 1.23, 95% CI 1.03-1.48). Other important risk factors that were revealed included age at birth (<18 years (AOR 1.42, 95% CI 1.11-1.83) and intervals between the number of births (<24 months (AOR 1.25, 95% CI 1.01-1.55). When taking multiple fertility behaviours together such as, the ages of the women at birth (<18 years with interval <24 months (AOR 1.26, 95% CI 1.02-1.57)

and birth order (>3 with interval <24 months (AOR 1.68, 95% CI 1.18-2.37), then the risk of having LBW babies significantly increased.

Conclusion: This study finds that adverse maternal circumstances combined with high-risk fertility behaviours are significantly associated with LBW in neonates. This situation could severely impede progress in Bangladesh towards achieving the sustainable development goal (SDG) concerned with the healthcare of newborns.

Keywords: Low birth weight (LBW), high-risk fertility behaviours, adverse maternal characteristics, Bangladesh, BDHS

Strengths and limitations of the study

- Analyzing the nationally representative data set helped to provide a wide picture of society in Bangladesh and provided more reliable results.
- A limitation of the data set occurred where the LBW was recorded based on the perceptions of the mothers as to the size of their children at birth instead of their actual birth weights due to the unavailability of official data.
- The study outcome and predictors were based on self-reporting and recall bias is commonly found with this type of data collection procedure.
- The use of secondary datasets limited our freedom to select variables for the analysis and perform model adjustment.

Acknowledgement: We gratefully acknowledge the Demographic and Health Survey programme for granting permission to use the data. Authors would like to express their gratitude to Dr. Helen Findlay for final checking and editing of the manuscript.

Ethical Statement

Ethical approval for all the BDHS surveys was received from the ICF Macro Institutional Review Board, Maryland, USA, and the National Research Ethics Committee of the Bangladesh Medical Research Council (BMRC), Dhaka, Bangladesh. The National Institute of Population Research and Training conducted these surveys with the support of the United States Agency for International Development (USAID). Informed consent was obtained from all participants. The BDHS is part of the worldwide Demography and Health Surveys (DHS) programme and is available in the public domain for research purposes.

Patient consent: Not required.

Introduction

Low birth weight (LBW) is a critical global concern particularly in low- and middle-income countries (LMICs) [1 2]. A newborn weighing less than 2.5 kilograms (5.5 pounds) is classed as an LBW baby [3]. It is one of the key underlying contributors for potentially increasing the risk of infant mortality, susceptibility to severe childhood illness [1 4] and malnutrition [5], and can impede the future cognitive development of the baby [6]. Unfortunately, around 20 million (15.5%) babies worldwide are born each year with LBW with around 96% of these in developing countries [7] like Bangladesh. Regional statistics illustrate that the global burden of LBW is severely skewed towards South Asia that has the highest prevalence (28%) followed by Sub-Saharan African countries (13%), then the Caribbean and Latin America (9%), and the Pacific and Eastern Asia (6%) [3]. The National Low Birth Weight Survey of Bangladesh reported that the prevalence of LBW decreased from around 36% in 2004 to 22.6% in 2015 [1 8] providing an indication of improvement.

Previous studies confirm that LBW contributes significantly to neonatal and infant mortality [7] with 60%-80% of neonatal deaths worldwide occurring within 28 days of life [7]. Infants with a significant LBW (<1500 g) are around 20 times more likely to die in infancy than those born within normal weight limits [9]. LBW is also accelerating the risk of mortality in later childhood and adolescence due to congenital malformations and perinatal factors [9]. Further adverse health and growth problems associated with LBW and identified in other studies include chronic disease such as childhood asthma [10], attention-deficit or hyperactivity disorder [11], post-natal growth failure [12], stunting, wasting and being underweight [13] . These negative health aspects can extend into adulthood and increase the risk of developing chronic diseases such as cardiovascular disease [14 15] and respiratory diseases [15 16] . The importance of preventing LBW therefore is vital for reducing the mortality and morbidity risk in childhood and adulthood.

Worldwide efforts have been made to reveal the etiology and identify the risk factors of LBW but these can be complex and vary amongst regions. Previous research findings from developed and developing regions suggest that potential risk factors for LBW include a history of premature delivery [17], maternal younger age (<18 years) and advanced age (>34 years) at childbirth [17 18], insufficient prenatal care [1 18 19], underweight mother [18 20], shorter birth interval [20], hard work and low nutritious food consumption during pregnancy [17], antepartum hemorrhage and anemia [19], hypertension disorder and diabetes during pregnancy [21]. Various socio-demographic factors affecting mothers such as living in rural territories [1], illiteracy [1 18], poor economic status [1 20] and victims of any kind of intimate partner violence (IPV) either physical, sexual or mental [22] are also significantly associated with risk factors for LBW. Therefore, an understanding of the etiology of LBW and various other factors affecting the health of newborns is vital for the development of effective prevention programmes.

The World Health Organization (WHO) set a goal of a 30% reduction in the rate of LBW worldwide to be achieved by 2025 in order to meet its sustainable development goals (SDGs). In common with other countries in South Asia, the lack of a monitoring and surveillance system, a well-developed birth registry system, and quality data on birth weight in Bangladesh pose key challenges for the country. This study aims to help redress this situation. This study analysed a nationwide population survey to explore the prevalence of LBW and also assess the association of various adverse maternal circumstances with LBW in Bangladesh.

Methodology

Data sources and sampling procedure

This study analysed data extracted from the 2014 "Bangladesh Demographic and Health Survey (BDHS)". A detailed explanation of the survey has been published elsewhere [23] but briefly, it is based on a two-stage stratified sampling procedure where the Bangladesh Bureau

of Statistics (BBS) divided the country into several primary sampling units [23] and the survey was then carried out in each of the seven administrative divisions of Bangladesh. In the first sampling stage, 600 enumeration areas (EA) were selected as the primary sampling unit (PSU) based on a probability proportional to their size (207 EAs in urban areas and 393 EAs in rural areas). In the second stage, 30 households were selected in each PSU by systematic random sampling [23]. Following this process, the BDHS identified 18,245 ever-married women of reproductive-age (15-49 years) from 18,000 households. There was an overall response rate of around 98% with 17,863 women interviewed and a wide range of data collected on women and their children covering a range of indicators including health and nutrition. The survey also collected data on 7,886 children that were born to women interviewees within five years prior to the year of the survey. This study excluded 3,158 individuals because of unavailability of data regarding birth weight or size. The eligible sample size for the analysis was n = 4728.

Outcome variable

LBW was considered to be the main outcome variable, dichotomised as Yes=1 (baby born with LBW) and No=0 (otherwise). A great number of deliveries in LMICs generally, including in Bangladesh, occur at home without appropriate measurement of birth weight [24]. The BDHS retrospectively gathered data on birth size based on the perceptions of the mothers, and questioned all women who had given birth within five years prior to the year of the survey. The question they were asked was: "was the baby very large, larger than average, average, smaller than average or very small at the time of birth?" The reporting of baby size at birth as "very small" or "smaller than average" were considered useful proxies for LBW [23 24]. Studies using other demographic and health survey data estimated that perceptions of mothers towards the birth weights of their babies were correct around 75% of the time [24 25].

Explanatory variables

The socio-demographic and adverse maternal circumstances of mothers including being under or overweight, having unwanted births, IPV, previous pregnancy terminations and maternal high-risk fertility behaviours were considered as explanatory variables of occurrence and non-occurrence of LBW in newborns. A complete list of explanatory variables is presented in Table 1. The selection process for these variables followed BDHS guidelines and also reviews of previous literature [1 17 23 26-31].

"Insert Table 1"

Statistical analysis

The prevalence of LBW was measured for the entire study population. The association between LBW and different socio-demographic and adverse maternal circumstances including high-risk fertility behaviours were assessed by Chi-square tests (set at $p<0.05$ level of significance). A binary logistic regression model was then fitted as the outcome variable had binary categories, and odds ratios (ORs), both unadjusted and adjusted, were estimated in order to measure the effect of explanatory variables on the outcome variable. Each of the ORs were assessed for 95% confidence intervals (CIs) to help identify their levels of significance. The dataset had fewer than 5% of missing variables. Multiple imputation techniques using linear regression were applied to known values in order to provide an estimate of the missing values [32]. This analysis was intended to ensure representativeness and to prevent misinterpretation or any bias [32]. Place of residence, education, economic status and employment status were used as covariates. The analysis for this study took into account complex survey design and sample weights (*svy:* command in Stata) and was performed using the computer programme Stata in Windows version 13.0 (Stata Corporation, College Station, TX, USA).

Patient and public involvement

The BDHS 2014 questionnaires were based on the MEASURE DHS model questionnaires with. patients not directly involved in the study. The country representative survey was conducted in seven administrative divisions of Bangladesh involving women of reproductive age. Information collected about the birth weight of the children was based on the perceptions of the mothers. While it was not possible to disseminate the study results to the survey participants, the results will be used by health researchers and policy makers.

Results

Prevalence and distribution of LBW

The prevalence of LBW and its association with several adverse maternal circumstances are presented in Table 2. The prevalence of LBW in newborns in Bangladesh was found to be at 19.9%. The geographical prevalence of LBW across the seven administrative regions, based on the 2014 BDHS dataset, is presented in Figure 1 that shows the highest prevalence of LBW occurred in the Sylhet region (26.2%) while the lowest prevalence was found in the Rangpur region (13.5%). Prevalence was also noticeably higher in the Dhaka (20.9%) and Chittagong (21.8%) regions.

"Insert Figure 1."

The prevalence of LBW was observed to be significantly higher in rural territories (20.8%), in poor households (22.3%), and among uneducated mothers (26.6%). Several adverse maternal circumstances were significantly related to the higher prevalence of LBW including underweight mothers (24.9%), women who did not have ANC at least four times (21.6%) during pregnancy, unwanted births (24.6%) and mothers who were victims of IPV (21.0%). Similarly, the LBW prevalence was also observed to be remarkably higher for women with high-risk

fertility behaviours such as aged <18 years at the time of birth (29.2%), and for women whose birth interval was <24 months (26.6%). The prevalence of LBW in newborns was noticeably increased if multiple characteristics of high-risk fertility behaviours were taken together. For instance, LBW in newborns was found among mothers aged <18 years at the time of childbirth with birth intervals <24 months (22.4%); maternal age at birth >34 years with birth interval <24 months (27.1%) and birth order >3 with birth interval <24 months (24.5%).

"Insert Table 2"

Association of adverse maternal situations with LBW

Table 3 illustrates a logistic regression analysis that assessed the effect that several adverse maternal circumstances can have on LBW. The risk was shown to be higher in rural territories (adjusted odds ratio (AOR) 1.22, 95% CI 1.02-1.46) compared to urban areas. Maternal education, however, was found to offer some protection against LBW. The likelihood of women giving birth to LBW babies decreased for those with primary (AOR 0.72, 95% CI 0.57-0.90) and secondary and above levels of education (AOR 0.57, 95% CI 0.45-0.73) compared to uneducated women. The odds of having an LBW baby were significantly increased for underweight mothers (AOR 1.26, 95% CI 1.06-1.49), and for mothers who did not utilize ANC at least four times (AOR 1.23, 95% CI 1.03-1.48) during pregnancy compared to their counterparts. The risk of LBW also increased in the case of unwanted births (AOR 1.22, 95% CI 1.03-1.44), a history of previous pregnancy terminations (AOR 1.28, 95% CI 1.05-1.57), and victims of IPV (AOR 1.23, 95% CI 1.05-1.45) compared to their counterparts. A young age at childbirth (<18 years) and birth intervals <24 months indicated that these women had a 1.42 times (95% CI 1.11-1.83) and a 1.26 times (95% CI 1.02-1.57) increased risk of LBW in their newborns respectively, compared to women that did not have such risky fertility behaviour.

Other risk factors could also have an effect on LBW such as birth order >3 with interval <24 months (AOR 1.68, 95% CI 1.18-2.37).

"Insert Table 3"

Discussion

This study analysed a country representative sample size of 4,728 and found that various types of socio-demographic and adverse maternal factors, including high-risk fertility behaviours, are significantly increasing the likelihood of giving birth to an LBW child. The prevalence of LBW in Bangladesh was observed to be around 20% and the regional burden varying significantly with a very high prevalence in the Sylhet region and comparatively low prevalence in the Rangpur region. Though a significant reduction of the LBW rate in Bangladesh has been noted, it is still much higher than the global average [1 7 8]. According to this study, the burden is comparatively higher in rural areas and within the illiterate community. Another study in a developing country had similar findings to this study by identifying that illiterate and poor women had a significantly higher risk of giving birth to an LBW baby [33]. Other research projects have found a significant association of LBW with a household's economic situation, but this study did not discover any corroborative evidence for this particular finding. [18 34].

A well-established risk factor for giving birth to an LBW baby is for mothers to be underweight [29 35] and this study corroborates earlier research findings where underweight mothers were found to be at higher risk than their counterparts [29 30 36]. In underweight mothers, a deficiency of micronutrients and calories can impede the proper growth of the foetus so leading to an LBW newborn [37]. In order to reduce this risk, the importance of proper maternal nutrition comes to the fore and taking ANC ≥4 times can help mitigate the incidence of LBW. The findings of this study regarding the higher chance of giving birth to an LBW baby among mothers who used ANC <4 times is consistent with other study results [18 38]. In general, ANC provides the

appropriate care required for both mother and newborn babies by addressing all forms of maternal health complications [25 34 38]. In Ethiopia, Assefa et al. (2012) noted that women who did not use at least one ANC during pregnancy had a 1.6 times higher risk of giving birth to an LBW baby [34]. A key challenge for reducing such risk is to reach those women and newborns in the greatest need.

Wado et al. (2014) [39] and Shah et al. (2009) [31] discovered that the risk of LBW in newborns was higher for unwanted births so supporting the findings in this study. Unwanted pregnancy also profoundly increases the risk of antenatal depression that is a crucial predictor of LBW [39 40]. An unwanted pregnancy can cause a woman to feel anxiety, fear, excitement and happiness that may all fluctuate over the course of the pregnancy period and may cause variation in birth outcomes [31 41]. The findings of this study indicate there is a higher likelihood for women who had ever had a pregnancy terminated of giving birth to LBW babies that resonates with other research projects [27 42]. However, contrary to these findings, Li Ke et al. (2018) observed no significant association between induced abortion and LBW for first-time mothers among southern Chinese women [43]. This study's findings of the high likelihood of women giving birth to LBW babies that had experienced any form of IPV, either physical or sexual, is supported by earlier study results [22 34 44 45]. The LBW burden is much higher for women that experienced both physical and sexual IPV [22]. IPV can also increase the risk of unintended pregnancies and be responsible for pregnancy complications that can both lead to LBW babies [31 46 47]. Unintended pregnancies and IPV have direct connections with chronic psychosocial stress in women, that leads to a higher risk of giving birth to LBW babies [48].

This study shows that a number of maternal high-risk fertility behaviours such as, young maternal age when giving birth (<18 years) and birth interval <24 months, are significantly increasing the risk of LBW in newborns [49] that has also been shown in other research projects [17 28 50]. Childbirth in adolescence is detrimental for child health due to maternal socio-economic

factors, immature behaviour and biological factors as adolescent females have comparatively underdeveloped reproductive systems. [50] Consequently, a woman of this age cluster is often unable to handle the complexities of pregnancy and the foetus can be deprived of adequate nutrition required for proper growth and development [50]. Giving birth again within a short interval (<24 months) markedly increases the risk of women having LBW babies that is consistent with previous findings [20 51 52]. In northern Tanzania, a retrospective cohort study concluded that a shorter interpregnancy interval (<24 months) was 1.61 times more likely to increase the risk of giving birth to an LBW infant compared to an interpregnancy interval of 24–36 months [51]. Among those women with a shorter interpregnancy interval, the depletion of iron and folic acid is observed that is related to an increased risk of foetal growth restriction [53]. The risks of giving birth to an LBW baby is further increased if multiple high-risk behaviors are considered together. For example, if a woman gives birth during adolescence (<18 years) with a shorter birth interval (<24 months), then it is highly likely that the newborn will have a LBW. A similar risk was observed for a maternal higher birth order (>3) compared to a lower birth interval. It can be concluded, therefore, that maternal high-risk fertility behaviours have significant influence on women giving birth to LBW babies.

Strengths and limitations of the study

The strengths of this study include the use of nationally representative data involving a large sample size that enabled the study to show reliable and precise results. In addition, the 2014 BDHS used a globally standardized method that enabled the results of this study to be compared with research in other countries that used a similar methodology. The study analysis took into account the complex survey design and sample weights that helped to provide greater accuracy in representing the country. However, some important limitations of this study should be mentioned. The measurement of LBW was defined by using a mother's perception of the size of their child at birth instead of the actual birth weight due to the unavailability of official data. This

therefore meant that underreporting was likely as many mothers could only remember if LBW was a factor if the newborn was very small in size. In addition, the study outcome and predictors were based on self-reporting and past events were related through the recall method. Data collected through these methods mean that recall bias is common. The cross-sectional nature of the 2014 BDHS data did not allow for any causal inferences to be drawn between outcome variables and predictors and the use of secondary data limits the analysis in variable selection. For example, pre-term birth is responsible for a large no of LBW babies, but the dataset had no information about gestational age.

Conclusion

The high prevalence of LBW indicates a serious health hazard for newborn babies in Bangladesh. This study has explored the risk factors that increase the prevalence of LBW in newborns and can be used as a basis for developing prevention strategies. This study also reveals that several socio-demographic and adverse maternal circumstances along with multiple high-risk fertility behaviours appear to impact on a newborn baby's birth weight thereby increasing the risk of LBW. These findings highlight the vital importance of early screening and interventions targeted at all women. This study recommends that policymakers and public health authorities address these adverse maternal factors when designing prevention interventions to reduce LBW in newborns. In this regard, reproductive health promotion programmes among targeted individuals could be introduced to help in limiting adverse factors as well as LBW. In conclusion, adverse maternal circumstances can impede progress towards achieving the SDG target regarding newborn health care. There is no doubt that a continued effort for reducing the LBW prevalence in Bangladesh is of paramount importance.

Abbreviations

LBW, Low Birth Weight; LMIC, Low- and Middle-Income Country; SDG, Sustainable Development Goal; BDHS, Bangladesh Demographic and Health Survey; ANC, Antenatal Care; CI, Confidence Interval; OR, Odds Ratio.

Authors Contribution: MMAK conceptualized the study and designed the analytical approach. MMAK, MGM, and MSK performed the data analyses and interpreted the findings. MMAK, and MGM drafted the manuscript. MRI, and HTAK helped in variable selection, revised the manuscript critically for important intellectual content, and helped in the final approval of the version to be submitted. All authors helped to write the manuscript. All authors read and approved the final manuscript.

Competing interests: None declared.

Funding: This study did not receive any specific grant either from the university or any funding agencies in the public, commercial, or not-for-profit sectors.

Data sharing statement: The data sets used for the current study are publicly available upon request at http://dhsprogram.com/data/available-datasets.cfm

References

1. Khan JR, Islam MM, Awan N, et al. Analysis of low birth weight and its co-variants in Bangladesh based on a sub-sample from nationally representative survey. *BMC pediatrics* 2018;18(1):100. doi: 10.1186/s12887-018-1068-0
2. Katz J, Lee AC, Kozuki N, et al. Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. *The Lancet* 2013;382(9890):417-25.
3. WHO. Global nutrition targets 2025: low birth weight policy brief (WHO/NMH/NHD/14.5). *World Health Organization, Geneva, Switzerland* 2014:8.
4. Wilcox AJ. On the importance—and the unimportance—of birthweight. *International journal of epidemiology* 2001;30(6):1233-41.
5. Saville NM, Shrestha BP, Style S, et al. Impact on birth weight and child growth of Participatory Learning and Action women's groups with and without transfers of food or cash during pregnancy: Findings of the low birth weight South Asia cluster-randomised controlled trial (LBWSAT) in Nepal. *PLOS ONE* 2018;13(5):e0194064. doi: 10.1371/journal.pone.0194064
6. Veena SR, Krishnaveni GV, Wills AK, et al. Association of birthweight and head circumference at birth to cognitive performance in 9-to 10-year-old children in South India: prospective birth cohort study. *Pediatric research* 2010;67(4):424.
7. WHO. WHO | Care of the preterm and low-birth-weight newborn: World Health Organization, Geneva, Switzerland; 2018 [updated 2018-11-14 15:51:42. Available from: https://www.who.int/maternal_child_adolescent/newborns/prematurity/en/.
8. NNS. National Low Birth Weight Survey (NLBWS) Bangladesh, 2015. *National Nutrition Services, Institute of public health nutrition, Directorate general of health services, Ministry of Health & Family Welfare, Dhaka, Bangladesh* 2017
9. Watkins WJ, Kotecha SJ, Kotecha S. All-Cause Mortality of Low Birthweight Infants in Infancy, Childhood, and Adolescence: Population Study of England and Wales. *PLOS Medicine* 2016;13(5):e1002018. doi: 10.1371/journal.pmed.1002018
10. Brooks A-M, Byrd RS, Weitzman M, et al. Impact of Low Birth Weight on Early Childhood Asthma in the United States. *Archives of Pediatrics & Adolescent Medicine* 2001;155(3):401-06. doi: 10.1001/archpedi.155.3.401
11. Franz AP, Bolat GU, Bolat H, et al. Attention-Deficit/Hyperactivity Disorder and Very Preterm/Very Low Birth Weight: A Meta-analysis. *Pediatrics* 2018;141(1):e20171645. doi: 10.1542/peds.2017-1645
12. Lee SM, Kim N, Namgung R, et al. Prediction of Postnatal Growth Failure among Very Low Birth Weight Infants. *Scientific Reports* 2018;8(1):3729. doi: 10.1038/s41598-018-21647-9
13. Sania A, Fall CH, Victora CG, et al. Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. *International Journal of Epidemiology* 2013;42(5):1340-55. doi: 10.1093/ije/dyt109
14. Tian J, Qiu M, Li Y, et al. Contribution of birth weight and adult waist circumference to cardiovascular disease risk in a longitudinal study. *Scientific reports* 2017;7(1):9768-68. doi: 10.1038/s41598-017-10176-6
15. Belbasis L, Savvidou MD, Kanu C, et al. Birth weight in relation to health and disease in later life: an umbrella review of systematic reviews and meta-analyses. *BMC Medicine* 2016;14(1):147. doi: 10.1186/s12916-016-0692-5
16. Mebrahtu TF, Feltbower RG, Greenwood DC, et al. Birth weight and childhood wheezing disorders: a systematic review and meta-analysis. *J Epidemiol Community Health* 2015;69(5):500-08.
17. Sharma SR, Giri S, Timalsina U, et al. Low Birth Weight at Term and Its Determinants in a Tertiary Hospital of Nepal: A Case-Control Study. *PLOS ONE* 2015;10(4):e0123962. doi: 10.1371/journal.pone.0123962
18. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. *Journal of preventive medicine and public health = Yebang Uihakhoe chi* 2017;50(1):18-28. doi: 10.3961/jpmph.16.087 [published Online First: 12/27]

19. Feresu SA, Harlow SD, Woelk GB. Risk Factors for Low Birthweight in Zimbabwean Women: A Secondary Data Analysis. *PLOS ONE* 2015;10(6):e0129705. doi: 10.1371/journal.pone.0129705
20. Silveira MF, Victora CG, Horta BL, et al. Low birthweight and preterm birth: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015. *International Journal of Epidemiology* 2018;48 doi: 10.1093/ije/dyy106
21. Rao J, Fan D, Wu S, et al. Trend and risk factors of low birth weight and macrosomia in south China, 2005–2017: a retrospective observational study. *Scientific Reports* 2018;8(1):3393. doi: 10.1038/s41598-018-21771-6
22. Ferdos J, Rahman MM. Maternal experience of intimate partner violence and low birth weight of children: A hospital-based study in Bangladesh. *PLOS ONE* 2017;12(10):e0187138. doi: 10.1371/journal.pone.0187138
23. NIPORT. Bangladesh Demographic and Health Survey 2014. *National Institute of Population Research and Training (NIPROT), Mitra and Associates & Macro International, Dhaka, Bangladesh and Calverton, Maryland, USA* 2016
24. Rahman MS, Howlader T, Masud MS, et al. Association of Low-Birth Weight with Malnutrition in Children under Five Years in Bangladesh: Do Mother's Education, Socio-Economic Status, and Birth Interval Matter? *PLOS ONE* 2016;11(6):e0157814. doi: 10.1371/journal.pone.0157814
25. Haque SR, Tisha S, Huq NJB. Poor birth size a badge of low birth weight accompanying less antenatal care in Bangladesh with substantial divisional variation: evidence from BDHS-2011. 2015;1(2476):33.8.
26. Rahman M, Islam MJ, Haque SE, et al. Association between high-risk fertility behaviours and the likelihood of chronic undernutrition and anaemia among married Bangladeshi women of reproductive age. *Public health nutrition* 2017;20(2):305-14. doi: 10.1017/s136898001600224x [published Online First: 2016/09/10]
27. Brown JS, Jr., Adera T, Masho SW. Previous abortion and the risk of low birth weight and preterm births. *J Epidemiol Community Health* 2008;62(1):16-22. doi: 10.1136/jech.2006.050369 [published Online First: 2007/12/15]
28. Dennis JA, Mollborn S. Young maternal age and low birth weight risk: An exploration of racial/ethnic disparities in the birth outcomes of mothers in the United States. *The Social science journal* 2013;50(4):625-34. doi: 10.1016/j.soscij.2013.09.008
29. He Z, Bishwajit G, Yaya S, et al. Prevalence of low birth weight and its association with maternal body weight status in selected countries in Africa: a cross-sectional study. *BMJ open* 2018;8(8):e020410.
30. Karim MR, Mondal MNI, Rana MM, et al. Maternal Factors are Important Predictors of Low Birth Weight: Evidence from Bangladesh Demographic & Health Survey-2011. *Malaysian Journal of Nutrition* 2016;22(2)
31. Shah PS, Balkhair T, Ohlsson A, et al. Intention to become pregnant and low birth weight and preterm birth: a systematic review. *Matern Child Health J* 2011;15(2):205-16. doi: 10.1007/s10995-009-0546-2 [published Online First: 2009/12/17]
32. Sterne JA, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *Bmj* 2009;338:b2393.
33. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. *J Prev Med Public Health* 2017;50(1):18-28. doi: 10.3961/jpmph.16.087
34. Assefa N, Berhane Y, Worku A. Wealth Status, Mid Upper Arm Circumference (MUAC) and Antenatal Care (ANC) Are Determinants for Low Birth Weight in Kersa, Ethiopia. *PLOS ONE* 2012;7(6):e39957. doi: 10.1371/journal.pone.0039957
35. Britto RPdA, Florêncio TMT, Benedito Silva AA, et al. Influence of Maternal Height and Weight on Low Birth Weight: A Cross-Sectional Study in Poor Communities of Northeastern Brazil. *PLOS ONE* 2013;8(11):e80159. doi: 10.1371/journal.pone.0080159
36. Patel A, Prakash AA, Das PK, et al. Maternal anemia and underweight as determinants of pregnancy outcomes: cohort study in eastern rural Maharashtra, India. *BMJ Open* 2018;8(8):e021623. doi: 10.1136/bmjopen-2018-021623
37. Razak F, Finlay JE, Subramanian SV. Maternal underweight and child growth and development. *The Lancet* 2013;381(9867):626-27. doi: 10.1016/S0140-6736(13)60344-X

38. Pinzón-Rondón ÁM, Gutiérrez-Pinzon V, Madriñan-Navia H, et al. Low birth weight and prenatal care in Colombia: a cross-sectional study. *BMC pregnancy and childbirth* 2015;15(1):118.
39. Wado YD, Afework MF, Hindin MJ. Effects of Maternal Pregnancy Intention, Depressive Symptoms and Social Support on Risk of Low Birth Weight: A Prospective Study from Southwestern Ethiopia. *PLOS ONE* 2014;9(5):e96304. doi: 10.1371/journal.pone.0096304
40. Niemi M, Falkenberg T, Petzold M, et al. Symptoms of antenatal common mental disorders, preterm birth and low birthweight: a prospective cohort study in a semi-rural district of V ietnam. *Tropical medicine & international health* 2013;18(6):687-95.
41. Sable MR, Spencer JC, Stockbauer JW, et al. Pregnancy wantedness and adverse pregnancy outcomes: differences by race and Medicaid status. *Family planning perspectives* 1997;29:76-81.
42. Kc S, Hemminki E, Gissler M, et al. Perinatal outcomes after induced termination of pregnancy by methods: A nationwide register-based study of first births in Finland 1996–2013. *PLOS ONE* 2017;12(9):e0184078. doi: 10.1371/journal.pone.0184078
43. Ke L, Lin W, Liu Y, et al. Association of induced abortion with preterm birth risk in first-time mothers. *Scientific Reports* 2018;8(1):5353. doi: 10.1038/s41598-018-23695-7
44. Henriksen L, Schei B, Vangen S, et al. Sexual violence and neonatal outcomes: a Norwegian population-based cohort study. *BMJ Open* 2014;4(10):e005935. doi: 10.1136/bmjopen-2014-005935
45. Chambliss LR. Intimate partner violence and its implication for pregnancy. *Clinical obstetrics and gynecology* 2008;51(2):385-97.
46. Rahman M, Sasagawa T, Fujii R, et al. Intimate Partner Violence and Unintended Pregnancy Among Bangladeshi Women. *Journal of Interpersonal Violence* 2012;27(15):2999-3015. doi: 10.1177/0886260512441072
47. Ferdos J, Rahman MM, Jesmin SS, et al. Association between intimate partner violence during pregnancy and maternal pregnancy complications among recently delivered women in Bangladesh. *Aggressive behavior* 2018;44(3):294-305. doi: 10.1002/ab.21752
48. Borders AE, Grobman WA, Amsden LB, et al. Chronic stress and low birth weight neonates in a low-income population of women. *Obstet Gynecol* 2007;109(2 Pt 1):331-8. doi: 10.1097/01.AOG.0000250535.97920.b5 [published Online First: 2007/02/03]
49. Rahman M, Hosen A, Khan MA. Association between Maternal High-Risk Fertility Behavior and Childhood Morbidity in Bangladesh: A Nationally Representative Cross-Sectional Survey. *The American journal of tropical medicine and hygiene* 2019 doi: 10.4269/ajtmh.19-0221 [published Online First: 2019/07/25]
50. Fall CHD, Sachdev HS, Osmond C, et al. Association between maternal age at childbirth and child and adult outcomes in the offspring: a prospective study in five low-income and middle-income countries (COHORTS collaboration). *The Lancet Global Health* 2015;3(7):e366-e77. doi: 10.1016/S2214-109X(15)00038-8
51. Mahande MJ, Obure J. Effect of interpregnancy interval on adverse pregnancy outcomes in northern Tanzania: a registry-based retrospective cohort study. *BMC Pregnancy and Childbirth* 2016;16(1):140. doi: 10.1186/s12884-016-0929-5
52. Veloso HJF, da Silva AAM, Bettiol H, et al. Low birth weight in São Luís, northeastern Brazil: trends and associated factors. *BMC Pregnancy and Childbirth* 2014;14(1):155. doi: 10.1186/1471-2393-14-155
53. Winkvist A, Rasmussen KM, Habicht J-P. A new definition of maternal depletion syndrome. *American journal of public health* 1992;82(5):691-94.

Table 1. A complete list and details of explanatory variables.

Variables	Collected data	Answer category
Socio-demographic variables		
Maternal education[1]	Maternal highest level of education	1 = No education; 2 = Primary; 3 = Secondary & above
Residence	Place of residence	1 = Urban; 2 = Rural
Economic status[2]	Wealth index of the family	1 = Poor; 2 = Middle; 3 = Rich
Employment status[2]	Employment status of the individuals	1 = Unemployed; 2 = Employed
Adverse maternal characteristics		
Underweight mother	The nutritional status (BMI) of mother was measured and if BMI was less than 18.5 kg/m^2 then she was underweight.	0 = No; 1 = Yes
Overweight/obese mother	The nutritional status (BMI) of mother was measured and if BMI was higher than 25.0 kg/m^2 then she was overweight and BMI was higher than 30.0 kg/m^2 then she was obese.	0 = No; 1 = Yes
Unwanted birth	The child birth was not wanted at that time	0 = No; 1 = Yes
Ever had a terminated pregnancy	The mother had a previous pregnancy termination history (abortion, miscarriage etc.)	0 = No; 1 = Yes
Victim of intimate partner violence (IPV)	The mother who were a victim of IPV such as beaten in front of child, beaten by husband when refuse to intercourse or burn food etc.	0 = No; 1 = Yes
ANC <4 times	The mother who had utilized ANC less than 4 times during pregnancy	0 = No; 1 = Yes
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years	The mother whose age at the time of the birth was less than 18 years	0 = No; 1 = Yes
Maternal age at birth >34 years	The mother whose age at the time of the birth was greater than 34 years	0 = No; 1 = Yes
Birth interval <24 months	The mother who gave birth with a birth interval of less than 24 months	0 = No; 1 = Yes
Birth order >3	The mother whose birth order was higher than 3	0 = No; 1 = Yes
Maternal age at birth <18 years and Birth interval <24 months[3]	The mother whose age at the time of the birth was less than 18 years with an interval of less than 24 months	0 = No; 1 = Yes
Maternal age at birth >34 years and Birth interval <24 months[4]	The mother whose age at the time of the birth was greater than 34 years with an interval of less than 24 months	0 = No; 1 = Yes
Birth interval <24 months and birth order >3	The mother whose birth order was higher than 3 with interval of less than 24 months	0 = No; 1 = Yes

Note: The analysis was restricted for children who were born within 5 years prior to the survey. High-risk fertility behavior variables categorization followed BDHS standard measure. [1] Primary and secondary education is defined as completing grade 5 and 10, respectively. [2] followed standard BDHS measure. [3] includes the categories "age at birth <18 years with birth order >3" and "age at birth <18 years with interval <24 months and birth order >3". [4] includes the categories "age at birth <34 years with interval <24 months" and "age at birth <34 years with interval <24 months and birth order >3". [5] includes obesity (BMI > 30.0 kg/m^2)

Table 2. The prevalence of low birth weight and its association with socio demographic risk factors, adverse maternal characteristics including maternal high-risk fertility behaviors in Bangladesh, BDHS 2014.

Background characteristics	Low birth weight (%, 95% CI)	p-value
Overall	19.9 (18.5-21.5)	
Socio-demographic variables:		
Residence		<0.001
Urban	17.5 (15.1-20.2)	
Rural	20.8 (18.9-22.8)	
Maternal education		<0.001
No education	26.6 (22.2-31.5)	
Primary	21.1 (18.2-24.3)	
Secondary and above	17.7 (16.0-19.7)	
Economic status		<0.001
Poor	22.3 (19.8-24.9)	
Middle	19.7 (15.8-24.3)	
Rich	17.7 (15.5-20.1)	
Employment status		0.683
Unemployed	19.6 (17.7-21.6)	
Employed	21.1 (18.1-24.4)	
Adverse maternal characteristics		
Underweight mother		<0.001
No	18.4 (16.6-20.2)	
Yes	24.9 (21.9-28.1)	
Overweight/obese mother		0.004
No	20.8 (19.1-22.5)	
Yes	15.9 (12.9-19.3)	
Taken ANC <4 times		<0.001
No	16.3 (14.4-18.4)	
Yes	21.6 (19.6-23.7)	
Unwanted birth		0.002
No	19.0 (17.4-20.7)	
Yes	24.6 (20.9-26.6)	
Ever had a terminated pregnancy		0.096
No	19.5 (17.9-21.2)	
Yes	22.8 (18.8-27.2)	
Victim of intimate partner violence		0.014
No	19.5 (17.8-21.4)	
Yes	21.0 (18.6-23.6)	
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years		<0.001
No	18.5 (17.0-20.2)	
Yes	29.2 (25.1-33.7)	
Maternal age at birth >34 years		0.204
No	19.5 (18.1-21.2)	
Yes	23.0 (19.9-30.9)	
Birth interval <24 months		<0.001
No	17.9 (16.7-19.7)	
Yes	26.6 (23.5-29.8)	
Birth order >3		0.008
No	19.3 (17.7-21.0)	
Yes	24.0 (20.2-28.3)	
Maternal age at birth <18 years and birth interval <24 months		<0.001
No	18.8 (17.3-20.5)	
Yes	22.4 (19.6-25.5)	
Maternal age at birth >34 years and birth interval <24 months		0.003
No	18.8 (17.2-20.5)	
Yes	27.1 (23.1-31.5)	
Birth order >3 and birth interval <24 months		0.011
No	19.7 (18.3-21.4)	
Yes	24.5 (18.0-32.5)	

Note: The sample was weighted. "No" values for low birth weight was omitted from the table and calculated for row percentage.

Table 3. Unadjusted and adjusted odds ratio to measure the association size of adverse maternal characteristics on newborn's low birth weight in Bangladesh, BDHS 2014.

Background characteristics	Low birth weight (LBW)	
	UOR (95% CI)	AOR (95% CI)
Socio-demographic variables:		
Residence		
Urban (RC)	1.00	1.00
Rural	1.34 (1.16-1.61) ***	1.22 (1.02-1.46) *
Maternal education		
No education (RC)	1.00	1.00
Primary	0.73 (0.59-0.90) **	0.72 (0.57-0.90) **
Secondary and above	0.54 (0.44-0.66) ***	0.57 (0.45-0.73) ***
Economic status		
Poor (RC)	1.00	1.00
Middle	0.87 (0.71-1.06)	1.03 (0.84-1.26)
Rich	0.68 (0.58-0.80) ***	0.97 (0.79-1.18)
Employment status		
Unemployed (RC)	1.00	1.00
Employed	1.04 (0.88-1.23)	1.02 (0.86-1.21)
Adverse maternal characteristics		
Underweight mother		
No (RC)	1.00	1.00
Yes	1.48 (1.25-1.72) ***	1.26 (1.06-1.49) **
Overweight/obese mother		
No (RC)	1.00	1.00
Yes	0.74 (0.61-0.91) **	0.98 (0.78-1.23)
Taken ANC <4 times		
No (RC)	1.00	1.00
Yes	1.44 (1.23-1.70) ***	1.23 (1.03-1.48) *
Unwanted birth		
No (RC)	1.00	1.00
Yes	1.29 (1.10-1.51) **	1.22 (1.03-1.44) *
Ever had a terminated pregnancy		
No (RC)	1.00	1.00
Yes	1.18 (0.97-1.43)	1.28 (1.05-1.57) **
Victim of intimate partner violence		
No (RC)	1.00	1.00
Yes	1.22 (1.04-1.42) **	1.23 (1.05-1.45) *
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years		
No (RC)	1.00	1.00
Yes	1.81 (1.50-2.19) ***	1.42 (1.11-1.83) **
Maternal age at birth >34 years		
No (RC)	1.00	1.00
Yes	1.23 (0.89-1.71)	0.93 (0.63-1.39)
Birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.54 (1.32-1.80) ***	1.25 (1.01-1.55) *
Birth order >3		
No (RC)	1.00	1.00
Yes	1.30 (1.07-1.59) **	1.04 (0.83-1.33)
Maternal age at birth <18 years and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.31 (1.12-1.53) ***	1.26 (1.02-1.57) **
Maternal age at birth >34 years and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.34 (1.11-1.64) **	1.22 (0.97-1.54)
Birth order >3 and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.50 (1.09-2.06) *	1.68 (1.18-2.37) **

Note: Model was adjusted for all the predictors included in this table. Values with superscript asterisks *, **, and *** indicate $p<0.05$, $p<0.01$, and $p<0.001$, respectively. UOR: unadjusted odds ratio; AOR: adjusted odds ratio; CI: confidence interval; ANC: antenatal care.

Figure legend

Figure 01. Geographical prevalence (%, 95% CI) of low birth weight according to seven administrative divisions in Bangladesh (using data BDHS 2014).

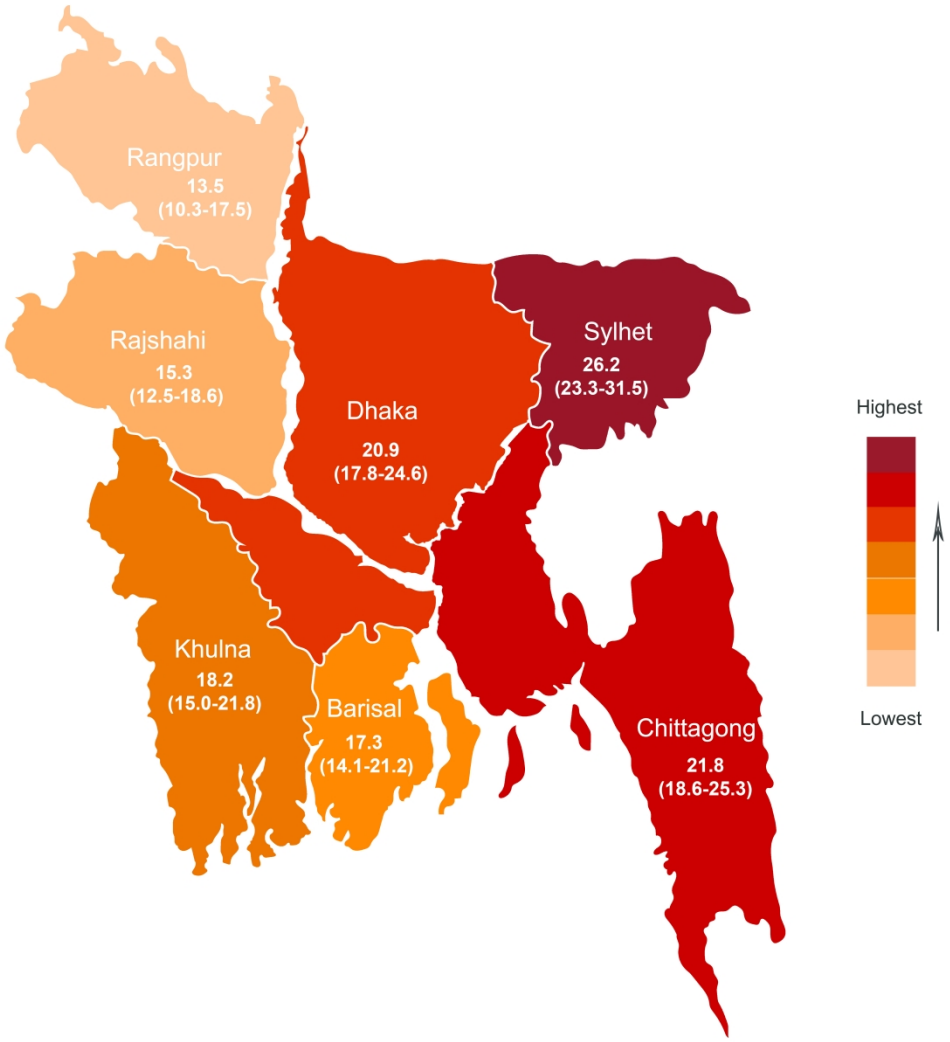

Fig 1. Geographical prevalence (%, 95% CI) of low birth weight according to seven administrative divisions in Bangladesh (using data BDHS 2014).

Table S1. STROBE checklist of items for observational studies

	Item No	Recommendation	Page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7*
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	NA

Results			**Page #**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	Table 1
		Cross-sectional study—Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	3

*Give information separately for exposed and unexposed groups in cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Exploring the association between adverse maternal circumstances and low birth weight in neonates: a nationwide population-based study in Bangladesh

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-036162.R3
Article Type:	Original research
Date Submitted by the Author:	27-Aug-2020
Complete List of Authors:	Khan, Md. Mostaured; University of Rajshahi, Population Science and Human Resource Development Mustagir, Md. Golam; University of Rajshahi, Population Science and Human Resource Development Islam, Md; University of Rajshahi, Population Science and Human Resource Development Kaikobad, Md. Sharif; University of Rajshahi, Population Science and Human Resource Development Khan, Hafiz; University of West London, College of Nursing, Midwifery and Healthcare
Primary Subject Heading:	Paediatrics
Secondary Subject Heading:	Paediatrics, Nutrition and metabolism
Keywords:	NEONATOLOGY, Community child health < PAEDIATRICS, Nutrition < TROPICAL MEDICINE

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Exploring the association between adverse maternal circumstances and low birth weight in neonates: *a nationwide population-based study in Bangladesh*

Authors: Md. Mostaured Ali Khan[1,2], Md. Golam Mustagir[1], Md. Rafiqul Islam[1*], Md. Sharif Kaikobad[1], and Hafiz T.A. Khan[3]

Affiliations:

[1] Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh.

[2]MEL and Research, Practical Action, House no. 28/A, Road no. 5, Dhanmondi, Dhaka-1205, Bangladesh

[3]Professor of Public Health & Statistics, College of Nursing, Midwifery and Healthcare, University of West London, Paragon House, Boston Manor Road, Brentford TW8 9GB, United Kingdom

Corresponding Author:

Md. Rafiqul Islam, PhD
Professor, Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh.
E-mail: rafique_pops@yahoo.com

Exploring the association between adverse maternal circumstances and low birth weight in neonates: *a nationwide population-based study in Bangladesh*

Abstract

Objective: This study is concerned with helping to improve the health and care of newborn babies in Bangladesh by exploring adverse maternal circumstances and assessing whether these are contributing towards low birth weight (LBW) in neonates.

Study designs and settings: Data was drawn and analysed from the "Bangladesh Demographic and Health Survey (BDHS), 2014." Any association between LBW and adverse maternal circumstances were assessed using a Chi-square test with determinants of LBW identified by multivariate logistic regression analysis.

Participants: The study is based on 4,728 children aged below 5 years and born to women from selected households.

Results: The rate of LBW was around 19.9% (199 per 1000 live births) with the highest level found in the Sylhet region (26.2%). The rate was even higher in rural areas (20.8%) and among illiterate mothers (26.6%). Several adverse maternal circumstances of the women included in the survey were found to be significant for increasing the likelihood of giving birth to LBW babies. These circumstances included the women being underweight (Adjusted Odds Ratio (AOR) 1.26, 95% Confidence Interval (CI) 1.06-1.49); having unwanted births (AOR 1.22, 95% CI 1.03-1.44); had previous pregnancies terminated (AOR 1.28, 95% CI 1.05-1.57); were victims of intimate partner violence (AOR 1.23, 95% CI 1.05-1.45) and taking ANC <4 times (AOR 1.23, 95% CI 1.03-1.48). Other important risk factors that were revealed included age at birth <18 years (AOR 1.42, 95% CI 1.11-1.83) and intervals between the number of births <24 months (AOR 1.25, 95% CI 1.01-1.55). When taking multiple fertility behaviours together such as, the ages of the women at birth (<18 years with interval <24 months (AOR 1.26, 95% CI 1.02-1.57)

and birth order (>3 with interval <24 months (AOR 1.68, 95% CI 1.18-2.37), then the risk of having LBW babies significantly increased.

Conclusion: This study finds that adverse maternal circumstances combined with high-risk fertility behaviours are significantly associated with LBW in neonates. This situation could severely impede progress in Bangladesh towards achieving the sustainable development goal (SDG) concerned with the healthcare of newborns.

Keywords: Low birth weight (LBW), high-risk fertility behaviours, adverse maternal characteristics, Bangladesh, BDHS

Strengths and limitations of the study

- Analyzing the nationally representative data set helped to provide a wide picture of society in Bangladesh and provided more reliable results.
- A limitation of the data set occurred where the LBW was recorded based on the perceptions of the mothers as to the size of their children at birth instead of their actual birth weights due to the unavailability of official data.
- The study outcome and predictors were based on self-reporting and recall bias is commonly found with this type of data collection procedure.
- The use of secondary datasets limited our freedom to select variables for the analysis and perform model adjustment.

Acknowledgement: We gratefully acknowledge the Demographic and Health Survey programme for granting permission to use the data. Authors would like to express their gratitude to Dr. Helen Findlay for final checking and editing of the manuscript.

Ethical Statement

Ethical approval for all the BDHS surveys was received from the ICF Macro Institutional Review Board, Maryland, USA, and the National Research Ethics Committee of the Bangladesh Medical Research Council (BMRC), Dhaka, Bangladesh. The National Institute of Population Research and Training conducted these surveys with the support of the United States Agency for International Development (USAID). Informed consent was obtained from all participants. The BDHS is part of the worldwide Demography and Health Surveys (DHS) programme and is available in the public domain for research purposes.

Patient consent: Not required.

Introduction

Low birth weight (LBW) is a critical global concern particularly in low- and middle-income countries (LMICs) [1 2]. A newborn weighing less than 2.5 kilograms (5.5 pounds) is classed as an LBW baby [3]. It is one of the key underlying contributors for potentially increasing the risk of infant mortality, susceptibility to severe childhood illness [1 4] and malnutrition [5], and can impede the future cognitive development of the baby [6]. Unfortunately, around 20 million (15.5%) babies worldwide are born each year with LBW with around 96% of these in developing countries [7] like Bangladesh. Regional statistics illustrate that the global burden of LBW is severely skewed towards South Asia that has the highest prevalence (28%) followed by Sub-Saharan African countries (13%), then the Caribbean and Latin America (9%), and the Pacific and Eastern Asia (6%) [3]. The National Low Birth Weight Survey of Bangladesh reported that the prevalence of LBW decreased from around 36% in 2004 to 22.6% in 2015 [1 8] providing an indication of improvement.

Previous studies confirm that LBW contributes significantly to neonatal and infant mortality [7] with 60%-80% of neonatal deaths worldwide occurring within 28 days of life [7]. Infants with a significant LBW (<1500 g) are around 20 times more likely to die in infancy than those born within normal weight limits [9]. LBW is also accelerating the risk of mortality in later childhood and adolescence due to congenital malformations and perinatal factors [9]. Further adverse health and growth problems associated with LBW and identified in other studies include chronic disease such as childhood asthma [10], attention-deficit or hyperactivity disorder [11], post-natal growth failure [12], stunting, wasting and being underweight [13] . These negative health aspects can extend into adulthood and increase the risk of developing chronic diseases such as cardiovascular disease [14 15] and respiratory diseases [15 16] . The importance of preventing LBW therefore is vital for reducing the mortality and morbidity risk in childhood and adulthood.

Worldwide efforts have been made to reveal the etiology and identify the risk factors of LBW but these can be complex and vary amongst regions. Previous research findings from developed and developing regions suggest that potential risk factors for LBW include a history of premature delivery [17], maternal younger age (<18 years) and advanced age (>34 years) at childbirth [17 18], insufficient prenatal care [1 18 19], underweight mother [18 20], shorter birth interval [20], hard work and low nutritious food consumption during pregnancy [17], antepartum hemorrhage and anemia [19], hypertension disorder and diabetes during pregnancy [21]. Various socio-demographic factors affecting mothers such as living in rural territories [1], illiteracy [1 18], poor economic status [1 20] and victims of any kind of intimate partner violence (IPV) either physical, sexual or mental [22] are also significantly associated with risk factors for LBW. Therefore, an understanding of the etiology of LBW and various other factors affecting the health of newborns is vital for the development of effective prevention programmes.

The World Health Organization (WHO) set a goal of a 30% reduction in the rate of LBW worldwide to be achieved by 2025 in order to meet its sustainable development goals (SDGs). In common with other countries in South Asia, the lack of a monitoring and surveillance system, a well-developed birth registry system, and quality data on birth weight in Bangladesh pose key challenges for the country. This study aims to help redress this situation. This study analysed a nationwide population survey to explore the prevalence of LBW and also assess the association of various adverse maternal circumstances with LBW in Bangladesh.

Methodology

Data sources and sampling procedure

This study analysed data extracted from the 2014 "Bangladesh Demographic and Health Survey (BDHS)". A detailed explanation of the survey has been published elsewhere [23] but briefly, it is based on a two-stage stratified sampling procedure where the Bangladesh Bureau

of Statistics (BBS) divided the country into several primary sampling units [23] and the survey was then carried out in each of the seven administrative divisions of Bangladesh. In the first sampling stage, 600 enumeration areas (EA) were selected as the primary sampling unit (PSU) based on a probability proportional to their size (207 EAs in urban areas and 393 EAs in rural areas). In the second stage, 30 households were selected in each PSU by systematic random sampling [23]. Following this process, the BDHS identified 18,245 ever-married women of reproductive-age (15-49 years) from 18,000 households. There was an overall response rate of around 98% with 17,863 women interviewed and a wide range of data collected on women and their children covering a range of indicators including health and nutrition. The survey also collected data on 7,886 children that were born to women interviewees within five years prior to the year of the survey. This study excluded 3,158 individuals because of unavailability of data regarding birth weight or size. The eligible sample size for the analysis was n = 4728.

Outcome variable

LBW was considered to be the main outcome variable, dichotomised as Yes=1 (baby born with LBW) and No=0 (otherwise). A great number of deliveries in LMICs generally, including in Bangladesh, occur at home without appropriate measurement of birth weight [24]. The BDHS retrospectively gathered data on birth size based on the perceptions of the mothers, and questioned all women who had given birth within five years prior to the year of the survey. The question they were asked was: "was the baby very large, larger than average, average, smaller than average or very small at the time of birth?" The reporting of baby size at birth as "very small" or "smaller than average" were considered useful proxies for LBW [23 24]. Studies using other demographic and health survey data estimated that perceptions of mothers towards the birth weights of their babies were correct around 75% of the time [24 25].

Explanatory variables

The socio-demographic and adverse maternal circumstances of mothers including being under or overweight, having unwanted births, IPV, previous pregnancy terminations and maternal high-risk fertility behaviours were considered as explanatory variables of occurrence and non-occurrence of LBW in newborns. A complete list of explanatory variables is presented in Table 1. The selection process for these variables followed BDHS guidelines and also reviews of previous literature [1 17 23 26-31].

"Insert Table 1"

Statistical analysis

The prevalence of LBW was measured for the entire study population. The association between LBW and different socio-demographic and adverse maternal circumstances including high-risk fertility behaviours were assessed by Chi-square tests (set at $p<0.05$ level of significance). A binary logistic regression model was then fitted as the outcome variable had binary categories, and odds ratios (ORs), both unadjusted and adjusted, were estimated in order to measure the effect of explanatory variables on the outcome variable. Each of the ORs were assessed for 95% confidence intervals (CIs) to help identify their levels of significance. The dataset had fewer than 5% of missing variables. Multiple imputation techniques using linear regression were applied to known values in order to provide an estimate of the missing values [32]. This analysis was intended to ensure representativeness and to prevent misinterpretation or any bias [32]. Place of residence, education, economic status and employment status were used as covariates. The analysis for this study took into account complex survey design and sample weights (*svy:* command in Stata) and was performed using the computer programme Stata in Windows version 13.0 (Stata Corporation, College Station, TX, USA).

Patient and public involvement

The BDHS 2014 questionnaires were based on the MEASURE DHS model questionnaires with. patients not directly involved in the study. The country representative survey was conducted in seven administrative divisions of Bangladesh involving women of reproductive age. Information collected about the birth weight of the children was based on the perceptions of the mothers. While it was not possible to disseminate the study results to the survey participants, the results will be used by health researchers and policy makers.

Results

Prevalence and distribution of LBW

The prevalence of LBW and its association with several adverse maternal circumstances are presented in Table 2. The prevalence of LBW in newborns in Bangladesh was found to be at 19.9%. The geographical prevalence of LBW across the seven administrative regions, based on the 2014 BDHS dataset, is presented in Figure 1 that shows the highest prevalence of LBW occurred in the Sylhet region (26.2%) while the lowest prevalence was found in the Rangpur region (13.5%). Prevalence was also noticeably higher in the Dhaka (20.9%) and Chittagong (21.8%) regions.

"Insert Figure 1."

The prevalence of LBW was observed to be significantly higher in rural territories (20.8%), in poor households (22.3%), and among uneducated mothers (26.6%). Several adverse maternal circumstances were significantly related to the higher prevalence of LBW including underweight mothers (24.9%), women who did not have ANC at least four times (21.6%) during pregnancy, unwanted births (24.6%) and mothers who were victims of IPV (21.0%). Similarly, the LBW prevalence was also observed to be remarkably higher for women with high-risk

fertility behaviours such as aged <18 years at the time of birth (29.2%), and for women whose birth interval was <24 months (26.6%). The prevalence of LBW in newborns was noticeably increased if multiple characteristics of high-risk fertility behaviours were taken together. For instance, LBW in newborns was found among mothers aged <18 years at the time of childbirth with birth intervals <24 months (22.4%); maternal age at birth >34 years with birth interval <24 months (27.1%) and birth order >3 with birth interval <24 months (24.5%).

"Insert Table 2"

Association of adverse maternal situations with LBW

Table 3 illustrates a logistic regression analysis that assessed the effect that several adverse maternal circumstances can have on LBW. The risk was shown to be higher in rural territories (adjusted odds ratio (AOR) 1.22, 95% CI 1.02-1.46) compared to urban areas. Maternal education, however, was found to offer some protection against LBW. The likelihood of women giving birth to LBW babies decreased for those with primary (AOR 0.72, 95% CI 0.57-0.90) and secondary and above levels of education (AOR 0.57, 95% CI 0.45-0.73) compared to uneducated women. The odds of having an LBW baby were significantly increased for underweight mothers (AOR 1.26, 95% CI 1.06-1.49), and for mothers who did not utilize ANC at least four times (AOR 1.23, 95% CI 1.03-1.48) during pregnancy compared to their counterparts. The risk of LBW also increased in the case of unwanted births (AOR 1.22, 95% CI 1.03-1.44), a history of previous pregnancy terminations (AOR 1.28, 95% CI 1.05-1.57), and victims of IPV (AOR 1.23, 95% CI 1.05-1.45) compared to their counterparts. A young age at childbirth (<18 years) and birth intervals <24 months indicated that these women had a 1.42 times (95% CI 1.11-1.83) and a 1.26 times (95% CI 1.02-1.57) increased risk of LBW in their newborns respectively, compared to women that did not have such risky fertility behaviour.

Other risk factors could also have an effect on LBW such as birth order >3 with interval <24 months (AOR 1.68, 95% CI 1.18-2.37).

"Insert Table 3"

Discussion

This study analysed a country representative sample size of 4,728 and found that various types of socio-demographic and adverse maternal factors, including high-risk fertility behaviours, are significantly increasing the likelihood of giving birth to an LBW child. The prevalence of LBW in Bangladesh was observed to be around 20% and the regional burden varying significantly with a very high prevalence in the Sylhet region and comparatively low prevalence in the Rangpur region. Though a significant reduction of the LBW rate in Bangladesh has been noted, it is still much higher than the global average [1 7 8]. According to this study, the burden is comparatively higher in rural areas and within the illiterate community. Another study in a developing country had similar findings to this study by identifying that illiterate and poor women had a significantly higher risk of giving birth to an LBW baby [33]. Other research projects have found a significant association of LBW with a household's economic situation, but this study did not discover any corroborative evidence for this particular finding. [18 34].

A well-established risk factor for giving birth to an LBW baby is for mothers to be underweight [29 35] and this study corroborates earlier research findings where underweight mothers were found to be at higher risk than their counterparts [29 30 36]. In underweight mothers, a deficiency of micronutrients and calories can impede the proper growth of the foetus so leading to an LBW newborn [37]. In order to reduce this risk, the importance of proper maternal nutrition comes to the fore and taking ANC ≥4 times can help mitigate the incidence of LBW. The findings of this study regarding the higher chance of giving birth to an LBW baby among mothers who used ANC <4 times is consistent with other study results [18 38]. In general, ANC provides the

appropriate care required for both mother and newborn babies by addressing all forms of maternal health complications [25 34 38]. In Ethiopia, Assefa et al. (2012) noted that women who did not use at least one ANC during pregnancy had a 1.6 times higher risk of giving birth to an LBW baby [34]. A key challenge for reducing such risk is to reach those women and newborns in the greatest need.

Wado et al. (2014) [39] and Shah et al. (2009) [31] discovered that the risk of LBW in newborns was higher for unwanted births so supporting the findings in this study. Unwanted pregnancy also profoundly increases the risk of antenatal depression that is a crucial predictor of LBW [39 40]. An unwanted pregnancy can cause a woman to feel anxiety, fear, excitement and happiness that may all fluctuate over the course of the pregnancy period and may cause variation in birth outcomes [31 41]. The findings of this study indicate there is a higher likelihood for women who had ever had a pregnancy terminated of giving birth to LBW babies that resonates with other research projects [27 42]. However, contrary to these findings, Li Ke et al. (2018) observed no significant association between induced abortion and LBW for first-time mothers among southern Chinese women [43]. This study's findings of the high likelihood of women giving birth to LBW babies that had experienced any form of IPV, either physical or sexual, is supported by earlier study results [22 34 44 45]. The LBW burden is much higher for women that experienced both physical and sexual IPV [22]. IPV can also increase the risk of unintended pregnancies and be responsible for pregnancy complications that can both lead to LBW babies [31 46 47]. Unintended pregnancies and IPV have direct connections with chronic psychosocial stress in women, that leads to a higher risk of giving birth to LBW babies [48].

This study shows that a number of maternal high-risk fertility behaviours such as, young maternal age when giving birth (<18 years) and birth interval <24 months, are significantly increasing the risk of LBW in newborns [49] that has also been shown in other research projects [17 28 50]. Childbirth in adolescence is detrimental for child health due to maternal socio-economic

factors, immature behaviour and biological factors as adolescent females have comparatively underdeveloped reproductive systems. [50] Consequently, a woman of this age cluster is often unable to handle the complexities of pregnancy and the foetus can be deprived of adequate nutrition required for proper growth and development [50]. Giving birth again within a short interval (<24 months) markedly increases the risk of women having LBW babies that is consistent with previous findings [20 51 52]. In northern Tanzania, a retrospective cohort study concluded that a shorter interpregnancy interval (<24 months) was 1.61 times more likely to increase the risk of giving birth to an LBW infant compared to an interpregnancy interval of 24–36 months [51]. Among those women with a shorter interpregnancy interval, the depletion of iron and folic acid is observed that is related to an increased risk of foetal growth restriction [53]. The risks of giving birth to an LBW baby is further increased if multiple high-risk behaviors are considered together. For example, if a woman gives birth during adolescence (<18 years) with a shorter birth interval (<24 months), then it is highly likely that the newborn will have a LBW. A similar risk was observed for a maternal higher birth order (>3) compared to a lower birth interval. It can be concluded, therefore, that maternal high-risk fertility behaviours are significantly associated with women giving birth to LBW babies.

Strengths and limitations of the study

The strengths of this study include the use of nationally representative data involving a large sample size that enabled the study to show reliable and precise results. In addition, the 2014 BDHS used a globally standardized method that enabled the results of this study to be compared with research in other countries that used a similar methodology. The study analysis took into account the complex survey design and sample weights that helped to provide greater accuracy in representing the country. However, some important limitations of this study should be mentioned. The measurement of LBW was defined by using a mother's perception of the size of their child at birth instead of the actual birth weight due to the unavailability of official data. This

therefore meant that underreporting was likely as many mothers could only remember if LBW was a factor if the newborn was very small in size. In addition, the study outcome and predictors were based on self-reporting and past events were related through the recall method. Data collected through these methods mean that recall bias is common. The cross-sectional nature of the 2014 BDHS data did not allow for any causal inferences to be drawn between outcome variables and predictors and the use of secondary data limits the analysis in variable selection. For example, pre-term birth is responsible for a large no of LBW babies, but the dataset had no information about gestational age.

Conclusion

The high prevalence of LBW indicates a serious health hazard for newborn babies in Bangladesh. This study has explored the risk factors that may increase the prevalence of LBW in newborns and can be used as a basis for developing prevention strategies. This study also suggests that several socio-demographic and adverse maternal circumstances along with multiple high-risk fertility behaviours may impact on a newborn baby's birth weight thereby increasing the risk of LBW. These findings highlight the vital importance of early screening and interventions targeted at all women. This study recommends that policymakers and public health authorities address these adverse maternal factors when designing prevention interventions to reduce LBW in newborns. In this regard, reproductive health promotion programmes among targeted individuals could be introduced to help in limiting adverse factors as well as LBW. In conclusion, adverse maternal circumstances can impede progress towards achieving the SDG target regarding newborn health care. There is no doubt that a continued effort for reducing the LBW prevalence in Bangladesh is of paramount importance.

Abbreviations

LBW, Low Birth Weight; LMIC, Low- and Middle-Income Country; SDG, Sustainable Development Goal; BDHS, Bangladesh Demographic and Health Survey; ANC, Antenatal Care; CI, Confidence Interval; OR, Odds Ratio.

Authors Contribution: MMAK conceptualized the study and designed the analytical approach. MMAK, MGM, and MSK performed the data analyses and interpreted the findings. MMAK, and MGM drafted the manuscript. MRI, and HTAK helped in variable selection, revised the manuscript critically for important intellectual content, and helped in the final approval of the version to be submitted. All authors helped to write the manuscript. All authors read and approved the final manuscript.

Competing interests: None declared.

Funding: This study did not receive any specific grant either from the university or any funding agencies in the public, commercial, or not-for-profit sectors.

Data sharing statement: The data sets used for the current study are publicly available upon request at http://dhsprogram.com/data/available-datasets.cfm

References

1. Khan JR, Islam MM, Awan N, et al. Analysis of low birth weight and its co-variants in Bangladesh based on a sub-sample from nationally representative survey. *BMC pediatrics* 2018;18(1):100. doi: 10.1186/s12887-018-1068-0
2. Katz J, Lee AC, Kozuki N, et al. Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. *The Lancet* 2013;382(9890):417-25.
3. WHO. Global nutrition targets 2025: low birth weight policy brief (WHO/NMH/NHD/14.5). *World Health Organization, Geneva, Switzerland* 2014:8.
4. Wilcox AJ. On the importance—and the unimportance—of birthweight. *International journal of epidemiology* 2001;30(6):1233-41.
5. Saville NM, Shrestha BP, Style S, et al. Impact on birth weight and child growth of Participatory Learning and Action women's groups with and without transfers of food or cash during pregnancy: Findings of the low birth weight South Asia cluster-randomised controlled trial (LBWSAT) in Nepal. *PLOS ONE* 2018;13(5):e0194064. doi: 10.1371/journal.pone.0194064
6. Veena SR, Krishnaveni GV, Wills AK, et al. Association of birthweight and head circumference at birth to cognitive performance in 9-to 10-year-old children in South India: prospective birth cohort study. *Pediatric research* 2010;67(4):424.
7. WHO. WHO | Care of the preterm and low-birth-weight newborn: World Health Organization, Geneva, Switzerland; 2018 [updated 2018-11-14 15:51:42. Available from: https://www.who.int/maternal_child_adolescent/newborns/prematurity/en/.
8. NNS. National Low Birth Weight Survey (NLBWS) Bangladesh, 2015. *National Nutrition Services, Institute of public health nutrition, Directorate general of health services, Ministry of Health & Family Welfare, Dhaka, Bangladesh* 2017
9. Watkins WJ, Kotecha SJ, Kotecha S. All-Cause Mortality of Low Birthweight Infants in Infancy, Childhood, and Adolescence: Population Study of England and Wales. *PLOS Medicine* 2016;13(5):e1002018. doi: 10.1371/journal.pmed.1002018
10. Brooks A-M, Byrd RS, Weitzman M, et al. Impact of Low Birth Weight on Early Childhood Asthma in the United States. *Archives of Pediatrics & Adolescent Medicine* 2001;155(3):401-06. doi: 10.1001/archpedi.155.3.401
11. Franz AP, Bolat GU, Bolat H, et al. Attention-Deficit/Hyperactivity Disorder and Very Preterm/Very Low Birth Weight: A Meta-analysis. *Pediatrics* 2018;141(1):e20171645. doi: 10.1542/peds.2017-1645
12. Lee SM, Kim N, Namgung R, et al. Prediction of Postnatal Growth Failure among Very Low Birth Weight Infants. *Scientific Reports* 2018;8(1):3729. doi: 10.1038/s41598-018-21647-9
13. Sania A, Fall CH, Victora CG, et al. Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. *International Journal of Epidemiology* 2013;42(5):1340-55. doi: 10.1093/ije/dyt109
14. Tian J, Qiu M, Li Y, et al. Contribution of birth weight and adult waist circumference to cardiovascular disease risk in a longitudinal study. *Scientific reports* 2017;7(1):9768-68. doi: 10.1038/s41598-017-10176-6
15. Belbasis L, Savvidou MD, Kanu C, et al. Birth weight in relation to health and disease in later life: an umbrella review of systematic reviews and meta-analyses. *BMC Medicine* 2016;14(1):147. doi: 10.1186/s12916-016-0692-5
16. Mebrahtu TF, Feltbower RG, Greenwood DC, et al. Birth weight and childhood wheezing disorders: a systematic review and meta-analysis. *J Epidemiol Community Health* 2015;69(5):500-08.
17. Sharma SR, Giri S, Timalsina U, et al. Low Birth Weight at Term and Its Determinants in a Tertiary Hospital of Nepal: A Case-Control Study. *PLOS ONE* 2015;10(4):e0123962. doi: 10.1371/journal.pone.0123962
18. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. *Journal of preventive medicine and public health = Yebang Uihakhoe chi* 2017;50(1):18-28. doi: 10.3961/jpmph.16.087 [published Online First: 12/27]

19. Feresu SA, Harlow SD, Woelk GB. Risk Factors for Low Birthweight in Zimbabwean Women: A Secondary Data Analysis. *PLOS ONE* 2015;10(6):e0129705. doi: 10.1371/journal.pone.0129705
20. Silveira MF, Victora CG, Horta BL, et al. Low birthweight and preterm birth: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015. *International Journal of Epidemiology* 2018;48 doi: 10.1093/ije/dyy106
21. Rao J, Fan D, Wu S, et al. Trend and risk factors of low birth weight and macrosomia in south China, 2005–2017: a retrospective observational study. *Scientific Reports* 2018;8(1):3393. doi: 10.1038/s41598-018-21771-6
22. Ferdos J, Rahman MM. Maternal experience of intimate partner violence and low birth weight of children: A hospital-based study in Bangladesh. *PLOS ONE* 2017;12(10):e0187138. doi: 10.1371/journal.pone.0187138
23. NIPORT. Bangladesh Demographic and Health Survey 2014. *National Institute of Population Research and Training (NIPROT), Mitra and Associates & Macro International, Dhaka, Bangladesh and Calverton, Maryland, USA* 2016
24. Rahman MS, Howlader T, Masud MS, et al. Association of Low-Birth Weight with Malnutrition in Children under Five Years in Bangladesh: Do Mother's Education, Socio-Economic Status, and Birth Interval Matter? *PLOS ONE* 2016;11(6):e0157814. doi: 10.1371/journal.pone.0157814
25. Haque SR, Tisha S, Huq NJB. Poor birth size a badge of low birth weight accompanying less antenatal care in Bangladesh with substantial divisional variation: evidence from BDHS-2011. 2015;1(2476):33.8.
26. Rahman M, Islam MJ, Haque SE, et al. Association between high-risk fertility behaviours and the likelihood of chronic undernutrition and anaemia among married Bangladeshi women of reproductive age. *Public health nutrition* 2017;20(2):305-14. doi: 10.1017/s136898001600224x [published Online First: 2016/09/10]
27. Brown JS, Jr., Adera T, Masho SW. Previous abortion and the risk of low birth weight and preterm births. *J Epidemiol Community Health* 2008;62(1):16-22. doi: 10.1136/jech.2006.050369 [published Online First: 2007/12/15]
28. Dennis JA, Mollborn S. Young maternal age and low birth weight risk: An exploration of racial/ethnic disparities in the birth outcomes of mothers in the United States. *The Social science journal* 2013;50(4):625-34. doi: 10.1016/j.soscij.2013.09.008
29. He Z, Bishwajit G, Yaya S, et al. Prevalence of low birth weight and its association with maternal body weight status in selected countries in Africa: a cross-sectional study. *BMJ open* 2018;8(8):e020410.
30. Karim MR, Mondal MNI, Rana MM, et al. Maternal Factors are Important Predictors of Low Birth Weight: Evidence from Bangladesh Demographic & Health Survey-2011. *Malaysian Journal of Nutrition* 2016;22(2)
31. Shah PS, Balkhair T, Ohlsson A, et al. Intention to become pregnant and low birth weight and preterm birth: a systematic review. *Matern Child Health J* 2011;15(2):205-16. doi: 10.1007/s10995-009-0546-2 [published Online First: 2009/12/17]
32. Sterne JA, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *Bmj* 2009;338:b2393.
33. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. *J Prev Med Public Health* 2017;50(1):18-28. doi: 10.3961/jpmph.16.087
34. Assefa N, Berhane Y, Worku A. Wealth Status, Mid Upper Arm Circumference (MUAC) and Antenatal Care (ANC) Are Determinants for Low Birth Weight in Kersa, Ethiopia. *PLOS ONE* 2012;7(6):e39957. doi: 10.1371/journal.pone.0039957
35. Britto RPdA, Florêncio TMT, Benedito Silva AA, et al. Influence of Maternal Height and Weight on Low Birth Weight: A Cross-Sectional Study in Poor Communities of Northeastern Brazil. *PLOS ONE* 2013;8(11):e80159. doi: 10.1371/journal.pone.0080159
36. Patel A, Prakash AA, Das PK, et al. Maternal anemia and underweight as determinants of pregnancy outcomes: cohort study in eastern rural Maharashtra, India. *BMJ Open* 2018;8(8):e021623. doi: 10.1136/bmjopen-2018-021623
37. Razak F, Finlay JE, Subramanian SV. Maternal underweight and child growth and development. *The Lancet* 2013;381(9867):626-27. doi: 10.1016/S0140-6736(13)60344-X

38. Pinzón-Rondón ÁM, Gutiérrez-Pinzon V, Madriñan-Navia H, et al. Low birth weight and prenatal care in Colombia: a cross-sectional study. *BMC pregnancy and childbirth* 2015;15(1):118.
39. Wado YD, Afework MF, Hindin MJ. Effects of Maternal Pregnancy Intention, Depressive Symptoms and Social Support on Risk of Low Birth Weight: A Prospective Study from Southwestern Ethiopia. *PLOS ONE* 2014;9(5):e96304. doi: 10.1371/journal.pone.0096304
40. Niemi M, Falkenberg T, Petzold M, et al. Symptoms of antenatal common mental disorders, preterm birth and low birthweight: a prospective cohort study in a semi-rural district of V ietnam. *Tropical medicine & international health* 2013;18(6):687-95.
41. Sable MR, Spencer JC, Stockbauer JW, et al. Pregnancy wantedness and adverse pregnancy outcomes: differences by race and Medicaid status. *Family planning perspectives* 1997;29:76-81.
42. Kc S, Hemminki E, Gissler M, et al. Perinatal outcomes after induced termination of pregnancy by methods: A nationwide register-based study of first births in Finland 1996–2013. *PLOS ONE* 2017;12(9):e0184078. doi: 10.1371/journal.pone.0184078
43. Ke L, Lin W, Liu Y, et al. Association of induced abortion with preterm birth risk in first-time mothers. *Scientific Reports* 2018;8(1):5353. doi: 10.1038/s41598-018-23695-7
44. Henriksen L, Schei B, Vangen S, et al. Sexual violence and neonatal outcomes: a Norwegian population-based cohort study. *BMJ Open* 2014;4(10):e005935. doi: 10.1136/bmjopen-2014-005935
45. Chambliss LR. Intimate partner violence and its implication for pregnancy. *Clinical obstetrics and gynecology* 2008;51(2):385-97.
46. Rahman M, Sasagawa T, Fujii R, et al. Intimate Partner Violence and Unintended Pregnancy Among Bangladeshi Women. *Journal of Interpersonal Violence* 2012;27(15):2999-3015. doi: 10.1177/0886260512441072
47. Ferdos J, Rahman MM, Jesmin SS, et al. Association between intimate partner violence during pregnancy and maternal pregnancy complications among recently delivered women in Bangladesh. *Aggressive behavior* 2018;44(3):294-305. doi: 10.1002/ab.21752
48. Borders AE, Grobman WA, Amsden LB, et al. Chronic stress and low birth weight neonates in a low-income population of women. *Obstet Gynecol* 2007;109(2 Pt 1):331-8. doi: 10.1097/01.AOG.0000250535.97920.b5 [published Online First: 2007/02/03]
49. Rahman M, Hosen A, Khan MA. Association between Maternal High-Risk Fertility Behavior and Childhood Morbidity in Bangladesh: A Nationally Representative Cross-Sectional Survey. *The American journal of tropical medicine and hygiene* 2019 doi: 10.4269/ajtmh.19-0221 [published Online First: 2019/07/25]
50. Fall CHD, Sachdev HS, Osmond C, et al. Association between maternal age at childbirth and child and adult outcomes in the offspring: a prospective study in five low-income and middle-income countries (COHORTS collaboration). *The Lancet Global Health* 2015;3(7):e366-e77. doi: 10.1016/S2214-109X(15)00038-8
51. Mahande MJ, Obure J. Effect of interpregnancy interval on adverse pregnancy outcomes in northern Tanzania: a registry-based retrospective cohort study. *BMC Pregnancy and Childbirth* 2016;16(1):140. doi: 10.1186/s12884-016-0929-5
52. Veloso HJF, da Silva AAM, Bettiol H, et al. Low birth weight in São Luís, northeastern Brazil: trends and associated factors. *BMC Pregnancy and Childbirth* 2014;14(1):155. doi: 10.1186/1471-2393-14-155
53. Winkvist A, Rasmussen KM, Habicht J-P. A new definition of maternal depletion syndrome. *American journal of public health* 1992;82(5):691-94.

Table 1. A complete list and details of explanatory variables.

Variables	Collected data	Answer category
Socio-demographic variables		
Maternal education[1]	Maternal highest level of education	1 = No education; 2 = Primary; 3 = Secondary & above
Residence	Place of residence	1 = Urban; 2 = Rural
Economic status[2]	Wealth index of the family	1 = Poor; 2 = Middle; 3 = Rich
Employment status[2]	Employment status of the individuals	1 = Unemployed; 2 = Employed
Adverse maternal characteristics		
Underweight mother	The nutritional status (BMI) of mother was measured and if BMI was less than 18.5 kg/m^2 then she was underweight.	0 = No; 1 = Yes
Overweight/obese mother	The nutritional status (BMI) of mother was measured and if BMI was higher than 25.0 kg/m^2 then she was overweight and BMI was higher than 30.0 kg/m^2 then she was obese.	0 = No; 1 = Yes
Unwanted birth	The child birth was not wanted at that time	0 = No; 1 = Yes
Ever had a terminated pregnancy	The mother had a previous pregnancy termination history (abortion, miscarriage etc.)	0 = No; 1 = Yes
Victim of intimate partner violence (IPV)	The mother who were a victim of IPV such as beaten in front of child, beaten by husband when refuse to intercourse or burn food etc.	0 = No; 1 = Yes
ANC <4 times	The mother who had utilized ANC less than 4 times during pregnancy	0 = No; 1 = Yes
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years	The mother whose age at the time of the birth was less than 18 years	0 = No; 1 = Yes
Maternal age at birth >34 years	The mother whose age at the time of the birth was greater than 34 years	0 = No; 1 = Yes
Birth interval <24 months	The mother who gave birth with a birth interval of less than 24 months	0 = No; 1 = Yes
Birth order >3	The mother whose birth order was higher than 3	0 = No; 1 = Yes
Maternal age at birth <18 years and Birth interval <24 months[3]	The mother whose age at the time of the birth was less than 18 years with an interval of less than 24 months	0 = No; 1 = Yes
Maternal age at birth >34 years and Birth interval <24 months[4]	The mother whose age at the time of the birth was greater than 34 years with an interval of less than 24 months	0 = No; 1 = Yes
Birth interval <24 months and birth order >3	The mother whose birth order was higher than 3 with interval of less than 24 months	0 = No; 1 = Yes

Note: The analysis was restricted for children who were born within 5 years prior to the survey. High-risk fertility behavior variables categorization followed BDHS standard measure. [1] Primary and secondary education is defined as completing grade 5 and 10, respectively. [2] followed standard BDHS measure. [3] includes the categories "age at birth <18 years with birth order >3" and "age at birth <18 years with interval <24 months and birth order >3". [4] includes the categories "age at birth <34 years with interval <24 months" and "age at birth <34 years with interval <24 months and birth order >3". [5] includes obesity (BMI > 30.0 kg/m^2)

Table 2. The prevalence of low birth weight and its association with socio demographic risk factors, adverse maternal characteristics including maternal high-risk fertility behaviors in Bangladesh, BDHS 2014.

Background characteristics	Low birth weight (%, 95% CI)	p-value
Overall	19.9 (18.5-21.5)	
Socio-demographic variables:		
Residence		<0.001
Urban	17.5 (15.1-20.2)	
Rural	20.8 (18.9-22.8)	
Maternal education		<0.001
No education	26.6 (22.2-31.5)	
Primary	21.1 (18.2-24.3)	
Secondary and above	17.7 (16.0-19.7)	
Economic status		<0.001
Poor	22.3 (19.8-24.9)	
Middle	19.7 (15.8-24.3)	
Rich	17.7 (15.5-20.1)	
Employment status		0.683
Unemployed	19.6 (17.7-21.6)	
Employed	21.1 (18.1-24.4)	
Adverse maternal characteristics		
Underweight mother		<0.001
No	18.4 (16.6-20.2)	
Yes	24.9 (21.9-28.1)	
Overweight/obese mother		0.004
No	20.8 (19.1-22.5)	
Yes	15.9 (12.9-19.3)	
Taken ANC <4 times		<0.001
No	16.3 (14.4-18.4)	
Yes	21.6 (19.6-23.7)	
Unwanted birth		0.002
No	19.0 (17.4-20.7)	
Yes	24.6 (20.9-26.6)	
Ever had a terminated pregnancy		0.096
No	19.5 (17.9-21.2)	
Yes	22.8 (18.8-27.2)	
Victim of intimate partner violence		0.014
No	19.5 (17.8-21.4)	
Yes	21.0 (18.6-23.6)	
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years		<0.001
No	18.5 (17.0-20.2)	
Yes	29.2 (25.1-33.7)	
Maternal age at birth >34 years		0.204
No	19.5 (18.1-21.2)	
Yes	23.0 (19.9-30.9)	
Birth interval <24 months		<0.001
No	17.9 (16.7-19.7)	
Yes	26.6 (23.5-29.8)	
Birth order >3		0.008
No	19.3 (17.7-21.0)	
Yes	24.0 (20.2-28.3)	
Maternal age at birth <18 years and birth interval <24 months		<0.001
No	18.8 (17.3-20.5)	
Yes	22.4 (19.6-25.5)	
Maternal age at birth >34 years and birth interval <24 months		0.003
No	18.8 (17.2-20.5)	
Yes	27.1 (23.1-31.5)	
Birth order >3 and birth interval <24 months		0.011
No	19.7 (18.3-21.4)	
Yes	24.5 (18.0-32.5)	

Note: The sample was weighted. "No" values for low birth weight was omitted from the table and calculated for row percentage.

Table 3. Unadjusted and adjusted odds ratio to measure the association size of adverse maternal characteristics on newborn's low birth weight in Bangladesh, BDHS 2014.

Background characteristics	Low birth weight (LBW)	
	UOR (95% CI)	AOR (95% CI)
Socio-demographic variables:		
Residence		
Urban (RC)	1.00	1.00
Rural	1.34 (1.16-1.61) ***	1.22 (1.02-1.46) *
Maternal education		
No education (RC)	1.00	1.00
Primary	0.73 (0.59-0.90) **	0.72 (0.57-0.90) **
Secondary and above	0.54 (0.44-0.66) ***	0.57 (0.45-0.73) ***
Economic status		
Poor (RC)	1.00	1.00
Middle	0.87 (0.71-1.06)	1.03 (0.84-1.26)
Rich	0.68 (0.58-0.80) ***	0.97 (0.79-1.18)
Employment status		
Unemployed (RC)	1.00	1.00
Employed	1.04 (0.88-1.23)	1.02 (0.86-1.21)
Adverse maternal characteristics		
Underweight mother		
No (RC)	1.00	1.00
Yes	1.48 (1.25-1.72) ***	1.26 (1.06-1.49) **
Overweight/obese mother		
No (RC)	1.00	1.00
Yes	0.74 (0.61-0.91) **	0.98 (0.78-1.23)
Taken ANC <4 times		
No (RC)	1.00	1.00
Yes	1.44 (1.23-1.70) ***	1.23 (1.03-1.48) *
Unwanted birth		
No (RC)	1.00	1.00
Yes	1.29 (1.10-1.51) **	1.22 (1.03-1.44) *
Ever had a terminated pregnancy		
No (RC)	1.00	1.00
Yes	1.18 (0.97-1.43)	1.28 (1.05-1.57) **
Victim of intimate partner violence		
No (RC)	1.00	1.00
Yes	1.22 (1.04-1.42) **	1.23 (1.05-1.45) *
Maternal high-risk fertility behaviors		
Maternal age at birth <18 years		
No (RC)	1.00	1.00
Yes	1.81 (1.50-2.19) ***	1.42 (1.11-1.83) **
Maternal age at birth >34 years		
No (RC)	1.00	1.00
Yes	1.23 (0.89-1.71)	0.93 (0.63-1.39)
Birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.54 (1.32-1.80) ***	1.25 (1.01-1.55) *
Birth order >3		
No (RC)	1.00	1.00
Yes	1.30 (1.07-1.59) **	1.04 (0.83-1.33)
Maternal age at birth <18 years and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.31 (1.12-1.53) ***	1.26 (1.02-1.57) **
Maternal age at birth >34 years and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.34 (1.11-1.64) **	1.22 (0.97-1.54)
Birth order >3 and birth interval <24 months		
No (RC)	1.00	1.00
Yes	1.50 (1.09-2.06) *	1.68 (1.18-2.37) **

Note: Model was adjusted for all the predictors included in this table. Values with superscript asterisks *, **, and *** indicate $p<0.05$, $p<0.01$, and $p<0.001$, respectively. UOR: unadjusted odds ratio; AOR: adjusted odds ratio; CI: confidence interval; ANC: antenatal care.

Figure legend

Figure 01. Geographical prevalence (%, 95% CI) of low birth weight according to seven administrative divisions in Bangladesh (using data BDHS 2014).

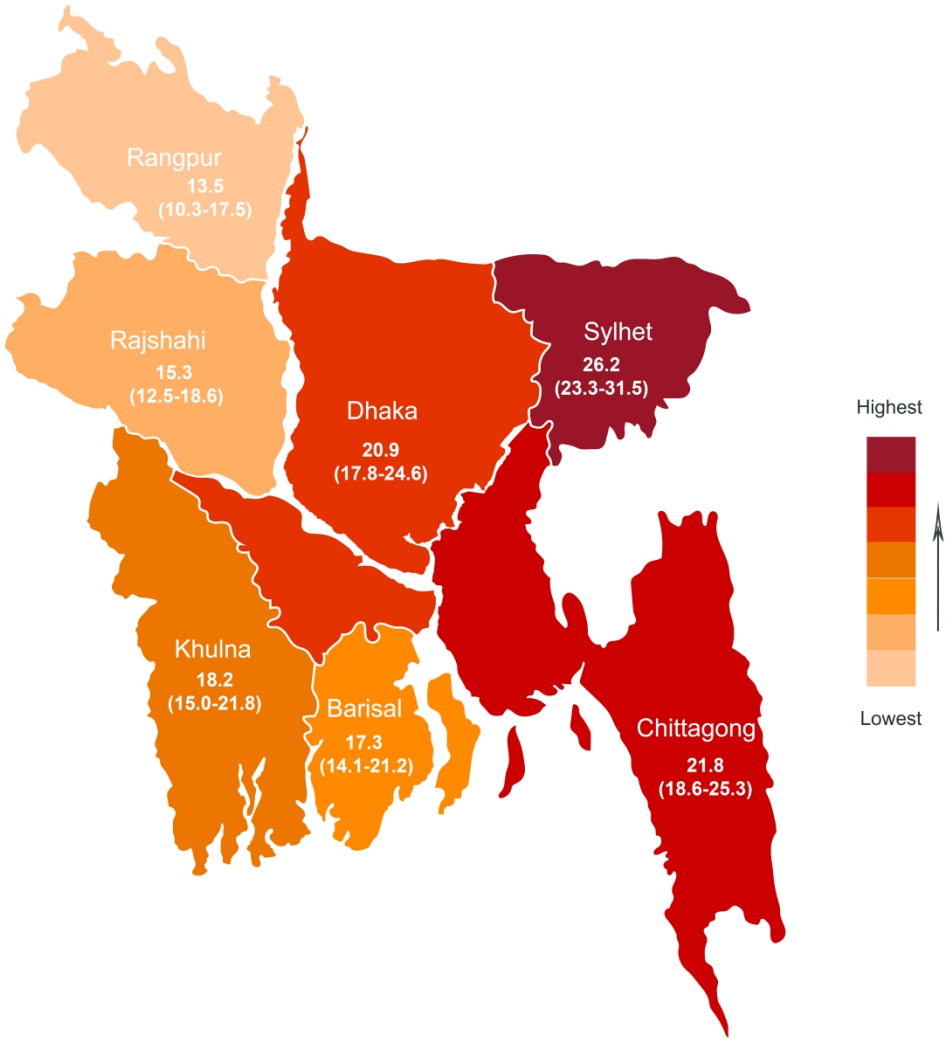

Fig 1. Geographical prevalence (%, 95% CI) of low birth weight according to seven administrative divisions in Bangladesh (using data BDHS 2014).

Table S1. STROBE checklist of items for observational studies

	Item No	Recommendation	Page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7*
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	NA

Results			**Page #**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	Table 1
		Cross-sectional study—Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	3

*Give information separately for exposed and unexposed groups in cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.