REVIEW ARTICLE

The Impact of Dietary Intake and Nutritional Status on Birth Outcomes Among Pregnant Adolescents: A Systematic Review

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Abstract

Birth outcomes have been linked to the overall maternal general health including nutrition as well as maternal age during pregnancy. Compared to adults, delivery outcomes during adolescence are poor. Nutrient intake and nutrition status during adolescent pregnancy may be linked to birth outcomes. This review aims to identify the association between dietary intake and nutrition status of pregnant adolescents and their maternofetal outcomes. Literature search on nutrient intake and nutritional status of pregnant adolescents (aged 11-19 years) which identified 17 English papers from 1995 to 2019 was reviewed. Papers that did not include data on birth outcomes in relation to nutrient intake or nutritional status were excluded. The review showed that most micronutrients with the exception of Riboflavin, vitamins B12 and C were below the recommended levels whilst macronutrients levels were above the recommended levels. Energy intakes were also below the recommended levels. Most studies presented normal hemoglobin levels in the first trimester of pregnancy but these levels decreased as pregnancy progressed to the third trimester leading to a high prevalence of anemia. Well-regulated provision and intake of micronutrient supplementation and nutrition education to improve healthy eating habits will significantly reduce poor birth outcomes such as low birth weights (LBW), still births, preterm deliveries, small or large for gestational age (SGA and LGA) and intrauterine growth restrictions in pregnant adolescents. This review provides to a large extent evidence to support the importance of adolescent nutrition and birth outcomes. There is the need to implement policies to improve adolescent nutrition through a multisectoral approach.

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Introduction

Adolescent pregnancy can be defined as pregnancy in girls between 10 to 19 years (WHO, 2004). Adolescence, a growth period, is characterised by fast physical, social and emotional changes. These changes during adolescence affects nutritional needs in addition to the ability to supply these needs (Jacobson, 1997). There is therefore an increase in nutrients demand during adolescence due to the increase in the growth process. For instance, there is a rapid increase in bone mass which requires proteins, vitamins D and calcium (Ca), increase in blood volume and muscle mass which also requires iron. Adolescent pregnancy may contribute to high risk of poor fetal outcomes because of continuous maternal growth (if the mother is still growing) leading to competition for nutrients which limits the overall nutrients required of a growing fetus. Maternal undernutrition may be related to low intake of dietary needs as well as severe nausea and vomiting (Snell *et al*., 1998) and placental insufficiency which lowers the transfer of nutrients from the mother to the fetus (Ehrhardt and Bell, 1995). Poorly spaced child birth can also lead to a depletion of maternal nutrition status (King, 2003). Poor nutritional status during adolescence can therefore have dire consequences on both maternal and fetal outcomes as well as long term consequences on individuals such as sexual maturation delay, loss of final adult height, osteoporosis, hyperlipidemia, diabetes mellitus type 2, obesity (Stanner, 2004), stunting which leads to underdeveloped pelvic bones, and consequently a contracted pelvis (Kavishe, 1993). Alternatively, when good dietary habits are established during adolescence it promotes growth and development, decreases risk of chronic disease and improves quality of life (Caldwell *et. al.,* 1998). Kramer (1987) suggested that the age at which mothers give birth and poor nutritional status are not the only factors that contribute to poor birth outcomes; primiparity and low socio economic status can also affect birth outcomes. A symposium held in Washington on iron status before child birth noted that about 16 – 55% of adolescents are anemic before pregnancy occurs and that preventing existing anemia during pregnancy is not enough considering the fact that most girls seek ante natal care in their second or third trimesters. Thus, pre-pregnancy programs to improve iron levels should be emphasized (Kurz and Galloway, 2000).

Globally, about 16 million adolescent girls aged between 15 to 19 years give birth each year which is roughly 11% of all births, with 95% occurring in developing countries (World Health Organisation, 2011). The leading cause of death among adolescent girls globally is complications in pregnancy and childbirth such as maternal mortality, low birth weight, preterm delivery and severe neonatal conditions (Ganchimeg *et al*., 2014). Some studies have assessed the complications in adolescent pregnancy in relation to other socio – economic factors (Loto *et al*., 2004; de Vienne *et al*., 2009). Several studies have also focused on nutritional status as well as the intake of micro and macro nutrients of pregnant adolescents. Systematic reviews that have been published have concentrated on micronutrients and macronutrient (Marvin-Dowle, 2016) or complications in adolescents pregnancy (Grønvik and Sandøy, 2018) without relating them to specific maternofetal outcomes or nutritional deficiencies. Some aspects of diets like iodine, caffeine, alcohol and fiber intake have not been considered. A few of the studies have been conducted in developing and under developed countries where most of these complications of adolescent pregnancy outcomes were predominant. This review seeks to identify the impact of nutrient intake and nutritional status of pregnant adolescents on birth outcomes.

Search Strategy

The following databases were searched to access the data; Science Direct, Journal of Nutrition, Plos One, PubMed, Cochrane, Directory of Open Access Journals and Journal of Adolescent Health. The search was developed by combining the terms in Table 1 for publications from 1995 to 2019.

Table 1. Search Terms

Theme	Pregnancy	Nutrition	Birth Outcomes
Search terms	pregnant adolescent teenage pregnancy young maternal age	nutrient intake dietary intake micronutrients energy/protein macronutrients supplemen*	birth weight pre term delivery neonatal deaths perinatal deaths

**truncation of search term*

Inclusion and Exclusion Criteria

Studies used for this review were limited to English publications from 1995 to March 2019 that provided data regarding nutritional status and birth outcomes in healthy pregnant adolescents (aged 11-19 years). Studies which used a small number of adolescent in comparison with their adult counterpart were excluded. Systematic reviews, studies with medical complications like HIV, diabetes as well as animal studies were excluded. Studies that did not relate nutrient/dietary intake or nutritional status of pregnant adolescents to birth outcomes were also excluded.

Search Results

The search from the databases used offered over 4375 papers and 4 papers from hand searching of reference lists and citations. A review of the references led to the rejection of 4014 papers leaving 343 papers. Further evaluation of abstracts led to the elimination of 311 papers. The full articles of the 32 papers remaining were reviewed on their methods, inclusion criteria and abstracts resulting in 17 papers being retained (the selection process is shown in fig. 1 below). The selected papers were further categorized into 3;

1. Dietary intakes and birth outcomes
2. Micronutrient supplementation and birth outcomes

3. Nutritional status and birth outcomes

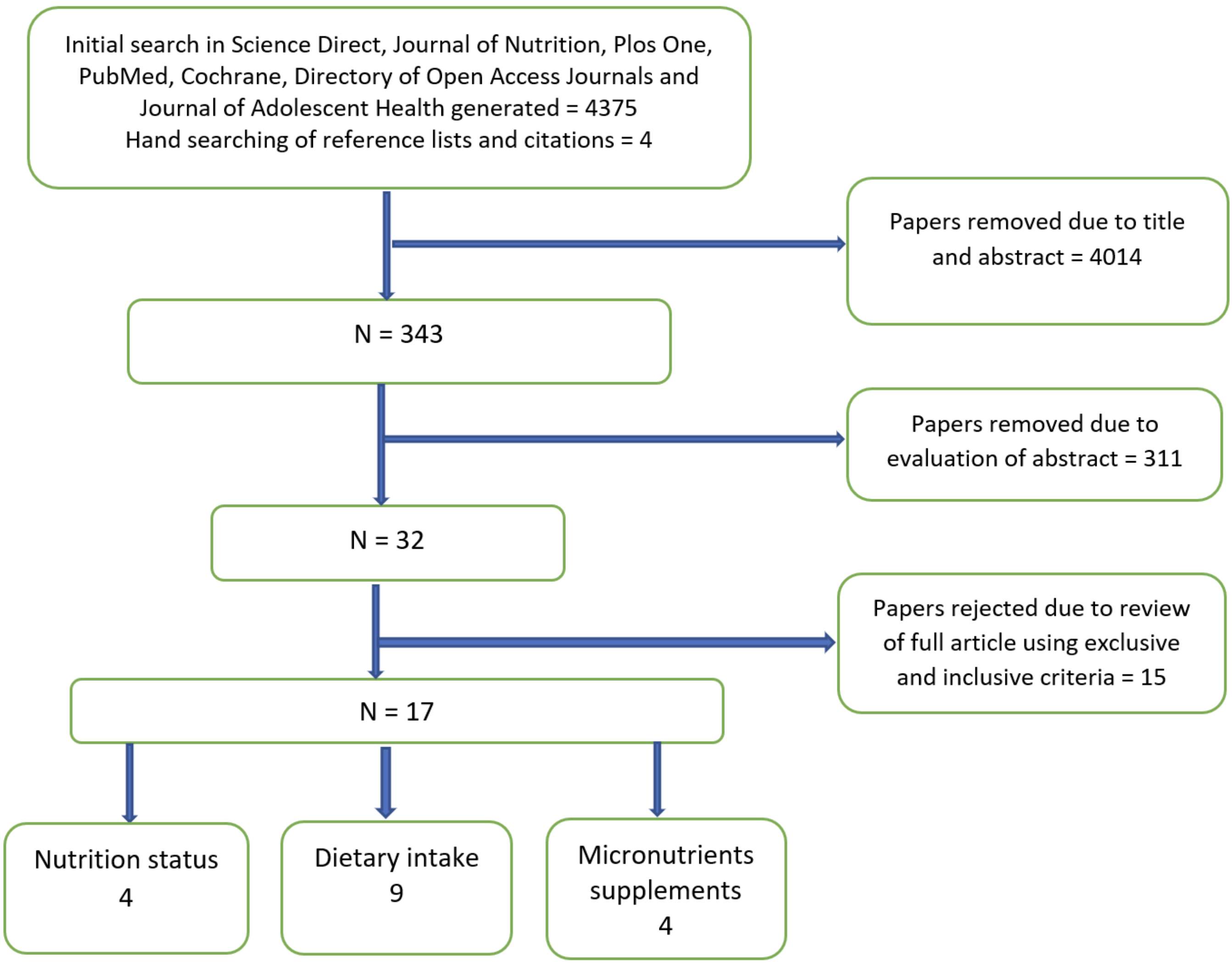

Figure 1. Search flow diagram for articles

Data Extraction

Extraction of the data was done using the following criteria:

- Author and date of publication
- Study design
- Characteristics and number of subjects
- Objectives of the study

- Data collected
- Outcome measures
- Findings and conclusions

Study Characteristics and Findings

In all, 17 papers published from 1995 to 2019 were included in this study (table 2). Subjects were healthy pregnant adolescents devoid of any medical conditions. There were 9 studies that focused on the impact of dietary intake and birth outcomes and 4 each on the effect of nutritional status and micronutrient supplementation on birth outcomes in pregnant adolescents. USA was the most represented country of this review with about 53% (9) and only one from Africa, Tanzania. All the studies involved pregnant adolescents < 20 years. Adolescents were recruited from ante natal clinics or from cohort of population studies. 6 studies were interventional studies and others observational.

Dietary intake and Birth outcomes

Nine papers highlighted the impact of dietary intake on birth outcomes in pregnant adolescents. Four of these papers (Chang *et al*., 2003[a]; Chan *et al*., 2006; Davis *et al*., 2010; Young *et al*., 2012) concentrated on the effect of maternal dietary intake of Ca and vitamin D on birth outcomes. Findings from these studies indicated that consumption of optimal amount of Ca, dairy products and vitamins D contributed to better birth outcomes. Chan *et al.* (2006) and Chang *et al.* (2003[a]) indicated that adolescents who consumed more than 2 servings of dairy products reduce the risk of preterm births and help improve fetal bone development. The mean birth weights from the dairy group in both studies were higher compared to those whose diet were insufficient. Davis *et al.* (2010) reported that excess calorie consumption (P = 0.035), and 3rd trimester hemoglobin status (P = 0.05) remained statistically significant predictors of vitamin D status (R^2 = 0.30, n = 50) when the following factors were controlled for; age, calcium intake, season of 25(OH) D measurement (winter), excess calorie consumption, and 3rd trimester hemoglobin concentration, Season (P = 0.005). According to their dietary intake, 87% of the subjects consumed excess calories and lower hemoglobin concentration (anemia prevalence - 59%) was related to lower levels of vitamin D. Low birth weight (LBW) was 7.5% of the infants delivered and the mean birth weight was 3108.7±697.4 g. Young *et al.* (2012) also reported an increase in fetal bone growth (1.24 cm longer) in adolescents whose maternal 25(OH) D status was more than 50 nmol/L and dietary intake of ≥ 1100 mg Ca/d. Vitamin D deficiency in this study was 47.6%. The dietary Ca intake of the pregnant adolescents ranged from 257 to 3220 mg with only 29.4% and 15.3% of adolescents meeting the recommended levels (Institute of Medicine, 2011).

The other part of this group looked at the impact of dietary intake including energy, protein, vitamins and minerals, sugar as well as nutritional knowledge on birth outcomes in pregnant adolescents. Sokulmez and Ozenoglu, (2014) reported that with the exception of vitamin C, all nutrients consumed were below the RDA: energy, calcium, zinc and vitamin A consumption levels - 77%, 35.2%, 54% and 63.2% respectively. In all, 28% of the babies had health problems including;

LBW (1.8%), meconium aspiration syndrome (9.5%), jaundice (5.4%), problematic prematurity (5.3%), hypoglycemia (0.6%) among others. Still birth and neonatal mortality rate were 3.1% and 3.2% respectively in this study. A study by Lenders *et al.* (1997) also revealed that pregnant adolescents who consumed high sugar diet had a relatively lower intake of protein, fat and all micronutrients except for manganese, magnesium and iron as compared to their RDA's. The total sugar for adolescents who consumed high sugar diet was 44% as compared to 19% in the reference group which resulted in a doubled rate of SGA and LBW infants. The rates for LBW was 10% (59), 8% (45) for SGA and 12% (69) for preterm delivery. Sámano *et al.* (2017) also looked at prenatal leptin concentration with gestational weight gain on birth outcomes in Mexican pregnant adolescents. Their study showed a greater weight gain of 6kg more in pregnant adolescents who had over 20ng/mL leptin concentration. Leptin concentration correlated with length ($p = 0.003$) and weight ($p = 0.024$) of the newborn. A study by Long *et al.* (2002) showed a significant difference ($p =.000$) in pregnant teens who participated in the nutrition curriculum. The participants were able to meet the recommended levels of 17 nutrients including energy, proteins, minerals and vitamins, caffeine and fiber and produced better maternal and infant weight outcomes. Xie *et al.* (2015) looked at the impact of preconception nutrition and physical activity on birth outcomes. It was reported that 12.67% of the participants did not consume fruits or vegetables at all while 21.62% ate these foods only once on the previous day. Those who ate 2 or more servings of fruits and vegetables were 345 (39.70%) and 208 (27.70%) respectively while those who ate 2 or more servings of both were 13.49%. In this study, subjects who engaged in more episodes of active behavior had comparably higher birth weights ($P < 0.01$).

Micronutrient Supplementation and Birth Outcomes

This group also focused on the effect of micronutrient supplement on birth outcomes in pregnant adolescents. Castillo-Durán *et al.* (2001) reported on the effect of zinc supplementation on birth outcomes in Chilean pregnant adolescents. An increase of 69 grams of birthweight due to zinc supplementation was observed while the rate of low birthweight for the placebo group was 6.2%. Using ferritin concentration, 21% of the subject had iron depleted stores. The result shows a positive effect of zinc supplementation in reducing low birth weight ($p = 0.036$) and risk of prematurity. Another study (Baker *et al.*, 2009) reported the link between tissue iron deficiency (34%) and preterm birth ($p = 0.042$). SGA births was higher in subjects who had poor folate status ($p = 0.02$) and low folate intake even when intake from supplements were included ($p = 0.021$) or excluded ($p = 0.049$). Again, subjects with low iron intake presented high rate of SGA births ($p = 0.049$) but not when iron supplements were included ($p = 0.21$). Basbug and Sonmez (2018) looked at the frequency of iron deficiency anemia and their effects on maternal and fetal outcomes. Nearly one third of their subjects had Iron Deficiency Anemia (IDA) with the mean age of the anemic group being lower than that of the non-anemic group. About 45% of pregnant adolescents in this study did not receive iron supplementation. Serum ferritin (µg/L) and hemoglobin (g/dL) levels were lower in the anemic group (12.31 and 9.43) than the non-anemic group (26.42 and 11.41). The rate of preterm and SGA births was high in the anemic group (13.8% and 8.3%) whilst LGA was low in the anemic group compared to the non-anemic group (5.5% and 13.9%). Mean birth weight was 2.956 kg in the anemic group but 3.408 kg in the comparison group. Dubois *et al.* (1997) examined the extent to which a supplemental program can reduce adverse pregnancy outcomes in adolescents. It was observed that adolescents who participated in the program had significantly lower rates (39% to 56%) of low birth weight and preterm delivery as compared to those in the nonintervention group.

Pregnant adolescents on the program were given supplement of milk, egg, vitamin/mineral and also encouraged to increase consumption levels of energy and protein to 900 kCal and 52 g respectively.

Nutritional Status and Birth Outcomes

This group investigated the effect of nutritional status such as hemoglobin concentration, MUAC, weight gain of pregnant adolescents on birth outcomes. A study in Tanzania by Shirima and Kinabo (2005) reported a mean infant birth weight of 2.600 kg among subjects with about 48% having low birth weight and only 14% having weights above 3.000 kg. Using their MUAC measurements, 26% were severely wasted while 33% were classified as normal. The study also reported a strong correlation between birth weight and hemoglobin concentration of these pregnant adolescents. Most pregnant adolescents in this study (86%) were anemic with 5% being severely anemic. In this study, as pregnancy advanced, the prevalence of anemia also increased; 10-13% during the first trimester, 20 – 33% during the second trimester and 57 – 66% in the third trimester. Other studies reported of this same trend of anemia prevalence progression form early pregnancy to the delivery stage; from 15.4 to 59.2% (Davis *et al*., 2010) and 11.9 to 63.5% (Baker*et al*., 2009). High hemoglobin levels (> 120 g/L) as reported by Chang *et al.* (2003[b]) were associated with increased risk of both LBW (RR=3.11; P=0.007) and preterm birth (RR = 2.33; P = 0.033) during the second trimester and a high incidence of LBW (RR = 1.88; P = 0.018) during the third trimester. Lower hemoglobin concentrations were associated with higher risks of preterm delivery (RR = 2.06; P = 0.047). Contrary to these results, two studies (Basbug and Sonmez, 2018 and Yilmaz *et al*., 2018) recorded no relationship on the effect of anemia on birth outcomes such as weight, SGA and gestational age during a study on the impact of anemia on fetal outcomes in Turkish pregnant adolescents. Prevalence of anemia were 30% and 36% respectively. Sokulmez and Ozenoglu (2014) reported that 40% of pregnant adolescents in Turkey were anemic as they consumed only 41.6% of the recommended iron levels. In another study, Young *et al.* (2010) evaluated the effect of maternal and fetal iron status on transferrin receptor. In their findings, iron deficiency was prevalent with 29% and 19% of the subjects being anemic at delivery and during the second trimester respectively. For pre-pregnancy BMI, about 37% were overweight and 7% underweight. There were 2 preterm deliveries and 3 low birth weight infants. About 9% of the deliveries recorded ≤34 µg/L cord serum ferritin values, a risk level for developing brain iron deficiency.

Table 2. Characteristics of Studies Included

Author (Year)	Country	Study Design/ Intervention	Age Range (Years)/ Target Population	Objectives Of The Study	Outcomes Assessed	Findings/ Conclusions
A. Dietary Intake and Birth Outcomes						
		RCT/	15 -17	Evaluate the effects of dietary Ca intervention	- Dietary intake (dietary recall); total calories, Ca, Phosphate (P), protein, fats, and vitamin 25-hydroxyvitamin D	Dietary intake of Ca supplemented with dairy

Chan *et al.* (2006)	USA	Orange juice fortified with Calcium (Ca), 4 servings of Dairy per day	Control – 23 Orange + Ca group – 24 Dairy group – 25	on adolescent pregnant mothers and their newborn from two different food sources, dairy and orange juice plus Ca.	hydroxyvitamin D (25OHD). - Birth weight, length, head circumference. - weight gain - Body Mass Index (BMI)	products during adolescent pregnancy resulted in higher maternal vitamin D and folate serum levels and higher newborn weight and bone mineralization compared with controls
Chang *et al.* (2003[a])	USA	Retrospective chart review	< 17 N = 1120	Address the effect of early childbearing on fetal bone development,	- Fetal femur length - food frequency and dietary recall - hemoglobin concentration - Birth weight, preterm birth - BMI	The intake of < 2 servings of dairy products/d were associated with significantly lower fetal femur lengths. Increasing the dairy intake of adolescents during pregnancy may benefit both maternal bone mass and fetal bone development
Young *et al.* (2012)	USA	Cross sectional	≤ 18 N = 171	Address possible associations and interactions between maternal calcium intake and 25(OH) D status with fetal bone growth	- Fetal femur, humerus, neonatal birth length - Dietary intake (dietary recalls); Calcium and Vitamin D	Consuming either an adequate calcium intake or achieving sufficient 25(OH) D status may partially attenuate the deficits in fetal long-bone growth and neonatal birth length observed in pregnant adolescents who were Ca/D insufficient.
Long *et al.* (2002)	USA	Quasi/ Nutrition Curriculum	< 20 Experimental -165 Control – 65	Determine the impact of a nutrition curriculum for pregnant and parenting teens on nutrition knowledge diet quality, birth outcomes	- birth weight - maternal weight - dietary intake (dietary recall)	Pregnant adolescents participating in the Great Beginnings nutrition curriculum had healthier birth outcomes and better health status.
Xie *et al.* (2015)	USA	Longitudinal/ Preconception nutrition	N/S N = 833	Examine how maternal preconception nutrition and physical activity is related to birth outcomes among adolescent mothers	- dietary intake (food frequency) - physical activity - birth weight	Girls who engage in physical activity and later become pregnant are more likely to have better birth outcomes as represented by birth weight
Davis *et al.* (2010)	USA	Screening	≤ 18 N = 80	Identify the prevalence and determinants of vitamin D status among pregnant minority adolescents	- birth weight - Vitamin D status - hemoglobin - food frequency and dietary recall - BMI	Vitamin D insufficiency was prevalent (46%) among urban pregnant minority adolescents. LBW was about 8%

Sokulmez and Ozenoglu (2014)	Turkey	Survey	15 – 18 N = 220	Determine general health and nutritional status of adolescent pregnant and to search the effects of these on newborn.	- dietary intake (food frequency and food consumption) - birth outcomes	Nutrition is of utmost importance in pregnant adolescents due to the growth of both mother and baby. About 33% of birth complications and 10.1% ≤ 36 weeks deliveries were recorded.
Lenders *et al.* (1997)	USA	Prospective	12 – 15 N = 594	Association between sugar intake and intrauterine growth restriction	- dietary intake (dietary recall) - birth weight - gestational age at delivery	Pregnant adolescents who consume high sugar diets are at increased risk for SGA births.
Sámano et al. (2017)	Mexico	Cohort	10-19 N = 168	Determine the correlation between the serum concentration of leptin in pregnant adolescents and gestational weight gain, postnatal weight retention, and the weight and length of the newborn.	- energy intake -leptin concentration - birth outcomes - gestational weight gain	Leptin concentration correlated with length and weight of the newborn.
B. Micronutrient Supplement and Birth Outcomes						
Castillo-Durán *et al.* (2001)	Chile	RCT/ Supplements; Iron and Zinc	< 19 Zn group – 249 Placebo – 258	Analyze the effect of zinc supplementation on pregnancy outcome of Chilean adolescents from low socio-economic status	- birth weight, length, head circumference - dietary intake (dietary recall)	Positive effect of zinc supplementation during pregnancy on decreasing the rate of low birthweight and the risk of prematurity
Dubois *et al.* (1997)	Canada	Retrospective chart review	14 – 18 Intervention: 1203 Nonintervention:1203	Determine the extent to which birth weight can be increased when adolescents participate in the Higgins Intervention Program	- low birth weight - preterm weight, - perinatal mortality	Individualized nutrition intervention (Higgins Intervention Program) improves outcome of adolescent pregnancy.
Baker *et al.*	UK	Prospective	14 – 18	Assess micronutrient intake and blood biomarkers prospectively in pregnant adolescents recruited to the About	- small for gestational age (SGA) birth - preterm delivery	Poor micronutrient intake and status increase the

(2009)			N = 500	Teenage Eating (ATE) Study and to determine associations with pregnancy outcome.	- iron and folate deficiency anemia - dietary intake (dietary recall)	risk of SGA births in pregnant adolescents
Basbug and Sonmez (2018)	Turkey	Case Control	< 19 Anemic – 36 Non anemic – 86	Study the effects of IDA on maternal and fetal outcomes.	- birth weight - SGA and LGA - hemoglobin - ferritin	Iron supplementation improves perinatal outcomes
C. Nutritional Status and Birth Outcomes						
Shirima and Kinabo (2005)	Tanzania	Survey	15 – 19 N = 180	Examine the nutritional status and birth outcomes of pregnant adolescent girls from rural and urban areas	- hemoglobin - mid upper arm circumference - weight gain - birth weight	The nutritional status of pregnant adolescent girls in the study areas was poor and resulted in poor pregnancy outcome.
Chang *et al.* (2003[b])	USA	Retrospective chart review	≤ 17 N = 918	Characterize the prevalence of prenatal anemia and the impact of maternal factors on anemia	- hemoglobin - birth weight - preterm delivery	Additional medical attention may be warranted in pregnant African-American adolescents with hemoglobin concentrations
Yilmaz *et al.* (2018)	Turkey	Retrospective	≤ 19 Anemic – 507 Non anemic - 900	The influence of anemia on maternal and neonatal outcomes in adolescent pregnant.	- birth weight - SGA - gestational age	No statistically significant impact of anemia was found on birth weight, gestational age, small for gestational age or Apgar scores of the infants (p>0.05). Anemia should be carefully considered during pregnancy in adolescent girls due to its frequency.
Young *et al.* (2010)	USA	Longitudinal	14 – 18 N = 92	Elucidate the role of maternal and neonatal iron status on placental transferrin receptor (TfR) expression	- iron status - fetal bone health	Maternal hemoglobin at mid-gestation were highly correlated with both maternal iron status at delivery and with placental TfR expression at delivery. Increased expression of placental TfR may be an important compensatory mechanism in response to iron deficiency in otherwise healthy pregnant women.

RCT – Randomized Controlled Trial

N/S – Not stated

Discussion

The methods used in assessing dietary intake in this review varied; dietary recalls, food diaries and food frequencies with dietary recall being used most. From the review, consumption of diets rich in Ca and dairy products increased nutrient levels (vitamin D and serum folate) and contributed to higher birth weights, bone mineralization, total body Ca, vitamin D content and fetal bone growth (Chang *et al*., 2003[a]; Chan *et al*., 2006; Young *et al*., 2012) in infants delivered by adolescents. However, most pregnant adolescents in this review had low food intake of Ca and Vitamin D when compared with the RDA (Table 3). Vitamin D is important in regulating the concentration of calcium ions in the extracellular fluid (homeostasis) as well as healthy bones. During pregnancy, absorption of Ca doubles, thus, when the growing fetus does not receive the amount of calcium needed through maternal dietary sources, it relies on the reserves of the mother leading to the onset of health problems such as osteoporosis and osteomalacia (Giddens *et al*., 2000). Low dairy food intake in young pregnant girls has also been associated with neural tube defects in the fetus (Friel *et al.* 1995). According to Holick and Chen (2008), pregnant adolescents who are susceptible to poor diets, live in urban areas, underweight and overweight, dark skin may have vitamin D deficiency. Excess caloric intake, infection during pregnancy, season, increased second trimester leptin and decreased third trimester hemoglobin are also factors that were associated with vitamin D deficiency in the study by Davis *et al.* (2010). In their findings, mothers who received dairy supplements had higher serum folate levels which is important in enhancing the bioavailability of folate (Smith and Picciano, 1985) and preventing neural tube defects. Folate is a B vitamin important in the metabolism of amino acids, synthesis of proteins and cell multiplication which are all necessary during embryogenesis (rapid cell division and growth of tissue). Deficiency in folate has been related to complications in birth outcomes as well as maternal hypertension risk (De-Regil *et. al*., 2015). Sokulmez and Ozenoglu (2014) reported that micronutrients such as calcium, zinc and vitamin A levels were inadequate when compared to the RDA (Table 3). Vitamin C was however adequate among the adolescents in this study. Intake of milk, egg, vitamin and mineral supplement by pregnant adolescents in a nutrition intervention programme led to a reduced LBW rate (Dubois *et al*., 1997). In a study by Xie*et al.* (2015), though there were no association between food intake and delivery outcomes, most adolescents were not consuming the 5 servings daily recommendation of fruits or vegetables. This could be related to the one-time intake of diet which may not reflect the full summary of the nutrient intake of individuals due to change in appetite or psychological effects or pregnancy. Castillo-Durán *et al.* (2001) and Sokulmez and Ozenoglu (2014) reported that low zinc intake was associated with LBW and pre term deliveries. UNICEF (1998) reported a significant reduction in LBW to 2.4% due to zinc supplementation, a rate that is has not been attained in developed countries. Zinc is a useful nutrient during cell division and differentiation and its deficiency has been attributed to complications such as intrauterine growth restriction, pre term deliveries, miscarriages and vaginal bleeding (Sokulmez and Ozenoglu, 2014). According to Baker *et al.* (2009) low dietary iron and low folate status were associated with SGA deliveries ($p = 0.001$) except when iron supplements were included. In this study, intake of folic acid supplements during early pregnancy led to a higher red blood cell folate concentration during the third trimester than when these supplements were not taken.

Weight gain during pregnancy is as a result of energy intake levels (Institute of Medicine, 1990). Inadequate and excessive gestational weight can lead to adverse delivery outcomes such as LGA, SGA and birth trauma. This is because, energy is required to for the growth of the uterus, breast, adipose tissue in the mother and placental and amniotic fluid in the fetus. Energy intake reported in all the papers for this review (Lenders *et al*., 1997; Castillo-Durán *et al*., 2001; Long *et al*., 2002; Chan *et al*., 2006; Sokulmez and Ozenoglu, 2014; Sámano *et al*., 2017) were below the RDA (table 4). Lenders *et al. (*1997) suggested that the general poor quality of the adolescents' diet may be related to their intake of high sugar diets and birth outcomes (SGA and LBW). According to the National Research Council, (1987), an acceptable level of sugar intake of total energy is 10%. In this study however, the dietary energy intake as sugar is 22% which is well above the acceptable rate. Bread, fatty foods, carbonated drinks, fruit juices, ice cream, syrup and sweetened cereals are the most commonly listed products contributing to high sugar and energy diets among pregnant adolescents in this review. Preterm deliveries among pregnant adolescents have been associated with inadequate maternal weight gain (Kardjati, 1988). In this review, Davis *et al*. (2010) reported that higher levels of leptin, a marker of human obesity (Veniant and LeBel, 2003) was found to lead to lower levels of vitamin D status (P = 0.018) which contributed to low hemoglobin concentrations and low birth weights. Xie *et al*. (2015) also reported a positive association between prepregnancy physical activity and birthweight in pregnant adolescents. Lower levels of physical activity in the adolescents was related to insecure neighborhoods and inaccessible parks and gyms. The study by Sámano *et al.* (2017), also reported a positive relationship between leptin concentration (above 20 ng/mL) and gestational weight gain which also had an effect on birth weight (leptin – P = 0.024; gestational weight gain – P = 0.011) and birth length (leptin - P = 0.003; gestational weight gain - P = 0.722).

Proteins are involved in the growth, repair and maintenance of body tissues (hormones, keratin, collagen, protein transport, hormones and enzymes). During pregnancy, proteins help meet the demands of the fetus and prepares for lactation with an increase in protein synthesis during the 2nd and 3rd trimesters by 15% and 25% respectively (Elango and Ball, 2016). Mean protein intake (table 5) reported in pregnant adolescents from the USA were above the RDA (Lenders *et al*., 1997; Chan *et al*., 2006) while one study from Turkey recorded an amount below the RDA (Sokulmez and Ozenoglu, 2014). Castillo-Durán *et al*., (2001) reported less than 50% animal protein of total protein intake in pregnant adolescents. Only one study (Lenders *et al*., 1997) reported on carbohydrate consumption of pregnant adolescents whose mean intake by the high sugar group was twice the RDA (table 5).

Table 3. Mean Intakes of Micronutrients in Individual Studies Compared to RDA (The Institute of Medicine, 2011) for Pregnant Adolescents

Nutrient	Study	1st trimester	3rd trimester	RDA
Zinc (mg)	Lenders (1997)	11*		12
	Chan (2006)	16	18	
	Baker (2009)	8.1*		
	Sokulmez (2014)	8.1*		
	Castillo-Duran (2001)	7.4*	7.7*	
Iron (mg)	Lenders (1997)	21*		27
	Chan (2006)	22*	25*	
	Baker (2009)	17*		
	Sokulmez (2014)	12.5*	16.8*	
	Castillo-Duran (2001)	15.5*		
Sodium (mg)	Lenders (1997)	3536	2930	1500**
	Chan (2006)	3316	3323	
Potassium (mg)	Lenders (1997)	2623*	2396*	4700**
	Chan (2006)	2802*	2954*	
Phosphorus (mg)	Lenders (1997)	1441	1201*	1250
	Chan (2006)	934*	961*	
Magnesium (mg)	Lenders (1997)	269*	472	400
	Chan (2006)	263*	264*	
	Baker (2009)	236*		
Folate (µg)	Baker (2009)	285*		600
Vitamin A (µg)	Sokulmez (2014)	379*		750
	Baker (2009)	759		
Vitamin D (µg)	Chan (2006)	2.8*	3.1*	12
	Baker (2009)	2.1*		
	Young (2012)	5.4*		
Riboflavin (mg)	Chan (2006)	2.3	2.4	1.4
	Sokulmez (2014)	1.5		
Niacin (mg)	Sokulmez (2014)	12*		18
	Baker (2009)	33		
Vitamin B12 (µg)	Chan (2006)	5	5.2	2.6
	Baker (2009)	5.5		
Vitamin C (mg)	Baker (2009)	160		80

** value below RDA*

*** Adequate Intakes*

Table 4. Mean Energy Intakes in Individual Studies Compared to UK Estimated Average Requirements (1991) for Females (11-19 years)

	Study	1st trimester	3rd trimester
Energy (kCal/day)	Lenders (1997)	2247*	
	Long (2002)	2325*	1962*
	Chan (2006)	2223*	2276*
	Sokulmez (2014)	1927*	
	Sámano (2017)		2197*
	Castillo-Duran (2001)	1887*	2030*
	Baker (2009)		2147*

EAR for 1st trimester - 2355kcal/d, 3rd trimester – 2546kcal/d

** value below RDA*

Table 5. Mean Intakes of Macronutrients in Individual Studies Compared to Recommended Daily Allowance – RDA (The Institute of Medicine, 2011) for Pregnant Adolescents

Nutrient	Study	1st trimester	3rd trimester	RDA
Carbohydrates (g)	Lenders (1997)	279	352	175
Protein (g)	Lenders (1997)	92		71
	Chan (2006)	76	76	
	Sokulmez (2014)	61.9*		
	Castillo-Duran (2001)	60.4*	61.6*	
Fat (g)	Lenders (1997)	102		NS
	Chan (2006)	71		

** value below RDA*

NS – not stated

Globally, about half a billion females in their reproductive stage (15 – 49 years) are affected by anemia caused by iron deficiency anemia (IDA) yearly; over 60% of pregnant women in low-income and developing countries and less than 20% in developed countries (World Health Organization., 2014). To reduce the rate of anemia by 50% by the year 2025, WHO Regional Office for Africa, (2017) proposed among other measures, the integration of iron supplement. However, some pregnant adolescents in the papers reviewed did not receive iron supplementation (Basbug and Sonmez, 2018, Shirima and Kinabo, 2005). Chang *et al.* (2003[b]) reported a high prevalence of anemia (57- 66%) during the third trimester of pregnancy among African American pregnant adolescents in USA though they received nine prenatal visits averagely and prescribed prenatal supplements including iron supplements as needed. The prevalence of anemia in subjects based in USA were relatively high; from 59.2% to 66% (Davis *et al*., 2010 and Chang *et al*., 2003[b]) as well as their UK counterpart; 56% (Baker *et al*., 2009). Subjects in Canada (Young *et al*., 2010) presented a rather lower rate of 29% which is still above the reported anemia prevalence rates per country; Americas – 24.9% and Europe – 25.8% (WHO, 2015). In Turkey, the anemic rates (30% and 36%) suggested a moderate public health problem (severe public health problem – 40.2%) according to the WHO Global Database on anemia prevalence in Turkey (Basbug and Sonmez, 2018, Yilmaz *et al*., 2018). On the contrary, Sokulmez and Ozenoglu (2014) reported that 40% of pregnant adolescents in Turkey were anemic which classifies this population as severely anemic. The rate of anemia in pregnant adolescents in Tanzania was relatively on the higher side of about 86% (Shirima and Kinabo, 2005) which can be classified as a severe public health problem. The estimated prevalence of anemia among pregnant women (15-49 years) in Africa is 46.3% (WHO, 2015). In all the papers that reported on anemia in this review with the exception of (Shirima and Kinabo, 2005), there were no association between poor birth outcomes and anemia measured by low hemoglobin levels. However, there was a significant positive correlation (r = 0.67, P = 0.01) reported in the study by (Shirima and Kinabo, 2005) between birth weight and hemoglobin concentration. This report is consistent with a study by Klebanoff *et al.* (1989) where severe anemia was associated with poor birth outcomes. From this review, severe anemia rates included 5%, 1.2% and 0.5% (Shirima and Kinabo, 2005, Yilmaz *et al*., 2018, S.-C. Chang et al., 2003b). This suggest that when most of the population have mild to moderate anemia, it may not have a significant impact on birth outcomes but rather severe anemia. The rate of anemia was attributed to non-compliance with prenatal iron supplementation, increased iron demands of this age group, poor dietary quality (such as iron-rich foods) and other non-nutritional factors, hemodilution, and worm infestation and malaria (Shirima and Kinabo, 2005 and Chang *et al*., 2003[b]). Noncompliance of iron intake may be due to its high dosage and unpleasant side effects like nausea, vomit and constipation (Beard, 2000; Hyder *et al.,* 2002). Based on the degree of anemia in the papers reviewed, it is highly likely that noncompliance is the main cause. An estimate of 3-8 mg absorbed iron is required daily to meet iron demands of pregnancy and an addition of 0.33 mg for pregnant adolescents (Viteri, 1994; Beard, 2000). A current recommendation by WHO based on a 2012 Cochrane Review for a daily use of 30-160 mg elemental iron routinely during pregnancy have shown positive effects on perinatal outcomes (Pena-Rosas *et al*., 2012). Some studies have however related routine iron supplementation to SGA outcomes and hypertensive disorders and suggested giving iron to women who are anemic (Ziaei *et al.,* 2007; Shastri *et al.,* 2015). Similar to this assertion, Baker *et al.* (2009) reported a lower risk of SGA birth in subjects with iron deficiency anemia (P = 0.002). Chang *et al*. (2003[b]) also reported that high hemoglobin concentrations (> 120 g/L) during the second and third trimesters of pregnancy resulted in an increased 3.1 and 2.3 fold risk of having LBW and preterm infants respectively while lower concentration had just 2.0 fold higher risk of preterm delivery. High iron status, insufficient maternal blood volume expansion during pregnancy, high blood viscosity, pre-eclampsia and cigarette smoking may be attributed to elevated hemoglobin concentrations during pregnancy (Yip, 2000; Lund and Donovan, 1967). Factors relating to anemia during pregnancy should be considered carefully as plasma volume expansion and alterations that occur in the red-cell mass can also lead to lower concentration of hemoglobin. In the study by Chang *et al*. (2003[b]), significantly higher hemoglobin concentration were observed in pregnant women with pre-eclampsia.

Table 6. Biological Markers of Nutritional Status in Individual Studies Compared to Reference Values

Nutritional status marker	Study	1st trimester	2nd trimester	3rd trimester	Reference value
Hemoglobin (g/dL)	Baker (2009)	12		10*	11
	Chang (2003)	12	11	10*	
	Davis (2010)	11		10*	
	Sokulmez (2014)	10*			
	Young (2010)	11		11	
	Shirima (2005)	9*			
	Basbug (2018)	9*			
25 OHD (nmol/L)	Baker (2009)	33		33	25
	Chan (2006)	57		57	
	Davis (2010)	21*	20*	22*	
	Young (2012)			54	
Ferritin (µg/L or ng/L)	Young (2010)	16		17	15
	Basbug (2018)	12*			

** value below RDA*

Limitations

Though there have been several actions to minimize maternal undernutrition globally, the problem still exists in Sub-Sahara Africa (SSA) where most adolescent pregnancy cases have been recorded (WHO, 2014) leading to a rise in maternal mortality and poor birth outcomes. Most of the studies used in this review were from developed countries with only 1 from SSA where the problem is still prevalent. Also, none of the studies was conducted in Ghana. Methods used in assessing nutrient intake included food diaries, dietary recalls and food frequencies. Dietary recall was mostly used and it has been shown to have limitations such as inaccurate report of diet history by subjects and whether the intake recorded provides the actual representation of the regular diet of subjects. A lot of studies have concentrated on nutritional status and intake including supplementation in older pregnant women but only a few studies have been conducted on pregnant adolescents even though the adolescents are at a higher risk of being deficient due to their poor eating habits and increase in growth and development. Only one study in this review assessed the carbohydrate intake by the subjects (Lenders *et al.*, 1997). Proteins and fat intake were also conducted in 3 studies (Lenders*et al.*, 1997; Chan *et al.*, 2006; Sokulmez and Ozenoglu, 2014). Only a few studies reported on macronutrients, thus further research should be undertaken to know their effects on birth outcomes in pregnant adolescents. Nutrition education used as interventions were minimal in this review though they contributed to improved nutritional status and birth outcomes. None of the studies used reported on compliance of recommendations by the subjects. Though most of the studies used on this review reported an impact on the nutrient intake and nutritional status of pregnant adolescents on deliveries, two of the studies (Basbug and Sonmez, 2018 and Yilmaz *et al.*, 2018) did not find any association. Most of the studies failed to control for confounders which might have a strong influence on the findings as socio economic factors might have an influence on findings.

Conclusion

The papers used in this review shows that pregnant adolescents have lower than the recommended daily intakes of micronutrients and macronutrients for pregnant adolescents. This provides to a large extent evidence to support the importance of adolescent nutrition and birth outcomes. There is the need to implement policies to improve adolescent nutrition through a multisectoral approach. Specific programs should be designed and incorporated into schools with a greater focus on adolescent health needs and well-being including nutrition, eating patterns and behaviors, individualized dietary supplement programs, management and prevention of adolescent pregnancy, creation of adolescent health centers and counselling units.

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