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Review Article

Maternal dietary diversity during pregnancy and risk of low birth weight in newborns: a systematic review

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Abstract

Objective: Maternal nutrition during pregnancy is a key factor influencing birth outcome. Dietary diversity is a proxy for multiple macro- and/or micronutrient sufficiency of an individual's diet. This systematic review aimed to summarise the findings on the association between maternal dietary diversity during pregnancy and the risk of low birth weight (LBW) in newborns.
Design: This is a systematic review study.
Setting: Google and the PubMed, Scopus and Google Scholar databases were searched to extract original studies on humans published until June 2020, without date restrictions. There was no limitation regarding geographic region or economic condition of countries. Duplicated and irrelevant studies were screened out and data were obtained through critical analysis.
Participants: Articles that examined the association between maternal dietary diversity during pregnancy and the risk of LBW in infants were included.
Results: Of the ninety-eight studies retrieved, fifteen articles were included in the final review. All included articles represent low- and middle-income countries. Eighty percentage of the studies (*n* 12) indicated that low maternal dietary diversity during pregnancy is associated with an increased risk of LBW infants. Three studies that included a small number of LBW infants and did not take into account factors which may bias study results failed to show this association.
Conclusion: The results suggest that low maternal dietary diversity during pregnancy may be associated with the risk of LBW, more specifically in developing countries. Dietary diversity might be a valuable predictor of maternal nutrition during pregnancy and the chance of giving birth to a LBW infant.

Keywords
Dietary diversity
Maternal nutrition
Pregnancy
Low birth weight
Infant growth

Newborn birth weight <2500 g, regardless of gestational age, is defined as low birth weight (LBW)[1], a condition that compromises infant growth[2] and cognitive development[3] and is strongly linked to infant mortality, morbidity[4] and chronic diseases later in life[5]. Globally, it is estimated that 15–20 % of all births are LBW, corresponding to more than 20 million births per year[1]. One of the WHO global nutrition targets is to reduce the number of LBW babies by 30 % between 2012 and 2025[1]. At the population level, the proportion of LBW infants represents a multifarious public health problem. Known risk factors for LBW include preterm birth[6], intrauterine growth restriction[7], maternal factors such as young age[8], multiple pregnancies[9], poor nutrition[10], unfavourable work conditions[11], chronic disease[12], alcohol abuse[13], inadequate prenatal care[14] and environmental factors such as smoking[15], lead exposure[16] and air pollution[17].

Maternal nutrition during pregnancy is a key factor influencing birth outcomes. Pregnant women are at increased risk of various micronutrient deficiencies, particularly in developing countries[18,19]. Besides, most LBW infants in these countries are full-term newborns with intrauterine growth restriction due to maternal malnutrition and poor gestational weight gain[20,21]. Evidence also indicates that maternal malnutrition contributes to detrimental pregnancy outcomes[22,23], reduced newborn survival[23,24] and an increased risk of chronic diseases[19,25,26] and mental and

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cognitive impairment in later life[27,28]. Consuming invariant and monotonous diets can cause micronutrient deficiencies, which subsequently impact fetal growth and, hence, increase the odds of LBW[29,30].

Dietary diversity is a qualitative measure of food intake that, in a snapshot form, addresses individual access to different types of foods[31]. It is an indicator of nutrient adequacy of an individual's diet and is a proxy for multiple macro- and/or micronutrient sufficiency of the diet[31]. Different indicators are used for the assessment of dietary diversity. The Minimum Dietary Diversity for Women (MDD-W) and Women's Dietary Diversity Score (WDDS) are most used tools adopted by the FAO[32]. The tools advocated for use in women aged 15–49 years and validated against micronutrient adequacy assessed by multiple 24-h recalls[32]. Based on food items consumed in the past 24 h, individuals are allocated the number of food groups they consumed, ranging from 0 to 9 (for WDDS) or 0 to10 (for MDD-W).

Numerous investigations have evaluated the association between maternal dietary diversity during pregnancy and LBW risk in offspring[33–41]. However, there is still no comprehensive research summarising all of these reports. The research question was as follows: Is maternal dietary diversity associated with risk of LBW in newborns? Therefore, this systematic review was designed to systematically evaluate and summarise the literature in order to determine whether is there a relationship between maternal dietary diversity during pregnancy and the risk of LBW in newborns?

Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines (2015 Statement)[42].

Search strategy

A literature search was conducted in the PubMed, Google Scholar and Scopus databases, as well as Google, until June 2020, with no date restrictions. The following keywords were employed in the search: 'dietary diversity' OR 'diet diversity' OR 'food diversity' OR 'dietary variety' OR 'diet variety' OR 'food variety' in title-abstract-keywords AND 'birth weight' in title-abstract-keywords. Limits were English language and original articles. Details on the search strategy used for PubMed, Google Scholar and Scopus databases are included in Table 1. A manual search of the reference lists of the included articles was done to find further studies.

Eligibility criteria

Original articles published in English were included. There was no restriction regarding geographic region or economic condition of countries. Cohort, cross-sectional and case-control studies addressing the relationship between maternal dietary diversity and the risk of LWB in newborns were included. Studies referring to emergency conditions or natural disasters such as cyclones were excluded. Studies that assessed the relationship of dietary diversity with other health issues such as anaemia, diabetes or hypertension were excluded. Moreover, studies that investigated the effect of dietary patterns (e.g., Western, traditional, healthy and unhealthy patterns) during pregnancy on LBW were also excluded.

Selection of the studies

The extracted investigations were transferred to an Endnote file and arranged to remove duplicate articles. The titles and abstracts of the remaining articles were screened by two independent reviewers to identify articles potentially eligible for this review. The full texts of the screened studies were then critically reviewed separately for eligibility and data extraction. Any discrepancy in evaluation between the two reviewers was resolved through discussion.

Data extraction

The extracted data were as follows: first author and year of publication; country and study design; number of study population; maternal age and time of data collection; study location (urban or rural) and data collection location; method of dietary diversity assessment; duration of food intake information; number of food groups considered and cut-off point for inadequate dietary diversity; total number of LBW infants and number of LBW infants in low DDS group; covariates adjusted; findings accompanied by OR, CI or other indicators of correlation, P value, if available.

Quality assessment

Selected studies were assessed for methodologic quality by two independent reviewers. The Newcastle-Ottawa Quality Assessment tool for observational cohort and case-control studies[43] was used to evaluate the quality and risk of bias of the included studies based on three domains: the selection of exposed and non-exposed groups, ascertainment of exposure; the comparability of groups on the basis of the design or analysis controlled for confounders; and the outcome regarding assessment and follow-up time. A star system was applied to classify the articles as good, fair or poor quality. Studies with a total score of 6 or higher were classified as high quality.

Results

Selection of studies

As shown in Figure 1, ninety-four studies were first retrieved by the search strategy and four studies by manual searching. Duplicates were removed and sixty-four studies remained. Of those, twenty-three publications met the topic and scope of the study during the screening phase. During critical review, eight studies were excluded because

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Table 1 Association between maternal dietary diversity and risk of low birth weight: method of the database search strategy using PubMed and SCOPUS

Database	Search terms*
PubMed (search conducted up to 14 June 2020)	((((((dietary diversity[Title/Abstract]) OR (diet diversity[Title/Abstract])) OR (food diversity[Title/Abstract])) OR (dietary variety[Title/Abstract])) OR (diet variety[Title/Abstract])) OR (food variety[Title/Abstract])) AND (birth weight[Title/Abstract])
SCOPUS (search conducted up to 15 June 2020)	TITLE-ABS-KEY ('dietary diversity') OR TITLE-ABS-KEY ('diet diversity') OR TITLE-ABS-KEY ('food diversity') OR TITLE-ABS-KEY ('dietary variety') OR TITLE-ABS-KEY ('diet variety') OR TITLE-ABS-KEY ('food variety') AND TITLE-ABS-KEY ('birth weight') AND DOCTYPE (ar)
Google Scholar (search conducted up to 15 June 2020)	allintitle: 'dietary diversity' OR 'diet diversity' OR 'food diversity' OR 'dietary variety' OR 'diet variety' OR 'food variety' 'birth weight' with at least one of the words: 'dietary diversity' OR 'diet diversity' OR 'food diversity' OR 'dietary variety' OR 'diet variety' OR 'food variety' with the exact phrase: birth weight

*Searches were limited to observational studies, original articles and studies published in the English language using the appropriate filters and/or search terms depending on the database.

they did not meet the eligibility criteria or were conducted under emergency conditions. Finally, fifteen articles were included in the review (Fig. 1).

Characteristics of the included studies

As shown in Table 2, all included studies were from low- and middle-income countries and were published between 2013 and 2020. All studies applied a cohort, cross-sectional or case-control design. In ten of the studies, dietary intake information was collected only over the prior 24 h. All studies were conducted in hospitals or health facilities. All but two studies[37,44] used FAO adopted instrument for the assessment of DDS[32]. The time of data collection was after delivery in four of the included studies[34,36–38] and for the other studies it was in second and/or third trimesters[33,35,40,41,44,45,46] or between 34 and 36 weeks[39], first 8 weeks[47] and 9–15 weeks[48] of gestation. Several studies were conducted solely in urban areas (*n* 6). One of the studies was online Master's theses[45]. Various criteria or cut-off points were used to identify low DDS across the included studies. Low DDS ranged from <3 to ≤7, with most used cut-off of ≤3 or <5, across the studies.

Quality of articles

All included studies were rated as good quality (online supplementary material, Supplemental Tables 3 and 4). Quality scores for cohort studies ranged from six to eight (out of nine representing the lowest degree of bias) (online supplementary material, Supplemental Table 3). Main concern was comparability of exposed and unexposed participants based on design or analysis. The key potential confounding factors including age of mothers and infants' gender were not taken into account in the analysis of seven studies (out of ten cohort studies). Quality scores for case-control studies ranged from six to seven (out of nine) (online supplementary material, Supplemental Table 4). Main concerns were comparability of cases and controls on the basis of the design or analysis and non-response rate of the groups. None of the five case-control studies controlled the role of gender in the analysis and indicated dropout rate.

Dietary diversity and low birth weight

Eighty percentage of the studies (twelve of fifteen) indicated that a low maternal DDS during pregnancy is associated with an increased risk of LBW in infants. In a study on 578 singleton pregnant women, Abubakari *et al.*[33] showed that mothers with LBW infants had significantly lower DDS. Ahmed *et al.*[34], studying 279 singleton live births, found that mothers with low DDS had about seven times higher odds of having LBW babies. A significant negative correlation between mothers' dietary diversity and infant birth weight has also been reported by Madlala[45]. In a study involving 420 mothers, Quansah[36] observed that among mothers with low DDS, the number of LBW infants was about two-fold that of normal birth weight (NBW) infants and the risk of LBW infants was four times higher in the low DDS group compared with the high DDS group. Rammohan *et al.*[37], investigating 230 newly delivered women, indicated that women with low dietary diversity had a significantly higher proportion of LBW babies compared with those in the medium or high dietary diversity category. Saaka[39], in a study on 524 singleton pregnant women, showed that the mean birth weight of infants was significantly lower among women with low DDS compared with women who consumed diversified diets. The author reported that a high maternal DDS was significantly associated with a reduced risk of LBW and women with low DDS were 2·3 times more likely to deliver LBW babies than those with high DDS. Tela *et al.*[40], in a study on singleton pregnant mothers, showed that mothers' DDS was significantly associated with mean birth weight of infants and mothers with high DDS had significantly larger infants than those with low DDS. Zerfu *et al.*[41], studying 374 pregnant women, found that women with inadequate DDS had a significantly higher risk of LBW and the infants' mean birth weight was significantly lower in the inadequate group. Bekela *et al.*[49] in a study on 354 mother–neonate indicated that number of mothers with inadequate dietary diversity was higher among LBW infants. Nsereko *et al.*[48], studying 367 pregnant women, showed that maternal low dietary diversity was independent determinant of LBW. Vanié *et al.*[46] and Jamalzehi *et al.*[44] also reported that

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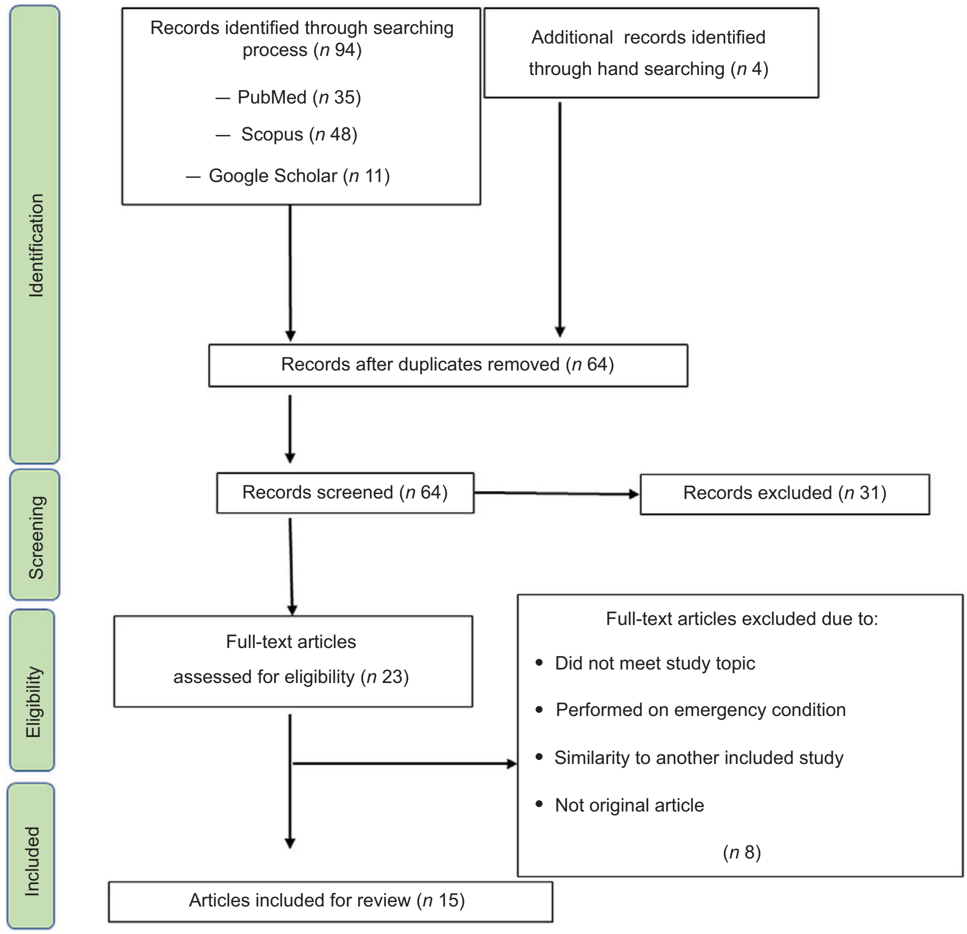

Fig. 1 (colour online) Flow diagram of the literature search and screening process for a systematic review assessing the relationship of dietary diversity and risk of low birth weight

the mean birth weight of newborns of mothers with low dietary diversity was significantly lower.

However, three of the included studies did not find any relationship between maternal DDS and newborn LBW. Manerkar *et al.*[35], studying 121 pregnant women (nineteen LBW, 102 NBW), reported no difference in maternal DDS between the LBW and NBW groups. Rashid *et al.*[38], in a study on sixty-six infants (thirty-two LBW and thirty-four NBW), showed that mean DDS did not differ between mothers giving birth to LBW and NBW infants. However, the number of mothers with low DDS was non-significantly higher in the LBW group (28 %) compared with the NBW group (18 %). Alemu and Gashu[47] also reported that maternal low dietary diversity is not associated with LBW.

Discussion

The current study identified fifteen observational studies that assessed the relationship of maternal dietary diversity during pregnancy and LBW risk in offspring. The results of the reviewed articles indicate that maternal gestational DDS is negatively associated with the risk of LBW in infants. However, Manerkar *et al.*[34], Rashid *et al.*[37] and Alemu and Gashu[47] did not observe such association. The small number of LBW infants and neglection of potential confounding factors on crosstalk between maternal dietary diversity and occurrence of LBW might have affected the finding.

Several maternal factors including age, smoking, chronic diseases, seasonality of food availability and socio-economic factors have been shown to be associated with maternal DDS. Gitagia *et al.*[50], in a cross-sectional study, reported age as an important determinant of dietary diversity among women of reproductive age. Alkerwi *et al.*[51] demonstrated an inverse association between the intensity of smoking and overall diet quality and reported that heavy smokers exhibited less dietary diversity in their food choices. The prospective cohort study of Conklin *et al.*[52] showed that higher diet diversity was correlated with a 30 % lower risk of developing type 2 diabetes in the United Kingdom. Besides, these maternal factors during pregnancy have been reported to act as risk factors for having LBW infants. The results of a systematic review showed that excessive gestational weight gain is associated with increased infant weight and that insufficient gestational weight gain is a risk factor for LBW infants[53]. In a

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Table 2 Summary and characteristics of the fifteen selected observational studies assessing the relationship of maternal dietary diversity and risk of low birth weight

Author(s), year, reference	Country/type of study	Study population	Maternal age (year)/time of data collection	Study location (%)/data collection location	Method of DD assessment	Duration of food intake information	No. of food groups considered/inadequate DDiv	Total no. of LBW infants/no. of LBW infants in low DDS group	%	Covariates adjusted	Findings
Abubakari and colleagues, 2016[33]	Ghana/cohort	578 singleton pregnant women and their newborns	≥ 15/second trimester followed until delivery	Urban: 78·20; rural: 21·8/hospital and child welfare clinics	FAO adopted women DDS using FFQ (analysis contained thirty-six food items)	Per week	9/–	162/–	28·0	Gestational age, women with regular antenatal care attendance and without severely ill state included	Mothers with high DDS had reduced risk of LBW infants (OR: 0·10; 95 % CI 0·04, 0·13; $P < 0·0001$) per SD change in scores
Ahmed and colleagues, 2018[34]	Ethiopia/case-control	279 singleton live births (93 < 2500 g and 186 births ≥ 2500 g) and their mothers	LBW: 27·3 (SD 5·5) NBW: 26·2 (SD 4·7)/after given birth	Urban: 58·4; rural: 41·6/hospitals and health centres	FAO adopted MDD-W	Based on past 24-h recall	10/MDD-W < 5	93/87	93·5	Potential confounders were controlled Neonates with major congenital anomalies, diabetic mothers and mothers with unknown last menstrual period were excluded	93·5 % of LBW and 62·9 % of NBW neonates were belonged to mothers with inadequate DDS ($P < 0·0001$) Mothers with inadequate DDS had about seven times higher odds of having LBW babies (OR: 6·65; 95 % CI 2·31, 19·16)
Alemu and Gashu, 2020[47]	Ethiopia/cohort	341 pregnant women	26·4 (SD 4·8)/first 8 weeks of pregnancy followed until delivery	Urban/antenatal care units	FAO adopted MDD-W	Based on past 24-h recall	10/MDD-W < 5	44/–	13·4	Maternal age, parity, educational status, BMI, Fe, folic acid supplementation, serum Zn and Hb concentration	Low dietary diversity was not associated with LBW (crude OR: 1·2; 95 % CI 0·5, 2·5; $P = 0·6$)
Bekela and colleagues, 2020[49]	Ethiopia/case-control	354 mother–neonate (118 LBW, 236 NBW)	-/-	Urban (*n* 38); rural (*n* 80)/public hospitals	FAO adopted MDD-W	Based on past 24-h recall	–	118		Time of ANC initiation, pregnancy-induced hypertension, Fe and folic acid supplementation	Number of mothers with inadequate DD was higher among LBW infants (adjusted OR = 3·75; 95 % CI 1·64, 8·57)
Jamalzehi and colleagues, 2018[44]	Iran/cohort	400 pregnant women	29·69 (SD 2·94)/third trimester	–/health centres	Kant method (based on the number of groups and subgroups of foods)	FFQ (for last 3 months) and 2 d 24-h recall	8/low DDS: < 3	–		–	There was significant negative correlation between mothers DD and infants birth weight ($\beta = -0·370$, $P = 0·008$)
Madlala, 2017[45]	South Africa/cohort	172 black singleton pregnant women	18–41/second and third trimester	Urban/antenatal care settings	FAO adopted DDS	Based on 24-h recall	9/low DDS: ≤ 3; medium DDS: 4–5; high	8/1	5		There was significant negative correlation between mothers DD and infants

Table 2 *Continued*

Author(s), year, reference	Country/ type of study	Study population	Maternal age (year)/time of data collection	Study location (%)/data collection location	Method of DD assessment	Duration of food intake information	No. of food groups considered/inadequate DDiv	Total no. of LBW infants/ no. of LBW infants in low DDS group	%	Covariates adjusted	Findings
							DDS: ≥ 6 food groups				birth weight (r −0·16; P = 0·04)
Manerkar and colleagues, 2017[35]	India/cohort	121 pregnant women	25·16 (SD 3·61)/second and third trimester	Urban/antenatal clinics	FAO adopted DDS	Based on 24-h recall	9/low DDS ≤ 3 food groups; high DDS ≥ 6 food groups	19/0	15·7	Chronic illness	Mothers DD did not differ between LBW and NBW infants
Nsereko and colleagues, 2020[48]	Rwanda/ prospective cohort	367 pregnant women	28·12 (SD 6·01)/9–15 gestational weeks followed until delivery	Urban (n 120); rural (n 247)/ health centres	FAO adopted MDD-W	FFQ previous day or night	10/low DDS < 5	7/–	2·1	–	Maternal low MDD-W (OR: 3·36; 95 % CI 1·37, 8·26) was independent determinant of LBW
Quansah and Boateng, 2020[36]	Ghana/ cross-sectional	420 mothers attending postnatal clinic	26·7 (SD 5·7)/ post-natal	–/hospital	FAO adopted MDD-W using FFQ	–	10/low DDS ≤ 5	184/88	43·8/60·7	Age, education, employment, marital status, income, birth-order, parity, ANC attendance, smoking, alcohol intake and supplement intake	Maternal low DDS was associated with higher odds of infant LBW (OR: 4·29; 95 % CI 1·24, 6·48)
Rammohan and colleagues, 2019[37]	India/cross-sectional	230 newly delivered women and their babies	–/During 24–48 h after delivery	Urban and rural/hospitals	DD index (based on the intake status of fifty-four food items)	Based on over the last 30 d of pregnancy	DD score range: −1·278– 4·063 Low DD score: < −0·622	/–	51	Women's pre-pregnancy weight, complications during pregnancy, parity, place of residence, religion, education, type of ration card, type of family, social network with any medical person and income tertile	Women with low DD had significantly higher proportion of LBW babies compared with those in the medium or high DD category (OR: 2·245; 95 % CI 1·107, 4·556; P = 0·025)
Rashid and colleagues, 2018[38]	Haiti/case-control	Sixty-six infants (thirty-two LBW and thirty-four NBW) and their mothers	LBW: 27·63 (SD 6·3) NBW: 27·6 (SD ± 5·5)/ after delivery	Urban/hospital	FAO adopted women's DDS	Based on past 24-h recall	9/low DD: <5; high DD: ≥5	32/9	28	–	Mean of DDS did not differ between mothers of LBW and NBW infants. Number of mothers with DDS <5 was non-significantly higher in LBW infants' group (28 %) compared with NBW infants' group (18 %)

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Table 2 *Continued*

Author(s), year, reference	Country/ type of study	Study population	Maternal age (year)/time of data collection	Study location (%)/data collection location	Method of DD assessment	Duration of food intake information	No. of food groups considered/inadequate DDiv	Total no. of LBW infants/ no. of LBW infants in low DDS group	%	Covariates adjusted	Findings
Saaka, 2013[39]	Ghana/ cohort	524 singleton pregnant women and their infants	26·7(SD 5·2)/ between 34 and 36 weeks of gestation	Urban/hospital	FAO modified DD questionnaire	FFQ based on past 24-h recall	12/low DD: ≤ 7 food groups; high DD: ≥ 8 food groups	89/	17·0	Maternal age, GA, educational level, gender of baby, GWG, uptake of sulphadoxine pyrimethamine, frequency of ANC attendance and anaemia during pregnancy, preterm delivery and household wealth index	There was a significant difference in adjusted mean birth weight between women on low and high diversified diets, $F(1, 415) = 8·935$, $P = 0·003$ Maternal high DDS was associated with reduced risk of LBW infants (adjusted OR: 0·43; 95 % CI 0·22, 0·85; $P = 0·014$) Mothers with low DDS had 2·3 times increased risk of delivery LBW babies compared to those with high DDS (adjusted OR: 2·3; 95 % CI 1·18, 4·78; $P = 0·014$)
Tela and colleagues, 2019[40]	Ethiopia/ cohort	332 singleton pregnant mothers and their infants	Mean 28·5/ before delivery	Urban (98·8 %)/private health facilities	Women's DDS	Based on past 24- h recall	9/low DDS: ≤3; medium DDS: 4–6; high DDS: 7–9	–	–	Women with hearing and speaking difficulty, with pre-existing or current medical conditions and women with twin pregnancy were excluded	Mothers with high DDS had significantly larger babies than those with the low score ($P < 0·0001$) There was no association between maternal DD and infant birth weight (β: 0·066; 95 % CI –13, 54; $P = 0·23$)
Vanié and colleagues, 2019[46]	Côte d'Ivoire/ retrospective	146 newborns and mothers	28·44 (SD 5·88)/third trimester	–/maternity hospitals	FAO adopted women's DDS	24-h recall	9/low DDS: ≤3; medium DDS: 4–5; high DDS: ≥6	11	7·6	Education, gestational weight gain, well-being index, alcohol consumption	The mean birth weight of newborns of mothers with medium and high DDS was higher (adjusted OR = 0·386; 95 % CI 0·072, 0·699; $P = 0·017$ and adjusted OR = 0·233; 95 % CI 0·016, 0·450; $P = 0·036$)
Zerfu and colleagues, 2016[41]	Ethiopia/ cohort	374 pregnant women (followed until delivery) and their infants	Low DDS: 25·54 (SD 0·347) Adequate DDS: 24·44 (SD 0·30)/ second trimester	Rural/health centres	Women's DDS	Four 24- h recall	9/inadequate DDS: ≤3 Adequate DDS: ≥4 food groups	34/ 23	9·1/ 67·65	MUAC, level of education, Hb, age, height, GA	Women with inadequate DDS had higher risk of LBW infants (ARR: 2·06; 95 % CI 1·03, 4·11). Mean infants' birth weight was significantly lower in mothers with low DDS ($P < 0·001$)

ARR, adjusted relative risk; DDiv, dietary diversity; DDS, dietary diversity score; FFQ, food frequency questionnaire; LBW, low birth weight; NBW, normal birth weight; ANC, antenatal clinic (care); GA, gestational age; GWG, gestational weight gain; OR, odds ratio; FAO, Food and Agriculture Organisation; MDD-W, Minimum Dietary Diversity for Women.

cohort study, Restrepo-Méndez[8] demonstrated that very young (< 16 years) or advanced maternal age (≥ 35 years) was associated with enhanced odds of LBW infants. Maternal smoking, heavy alcohol drinking and chronic diseases such as hypertension and diabetes have also been reported as risk factors for having LBW infants[12,13,15]. Moreover, seasonality of food availability may act as a confounder in dietary diversity surveys in developing countries. It has been reported that food availability and access are strongly affected by seasonality and are associated with both maternal and child nutritional status[54,55].

Socio-economic status of the household is another factor that may influence dietary diversity of both mother and child. Mayén *et al.*[56] in a systematic review study found that high socio-economic status was associated with higher diet quality and diversity, in low- and middle-income countries. Kiboi *et al.*[57] in a cross-sectional study on 254 pregnant women showed socio-economic factors including education level, employment status, monthly income, household assets and land ownership as effective factors on dietary diversity of the women. Rammohan *et al.*[37], in a study on 230 newly delivered women, reported that low maternal education and economic status were significantly associated with poor dietary diversity of the women.

Evidence from several studies indicated that nutrition supplements (such as Fe and folic acid) intake may be inversely or positively correlated with LBW[58–60]. Intake of nutrient supplements may promote maternal resistance to infections during pregnancy, ameliorate nutritional status and improve birth consequences[59]. An overview of twenty-three systematic reviews of randomised controlled trials focusing on nutritional interventions before or during gestation showed that multiple micronutrients supplementation and improving maternal nutritional status positively influence LBW[60].

Taken together, the above-mentioned factors can be interpreted as having a confounding effect on the relationship between DDS and LBW. However, this concern has not been addressed in several studies reviewed.

Apparently, dietary diversity during pregnancy prevents neonate LBW by affecting maternal gestational weight gain. It has been reported that high maternal dietary diversity during pregnancy positively contributes to her gestational weight gain[61]. Evidence indicates that mothers with higher gestational weight gain tend to deliver heavier babies[40,62]. Besides, dietary diversity during pregnancy minimises the occurrence of nutritional deficiencies, in particular the development of anaemia in mothers which, in turn, leads to the improvement of fetal growth. The results of systematic reviews and meta-analysis studies demonstrated a significant association between maternal anaemia and infant LBW[63,64]. Zerfu *et al.*[41] suggested that maternal dietary diversity during pregnancy is linked to a decreased risk of anaemia in the mother. In a cohort study involving 1675 pregnant women, Ghosh *et al.*[65] reported that dietary diversity is positively associated with serum Hb. However, other studies found no such association[66].

Various criteria or cut-off points were used to identify inadequate dietary diversity across the studies which may influence the accuracy of the results. None of the studies indicated accuracy of the criteria or cut-off points in predicting newborns' LBW risk. Thus, it was needed to perform appropriate statistical methods such as receiver operating characteristic analysis to determine optimal threshold and to calculate the sensitivity and specificity of the different criteria or cut-off points in predicting risk of LBW.

Dietary diversity scoring was based on the number of food groups consumed by individuals, in the reviewed articles. Around 86·6 % of the reviewed articles used FAO adopted tools of WDDS (53·33 %) or MDD-W (33·33 %) for the assessment of dietary diversity. The differences between the two indicators are in the number of food groups, with nine groups in WDDS and ten in MDD-W[32]. The food groups of WDDS include starchy foods, dark green leafy vegetables, meat and fish, other vegetables and fruits, vegetables and fruits rich in vitamin A,organ meats, milk and dairy products, eggs, legumes, nuts and seeds. The food groups of MDD-W are composed of grains, white roots and tubers, and plantains; pulses (beans, peas and lentils); nuts and seeds; dairy; meat, poultry and fish; eggs; dark green leafy vegetables; other vitamin A-rich fruits and vegetables; other vegetables and other fruits[32]. In MDD-W, vegetables and fruits combined in one group but have separated in MDD-W. Therefore, according to the similarity of food groups between the two indicators, it seems that the method of dietary diversity scoring or the type of tool used for dietary diversity assessment are not factors that bias the findings.

Limitations of the review

Most studies conducted in urban areas, while rural areas have been neglected. In several studies, the dietary diversity data were collected after giving birth, a time that might not reflect the infant birth weight. Food intake information was collected retrospectively in most of the studies, a fact that may increase reporting bias[67]. Using methods which employ health workers/proficient enumerators who are able to bring a cultural knowledge of local foods may help to avoid such biases[68]. In addition, the period of data collection only comprised the previous 24 h, which might not be indicative of individual habitual intake. The number of LBW infants was too small in several studies, which makes the results controversial. Furthermore, there are many potential variables that can influence maternal DDS and the risk of LBW, including maternal age, gestational weight gain, gestational age, chronic diseases, smoking, alcohol use, gender of baby, infant congenital anomalies, nutritional supplements intake, seasonality of food availability and socio-economic factors and twin pregnancy. However, the confounding effects of these variables have not been addressed in several studies or the number of factors taken into account was too small.

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This review is restricted by lack of study from developed countries. The scoring of low dietary diversity varied across the studies which make it difficult to compare results across studies. Lack of interventional study was another limitation. Further evidence from interventional studies is needed to confirm findings from observational studies.

Implication of the findings

The findings of the current study imply an interaction between DDS and LBW. Thus, it is suggested that implementation of nutrition education and counselling in pregnancy[69,70] and peri-conceptional[70] care processes are helpful to improve birth outcomes. In addition, improving maternal nutritional status through multiple micronutrients supplementation during pregnancy might be an effective strategy to reduce the risk of LBW in newborns[60,71,72,73]. Such interventions must be incorporated in health promotion strategies targeting the peri-conceptional and pregnant mothers in order to improve their dietary diversity. However, there is a need to further identify environmental factors contributing to poor DDS, in particular among low- and middle-income communities. Furthermore, pregnant mothers with poor dietary diversity must be regularly screened and properly identified and the importance of a healthy and diverse diet during pregnancy must be emphasised.

Conclusion

The results of the present study suggest that high maternal dietary diversity during pregnancy may be associated with the risk of LBW infants in developing countries.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980021000276

References

1. World Health Organization (2014) *Global Nutrition Targets 2025: Low Birth Weight Policy Brief, Nutrition*. WHO; available at https://www.who.int/nutrition/publications/globaltargets2025_policybrief_lbw/en/ (accessed March 2021).
2. Xiong X, Wightkin J, Magnus JH *et al.* (2007) Birth weight and infant growth: optimal infant weight gain versus optimal infant weight. *Matern Child Health J* **11**, 57–63.
3. Fan RG, Portuguez MW & Nunes ML (2013) Cognition, behavior and social competence of preterm low birth weight children at school age. *Clinics (Sao Paulo)* **68**, 915–921.
4. Chidiebere ODI, Ekwochi UE, Ndu Ikenna K *et al.* (2018) The low-birth weight infants: pattern of morbidity and mortality in a tertiary healthcare facility in the South Eastern Nigeria. *Ann Med Health Sci Res* **8**, 4–10.
5. Knop MR, Geng TT, Gorny AW *et al.* (2018) Birth weight and risk of type 2 diabetes mellitus, cardiovascular disease, and hypertension in adults: a meta-analysis of 7 646 267 participants from 135 studies. *J Am Heart Assoc* **7**, e008870.
6. Tshotetsi L, Dzikiti L, Hajison P *et al.* (2019) Maternal factors contributing to low birth weight deliveries in Tshwane District, South Africa. *PLoS One* **14**, e0213058.
7. Qian M, Chou SY, Gimenez L *et al.* (2017) The intergenerational transmission of low birth weight and intrauterine growth restriction: a large cross-generational cohort study in Taiwan. *Matern Child Health J* **21**, 1512–1521.
8. Restrepo-Méndez MC, Lawlor DA, Horta BL *et al.* (2015) The association of maternal age with birthweight and gestational age: a cross-cohort comparison. *Paediatr Perinat Epidemiol* **29**, 31–40.
9. Ooki S (2010) The effect of an increase in the rate of multiple births on low-birth-weight and preterm deliveries during 1975–2008. *J Epidemiol* **20**, 480–488.
10. Tran NT, Nguyen LT, Berde Y *et al.* (2019) Maternal nutritional adequacy and gestational weight gain and their associations with birth outcomes among Vietnamese women. *BMC Pregnancy Childbirth* **19**, 468.
11. Mahmoodi Z, Karimlou M, Sajjadi H *et al.* (2015) Association of maternal working condition with low birth weight: the social determinants of health approach. *Ann Med Health Sci Res* **5**, 385–391.
12. Graham J, Zhang L & Schwalberg R (2007) Association of maternal chronic disease and negative birth outcomes in a non-Hispanic Black-White Mississippi birth cohort. *Public Health Nurs* **24**, 311–317.
13. Chen JH (2012) Maternal alcohol use during pregnancy, birth weight and early behavioral outcomes. *Alcohol* **47**, 649–656.
14. Zhou H, Wang A, Huang X *et al.* (2019) Quality antenatal care protects against low birth weight in 42 poor counties of Western China. *PLoS One* **14**, e0210393.
15. Zheng W, Suzuki K, Tanaka T *et al.* (2016) Association between maternal smoking during pregnancy and low birthweight: effects by maternal age. *PLoS One* **11**, e0146241.
16. Zhang B, Xia W, Li Y *et al.* (2015) Prenatal exposure to lead in relation to risk of preterm low birth weight: a matched case-control study in China. *Reprod Toxicol* **57**, 190–195.
17. Liu Y, Xu J, Chen D *et al.* (2019) The association between air pollution and preterm birth and low birth weight in Guangdong, China. *BMC Public Health* **19**, 3.
18. Gernand AD, Schulze KJ, Stewart CP *et al.* (2016) Micronutrient deficiencies in pregnancy worldwide: health effects and prevention. *Nat Rev Endocrinol* **12**, 274–289.
19. Darnton-Hill I & Mkparu UC (2015) Micronutrients in pregnancy in low- and middle-income countries. *Nutrients* **7**, 1744–1768.
20. Salam RA, Das JK, Ali A *et al.* (2013) Maternal undernutrition and intrauterine growth restriction. *Expert Rev Obstet Gynecol* **8**, 559–567.

Public Health Nutrition

21. Hasan SMT, Khan MA & Ahmed T (2019) Inadequate maternal weight gain in the third trimester increases the risk of intrauterine growth restriction in rural Bangladesh. *PLoS One* **14**, e0212116.
22. Abu-Saad K & Fraser D (2010) Maternal nutrition and birth outcomes. *Epidemiol Rev* **32**, 5–25.
23. Black RE, Allen LH, Bhutta ZA *et al.* (2008) Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* **371**, 243–260.
24. Herring CM, Bazer FW, Johnson GA *et al.* (2018) Impacts of maternal dietary protein intake on fetal survival, growth, and development. *Exp Biol Med (Maywood)* **243**, 525–533.
25. Christian P & Stewart CP (2010) Maternal micronutrient deficiency, fetal development, and the risk of chronic disease. *J Nutr* **140**, 437–445.
26. Lee YQ, Collins CE, Gordon A *et al.* (2018) The relationship between maternal nutrition during pregnancy and offspring kidney structure and function in humans: a systematic review. *Nutrients* **10**, E241.
27. Veena SR, Gale CR, Krishnaveni GV *et al.* (2016) Association between maternal nutritional status in pregnancy and offspring cognitive function during childhood and adolescence: a systematic review. *BMC Pregnancy Childbirth* **16**, 220.
28. Borge TC, Aase H, Brantsæter AL *et al.* (2017) The importance of maternal diet quality during pregnancy on cognitive and behavioural outcomes in children: a systematic review and meta-analysis. *BMJ Open* **7**, e016777.
29. Henjum S, Torheim LE, Thorne-Lyman AL *et al.* (2015) Low dietary diversity and micronutrient adequacy among lactating women in a peri-urban area of Nepal. *Public Health Nutr* **18**, 3201–3210.
30. Yeneabat T, Adugna H, Asmamaw T *et al.* (2019) Maternal dietary diversity and micronutrient adequacy during pregnancy and related factors in East Gojjam Zone, Northwest Ethiopia, 2016. *BMC Pregnancy Childbirth* **19**, 173.
31. Kennedy G, Ballard T & Dop MC (2013) *Guidelines for Measuring Household and Individual Dietary Diversity. Nutrition and Consumer Protection Division*. Rome, Italy: Food and Agriculture Organization of the United Nations.
32. FAO & FHI 360 (2016) *Minimum Dietary Diversity for Women: A Guide for Measurement*. Rome: FAO.
33. Abubakari A & Jahn A (2016) Maternal dietary patterns and practices and birth weight in Northern Ghana. *PLoS One* **11**, e0162285.
34. Ahmed S, Hassen K & Wakayo T (2018) A health facility based case-control study on determinants of low birth weight in Dassie town, Northeast Ethiopia: the role of nutritional factors. *Nutr J* **17**, 103.
35. Manerkar K & Gokhale D (2017) Effect of maternal diet diversity and physical activity on neonatal birth weight: a study from urban slums of Mumbai. *J Clin Diagn Res* **11**, 7–11.
36. Quansah DY & Boateng D (2020) Maternal dietary diversity and pattern during pregnancy is associated with low infant birth weight in the Cape Coast metropolitan hospital, Ghana: a hospital based cross-sectional study. *Heliyon* **6**, e03923.
37. Rammohan A, Goli S, Singh D *et al.* (2019) Maternal dietary diversity and odds of low birth weight: empirical findings from India. *Women Health* **59**, 375–390.
38. Rashid A, Park T, Macneal K *et al.* (2018) Maternal diet and morbidity factors associated with low birth weight in Haiti: a case-control study. *Health Equity* **2**, 139–144.
39. Saaka M (2012) Maternal dietary diversity and infant outcome of pregnant women in Northern Ghana. *Int J Child Health Nutr* **1**, 148–156.
40. Tela FG, Bezabih AM & Adhanu AK (2019) Effect of pregnancy weight gain on infant birth weight among mothers attending antenatal care from private clinics in Mekelle City, Northern Ethiopia: a facility based follow-up study. *PLoS One* **14**, e0212424.
41. Zerfu TA, Umeta M & Baye K (2016) Dietary diversity during pregnancy is associated with reduced risk of maternal anemia, preterm delivery, and low birth weight in a prospective cohort study in rural Ethiopia. *Am J Clin Nutr* **103**, 1482–1488.
42. Moher D, Shamseer L, Clarke M *et al.* (2015) Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* **4**, 1.
43. Wells GA, Shea B, O'Connell D *et al. The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomised Studies in Meta-Analyse*s. Ottawa, Ontario: Department of Epidemiology and Community Medicine, University of Ottawa.
44. Jamalzehi A, Javadi M & Dashipour A (2018) The relationship between dietary diversity at third trimester of pregnancy and newborns' anthropometric indices at birth. *JNFS* **3**, 116–122.
45. Madlala SS (2017) The dietary diversity, household food security status and presence of depression in relation to pregnancy pattern of weight gain and infant birth weight. Pietermaritzburg. http://hdl.handle.net/10413/14522 (accessed March 2021).
46. Vanié SC, Gbogouri CA, Edjème-Aké A *et al.* (2019) Maternal anthropometry and dietary diversity associated with birth weight in maternity hospitals in Abidjan (Côte d'Ivoire). *Eur J Nutr Food Saf* **11**, 1–13.
47. Alemu B & Gashu D (2020) Association of maternal anthropometry, hemoglobin and serum zinc concentration during pregnancy with birth weight. *Early Hum Dev* **142**, 104949.
48. Nsereko E, Uwase A, Mukabutera A *et al.* (2020) Maternal genitourinary infections and poor nutritional status increase risk of preterm birth in Gasabo District, Rwanda: a prospective, longitudinal, cohort study. *BMC Pregnancy Childbirth* **20**, 345.
49. Bekela MB, Shimbre MS, Gebabo TF *et al.* (2020) Determinants of low birth weight among newborns delivered at public hospitals in Sidama Zone, South Ethiopia: unmatched case-control study. *J Pregnancy* **2020**, 4675701.
50. Gitagia MW, Ramkat RC, Mituki DM *et al.* (2019) Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food Nutr Res* **63**, 1553. doi: 10.29219/fnr.v63.1553.
51. Alkerwi A, Baydarlioglu B, Sauvageot N *et al.* (2017) Smoking status is inversely associated with overall diet quality: findings from the ORISCAV-LUX study. *Clin Nutr* **36**, 1275–1282.
52. Conklin AI, Monsivais P, Khaw KT *et al.* (2016) Dietary diversity, diet cost, and incidence of type 2 diabetes in the United Kingdom: a prospective cohort study. *PLoS Med* **13**, e1002085.
53. Siega-Riz AM, Viswanathan M, Moos MK *et al.* (2009) A systematic review of outcomes of maternal weight gain according to the Institute of Medicine recommendations: birthweight, fetal growth, and postpartum weight retention. *Am J Obstet Gynecol* **201**, 339.e1–339.e14.
54. Abizari AR, Azupogo F, Nagasu M *et al.* (2017) Seasonality affects dietary diversity of school-age children in northern Ghana. *PLoS One* **12**, e0183206.
55. Poole N, Amiri H, Amiri SM *et al.* (2019) Food production and consumption in Bamyan Province, Afghanistan: the challenges of sustainability and seasonality for dietary diversity. *Int J Agric Sustain* **17**, 413–430.
56. Mayén AL, Marques-Vidal P, Paccaud F *et al.* (2014) Socioeconomic determinants of dietary patterns in low- and middle-income countries: a systematic review. *Am J Clin Nutr* **100**, 1520–1531.
57. Kiboi W, Kimiywe J & Chege P (2017) Determinants of dietary diversity among pregnant women in Laikipia County, Kenya: a cross-sectional study. *BMC Nutrition* **3**, 12.

58. Adu-Afarwuah S, Lartey A, Okronipa H *et al.* (2015) Lipid-based nutrient supplement increases the birth size of infants of primiparous women in Ghana. *Am J Clin Nutr* **101**, 835–846.
59. Keats EC, Haider BA, Tam E *et al.* (2019) Multiple-micronutrient supplementation for women during pregnancy. *Cochrane Database Syst Rev* **3**, CD004905.
60. da Silva Lopes K, Ota E, Shakya P *et al.* (2017) Effects of nutrition interventions during pregnancy on low birth weight: an overview of systematic reviews. *BMJ Glob Health* **2**, e000389.
61. Ali F, Thaver I & Khan SA (2014) Assessment of dietary diversity and nutritional status of pregnant women in Islamabad, Pakistan. *J Ayub Med Coll Abbottabad* **26**, 506–509.
62. Lima RJCP, Batista RFL, Ribeiro MRC *et al.* (2018) Prepregnancy body mass index, gestational weight gain, and birth weight in the BRISA cohort. *Rev Saude Publica* **52**, 46.
63. Rahmati S, Delpishe A, Azami M *et al.* (2017) Maternal anemia during pregnancy and infant low birth weight: a systematic review and meta-analysis. *Int J Reprod Biomed (Yazd)* **15**, 125–134.
64. Figueiredo ACMG, Gomes-Filho IS, Silva RB *et al.* (2018) Maternal anemia and low birth weight: a systematic review and meta-analysis. *Nutrients* **10**, E601.
65. Ghosh S, Trevino JA, Davis D *et al.* (2017) Factors associated with anemia in pregnant women in Bank, Nepal. *FASEB J* **31**, Suppl. 1, 788.32–788.32.
66. Adokiya MN, Aryeetey R, Yost M *et al.* (2019) Determinants of anemia among pregnant women in Northern Ghana.
67. Ventura AK, Loken E, Mitchell DC *et al.* (2006) Understanding reporting bias in the dietary recall data of 11-year-old girls. *Obesity (Silver Spring)* **14**, 1073–1084.
68. Hanley-Cook GT, Tung J, Sattamini IF *et al.* (2020) Minimum dietary diversity for women of reproductive age (MDD-W) data collection: validity of the list-based and open recall methods as compared to weighed food record. *Nutrients* **12**, 2039.
69. Demilew YM, Getu Degu Alene GD & Belachew T (2020) Effect of guided counseling on nutritional status of pregnant women in west Gojjam zone, Ethiopia: a cluster-randomized controlled trial. *Nutr J* **19**, 38.
70. WHO & e-Library of Evidence for Nutrition Actions (eLENA) Nutrition counselling during pregnancy. WHO; available at https://www.who.int/elena/titles/nutrition_counselling_pregnancy/en/ (accessed March 2021).
71. Ramakrishnan U (2019) Nutrition education during the preconception period. *Nestle Nutr Inst Workshop Ser* **92**, 19–30.
72. Oh C, Keats EC & Bhutta ZA (2020) Vitamin and mineral supplementation during pregnancy on maternal, birth, child health and development outcomes in low- and middle-income countries: a systematic review and meta-analysis. *Nutrients* **12**, 491.
73. Zerfu TA & Ayele HT (2013) Micronutrients and pregnancy; effect of supplementation on pregnancy and pregnancy outcomes: a systematic review. *Nutr J* **12**, 20.

Public Health Nutrition