Effect of Maternal Exposure to Seasons during the Second and Third Trimesters of Pregnancy on Infant Birth Weight in Rural Bangladesh

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ABSTRACT

Background: Pregnant women belonging to agricultural communities of low- and middle-income countries often face seasonal food insecurity and energy stress.

Objectives: We aimed to investigate the effect of maternal exposure to different seasons during the second and third trimesters of pregnancy on infant birth weight in rural Bangladesh.

Methods: Information on 3831 singleton live births was obtained from the electronic databases of Matlab Health and Demographic Surveillance System and Matlab hospital of the International Centre for Diarrhoeal Disease Research, Bangladesh. We collected information on all term births from July 2011 to June 2015 and excluded congenital anomalies and observations with missing data. Each year was divided into 3 distinct seasons: the post-aman harvest period (January–April), the height of the monsoon (May–August), and the post-aus harvest period (September–December). Seasonal exposure was measured in weeks, and multivariable linear regression models were fitted to determine the independent effect of each week of exposure of different seasons during the second and third trimesters of pregnancy on birth weight.

Results: We observed peak birth weight in the post-aman harvest season, especially among infants born in March (mean ± SD: 2930.5 ± 462.1 g), and the lowest birth weight in the month of July (2830.6 ± 385.4 g) during the monsoon season. Regression analysis showed that exposure to the post-aman harvest season during the third trimester, and the post-aus harvest period during the second trimester of pregnancy had significant positive effects on birth weight. In the final adjusted model, each week of exposure to the post-aman harvest season during the third trimester was associated with a 6.3-g (95% CI: 1.6, 10.9 g; $P = 0.008$) increase in birth weight.

Conclusions: Infants born to women who were exposed to the post-aman harvest season for the entire third trimester (14 wk) were associated with 88.2-g higher weight at birth. Further investigations into the complex interplay between seasonal energy stress, maternal, and fetal nutrition and measures to alleviate it are warranted. *Curr Dev Nutr* 2020;4:nzaa016.

Keywords: seasonal food insecurity, prenatal exposure, birth weight, low birth weight, energy stress, rural, Bangladesh

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Abbreviations used: FSNSP, Food Security and Nutrition Surveillance Project; HDSS, Health and Demographic Surveillance System; icddr,b, International Centre for Diarrhoeal Disease Research, Bangladesh; LBW, low birth weight; LMIC, low- and middle-income country.

Introduction

Birth weight is a key determinant of infant health and survival (1). Infants born with low birth weight (LBW) are at increased risk of neonatal death, stunting, poor cognitive development, and chronic diseases such as ischemic heart disease, diabetes, and metabolic syndrome later in life (2). In low- and middle-income countries (LMICs), LBW is mostly attributed to intrauterine growth restriction, which itself is a consequence of chronic maternal undernutrition as well as acute nutritional insults during pregnancy. The prevalence of maternal and child undernutrition in Bangladesh is among the highest in the world. One in 3 pregnant women is underweight (3, 4) and 54% of women fall short of gaining adequate weight in the third trimester (5). Furthermore, 22.6% infants are born with LBW (6), and 36% of children aged <5 y are stunted (7).

Proper maternal nutrition before and during pregnancy is crucial for ensuring fetal growth and development. However, acute nutritional insults and inadequate weight gain during pregnancy can lead to LBW even if the mother has had a normal prepregnancy weight (8). Fetal growth has its peak velocity in the second and third trimesters of pregnancy and these are thus periods when fetal growth is particularly affected by nutritional perturbations (9).

In LMICs, rural communities with agriculture as the principal occupation are prone to seasonal energy stress due to an increase in food insecurity, agricultural activity, and infections, which affects maternal dietary intakes, nutritional status, gestational weight gain, and eventually birth weight (10–12). Asia has the highest number of adults exposed to severe agro-climatic seasonality and seasonal energy stress and South and South-East Asia are the largest contributors of adolescents and adults suffering from undernutrition (13, 14). Despite some recent development in crop production and employment generation in Bangladesh, a large number of people, especially in rural areas, are still at risk of seasonal food insecurity owing to dependency on manual labor and traditional agricultural strategies, which are highly affected by climatic variables (15).

In Bangladesh, the majority of people reside in rural areas and 87% of the rural households directly or indirectly rely on agriculture (16). About 80% of the total cropped area is occupied by rice cultivation, which accounts for >90% of total grain production (17). Ultimately, production of rice and the availability of agricultural work determine the household food security status in rural Bangladesh (18–20). Cultivation and production of rice vary across the country by regions and seasons. Traditionally, Bangladesh has 3 major rice crops: aus, aman, and boro. Aman is the most extensively cultivated rice crop during the wet monsoon season in the coastal (flood-prone islands and char areas of the country) areas as well as elsewhere and harvested from November to December. During the premonsoon season, the drought-resistant variety of rice "aus" is usually cultivated in the northern part of the country and harvested between July and August (21). However, the dry season "boro" rice (usually cultivated in November–December and harvested during March–April) is making an increasing contribution to the total rice production of Bangladesh and is grown throughout the country, especially in the northern part (21).

In Bangladesh, 57% of the people are food insecure (22), where food insecurity was defined as a situation when there is a lack of access among people toward safe and nutritious food in a sufficient amount (23). The food insecurity varies with the season because of the variations in crop production and agricultural employment. The seasonal pattern of food insecurity also varies between different regions of the country. For example, households from the areas of the costal belt, eastern hills, and haor (a wetland which is physically a bowl- or saucer-shaped shallow depression, also known as a back swamp) (24, 25) are more food insecure during the rainy monsoon season but households from the northern chars (a riverine island which is often unstable, usually temporary, and reformed during and after the monsoons each year) (24) and northwest are opposite in terms of food insecurity during that period of the year (24). This seasonal nutritional stress due to household-level food insecurity has been found to be associated with an increased rate of maternal and child undernutrition in Bangladesh (26, 27). However, how prenatal exposure to seasons by trimesters of gestation influences birth weight remains largely unknown. Such information might help design targeted intervention programs for pregnant women in rural agrarian communities. In this study, we aimed to investigate the effect of maternal exposure to seasons during the second and third trimesters of pregnancy on infant birth weight in rural Bangladesh at Matlab.

Methods

Setting

The study was conducted in rural Bangladesh at Matlab, a subdistrict of Chandpur, which is a low-lying riverine area situated 55 km southeast of the capital of Bangladesh. Matlab is located between the south of the Surma–Kusiyara floodplain and the northern edge of the Young Meghna estuarine floodplain. It is comprised of smooth, almost level, floodplain ridges and shallow basins. The river Dhonagoda flows from the north to the south, bisecting this area into 2 approximately equal parts. Numerous canals also exist in the study area. These canals remain dry in the winter and become full of water during the monsoon (28). Because of its similarity to the coastal areas in terms of geography, vulnerability, and agricultural practice, Matlab has been considered by some a part of the coastal belt food-insecure zone in Bangladesh (24). The areas under the coastal belt are prone to natural and manmade disasters owing to its constantly changing geographic and geomorphologic situation. This particular zone, similarly to Matlab, consists of chars (29, 30).

Since 1966, International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) has been running an internationally recognized and unique Health and Demographic Surveillance System (HDSS) involving 142 villages of Matlab, comprising a population of 230,000 (31). The total surveillance area is divided into 7 blocks, of which 4 blocks containing 67 villages are called the icddr,b service area. The people residing in those areas receive maternal and neonatal care services from icddr,b. The other 3 blocks consisting of 75 villages, called the comparison area, receive similar services from government hospitals (32). icddr,b has a large central health facility in Matlab, which provides free-of-cost maternity and child health care to the women of reproductive age and children <5 y of age coming from half of the HDSS service area (31).

Study population and data source

We used Matlab SHEBA, an electronic database of Matlab hospital, to extract data for this study. SHEBA contains birth history records, including birth weight of infants born at Matlab hospital as well as of those who are born at nearby hospitals/clinics and later admitted to Matlab hospital for neonatal care within 72 h of birth. We extracted birth-related data for all infants born during July 2011–June 2015 whose birth histories were recorded in SHEBA. Data on mothers' sociodemographic information were retrieved from the electronic database of Matlab HDSS.

A total of 10,332 births took place in the Matlab service area (67 villages of the study area), of which 5392 (52.2% of total births in the designated area) births were recorded in the Matlab SHEBA during the specified period. After retrieval of birth history, we excluded cases with abortions and stillbirths (44), preterm (child birth occurred before 37 completed weeks of gestation) (33) and postterm (child birth occurred after 42 completed weeks of gestation) (34) births (362), and any congenital anomaly (49). We also excluded births where information about birth weight (510), gestational age at birth (305), mother's height (69), and asset score (178) was missing. The final data set contains information on 3831 singleton live births (37.1% of the total childbirths in this area) at gestational ages 37–42 wk taking place during July 2011–June 2015 at Matlab. Gestational age was based on last menstrual period and confirmed by ultrasonography when mothers came for antenatal care services at Matlab hospital. Trained nurses conducted the weight measurements of the newborns at Matlab hospital using a Tanita-1584 Baby Scale (digital weighing scale) with 20-g sensitivity.

Climate and seasons

Bangladesh has a tropical climate with a hot and rainy summer and a dry winter. April and May are the hottest months of the year and temperatures range between 36 and 41°C. Temperature swoops in the winter and averages 15–20°C during December–February. The climate is one of the wettest in the world, having an average of 2320 mm rainfall yearly (21, 35), ∼80% of which falls during the rainy monsoon (36). The agriculture of this country largely depends on these variations in rainfall and temperature across the year. The nationally representative Food Security and Nutrition Surveillance Project (FSNSP) has used a meaningful and practical classification of seasons which separates the harvest and lean periods in Bangladesh. This classification is convenient for tracking the variation in food security and associated changes in nutritional status at the population level throughout the year. For the present study, following the FSNSP, each year was divided into 3 seasons: the post-aman harvest period (January–April), the height of the monsoon (May–August), and the post-aus harvest period (September–December) (24).

Variables of interest

In this study, the length of maternal exposure (wk) to a season during the second and third trimesters of pregnancy was the predictor variable and infant birth weight (g) was the outcome variable. The second and the third trimester were defined as the period of pregnancy from the beginning of the 15th to the 28th completed week (37) and from the beginning of the 29th through the 42nd completed week, respectively (37). Each trimester has an equal length of 14 wk. Therefore, maternal exposure to a certain season during a specific trimester could be as high as 14 wk or as low as no exposure at all.

The following maternal and infant characteristics were considered as covariates: maternal age (≤19 y, 20–34 y, or ≥35 y) (38, 39), height (≤145 cm or >145 cm) (40), religion (Muslim or Hindu), socioeconomic status (wealth quintile) (5), mode of delivery (vaginal or cesarean) (41), infant sex (male or female) (42), birth order (first, second, third, or fourth or more) (43), and gestational age at birth (wk) (42). Wealth quintile, an indicator of household-level wealth consistent with expenditure and income measures, was computed by the HDSS using household asset data via principal component analysis (31).

Ethics statement

This study used deidentified routinely collected data which were available through the electronic databases of Matlab HDSS and Matlab hospital. The study did not involve any interviews with the participants. The study protocol was reviewed and approved by the icddr,b research and ethical review committees (Institutional Review Board of icddr,b).

Statistical analysis

We found birth weight to be normally distributed, and did not consider any transformations (data not shown). We presented the background characteristics of the participants as mean ± SD for continuous variables and frequency measures for categorical variables. We visualized the mean maternal exposure to different seasons during the second and third trimesters of pregnancy and mean birth weight by seasons. We used Pearson correlation test to evaluate the bivariate relations between the length of exposure to seasons during each trimester and birth weight. We fitted 6 separate multiple linear regression models to estimate the independent effect of exposure to each individual season during each trimester on birth weight. To further investigate the effect of exposure during 1 trimester adjusted for the effect of exposure during another, we built 3 additional multiple linear regression models keeping both the second- and third-trimester exposure to 2 consecutive seasons. All the covariates of a priori interest were included in the multivariable models. To estimate the strength of association, we calculated regression coefficients (β) with 95% CIs. Statistical significance was set at $P < 0.05$. All the statistical analyses were performed with Stata/PC version 14.1 (StataCorp).

TABLE 1 Background characteristics of mothers and infants[1]

Characteristic	*n* (%)
Maternal age, y	
≤19	730 (19.04)
20–24	2865 (74.73)
≥35	239 (6.23)
Maternal height, cm	
≤145	570 (14.87)
>145	3264 (85.13)
Religion	
Muslim	3485 (90.9)
Hindu	349 (9.1)
Wealth quintile	
Lowest	665 (17.34)
Second	691 (18.02)
Middle	749 (19.54)
Fourth	797 (20.79)
Highest	932 (24.31)
Mode of delivery	
Vaginal	2977 (77.65)
Cesarean	857 (22.35)
Infant sex	
Male	1897 (49.48)
Female	1937 (50.52)
Birth order	
1st	1646 (42.93)
2nd	1103 (28.77)
3rd	711 (18.54)
≥4th	374 (9.75)

[1] $n = 3831$.

Results

The mean maternal age was 24.8 ± 5.7 y (data not shown in the tables), and 19.1% of the mothers were adolescents. About 15% of the women were short-statured (≤145 cm). The majority of women were Muslim (90.9%), and about half belonged to families in the fourth (20.8%) or the highest (24.3%) wealth quintiles. The majority of the infants were delivered vaginally (77.6%), and 43% were born to primiparous mothers (**Table 1**). The mean gestational age at birth was 39.2 ± 1.2 wk (**Table 2**). In the present sample, the mean birth weight of the infants was 2866.9 ± 417.3 g and 15.6% of children were born with LBW (Table 2).

Figure 1 demonstrates the monthly and seasonal variation of birth weight and maternal exposure to different seasons during the

TABLE 2 Characteristics related to birth distributed among the different seasons[1]

Variable	Post-aman harvest season (January–April)	Height of the monsoon (May–August)	Post-aus harvest (September–December)	Overall
Births, *n*	1218	1198	1415	3831
Birth weight, g	2879.07 ± 443.79	2868.02 ± 399.27	2855.41 ± 408.47	2866.88 ± 417.25
Low birth weight	202 (16.58)	169 (14.11)	228 (16.11)	599 (15.64)
Gestational age, wk	39.25 ± 1.25	39.16 ± 1.15	39.20 ± 1.13	39.20 ± 1.15

[1]Values are *n* (%) or mean ± SD unless otherwise indicated.

second and third trimesters of pregnancy. Birth weight was found to be the highest in March (2930.5 ± 462.2 g) and lowest in July (2830.7 ± 385.4 g). Pearson correlation showed that infant birth weight was significantly associated with the length of maternal exposure to the post-aus harvest period during the second trimester ($R = 0.034$, $P < 0.037$) and the post-aman harvest period during the third trimester ($R = 0.067$, $P < 0.001$) (**Table 3**).

Bivariate analysis of different periods with the second and third trimesters of pregnancy showed significant associations only between the post-aman harvest period and the third trimester, and between the post-aus harvest period and the second trimester (Table 3). In the adjusted model, a similar trend was present. We found a significant association along with an increase of infant birth weight of 4.7 g (95% CI: 1.9, 7.5 g; $P = 0.001$) and 2.7 g (95% CI: 0.2, 5.1 g; $P = 0.037$) for each week of exposure to the post-aman harvest period during the third trimester and to the post-aus harvest period during the second trimester, respectively (**Table 4**). However, the combined exposure models revealed that, when adjusted for the exposure to the post-aus harvest period during the second trimester, each 1-wk increase in the length of exposure to the post-aman harvest period during the third trimester was associated with a 6.3-g (95% CI: 1.6, 10.9 g; $P = 0.008$) increase in infant birth weight. The effect of exposure to the post-aus harvest period disappeared in this model (**Table 5**).

Discussion

This study evaluated the effect of prenatal exposure to the major seasons during different trimesters of gestation on birth weight. The mean birth weight found in this study (2866.9 ± 417.3 g) was similar to the estimate reported in a recent nationwide survey (2898.5 ± 405.3 g) (6). We found that exposure to the post-aman harvest season (January–April) in the third trimester of pregnancy was significantly associated with birth weight; there was a significant increase of 6.3 g in birth weight for each week of exposure to the post-aman harvest season during the third trimester of pregnancy. This can be interpreted as follows: infants born to women who have been exposed to the post-aman harvest season for the entire third trimester (14 wk) are likely to be heavier by 88.2 g at birth.

Our finding is consistent with that of a study previously done in developing countries, which concluded that those communities which heavily depend on agriculture experience seasonal variation in average birth weight (22). Our study conforms to a prospective study conducted in India which showed that seasonal energy insufficiency was associated with lower birth weight and the effect was trimester specific (15). Fallis and Hilditch (44) found that average monthly birth weight in Zaire was as high as 2806 g at the beginning of the dry season (June) and reached the minimum (2610 g) in the wet season (November). They reasoned

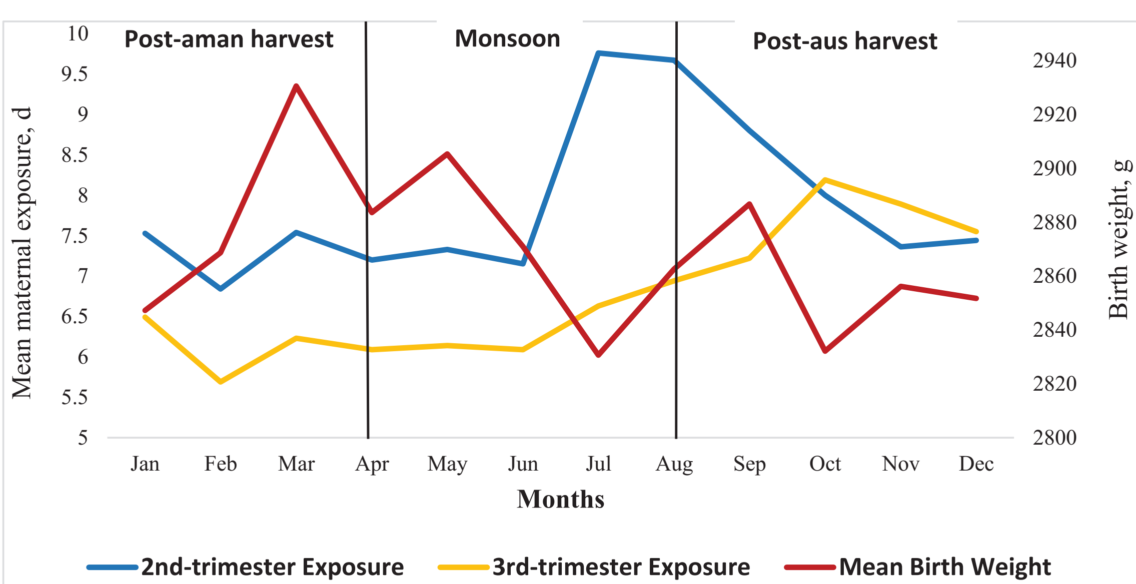

FIGURE 1 Mean maternal exposure to seasons during the second and third trimesters and birth weight by seasons.

TABLE 3 Results of Pearson correlation testing to evaluate the bivariate relations between the length of exposure to seasons during each trimester and birth weight

Exposure	Second trimester *r*, *P* value	Third trimester *r*, *P* value
Post-aman harvest period (January–April)	− 0.007, 0.683	0.067, 0.000
Height of the monsoon (May–August)	− 0.026, 0.109	− 0.002, 0.893
Post-aus harvest period (September–December)	0.034, 0.037	− 0.006, 0.722

that fetal growth was maximum during the dry season because of higher availability of food than during the wet season (44). Similar findings were reported by Prentice et al. (45) and Ceesay et al. (46) in a Gambian study and by Kinabo (47) in a study in Tanzania. Shaheen et al. (48) showed that birth weight had a dose–response relation with food supplementation among pregnant women in Bangladesh (49). Food insecurity was reported to have a strong association with birth size by another study done in Bangladesh; however, this study lacked data on actual birth weight and used mother's perceived size at birth instead (50).

Infant survival is directly related to fetal growth and birth weight. The difference in fetal growth is not only related to quantity and quality of the maternal diet but also to differences in timing and duration of nutritional insults during pregnancy. Food insecurity resulting from seasonal food shortages can cause energy stress to mothers. Like many developing countries, agriculture plays a vital role in the livelihood of Bangladesh. Rice is the staple cereal grain in Bangladesh, so its seasonal production and price dynamics have an immense effect on the food security situation of this country (18–20). In recent decades, it has been seen that an increase in rice production makes a major contribution to increasing food availability per capita, stability in grain price, and an overall reduction in poverty (19). However, this production of rice fluctuates owing to seasonal variation in different harvest periods (51–53). Traditionally, the largest harvest was aman followed by aus (54). However, boro has taken over the lead and is the high-yielding variety of rice transplanted mostly in the dry season during December–February and harvested in April–June (18, 21). In recent decades, boro has gained enormous popularity and is contributing to one-third of the total rice production (55), which ultimately creates a great amount of employment during its transplant and harvest seasons. During the monsoon season, aman is the principal crop, occupying almost half of the land for agricultural production and harvested in December (18). However, the post-harvest period of aman coincides with the transplant period of boro. This results in a lower price and an increase in the availability of rice along with higher income among the general population due to the increase in the opportunity for agricultural work. In recent years, there has also been an upward trend in the cultivation of winter robi crops and other cereal grains including maize, wheat and mung bean during October–November, which are harvested in winter (56). This ultimately generates additional employment, increases food sources, and improves dietary diversity in agricultural society during the post-aman harvest period. On the other hand, people living in coastal areas, where one-quarter of people are involved in unskilled labor, often are subjected to reduced working opportunities during the rainy monsoon season (35). In 2014 Bangladesh was ranked in the topmost position in the Climate Change Vulnerability Index, which will get worse by 2025, resulting in a reduction of overall crop production (57). Owing to its geographical characteristics Bangladesh is vulnerable to flood, land erosion, and crop damage in its riverine areas (58). Being flat and low-lying, and intersected with many canals and rivers, Matlab has to endure a high rainfall and annual flooding (59). All these phenomena have tremendous impacts on family income and food security during the monsoon season which exposes pregnant mothers to increased food insecurity and poor dietary diversity.

This study has several implications. First, this study identifies the vulnerable period of pregnancy that is more susceptible to possible energy stress and its effects such as LBW. Healthy birth weight may be achieved by consuming the proper amount of nutritious food during this period. Secondly, potential interventions such as giving supplementary food, food vouchers, or cash transfer during the lean periods can be evaluated through well-designed trials which will help improve maternal health and optimize birth weight. Thirdly, this finding affirms taking steps to include this information in the maternal counseling package given by the health workers. Pregnant women passing their third trimester during food-insecure seasons should be prioritized for intensive nutrition education and counseling during antenatal care. Counseling can also increase the diversity of food which will ultimately reduce the pressure on rice consumption and result in better nutritional outcomes for mothers. Fourthly, this result can give a hint to policy makers if and how they need to increase and rearrange the seasonal cultivation of rice and other food grains to increase production,

TABLE 4 Results of multiple linear regression showing the effect of maternal exposure (wk) to each season during the second and the third trimester on birth weight (g)[1]

Exposure	Second trimester		Third trimester	
	β (95% CI)	*P* value	*β* (95% CI)	*P* value
Post-aman harvest period (January–April)	− 0.82 (−3.3, 1.7)	0.520	4.73 (1.9, 7.5)	0.001
Height of the monsoon (May–August)	− 1.66 (−4.0, 0.7)	0.171	− 2.28 (−5.1, 0.5)	0.173
Post-aus harvest period (September–December)	2.67 (0.2, 5.1)	0.037	− 2.14 (−4.8, 0.5)	0.115

[1]All regression models are adjusted for maternal age, height, religion, socioeconomic status, mode of delivery, infant sex, birth order, birth period, and gestational age at birth.

TABLE 5 Results of multiple linear regression showing the effect of maternal exposure (wk) to 2 consecutive seasons during the second and the third trimester on birth weight (g)[1]

Combined exposure	β (95% CI)	P value
Scenario 1		
Exposure to the post-aman harvest period during the second trimester	2.25 (−1.9, 6.4)	0.291
Exposure to the height of the monsoon during the third trimester	− 4.31 (−9.0, 0.4)	0.073
Scenario 2		
Exposure to the height of the monsoon during the second trimester	− 0.38 (−4.3, 3.5)	0.850
Exposure to the post-aus harvest period during the third trimester	− 1.80 (−6.2, 2.6)	0.422
Scenario 3		
Exposure to the post-aus harvest period during the second trimester	− 1.69 (−5.8, 2.4)	0.416
Exposure to the post-aman harvest period during the third trimester	6.25 (1.6, 10.9)	0.008

[1]All regression models are adjusted for maternal age, height, religion, socioeconomic status, mode of delivery, infant sex, birth order, birth period, and gestational age at birth.

especially to address the issues of seasonal food insecurity. The nutritional supply of rural communities is highly dependent on rice production, but they have to rely on the mercy of nature to ensure the food supply. A better way can be introducing more flood- and salinity-resistant rice variants and increasing the productivity of the other food grains. Policy makers also need to focus on counseling among mothers to increase the food diversity. Finally, this result can help stakeholders to identify the most vulnerable populations such as pregnant women living in the food-insecure regions and redirect their current efforts to support the vulnerable population toward them in order to provide the necessary support packages during natural disasters and economic crises.

There have been several studies conducted in Bangladesh on food security where they tried to find out the lean season of the year and few of them wanted to look at the impact on growth among children and adults (49, 60). However, none of them have seen the impact of seasonal food insecurity on maternal pregnancy to find out the trimester-specific impact. Despite being a retrospective study, such uniqueness of this analysis has created food for thought for future researchers. The strengths of the present study include the availability of data on birth weight from ∼4000 infants along with maternal socioeconomic, demographic, and anthropometric data to adjust for which helps to understand the independent effect of seasonal food insecurity on birth weight. However, the study is not without limitations. The retrospective nature of the data which were collected as a part of routine measures makes it prone to measurement error. This study lacked data on individual-level prepregnancy weight, gestational weight gain, and nutrition intake during pregnancy. In addition, we didn't have trimester-specific fetal growth data to see the acute effect of nutritional insufficiency.

To conclude, exposure to the post-aman harvest period during the third trimester increases birth weight among infants in rural Bangladesh at Matlab. Policy makers may need to think about taking measures to address the issue of seasonal food insecurity, especially for the rural agrarian population.

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