

Nutritional status and birth outcomes among pregnant teenagers in Ghana

Linda Afriyie Gyimah (✉ lindagyimah17@gmail.com)

KNUST <https://orcid.org/0000-0002-8040-9396>

Reginald Adjetey Annan

Kwame Nkrumah University of Science and Technology

Charles Apprey

Kwame Nkrumah University of Science and Technology

Odeafo Asamoah-Boakye

Kwame Nkrumah University of Science and Technology College of Science

Wisdom Azanu

Komfo Anokye Teaching Hospital

Lutterodt E. Herman

Kwame Nkrumah University of Science and Technology College of Science

Anthony Kwaku Edusei

Kwame Nkrumah University of Science and Technology College of Health Sciences

Research article

Keywords: Pregnant adolescents, Nutritional factors, Birth outcomes, Gestational age, Anaemia

Posted Date: June 19th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-34839/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Background: Inadequate nutritional status during pregnancy can lead to adverse birth outcomes but this is more so for pregnant adolescents as they require nutrients to meet their needs for growth and that of the foetus. The study examined the relationship between nutritional status and birth outcomes among Ghanaian teenagers in rural and urban districts of the Ashanti Region, Ghana.

Methods In this prospective cohort study, 416 pregnant teenagers recruited at hospitals/health centres during antenatal care were followed until delivery. Data on weight, height (for body mass index), mid-upper arm circumference (MUAC), and nutrients intake using a repeated 24-hour dietary recall were determined. Blood samples were also taken and analysed for haemoglobin (Hb), serum levels of ferritin, prealbumin, vitamin A, total antioxidant capacity (TAC), C-reactive protein (CRP), and zinc protoporphyrin (ZPP). Birth weight, gestational age at birth, type of delivery, and outcome of delivery were collected as each teenager gave birth. Data were analysed using Chi-square (Fisher's exact) analysis, t-test, two-way ANOVA and multiple linear regression.

Results: 15.9% had low birth weight, 12.5% had preterm birth, 11.5% had a postpartum haemorrhage, and 3.1% neonatal deaths. Majority of the participants had inadequate intakes of energy (81.4%), protein (77.2%), vitamins A (97.1%) and E (97.7%), calcium (99.8%), iron (97.6%), folate (93.0%), zinc (83.7%), riboflavin (88.4%), thiamin (74.4%), and fiber (74.4%) intakes. Anaemia and wasting prevalence were 57.1% and 27.8%. Between-subject effects determined using Generalized Linear Modelling indicated MUAC ($p=0.058$), and gestational age at delivery ($p=0.023$) significantly affected birth weight. A multiple linear regression analysis indicated MUAC ($\beta=0.283$, $p=0.002$), BMI ($\beta=0.221$, $p=0.015$), gestational age ($\beta=0.285$, $p<0.001$), and ZPP ($\beta=0.131$, $p=0.057$) were significantly associated with birth weight ($F(23, 223)$, $P=0.008$, $R^2=1.941$).

Conclusions: Inadequate nutrients intake, anaemia, and LBW were found in these pregnant teenagers. Maternal MUAC, gestational age, and serum ZPP were associated with birth weight. Interventions for improving the nutritional status of teenagers before and during pregnancy are urgently needed to reduce the risk of adverse birth outcomes.

Background

Pregnancy comes along with physiological and metabolic changes that affect the developmental stages of the foetus, and consequently interrupt the birth weight of the newborn as well as other pregnancy outcomes such as gestation age at birth, stillbirth, and neonatal mortality [1]. Also, the needs for macro and micronutrients increase during pregnancy to cater for the changes in physiological and metabolic changes and fetal growth [1]. But for pregnant adolescent girls, the competition for nutrients that emerges when gravidity occurs coincides with their perpetuating teenage body development, and these increase their likelihood of undesirable birth outcomes [2]. The immediate shift involving nutrients reservation for the developing foetus in immature adolescent girls have created room for different maternal nutrition status to be explored. Besides the significant role of the maternal nutrient reserves, it is the aftermath of dietary changes during the pregnancy period which has the most significant effects on nutrition status and birth outcome [2].

Low birth weight (LBW) and preterm birth (PTB) prevention are among the maternal and public health priorities identified by the World Health Organization (WHO) [3]. Interventions by WHO were targeted at achieving a 30% reduction in LBW globally between 2012 and 2025 [3]. However, the progress of LBW reduction has been slower (1

percent worldwide yearly LBW reduction) from 2010 and 2015, compared to the 3 percent yearly target. Estimates by WHO show more than 20 million newborns globally suffered from LBW in 2015 [3], and adolescent pregnancy was a major contributor to LBW [4, 5]. In 2015, Ghana's LBW among women of reproductive age was 14.2% [3, 6].

Birth weight is a paramount health indicator, that reflects the nutrition status of mothers during conception, as well as newborn infants [7]. Children born to adolescent mothers are more likely to have low birth weight (LBW < 2.5 Kg), preterm birth, stillbirth, small-for-gestation age, and neonatal mortality [8, 9]. In Ghana, it is reported that children born by adolescent mothers have a 30% increased risk of neonatal death in the first 42 days of life and a 45% increased risk of stillbirth [10]. Additionally, LBW children have an increased risk of developing diabetes, hypertension, cardiovascular diseases, later in life [7].

A systematic review by Marvin-Dowle et al. [11] reported that pregnant adolescents have low macro and micronutrient intakes when compared to the recommended dietary allowances (RDA). Many studies suggest pre-pregnancy and pregnancy anthropometrics status such as excess weight gain, low weight, low MUAC, and maternal anaemia are strongly associated with preterm birth, and low birth weight infants in pregnant adults [12–18]. Another study in Ghana also reported an increase in oxidative biomarkers such as c-reactive protein, and low total antioxidant capacity during pregnancy [19]. During pregnancy, zinc protoporphyrin (ZPP) levels can be elevated when there is iron deficiency during erythropoiesis [20], and is less likely to be affected by inflammation [21]. It is therefore imperative to ensure adequate nutrition for women before and during pregnancy, to prevent adverse birth outcomes.

Because of the added nutrients requirements for teenage pregnant girls need for their growth, the above-reported deficiencies would have a severer consequence for pregnant teenagers. The lifelong negative consequences of poor birth outcomes make the need to address poor nutrition among adults, but more importantly teenagers even more crucial [2, 18].

However, among Ghanaian pregnant adolescents, much remains to be explored regarding the effects of nutrition on birth outcomes [22]. Ghana seeks to reach the set target for LBW reduction, giving considerable attention to pregnant adolescents is necessary [18]. This study sought to understand the determinants of birth outcomes among teenage pregnant girls in selected rural and urban districts of Ghana. To the best of our knowledge, this is the first of such studies and very timely as we seek to bridge the understanding gap on the influencers of birth outcomes in Ghana, to provide an impetus for strengthening interventions to improve birth outcomes among pregnant women in Ghana.

Methods

Study Design

This is a hospital-based longitudinal cohort study that involved 416 pregnant adolescents, aged 13 to 19 years old. Participants were recruited in communities in three urban districts (Kumasi Metropolis, Asante Akim Central and Ejisu Juaben) and five rural districts (Bosomtwi, Asante Akim South and North and Ahafo Ano North and South) in Ashanti Region, Ghana, from May to August 2018. The flow diagram for the study is shown in Fig. 1.

Study area and population

The study took place in 29 communities in three urban districts (Kumasi Metropolis, Asante Akim Central and Ejisu Juaben) and five rural districts (Bosomtwi, Asante Akim South and North and Ahafo Ano North and South) in Ashanti Region, Ghana. Ashanti Region has the largest population in Ghana, with an estimated population of 5,792,187, accounting for 19% of Ghana's total population in 2019 [23]. The adolescent population in 2017 stood at 19.8% of the total population, for those aged 15–19 years [24]. The report from the 2017 Ghana Maternal Health Survey showed a high prevalence of teenage pregnancy (12.2%) and adverse birth outcomes in the region [25]. All the selected districts have at least hospitals or Community-based Health Planning Services (CHPS) compounds/health centres depending on the geographical area of the district [26]. The study population were pregnant adolescents (aged 13 to 19 years old) with gestational age up to 32 gestational weeks, who were attending antenatal clinics at their district health facilities.

Recruitment

Using a reference low birth weight prevalence of 23% reported in a previous study by Ayensu et al. [27], and a marginal error of 5%, the sample size calculated was 420 but 416 pregnant adolescents were recruited within the study period. The sample size at birth outcome was reduced to 270, due to participants fallout from the study, while others traveled out of the region. Participants were recruited on a first come first served basis from hospitals and health centres during antenatal care visits. We obtained days in which antenatal clinics were held for pregnant adolescents in the hospitals/health centres involved in this study. On these dates, researchers visited the hospitals/health centres, and any pregnant adolescent within the required age group (13–19 years) was eligible for recruitment. Although special antenatal clinics were held for teenagers, attendance was low due to stigma. Hence, in the rural districts, community information centres were asked to announce and invite all pregnant adolescents to the health centres. Those that came and consented to the study were recruited.

Baseline study

Upon recruitment and signing of informed consent, dietary assessment and anthropometrics were done and blood samples collected for haematology and biochemical analysis. Questionnaires were used to collect data on antenatal visits, antenatal interventions uptake, and other pregnancy-related practices.

Dietary assessment

Dietary intakes of participants were taken using a repeated 24-hour dietary recall on 2 weekdays and 1 weekend. Household food measures were used to quantify food consumed by participants and these were later converted into grams using a standardized excel spreadsheet which has the measuring weight of Ghanaian foods. These grams were further computed into a nutrient analysis Microsoft excel software designed by the University of Ghana, Department of Food Science and Nutrition [28] which included mostly consumed Ghanaian foods. The mean nutrients intakes of macro and micronutrients were calculated by the software, and nutrients intakes were compared with recommended dietary allowances (RDAs)/estimated energy requirement (EER)/adequate intake (AI) [29].

Assessment of anthropometry

Weight, height, mid-upper arm circumference (MUAC) of participants was taken. Weight was measured with a weighing scale (model: DT602, India), to the nearest 0.1 kg while, height measurement in centimeter was taken using a portable stadiometer (Secca 213, India), all with barefoot. The values of the weight and height were used to calculate the body mass index (BMI) of the participants, and categorized using the WHO 2004 classification for BMI [30]. MUAC measurement was determined as a proxy indicator of maternal weight status since it has good

specificity in determining weight during pregnancy. An inelastic tape measure was used to take MUAC of participants by locating the midpoint between the acromion and olecranon bone on the left hand of participants. MUAC measurement less than 22.0 cm was termed severe wasting, 22.0 cm to less than 24.0 cm as mild/moderate wasting, and 24.0 cm and above as normal [31]. All anthropometric measurements were done in duplicates and averages were used.

Assessment of Haemoglobin (Hb) level

Two milliliters venous blood sample of participants was collected into anticoagulant EDTA tubes and used to determine haemoglobin levels. The haemoglobin level was determined using Sysmex Haematology system (USA). Using the WHO cut-off for Hb, haemoglobin values less than 11.0 g/dL was termed anaemia while, 11.0 g/dL, and above was termed no anaemia [32].

Assessment of Biochemical parameters

Serum ferritin is recommended by WHO in the assessment of iron levels [33]. Because serum ferritin is likely to be high in the presence of inflammation or infection, an inflammatory marker, CRP, was also assessed [34]. Five milliliters venous blood were taken from participants into serum gel separator tubes, and later centrifuged at 4000 rpm for 5 minutes. The supernatant serum was used for the analysis of serum levels of ferritin, prealbumin, vitamin A, c-reactive protein (CRP), total antioxidant capacity (TAC) and zinc protoporphyrin (ZPPP) using a sandwich enzyme-linked immunosorbent assay (ELISA) technique (from R&D system Inc, USA) at the Clinical Analysis Laboratory of the Department of Biochemistry and Biotechnology, Kwame Nkrumah University of Science and Technology. The optical density for serum ferritin, serum prealbumin, serum vitamin A and serum ZPP was measured at 450 nm wavelength within 15 minutes, with the help of multipurpose microplate ELISA reader (Mindray MR-96A). TAC was determined using the ferric reducing ability of plasma (FRAP) assay protocol described by Benzie and Strain [35]. TAC was estimated at wavelength 593 nm using a spectrophotometer (Mindray BA-88A, China). The standard curves of known concentrations of the respective recombinant value were used for the calculation of biochemical variables. All biochemical analyses were done in duplicates. Serum vitamin A deficiency was characterized when retinol levels were < 0.70 mmol/L [36]. Serum iron deficiency was termed as serum ferritin less than 15 $\mu\text{g/L}$ [37]. Low serum prealbumin was defined as serum levels less than 50–500 mg/L [38].

Follow up

After the baseline study, participants' telephone numbers and addresses were collected and entered into a book, and the expected date of delivery was entered for each participant. All participants were called the exact date to check if they had delivered, and if yes visited for the follow-up study.

Follow up study

A structured questionnaire was used to gather data on birth experiences for each participant. The questionnaire was divided into four sections; 1). birth outcome (e.g: mode of delivery, birth status, place of delivery), 2). maternal morbidity (e.g: postpartum haemorrhage, hypertension, pelvic inflammatory disease) and mortality (e.g: the period of death, cause of death), 3). infant mortality (e.g: the period of death, cause of death), and 4). infant anthropometrics (e.g: birth weight, birth length, head circumference, gestational age at delivery).

Birth outcomes were then recorded from birth records kept by the health centre/hospital for each participant.

Physical examination and clinical evaluation of the pregnant adolescent were done by qualified midwives to determine the gestation ages of some participants in the rural districts while, for others, a scan report of the gestation age from their antenatal card was collected. Birth outcomes such as gestational age at birth, birth weight, birth delivery method, neonatal mortality, stillbirth, spontaneous and induced abortions, postpartum morbidity of mothers were obtained from the hospitals/health centres records and categorized into those that were normal or adverse.

Preterm birth was defined as delivery less than 37 completed weeks of gestation [39]. Stillbirth was termed as the death of foetus that occurs before the complete ejection from its mother during conception, regardless of the duration of gravidity [39]. Postpartum haemorrhage was defined as a blood loss of more than 500 ml to 1,000 ml within the first day after birth [40]. Low birth weight was defined as a birth weight of newborns less than 2500 g (2.5 Kg) [41].

Data analysis

The IBM Statistical Package for Social Sciences version 25 (SPSS IBM Inc Chicago, USA) was used for data analysis. Data were thoroughly cleaned for missing data. Absolute and relative frequencies were determined for nutrients intake, anthropometric, haemoglobin level, and biochemical variables. Kolmogorov-Smirnov test of normality was performed to determine whether the continuous variables data met parametric assumptions. A chi-square (Fisher's exact test) cross-tabulation was performed to compare frequencies of nutrients intake, anthropometric variables, haemoglobin status, biochemical variables, and birth weight, and gestation age. An independent t-test and a two-way analysis of variance (ANOVA) (Generalized Linear Model test) were used for parametric comparisons, while Mann Whitney 'U' test was performed for non-parametric comparisons of all continuous variables, and birth weight, and gestation age. The mean differences of nutrients intake, anthropometric and biochemical variables were compared by birth weight and gestation age. Univariate and multivariate tests of variables associations were performed using the generalized linear model test. Data were presented as mean \pm SD for the continuous variable. Multiple linear regression test was performed to determine predictors of birth weight. All tests were 2-tailed, and p-values < 0.05 were termed significant.

Ethical approval for the study was obtained from the Committee on Human Research Publication and Ethics (CHRPE) of the Kwame Nkrumah University of Science and Technology, KNUST, (Kumasi, Ghana) (Reference: CHPRE/ AP/ 236/18). Study protocols/aims were first explained to all participants in their local language (Asante Twi). Written and signed informed consent was obtained from all participants by following CHRPE regulations before recruiting for the study. Also, parents/guardians signed a written consent form on behalf of participants less than 16 years old.

Results

Figure 2 shows birth outcomes associated with the pregnant adolescents. Adverse birth outcomes found among pregnant adolescents were low birth weight (15.9%), preterm birth (12.5%), stillbirth (2.2%), neonatal mortality (3.1%), postpartum haemorrhage (11.5%) and postpartum hypertension (2.2%). However, a greater percentage of the adolescent mothers had normal birth weight of child (84.1%), term birth (87.5%), and survived neonates (92.6%).

Nutrients adequacies and inadequacies among pregnant adolescents and their relationship with birth weight and gestational age are displayed in Table 1. The majority of the pregnant adolescents reported inadequacies in energy

(81.4%), protein (77.2%), vitamins A (97.1%) and E (97.7%), calcium (99.8%), iron (97.6%), folate (93.0%), zinc (83.7%), riboflavin (88.4%), thiamin (74.4%) and fiber (74.4%) intakes when compared to recommended dietary allowance (RDA)/estimated energy requirement (EER)/adequate intake (AI). The proportions of adolescent mothers who gave birth to low and normal-weight children did not significantly vary by nutrients intake ($p>0.05$).

Proportions of adolescent mothers who had preterm and term birth were not significantly related to nutrients intake except for fiber intake, in which, more teenagers who experienced preterm births had inadequate intake than termed birth participants (86.8% versus 70.6%, $p = 0.050$).

The relationship between anthropometric and birth outcomes is presented in Table 2. More than a fourth (27.8%) of the pregnant adolescents were either overweight/obese while, 1.9%, were underweight. Generally, 28.8% of the participants were wasted during pregnancy; of which, 5.5% were severely wasted. Higher proportions of adolescent mothers who had low birth weight (7.0%) were severely wasted than those who had normal birth weight (5.0%, $p = 0.032$). The proportions of adolescent mothers who had low and normal birth weight did not vary by BMI status ($p>0.05$). Also, proportions of adolescent mothers who had preterm and term birth did not vary by BMI status and MUAC status ($p>0.05$).

Table 3 indicates how haemoglobin, biochemical indices affect birth weight and gestation age. Anaemia prevalence (57.1%) was high among pregnant adolescents. The majority of the participants had low serum prealbumin (97.2%), serum vitamin A (86.4%) but normal serum ferritin (96.4%). The proportions for haemoglobin (Hb), serum ferritin, prealbumin, and vitamin A did not significantly vary by birth weight and gestation age ($p>0.05$). Also, the means of serum CRP, TAC, and ZPP did not vary by birth weight status and gestation ($p>0.05$).

The mean nutrients intake and anthropometrics by birth weight and gestational age at birth are presented in Supplement 1. The total mean intakes of carbohydrate ($268.1\pm 5.2\text{g}$), vitamin B₁₂ ($3.7\pm 0.3\text{mg}$), vitamin C ($103.1\pm 3.5\text{mg}$) and selenium ($79.5\pm 2.6\text{mg}$) were higher than the recommended dietary allowance (RDA). On the other hand, the total mean intakes for energy ($1811.3\pm 38.0\text{Kcal}$), protein ($56.1\pm 1.7\text{g}$), fiber ($22.9\pm 0.5\text{g}$), folate ($344.4\pm 9.9\mu\text{g}$), vitamins A ($216.8\pm 9.9\mu\text{g}$) and E ($7.6\pm 0.2\text{mg}$), iron ($12.1\pm 0.3\text{mg}$), and calcium ($304.9\pm 10.4\text{mg}$) were far lower than the RDA/EER/AI for the nutrients. The means intake of carbohydrate and fiber were significantly higher among adolescent mothers with term birth ($276.7\pm 6.8\text{g}$, $23.7\pm 0.7\text{g}$) than those with preterm birth ($237.3\pm 13.6\text{g}$, $19.4\pm 9.0\text{g}$) respectively. The mean nutrients intake did not vary by birth weight status ($p>0.05$). The mean MUAC differed slightly higher among adolescent mothers who had low birth weight ($26.7\pm 0.5\text{cm}$) than those who had normal birth weight ($26.1\pm 0.2\text{cm}$, $p = 0.051$). Also, mean serum ferritin was higher among adolescent mothers with term birth ($36.2\pm 1.0\mu\text{g/L}$) than those with preterm birth ($31.3\pm 2.4\mu\text{g/L}$, $p = 0.054$) respectively. All other mean nutrition status did not significantly differ by birth weight status and gestation age status.

The results of between-subject effects, conducted in univariate and multivariate Generalized Linear Model is presented in Table 4. Among all the multiple variables tests of associations on birth weight, only MUAC ($p=0.058$) and gestational age ($p=0.023$) had a significant effect on the child's birth weight.

A multiple regression analysis was run to predict birth weight from the study variables in Table 5. MUAC ($\beta= 0.283$, $p= 0.002$), BMI ($\beta= 0.221$, $p= 0.015$), gestation age ($\beta= 0.285$, $p<0.001$) and ZPP ($\beta= 0.131$, $p= 0.057$) were significantly associated with birth weight ($F(23, 223)$, $P = 0.008$, $R^2= 1.941$). All other variables were not significantly associated with birth weight.

Discussion

The present study aimed at determining nutritional factors influencing birth outcomes among pregnant adolescents in rural and urban communities in Ghana. The major findings are that the prevalence of low birth weight, preterm birth, stillbirth, neonatal mortality, haemorrhage, and postpartum hypertension were 15.9%, 12.5%, 2.2%, 3.1%, 11.5%, and 2.2%. Among the nutritional factors assessed, only MUAC status during pregnancy was associated with birth weight, while, fiber intake was associated with the gestational age of the mothers. Combined analyses of study variables showed that both the MUAC and gestational age of participants was effectual in determining birth weight. Gestational age and MUAC status during pregnancy were the significant predictors of birth weight.

The prevalence of low birth weight and preterm birth in our study is higher than that reported in other regions of Ghana [42, 43], the current 2017 Ghana Maternal Health Survey [44], in Brazil [8, 22], and Ethiopia [45]. Low birth weight is a significant underlying cause of neonatal and infant mortality in low-and-middle-income countries such as Ghana [44], which implies that participants with low birth weight are at increased risk of neonatal and infant mortality. A multiple regression analysis showed that maternal anthropometry and gestation age were co-effective in determining birth weight. The result indicated that MUAC ($\beta = 0.283$, $p = 0.002$), BMI ($\beta = 0.221$, $p = 0.015$), gestation age ($\beta = 0.285$, $p < 0.001$), and ZPP ($\beta = 0.131$, $p = 0.057$) were significantly associated with birth weight. The association from the standardized beta coefficient was positive which implies that a point increase in MUAC, BMI, gestation age, and ZPP values would likely result in an increase in the birth weight of babies, and vice versa. The results suggest that pregnancy anthropometrics and ZPP were the nutritional factors that co-effectively determined birth weight. Also, gestational age attained can predict birth weight in adolescent pregnancy. Studies have predicted that maternal gestational age and weight status are associated with birth weight [46–49].

The study found that the adolescent girls had inadequate intake of macronutrients; energy, protein, fiber, and micronutrients; thiamin, riboflavin, folate, vitamins A and E, iron, calcium during pregnancy and their mean intakes for the participants were far lower than RDA/EER/AI. Poor dietary intakes owing to their poor income status at that stage of life might have contributed to nutrients deficiencies in these populations. Another school of thought is that pregnancy comes along eating disorders including anorexia, food aversion, hyperemesis, and other conditions that might limit food intake [50, 51]. A study by Baker et al. [52] also found micronutrient deficiencies among pregnant adolescents in the United Kingdom. In our case, most of these teenagers were having their first pregnancy, and are less likely to adapt to these pregnancy symptoms, which can reduce their appetite for food, and consequently lead to nutrients deficiencies. However, there was no direct effect of nutrients intake on the infant's birth weight, which suggests dietary intake might be indirectly linked with birth weight, and influence by maternal weight. The same association was found between adolescent mothers with preterm and term birth, except for inadequate fiber intake, in which, preterm birth participants were more likely to have inadequate fiber intake. On the contrary, some studies had reported a relationship between maternal dietary intake and weight gain [53, 54], and weight gain and birth weight [49, 55, 56], low iron and folate intake and small-for-gestational-age babies [52] which suggest that fetal development may rely on nutrients stores during pregnancy. Notwithstanding to exception that, when maternal nutrients stores are depleted under certain circumstances such as severe hunger, there might also be an association between maternal diet and birth outcomes such as birth weight and gestation age [57, 58].

Although, maternal weight gain, nutritional status, and anaemia has a strong association with birth outcomes such as birth weight and gestational age [46–48, 54, 59]. Only a few prior studies have examined these risk associations among pregnant adolescents in a developing country like Ghana. In the current study, we found that 27.8% of the participants were either overweight or obese during pregnancy while, few of them were underweight. Based on the MUAC assessment, 28.8% of the participants were wasted. We found a significant relationship between birth

weight and MUAC status during pregnancy, which was consistent with a study by Assefa et al. [12]. Low birth weight adolescent mothers were more likely to be severely wasted during pregnancy. Additionally, we found a high prevalence of maternal anaemia, low serum levels of prealbumin (97.2%), and vitamin A (86.4%). High maternal anaemia prevalence among teenagers has been reported in the study area [60], another region in Ghana [61], and Malaysia [62]. This may be due to poor nutrition at adolescent age, since there is a competition of nutrients for their tissue growth, before that of the developing foetus [2, 60]. Anaemia prevalence was not significantly associated with birth outcome, but anaemic mothers had higher low birth weight. In contrast to our findings, studies done in Ghana, China and India have reported that iron deficiency anemia was significantly associated with low birth weight and preterm birth among pregnant adults [43, 63, 64]. Maternal low serum levels of prealbumin, ferritin, and vitamin A were found non-significantly higher among low birth weight participants than normal birth weight participants. In this study, adolescent mothers who had preterm birth were also non-significantly more likely to have anaemia, low serum levels of prealbumin, and vitamin A during pregnancy than those who had term birth. The study found that zinc protoporphyrin (ZPP) levels were associated with an infant's birth weight ($\beta = 0.131$, $p = 0.057$). ZPP as a biomarker is used to indicate an adequate supply of body iron to red blood cells (RBC) in the bone marrow [20]. ZPP is usually elevated when there is iron deficiency during erythropoiesis, which can be measured and used as a screening marker in pregnant women [20]. A study by Harthoorn-Lasthuizen et al. [65] reported that pregnant women who were anaemic throughout pregnancy had an elevated ZPP, indicating iron deficiency anaemia during RBC formation. Another study Schiman et al. [66] reported that an elevated ZPP level in the first trimester can predict 56% for third-trimester anaemia. In contrast to Schiman et al. findings, a study by Tchai et al. [67] reported that using only ZPP as a marker shows lower efficiency in predicting iron deficiency anaemia in pregnancy when compared to serum ferritin and ZPP/heme ratio. The current study did not report the prevalence of elevated ZPP in the participants, however, the majority of the study participants reported low haemoglobin levels (anaemia). It is unclear whether the anaemia prevalence in the participants affected the ZPP levels and/or, can result in elevated ZPP levels, which resulted in a significant association with birth weight. Therefore, using reports from previous studies of ZPP and iron deficiency anaemia in pregnancy, the current study suggests that monitoring of ZPP throughout pregnancy in the clinical setting can a good marker in deciding which maternal women will need iron supplementation. Maternal biochemical parameters such as total antioxidant capacity, c reactive protein did not show any significant association with birth outcomes, because some of these parameters are related in advanced maternal age births [19]. For adolescents, it is less likely to observe oxidative stress and other inflammatory conditions that would influence birth outcomes.

The implication of these results for clinical practice is that pre-pregnancy and pregnancy nutritional status of high-risk teenagers may need monitoring and intervention. Additionally, early intervention to modify the weight status of pregnant adolescents by improving the quantity and quality of maternal diet may influence the infant's birth weight and consequently lead to a reduction in other adverse birth outcomes such as preterm birth, stillbirth, neonatal, and infant mortality. In developing countries like Ghana, intervention programs and policies on women's health, especially pregnancy, have largely focused on the adults, with less attention to the vulnerable teenagers. This is because the ethical conduct of the society frowns at teenage pregnancy. Let not forget that, some of these nutritional factors such as maternal poor diet and low pregnancy anthropometry can alter fetal growth and development which would consequently harm their adult life [68]. We advocate that health intervention programs and nutrition education on improving nutritional status, and early recognition of pregnancy complications should be made inclusive, to incorporate the adolescents, to prevent poor nutritional status leading to adverse pregnancy outcomes among these populations.

Although the study reports interesting results among these cohorts in Ghana, some limitations may affect the interpretation of the results. To begin with, the small sample size for the birth outcome data might not have influenced some statistical associations and analyses. Secondly, we could not follow up on participants throughout pregnancy to collect nutritional factors, therefore the trends in changes in nutritional parameters that could affect birth outcomes were not observed. Lastly, this was a cross-sectional study, hence, future longitudinal cohorts/interventional studies would properly enlighten our understanding of nutritional factors underpinning adverse birth outcomes among teenagers.

Conclusions

Nutrients deficiencies, wasting, anaemia, low serum prealbumin, and vitamin A were found high among pregnant adolescents during pregnancy. Also, we observed poor adverse birth outcomes such as low birth weight, preterm birth, neonatal death, stillbirth, postpartum haemorrhage and hypertension among the participants. Maternal weight and gestational age were associated with birth weight. Health intervention programs and nutrition education on improving the nutritional status, and early recognition of pregnancy complications should be made inclusive, to incorporate the adolescents, to prevent poor nutritional status leading to adverse pregnancy outcomes among these populations.

Declarations

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Committee on Human Research Publication and Ethics (CHRPE) of the Kwame Nkrumah University of Science and Technology, KNUST, (Kumasi, Ghana) (Reference: CHPRE/ AP/ 236/18). Written and signed informed consent was obtained from all participants by following CHRPE regulations before recruiting for the study. Also, parents/guardians signed a written consent form on behalf of participants less than 16 years old.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no competing interests regarding the publication of this study.

Funding

The study received funding support from Nestle Foundation. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Authors' contribution

LAG, RAA, CA, HEL, WA, and AKE conceptualized the design and wrote the protocols for the study as well as participated in the supervision of data collection. LAG, RAA, CA, and OAB performed the analysis and interpretation of the results. LAG and OAB wrote the first and final draft manuscript. RAA and CA participated in the analysis and manuscript reviews. All authors read and approved the final manuscript.

Acknowledgments

The authors would like to acknowledge the field workers, staff nurses of all health centers in the two districts, and participants of this study.

Abbreviations

CRP- C-reactive protein, TAC- Total Antioxidant Capacity, ZPP- Zinc Protoporphyrin, MUAC- Mid-upper Arm Circumference, BMI- Body Mass Index, LBW- Low birth weight, PCS-Planned Caesarian Section, ECS-Emergency Caesarian Section, ND-Neonatal Deaths, SA-Spontaneous Abortion, and IA-Induced Abortion, OR- Odd ratio, AI- Adequate intake, RDA- Recommended Dietary Allowance, EER- Estimated Energy Requirement, WHO- World Health Organization.

References

1. Rohmawati L, Sari DK. and Sitepu M. Maternal zinc intake and its correlation with maternal serum zinc levels and neonatal birth weight and length. *Pakistan Journal of Nutrition*. 2020; 19: 245-252. DOI: 10.3923/pjn.2020.245.252.
2. Wallace JM. Competition for nutrients in pregnant adolescents: consequences for maternal, conceptus and offspring endocrine systems. *Journal of Endocrinology*. 2019; 242: T1-T19. <https://doi.org/10.1530/JOE-18-0670>.
3. World Health Organization. low birth weight estimates: levels and trends 2000–2015. 2019. Available at <https://www.who.int/news-room/detail/16-05-2019-too-many-babies-are-born-too-small>. Accessed 13 May 2020.
4. Ganchimeg T, Ota E, Morisaki N, Laopaiboon M, Lumbiganon P, Zhang J, et al. on behalf of the WHO Multi-country Survey on Maternal Newborn Health Research Network. Pregnancy and childbirth outcomes among adolescent mothers: A World Health Organization multi-country study. *BJOG*. 2014; 121 (Suppl. 1): 40–48.
5. Abebe AM, Fitie GW, Jember DA, Reda MM. and Wake GE. Teenage pregnancy and its adverse obstetric and perinatal outcomes at Lemlem Karl Hospital, Tigray, Ethiopia, 2018. *BioMed Research International*. 2020; 1-8. <https://doi.org/10.1155/2020/3124847>.
6. United Nations Children's Fund (UNICEF), World Health Organization (WHO). UNICEF-WHO Low birthweight estimates: Levels and trends 2000–2015. Geneva: World Health Organization; 2019. Available online at <https://apps.who.int/iris/bitstream/handle/10665/324783/WHO-NMH-NHD-19.21-eng.pdf>. Accessed 15 May 2020.
7. Alemu B. and Gashu D. Association between maternal anthropometry, hemoglobin and serum zinc concentration during pregnancy with birth weight. *Early Human Development*. 2020; 142: 104949. <https://doi.org/10.1016/j.earlhumdev.2019.104949>.

8. Ferreira VR, Jardim TV, Povia TR, Mendonca KL, Nascente FN, Carneiro CS, et al. Birth weight and its association with blood pressure. *J Pediatr (Rio J)*. 2018; 94(2): 184-191. <https://doi.org/10.1016/j.jped.2017.04.007>.
9. Wong SPW, Twynstra J, Gilliland JA, Cook JL. And Seabrook JA. Risk factors and birth outcomes associated with teenage pregnancy: A Canadian sample. *J Pediatr Adolesc Gynecol*. 2020; 33: 153-159. <https://doi.org/10.1016/j.jpag.2019.10.006>.
10. Yussif A, Ganyaglo GY, Kantelhardt EJ. and Kielstein H. The long-term effects of adolescent pregnancies in a community in Northern Ghana on subsequent pregnancies and births of the young mothers. *Reproductive Health*. 2017; 14: 178. DOI 10.1186/s12978-017-0443-x.
11. Marvin-Dowle K, Burley VJ. and Soltani H. Nutrient intakes and nutritional biomarkers in pregnant adolescents: a systematic review of studies in developed countries. *BMC Pregnancy and Childbirth*. 2016; 16: 268. DOI 10.1186/s12884-016-1059-9.
12. 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. <https://doi.org/10.1371/journal.pone.0039957>.
13. Sebayang SK, Dibley MJ, Kelly PJ, Shankar AV, Shankar AH. & Group SS. Determinants of low birthweight, small-for-gesta-tional-age and preterm birth in Lombok, Indonesia: Analyses of the birthweight cohort of the SUMMIT trial. *Tropical Medicine & International Health*. 2012; 17(8): 938–950. <https://doi.org/10.1111/j.1365-3156.2012.03039.x>
14. Cnattingius S, Villamor E, Johansson S, Bonamy AKE, Persson M, Wikström AK, et al. Maternal obesity and risk of preterm delivery, *JAMA*. 2013, 309, 2362–2370. <https://doi.org/10.1001/jama.2013.6295>.
15. Sharma M. and Mishra S. Effects of maternal health and nutrition on birth weight of infant. *Int J Sci Res*. 2014; 3(6): 855–858.
16. Gala UM, Godhia ML. and Nandanwar YS. Effect of maternal nutritional status on birth outcome. *Int J Adv Nutr Health Sci*. 2016; 4(2): 226–233.
17. Ahmed S, Hassen K. and Wakayo T. A health facility-based case-control study on determinants of low birth weight in Dasse town, Northeast Ethiopia: the role of nutritional factors. *Nutritional Journal*. 2018; 17: 103. <https://doi.org/10.1186/s12937-018-0409-z>.
18. Woldearmanuel GG, Geta TG, Mohammed TP, Shuba MB. and Bafa TA. Effect of nutritional status of pregnant women on birth weight of newborns at Butajira Referral Hospital, Butajira, Ethiopia. *SAGE Open Medicine*. 2019; 7: 1-7. DOI: 10.1177/2050312119827096.
19. Anto OE, Owiredu WKBA, Sakyi SA, Turpin CA, Ephraim RKD, Fondjo LA, et al. Adverse pregnancy outcomes and imbalance in angiogenic growth mediators and oxidative stress biomarkers is associated with advanced maternal age births: A prospective cohort study in Ghana. *PLoS ONE*. 2018; 13(7): e0200581. <https://doi.org/10.1371/journal.pone.0200581>.
20. Mwangi MN, Maskey S, Andang PEA, Shinali NK, Roth JM, et al. Diagnostic utility of zinc protoporphyrin to detect iron deficiency in Kenyan pregnant women. *BMC Medicine*. 2014; 12: 229.
21. Magge H, Sprinz P. and Adams WG. Zinc protoporphyrin and iron deficiency screening. *JAMA Pediatr*. 2013; 167(4): 361-367. doi:10.1001/jamapediatrics.2013.751.
22. Alves JGB, Cisneiros RMR, Dutra LPF. and Pinto RA. Perinatal characteristics among early (10–14 years old) and late (15–19 years old) pregnant adolescents. *BMC Research Notes*. 2012; 5: 531.

23. Ghana Statistical Service. Population by region. 2019. Retrieved 24 May 2020, from <http://www.statsghana.gov.gh/regionalpopulation.php?population=MTI5MzE30TU5OC40NDg1&&Ashanti®id=1>.
24. United Nations Population Fund. Adolescent and youth dashboard-Ghana. 2020. Available at <https://www.unfpa.org/data/adolescent-youth/GH>. Accessed 20 May 2020.
25. Ghana Statistical Service (GSS), Ghana Health Service (GHS), and ICF. Ghana Maternal Health Survey 2017: Key Indicators Report. 2018. Accra, Ghana: GSS, GHS, and ICF. Available online at <http://www2.statsghana.gov.gh/docfiles/PR95.pdf>. Accessed 20 May 2020.
26. Ghana Statistical Service. 2010 Population and housing census: District analytic report, Kumasi Metropolitan. 2014. Available at http://www2.statsghana.gov.gh/docfiles/2010_District_Report/Ashanti/KMA.pdf. Accessed 24 May 2020.
27. Ayensu J, Edusei A, Oduro I. & Larbie C. Status of some antioxidant micronutrient and pregnancy outcomes in Ghanaian status of some antioxidant micronutrient and pregnancy outcomes in Ghanaian Adolescents Attending Antenatal Clinic in Urban (Suntreso) and Rural (Mampong) Hospitals. *EJNFS*. 2017; 7(2): 120–127. <https://doi.org/10.9734/EJNFS/2017/24209>.
28. Food Science and Nutrition Department, University of Ghana. The nutrient analysis template software excel spreadsheet for Ghanaian foods, 2010.
29. National Academy of Sciences, Food and Nutrition Board, Institute of Medicine. Dietary reference intakes series. Washington, DC: National Academies Press, 2005. in text 'Mahan, L.K., Escott-Stump, S. and Raymond, J.L. (2012). Krause's Food and the Nutrition Care Process, 13th Editions, Elsevier Saunders Publication, Missouri, USA, page 1.
30. WHO expert consultation. Appropriate body mass index for Asian populations and its implications for policy and intervention strategies. *The Lancet*. 2004; 157-163.
31. World Health Organization (WHO). Maternal anthropometry and pregnancy outcomes. *Bull World Health Organ*. 1995, 73(suppl 1).
32. World Health Organization. Nutritional anaemias: tools for effective prevention and control. Geneva: World Health Organization; 2017; Available at: <https://apps.who.int/iris/rest/bitstreams/1091289/retrieve.pdf>. Accessed 4 June 2020.
33. WHO/CDC. Assessing the iron status of a population, second edition including literature reviews. Geneva, Switzerland; 2007.
34. University of Ghana. Ghana Micronutrient Survey 2017(GroundWork, University of Wisconsin-Madison, KEMRI-Wellcome Trust, UNICEF. Accra, Ghana).
35. Benzie I.F and Strain J.J. The Ferric Reducing Ability of Plasma (FRAP) as a Measure of "Antioxidant Power": The FRAP Assay. *Annal Biochem*. 1996; 239(1): 70-6. doi: 10.1006/abio.1996.0292
36. Global prevalence of vitamin A deficiency in populations at risk 1995-2005: WHO database on vitamin A deficiency. 2009, Geneva: WHO.
37. Serum Ferritin Concentrations for The Assessment of Iron Status and Iron Deficiency in Populations. Vitamin and Mineral Nutrition Information System. Geneva: World Health Organization; 2011.
38. Ozturk G, Ozgu-Erdinc AS, Ucar F, Ginis Z, Erden G. and Danisman N. Concentration of prealbumin and some appetite controlling hormones in pregnancies associated with hyperemesis gravidarum. *Annals of Biochemistry*. 2017; 54(2): 258-263. Doi.10.1177/0004563216654724.

39. Lawn JE, Gravett MG, Nunes TM, Rubens CE, Stanton C. Global report on preterm birth and stillbirth (1 of 7): definitions, description of the burden and opportunities to improve data. *BMC pregnancy and childbirth*. 2010; 10(Suppl 1): S1.
40. Kerr R, Eckert LO, Winikoff B, Durocher J, Meher S, Fawcus S, et al. Postpartum haemorrhage: Case definition and guidelines for data collection, analysis, and presentation of immunization safety data. *Vaccine*. 2016; 34(49): 6102–9. <https://doi.org/10.1016/j.vaccine.2016.03.039>.
41. United Nations Children’s Fund and World Health Organization. Low birth weight; country, regional and global estimate. 2004, UNICEF, New York. Available at https://www.unicef.org/publications/files/low_birthweight_from_EY.pdf. Accessed 20 May 2020.
42. Abubakari A, Taabia FZ. and Ali Z. Maternal determinant of low birth weight and neonatal asphyxia in the Upper West region of Ghana. *Midwifery*. 2019; 73: 1-7. <https://doi.org/10.1016/j.midw.2019.02.012>.
43. Adam Z, Ameme DK, Nortey P, Afari EA. and Kenu E. Determinants of low birth weight in neonates born in three hospitals in Brong Ahafo region, Ghana, 2016- an unmatched case-control study. *BMC Pregnancy and Childbirth*. 2019; 19: 174. <https://doi.org/10.1186/s12884-019-2315-6>.
44. Banchani E. and Tenkorang EY. Determinant of low birth weight in Ghana. Does quality of antenatal care matter?. *Maternal and Child Health Journal*. 2020; <https://doi.org/10.1007/s10995-020-02895-6>.
45. Wachamo TM, Bililign Yimer N, Bizuneh AD. Risk factors for low birth weight in hospitals of North Wello zone, Ethiopia: A case-control study. *PLoS ONE*. 2019; 14(3): e0213054. <https://doi.org/10.1371/journal.pone.0213054>.
46. Afriyie J, Bedu-Addo K, Asiamah EA, Boateng ST. Low birth weight among adolescents at Cape Coast Metropolitan Hospital of Ghana. *Int J Reprod Contracept Obstet Gynecol*. 2016; 5(12): 4242-424.
47. Belfort GP, Santos MMA, Pessoa LD, Dias JR, Heifelman SP. And Saunders C. Determinants of low birth weight in the children of adolescent mothers: a hierarchical analysis. *Ciência & Saúde Coletiva*. 2018; 23(8): 2609-2620, 2018. DOI: 10.1590/1413-81232018238.13972016.
48. Ukah UV, Bayrampour H, Sabr Y, Razaz N, Chan W-S, Lim KI, et al. Association between gestational weight gain and severe adverse birth outcomes in Washington State, US. A population-based retrospective cohort study, 2004-2013. *PLoS Med*. 2019; 16(12): e1003009. <https://doi.org/10.1371/journal.pmed.1003009>.
49. Skeith AE. And Caughey AB. Gestational weight gain and perinatal outcomes in adolescent births: A poster session. *American Journal of Obstetrics and Gynecology*. 2020; S750: 1219.
50. Charbonneau KD, Seabrook JA. Adverse birth outcomes associated with types of eating disorders: A review. *Can J Diet Pract Res*. 2019; 80(3): 131-136. doi: 10.3148/cjdpr-2018-044.
51. Dorsam AF, Preibl H, Micali N, Lorcher SB, et al. The Impact of Maternal Eating Disorders on Dietary Intake and Eating Patterns during Pregnancy: A Systematic Review. *Nutrients*. 2019; 11: 840; doi:10.3390/nu11040840.
52. Baker PN, Wheeler SJ, Sanders TA, Thomas JE, Clarke K, et al. A prospective study of micronutrient status in adolescent pregnancy. *Am J Clin Nutr*. 2009; 89: 1114–24.
53. Yin J, Quinn S, Dwyer T, et al. Maternal diet, breastfeeding and adolescent body composition: a 16-year prospective study. *Eur J Clin Nutr*. 2012; 66: 1329–1334. <https://doi.org/10.1038/ejcn.2012.122>.
54. Tran NT, Nguyen LT, Berde Y, et al. Maternal nutritional adequacy and gestational weight gain and their associations with birth outcomes among Vietnamese women. *BMC Pregnancy Childbirth*. 2019; 19: 468. <https://doi.org/10.1186/s12884-019-2643-6>.

55. Harper LM, Chang JJ. And Macones GA. Adolescent Pregnancy and Gestational Weight Gain: Do the Institute of Medicine Recommendations Apply? *Am J Obstet Gynecol*. 2011; 205(2): e1-e8. doi: 10.1016/j.ajog.2011.03.053.
56. Sahin ME. And Madendag IC. Effect of gestational weight gain on perinatal outcomes in low risk pregnancies with normal pre-pregnancy body mass index. *BioMed Research International*. 2019; 1-4. <https://doi.org/10.1155/2019/3768601>.
57. Lumey LH. and Stein AD. Offspring birth weights after maternal intrauterine undernutrition: a comparison within sibships. *American Journal of Epidemiology* 1997; 146:810–819.
58. Cates JE, Unger HW, Briand V, Fievet N, Valea I, Tinto H, et al. Malaria, malnutrition, and birth weight: A meta-analysis using individual participant data. *PLoS medicine*. 2017; 14(8):e1002373. <https://doi.org/10.1371/journal.pmed.1002373>.
59. Ayensu J, Annan R, Lutterodt H, Edusei A, Peng L. Prevalence of anaemia and low intake of dietary nutrients in pregnant women living in rural and urban areas in the Ashanti region of Ghana. *PLoS ONE*. 2020; 15(1): e0226026. <https://doi.org/10.1371/journal.pone.0226026>.
60. Ampiah MKM, Kovey JJ, Apprey C. and Annan RA. Comparative analysis of trends and determinants of anaemia between adult and teenage pregnant women in two rural districts of Ghana. *BMC Public Health*. 2019; 19: 1379. <https://doi.org/10.1186/s12889-019-7603-6>.
61. Tibamuya BA, Ganle JK, Ibrahim M. Anaemia at antenatal care initiation and associated factors among pregnant women in West Gonja District, Ghana: a cross-sectional study. *Pan Afr Med J*. 2019; 33: 325. doi: 10.11604/pamj.2019.33.325.17924.
62. Jusoh N, Ismail TAT. And Daud A. Anemia among teenage pregnancy in Northwestern Malaysia: What are the factors? *International Journal of Collaborative Research on Internal Medicine & Public Health*. 2015; 7(12): 196-205.
63. Yuan X, Hu H, Zhang M, Wei L, Liu J, Jiang J. and Yu B. Iron deficiency in late pregnancy and its associations with birth outcomes in Chinese pregnant women: a retrospective cohort study. *BMC Nutrition and Metabolism*. 2019; 16: 30. <https://doi.org/10.1186/s12986-019-0360-9>.
64. Kumari S, Garg N, Kumar A, Guru PKI, Ansari S, Anwar S, et al. Maternal and severe anaemia in delivering women is associated with risk of preterm and low birth weight: A cross sectional study from Jharkhand, India. *One Health*. 2019; 8: 100098. <https://doi.org/10.1016/j.onehlt.2019.10009>.
65. Harthoorn-Lasthuizen EJ, Lindemans J. and Lanfenhuijsen MMAC. Erythrocyte zinc protoporphyrin testing in pregnancy. *Acta Obstet Gynecol Scand*. 2000; 79: 660–666.
66. Schifman RB, Thomasson JE, Evers JM. Red blood cell zinc protoporphyrin testing for iron-deficiency anemia in pregnancy. *Am J Obstet Gynecol*. 1987; 157: 304–7
67. Tchai BS, Kwon SW. and Han JH. Evaluation of Erythrocyte Zinc Protoporphyrin/Heme Ratio for Iron-Deficiency Anemia in Pregnant Women. *The Seoul Journal of Medicine*. 1993; 34(3): 173-180.
68. Bjerregaard AA, Halldorsson TI, Tetens I, Frodi Olsen S. Mother's dietary quality during pregnancy and offspring's dietary quality in adolescence: Follow-up from a national birth cohort study of 19,582 mother-offspring pairs. *PLoS Med*. 2019; 16(9): e1002911. <https://doi.org/10.1371/journal.pmed.1002911>.

Tables

Table 1. Nutrients adequacies and inadequacies among pregnant adolescents and their relationship with birth weight and gestational age.

Nutrients	Total n(%)	Birth weight (Kg)		X ² (P value)	Gestational age (weeks)		
		Low BW	Normal BW		Pre-term	Term	X ² (P value)
Energy							
adequate	350(84.1)	35(81.4)	188(82.8)	0.051(0.827)	34(89.5)	218(82.3)	1.234(0.192)
dequate	66(15.9)	8(18.6)	43(17.2)		4(10.5)	47(17.7)	
Carbohydrate							
adequate	70(16.8)	5(11.6)	37(16.3)	0.601(0.646)	8(21.1)	41(15.5)	0.764(0.355)
dequate	346(83.2)	38(88.4)	190(83.7)		30(78.9)	224(84.5)	
Protein							
adequate	321(77.2)	35(81.4)	174(76.7)	0.465(0.557)	32(84.2)	204(77.0)	1.009(0.405)
dequate	95(22.8)	8(18.6)	53(23.3)		6(15.8)	61(23.0)	
Fiber							
adequate	310(74.5)	32(74.4)	162(71.4)	0.167(0.853)	33(86.8)	187(70.6)	4.427(0.050)
dequate	106(25.5)	11(25.6)	65(28.6)		5(13.2)	78(29.4)	
Thiamin							
adequate	315(75.7)	32(74.4)	173(76.2)	0.064(0.846)	32(84.2)	198(74.7)	1.638(0.230)
dequate	101(24.3)	11(25.6)	54(23.8)		6(15.8)	67(25.3)	
Riboflavin							
adequate	352(84.6)	38(88.4)	189(83.3)	0.706(0.500)	35(92.1)	223(84.2)	1.663(0.233)
dequate	64(15.4)	5(11.6)	38(16.7)		3(7.9)	42(15.8)	
Niacin							
adequate	252(60.6)	27(62.8)	133(58.6)	0.264(0.735)	26(68.4)	155(58.5)	1.363(0.290)
dequate	164(39.4)	16(37.2)	94(41.4)		12(31.6)	110(41.5)	
Vitamin B₆							
adequate	201(48.3)	19(44.2)	105(46.3)	0.062(0.868)	21(55.3)	121(45.7)	1.231(0.299)
dequate	215(51.7)	24(55.8)	122(53.7)		17(44.7)	144(54.3)	
Folate							
adequate	377(90.6)	40(93.0)	204(89.9)	0.414(0.778)	36(94.7)	240(90.6)	0.712(0.550)
dequate	39(9.4)	3(7.0)	23(10.1)		2(5.3)	25(9.4)	
Vitamin B₁₂							
adequate	226(54.3)	25(58.1)	123(54.2)	0.228(0.739)	26(68.4)	140(52.8)	3.261(0.082)
dequate	190(45.7)	18(41.9)	104(45.8)		12(31.6)	125(47.2)	
Vitamin A							
adequate	404(97.1)	42(97.7)	221(97.4)	0.014(1.000)	37(97.4)	258(97.4)	0.0(1.000)
dequate	12(2.9)	1(2.3)	6(2.6)		1(2.6)	7(2.6)	
Vitamin C							
adequate	179(43.0)	16(37.2)	96(42.3)	0.385(0.614)	21(55.3)	109(41.1)	2.709(0.116)
dequate	237(57.0)	27(62.8)	131(57.7)		17(44.7)	156(58.9)	
Vitamin E							
adequate	392(94.2)	42(97.7)	212(93.4)	1.189(0.481)	36(94.7)	251(97.4)	0.0(1.000)
dequate	24(5.8)	1(2.3)	15(6.6)		2(5.3)	14(5.3)	
Iron							
adequate	306(97.6)	43(100.0)	221(97.4)	1.162(0.594)	38(100.0)	260(98.1)	0.729(1.000)
dequate	10(2.4)	0(0.0)	6(2.6)		0(0.0)	5(1.9)	
Zinc							
adequate	348(83.7)	37(86.0)	187(82.4)	0.344(0.662)	33(86.8)	222(83.8)	0.235(0.813)
dequate	68(16.3)	6(14.0)	40(17.6)		5(13.2)	43(16.2)	
Selenium							
adequate	139(33.4)	12(12.9)	74(32.6)	0.367(0.597)	17(44.7)	83(31.3)	2.705(0.139)
dequate	277(66.6)	31(72.1)	153(67.4)		21(55.3)	182(68.7)	

Calcium	
adequate	415(99.8)
dequate	1(0.2)

Data are presented as frequency (percentage), BW- Birth weight, Fisher's exact P value, Bold value is significant at P < 0.05.

Table 2. Relationship between Anthropometric parameters and outcomes among Pregnant adolescents.

Variables	Total n(%)	Birth weight (Kg)		X ² (P value)	Gestational age (weeks)		X ² (P value)
		Low BW	Normal BW		Pre-term	Term	
status							
n (kg/m²)	23.1±0.1	23.4±0.5	23.3±0.2	0.985 [□]	23.6±0.5	23.3±0.2	0.683 [□]
Overweight	8(1.9)	0(0.0)	5(2.2)	2.041(0.564)	1(2.6)	5(1.9)	0.490(0.921)
Normal	294(70.7)	28(65.1)	156(68.7)		25(65.8)	184(69.4)	
Underweight	100(24.0)	14(32.6)	57(25.1)		10(26.3)	67(25.3)	
Missing	14(3.4)	1(2.3)	9(4.0)		2(5.3)	9(3.4)	
AC status							
n (cm)	26.2±0.1	26.7±0.5	26.1±0.2	0.051[□]	26.6±0.7	26.3±0.2	0.221 [□]
Severe	23(5.5)	3(7.0)	13(5.7)	6.879(0.032)	3(7.9)	13(4.9)	3.390(0.184)
Moderate/Mild	97(23.3)	3(7.0)	57(25.1)		4(10.5)	61(23.0)	
Normal	296(71.2)	37(86.0)	157(69.2)		31(81.6)	191(72.1)	

Data are presented as frequency (percentage), □- Mean±SEM (standard error mean) reported, □- Mann Whitney test performed, BMI- Body mass index, MUAC- Mid-upper arm circumference, some cells were less than 5, so Fisher's exact P value was reported, Bold value is significant at p < 0.05.

Table 3. Haemoglobin, biochemical indices and their relationship with birth outcomes

Variables	Birth weight (Kg)			X ² (P value)	Gestational age (weeks)		X ² (P value)
	Total n(%)	Low BW	Normal BW		Pre-term	Term	
Hb	10.2±0.1	9.9±0.2	10.1±0.1	0.234 [□]	10.2±0.2	10.1±0.1	0.983 [□]
Hbemia	232(57.1)	28(66.7)	121(54.3)	2.210(0.175) [¥]	24(64.9)	144(55.6)	1.133(0.375) [¥]
ZPP	174(42.9)	14(33.3)	102(45.7)		13(35.1)	115(44.4)	
TAC	36.0±0.8	35.8±2.6	35.4±1.1	0.949 [□]	31.3±2.4	36.2±1.0	0.054 [□]
TAC deficiency	14(3.6)	3(7.5)	7(3.3)	1.556(0.200) [¥]	1(2.7)	9(3.7)	0.086(1.000) [¥]
Prealbumin	375(96.4)	37(92.5)	205(96.7)		36(97.3)	237(96.3)	
Prealbumin	11.6±0.7	10.1±0.5	12.4±0.9	0.897 [□]	10.9±0.9	11.6±0.7	0.461 [□]
Prealbumin	382(97.2)	40(100.0)	208(97.2)	1.149(0.594) [¥]	37(100.0)	243(98.0)	0.759(1.000) [¥]
Prealbumin	11(2.8)	0(0.0)	6(2.8)		0(0.0)	5(2.0)	
CRP	0.7±0.1	0.4±0.0	0.8±0.1	0.306	1.1±0.4	0.6±0.1	0.834 [□]
CRP	336(86.4)	36(90.0)	180(84.9)	0.713(0.471) [¥]	33(89.2)	213(86.6)	0.192(0.798) [¥]
CRP	53(13.6)	4(10.0)	32(15.1)		4(10.8)	5(13.4)	
CRP	5.0±0.4	3.8±0.5	5.4±0.6	0.358 [□]	5.3±1.4	6.5±1.7	0.380 [□]
CRP	1.2±0.0	1.1±0.0	1.2±0.0	0.702 [□]	1.3±0.1	1.2±0.1	0.118 [□]
CRP	34.0±1.0	35.8±6.3	32.7±2.2	0.258 [□]	35.6±7.4	32.1±1.9	0.523 [□]

¥Data are presented as frequency (percentage), ¥Fisher's exact P value, □- Mean±SEM (standard error mean) reported, □- Mann Whitney test performed, BW- Birth weight, Hb- Haemoglobin, ZPP- Zinc protoporphyrin, TAC- Total antioxidant capacity, CRP- C-reactive protein, P values are significant at p < 0.05.

Table 4. Tests of between-subject effects of multiple variables on birth weight

Tests of Between-subjects Effects						
Measured: Birth weight						
Transformed variable: Average						
Source	Type III Sum of Squares	df	Mean Square	F	P value	
Intercept	2.154	1	2.154	47.327	0.033	
Energy	0.207	1	0.207	1.526	0.218	
Carbohydrate	0.036	1	0.036	0.269	0.605	
Protein	0.078	1	0.078	0.577	0.448	
Vitamin B ₁₂	0.003	1	0.003	0.02	0.873	
Folate	0.064	1	0.064	0.473	0.492	
Vitamin A	0.036	1	0.036	0.265	0.607	
Vitamin E	0.031	1	0.036	0.228	0.634	
Iron	0.059	1	0.059	0.436	0.510	
Zinc	0.011	1	0.011	0.082	0.775	
BMI	0.236	3	0.079	0.58	0.629	
MUAC	0.783	2	0.391	2.89	0.058	
Hb	0.247	1	0.247	1.82	0.179	
Serum Ferritin	0.196	1	0.196	1.448	0.230	
Serum Prealbumin	0.204	1	0.204	1.504	0.221	
Serum vitamin A	0.063	1	0.063	0.467	0.495	
Gestational age	0.713	1	0.713	5.265	0.023	
MUAC vs Gestational age	0.190	2	0.095	0.261	0.770	
Error	94.153	259	0.364			

General Linear Model test for univariate and multivariate parameters, BMI- Body mass index, Hb- Haemoglobin, MUAC- Mid-upper arm circumference, Bold values are significant at p<0.05.

Table 5. Multiple Linear regression analysis predicting birth weight

Variable	Unstandardized	standardized	P	95% Confidence	
	coefficient	coefficient		Interval	
	B	Beta, β	value	Lower	Upper
Energy	0.0	0.081	0.742	0.0	0.0
Carbohydrate	0.01	0.119	0.623	-0.022	0.012
Protein	0.004	0.180	0.300	-0.012	0.004
Fiber	0.005	0.091	0.572	-0.022	0.012
Thiamin	0.076	0.107	0.420	-0.261	0.109
Vitamin B ₆	0.096	0.144	0.305	-0.280	0.088
Folate	0.0	0.061	0.381	0.0	0.001
Vitamin B ₁₂	0.008	0.051	0.559	-0.018	0.033
Vitamin A	0.0	0.008	0.944	-0.001	0.001
Vitamin C	0.001	0.068	0.470	-0.001	0.003
Vitamin E	0.008	0.060	0.686	-0.033	0.050
Iron	0.013	0.135	0.552	-0.030	0.057
Zinc	0.009	0.061	0.718	-0.040	0.057
BMI	0.042	0.221	0.015	0.008	0.076
MUAC	0.054	0.283	0.002	-0.088	0.020
Hb	0.034	0.071	0.269	-0.027	0.096
Ferritin	0.002	0.047	0.471	-0.003	0.007
Prealbumin	0.002	0.040	0.549	-0.009	0.005
CRP	0.0	0.006	0.938	-0.013	0.012
serum vitamin					
A	0.049	0.106	0.182	-0.023	0.121
TAC	0.023	0.022	0.748	-0.119	0.165
ZPP	0.002	0.131	0.057	-0.005	0.000
Gestation age	0.086	0.285	<0.001	0.048	0.124

β - Slope/regression co-efficient, BMI- Body mass index, Hb- Haemoglobin, MUAC- Mid-upper arm circumference, ZPP- Zinc protoporphyrin, TAC- Total antioxidant capacity, CRP- C-reactive protein, Bold values are significant at $p < 0.05$.

Figures

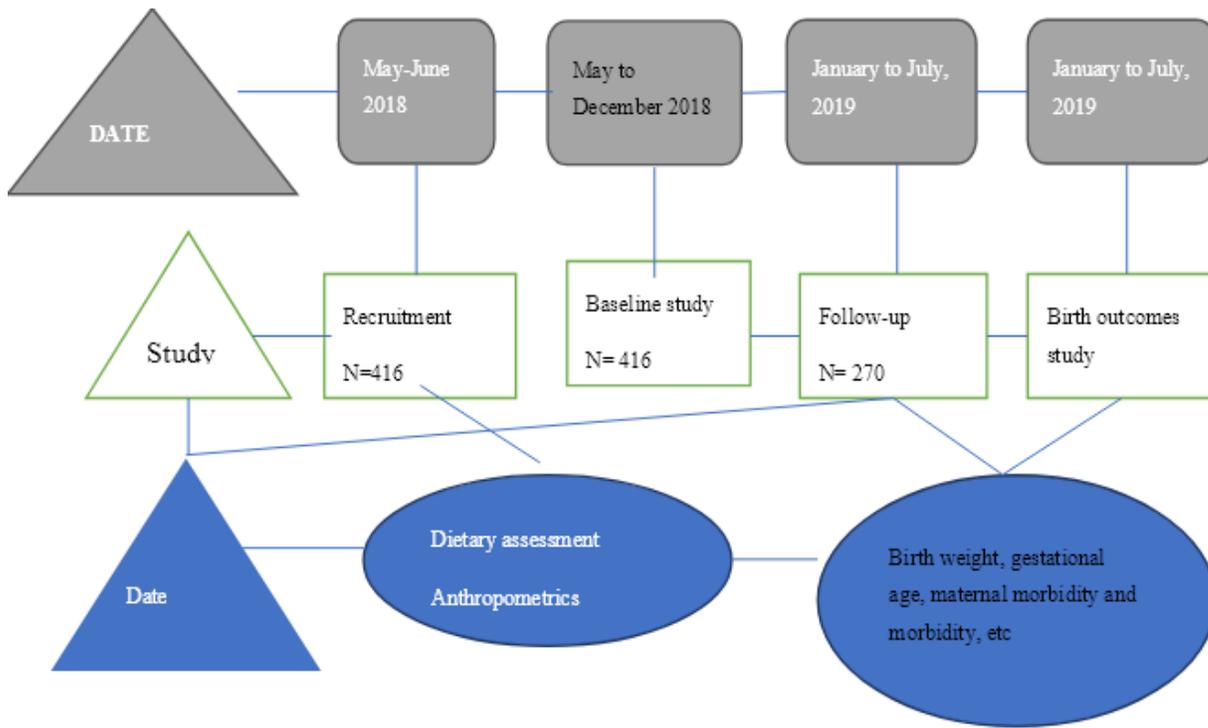


Figure 1

Study flow show date and duration, study design and data collected

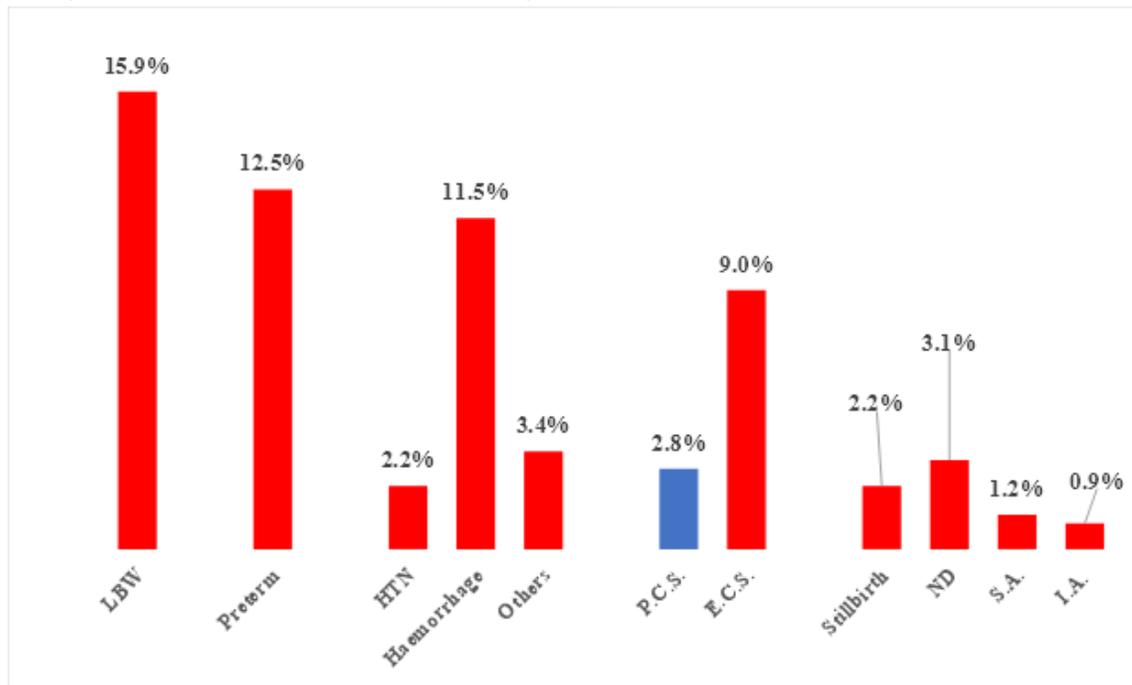


Figure 2

Birth outcomes associated with pregnant adolescents: LBW-Low birth weight, HTN- Hypertension, PCS-Planned Caesarian Section, ECS-Emergency Caesarian Section, ND-Neonatal Deaths, SA-Spontaneous Abortion and IA- Induced Abortion

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [ManuscriptSTROBEchecklistv4combined1.doc](#)