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Public Health Nutrition

Review Article

Maternal dietary patterns and risk of adverse pregnancy (hypertensive disorders of pregnancy and gestational diabetes mellitus) and birth (preterm birth and low birth weight) outcomes: a systematic review and meta-analysis

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Abstract

Objective: Epidemiological studies have indicated that dietary patterns during pregnancy are associated with adverse pregnancy and birth outcomes such as hypertensive disorders of pregnancy (HDP), gestational diabetes mellitus (GDM), preterm birth (PTB) and low birth weight (LBW). However, the results of these studies are varied and inconsistent. The present study aimed to assess the association between dietary patterns and the risk of adverse pregnancy and birth outcomes.

Design: Systematic review and meta-analysis. Seven databases were searched for articles. Two reviewers performed the study selection and data extraction. A random-effects model was used to estimate pooled effect sizes of eligible studies.

Setting: Studies conducted all over the world were incorporated.

Subjects: The review focused on pregnant women.

Results: A total of twenty-one studies were identified. Adherence to a healthy dietary pattern (intake of vegetables, fruits, legumes, whole grains) was significantly associated with lower odds (OR; 95 % CI) of pre-eclampsia (0·78; 0·70, 0·86; $I^2 = 39{\cdot}0\,\%$, $P = 0{\cdot}178$), GDM (0·78; 0·56, 0·99; $I^2 = 68{\cdot}6\,\%$, $P = 0{\cdot}013$) and PTB (0·75; 0·57, 0·93; $I^2 = 89{\cdot}6\,\%$, $P = 0{\cdot}0001$).

Conclusions: Our review suggests that dietary patterns with a higher intake of fruits, vegetables, legumes, whole grains and fish are associated with a decreased likelihood of adverse pregnancy and birth outcomes. Further research should be conducted in low-income countries to understand the impact of limited resources on dietary intake and adverse pregnancy and birth outcomes.

Keywords
Dietary patterns
Dietary intake
Pregnancy
Pregnant women

Hypertensive disorders of pregnancy (HDP) are a group of conditions related to high blood pressure during pregnancy, proteinuria and in some cases convulsions[1]. HDP are responsible for increased morbidity and mortality in mothers and newborns, accounting for approximately 14 % of maternal deaths globally between 2003 and 2009[2]. According to an analysis of international cohorts from six countries (Australia/New Zealand, Canada, Israel, Japan, Spain and Sweden), the incidence rate of HDP was 13 % (ranging from 10·3 to 16·4 %)[3].

Preterm birth (PTB) is the premature delivery of a neonate before 37 weeks of gestation[4]. PTB is most common in low- and middle-income countries and is one of the leading causes of direct neonatal deaths and complications[4], responsible for more than 50 % of neonatal mortality in 2010[5]. According to a systematic analysis and estimation of PTB, the rate of PTB was 11 % in 2010 globally, ranging from 5 % in European countries to 18 % in some African countries[6]. Likewise, low birth weight (LWB), which refers to a newborn birth weight of less than 2·5 kg, is

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common (15 %). High rates are reported in many developing countries, especially South Asia (25 %), sub-Saharan Africa (12 %)[7], Pakistan (35 %), Nepal (30 %) and Jordan (22 %)[8].

Evidence has shown that dietary patterns have an influence on adverse pregnancy and birth outcomes[9,10]. When individuals consume foods, they consume a combination of nutrients, not single nutrients[11]. The whole diet with its expected synergistic effects may have a greater influence on the occurrence of health outcomes than single nutrients[11]. Hence, it appears more complete to examine the effect of the whole diet by applying a more all-inclusive method of dietary pattern analysis, because dietary patterns evaluate the usual diet as one complete dietary exposure[12,13].

Dietary pattern analysis aims to assess the usual foods consumed as one overall dietary exposure[12,14]. Dietary patterns are defined as the quantities, proportions, variety or combinations of different foods and beverages in diets and the frequency with which they are regularly consumed[15]. Dietary patterns can be determined by three approaches. The first is the *a priori* approach, which constructs dietary scores or indices based on predefined dietary recommendations[12,14,16]. The second is the *a posteriori* approach, which identifies data-driven dietary patterns using statistical methods (cluster analysis and principal component analysis (PCA))[12,14,16]. The third approach consists of hybrid methods such as reduced rank regression, which combine aspects of the *a priori* and *a posteriori* approaches[16].

Previous studies have indicated that dietary patterns during pregnancy have a varied effect on maternal health and pregnancy outcomes such as HDP[10,17], GDM[18,19], PTB[9,20,21] and LBW[22]. For HDP, intake of vegetables, legumes, nuts, tofu, rice, pasta, rye bread, fish, milk, green leafy vegetables and pulses/beans was associated with a lower odds of pre-eclampsia/eclampsia[10,23], while the consumption of meat and potatoes, processed meat, sweet drinks and salty snacks increased the likelihood of pre-eclampsia[10,24,25]. Other studies have reported contradictory findings; a cohort study in the USA[17] reported that a higher Alternate Healthy Eating Index (AHEI) score comprising vegetables, fruit, fibre, *trans* fat, high PUFA:SFA, folate, Ca and Fe from foods was not associated with pre-eclampsia. For GDM, a Western dietary pattern (high intake of red meat, processed meat, refined grain products, sweets, French fries and pizza) among pregnant women in the USA[26], a pasta–cheese–processed-meat pattern[18] in a Singaporean population and a sweet and seafood pattern in China[19] have been associated with increased odds of GDM.

Regarding the birth outcomes, a 'prudent' dietary pattern with a high intake of vegetables, fruits, oils, water (beverage), wholegrain cereals and fibre-rich breads was associated with a reduced occurrence of PTB[9]. In contrast, a Western pattern (salty and sweet snacks, white bread, desserts and processed meat products)[9] and a Mediterranean diet with a high intake of fish, fruit, vegetables, olive/canola oil, and a low intake of red meat and coffee had no effect on PTB[20]. Contrary to this, in a Danish birth cohort study, the odds of PTB increased in women who adhered to a Western pattern (high in meat and fats and low in fruits and vegetables)[21]. A study from the USA[27] revealed that birth weight and fetal growth were not associated with the maternal AHEI score (high intakes of vegetables, fruit, whole grains, nuts and legumes, long-chain (n-3) fats, polyunsaturated fats, folate, Ca and Fe).

Current epidemiological studies show some evidence for an association between dietary patterns and adverse pregnancy and birth outcomes. However, the findings are inconsistent and there is a need to identify which dietary patterns could have health benefits for pregnant women in preventing adverse pregnancy and birth outcomes. Therefore, our aim was to determine the association between dietary patterns during pregnancy and the risk of pregnancy (HDP, GDM) and birth (PTB and LBW) outcomes through a systematic review and meta-analysis.

Methods

Search strategy

Seven databases were searched, including MEDLINE, EMBASE, CINAHL, Scopus, Cochrane Library, Web of Science, and Maternity and Infant Care. The reference lists of all previous articles were hand-searched.

The following terms, words and combinations of words were searched: ('diet' OR 'nutrition' OR 'food pattern' OR 'meal pattern' OR 'eating practice' OR 'food intake' OR 'food habits' OR 'eating behaviour' OR 'dietary pattern' OR 'dietary diversity score' AND 'pregnancy' OR 'pregnant women' OR 'gravid' OR 'gestation' OR 'prenatal care' OR 'antenatal care' AND 'gestational hypertension' OR 'pregnancy-induced hypertension' OR 'preeclampsia' OR 'pre-eclampsia' OR 'low birth weight' OR 'premature infant' OR 'premature birth' OR 'preterm birth' OR 'pregnancy in diabetics' OR 'gestational diabetes mellitus').

The search was comprised of free text words, title and Medical Subject Heading for outcomes, exposure and participants, as well as applying limits including English language and human subjects.

Study selection

The studies were screened by title and then by abstract by two reviewers (K.T.K., T.K.T.). The full texts of all selected studies were critically reviewed based on the inclusion/exclusion criteria summarized in Table 1.

Data extraction

The following variables were extracted by two reviewers (K.T.K., T.K.T.): authors, publication year, study period, study design, settings/country, sample, dietary patterns with food details, dietary assessment methods and

Table 1 Inclusion and exclusion criteria for the current systematic review and meta-analysis on maternal dietary patterns and risk of adverse pregnancy and birth outcomes

Inclusion criteria
- Pregnant women
- No date restrictions
- Original articles (randomized trials and observational studies)
- Dietary pattern as the exposure variable
- Included one or more of the following outcome variables: HDP, GDM, LBW, PTB

Exclusion criteria
- High-risk populations: women with heart diseases, diabetes, pre-eclampsia or gestational hypertension at baseline
- Unpublished papers
- Animal studies
- Brief communications, case series, editorials, review studies
- Studies that focused on single nutrients

HDP, hypertensive disorders of pregnancy (gestational hypertension, pre-eclampsia and eclampsia); GDM, gestational diabetes mellitus; LBW, low birth weight; PTB, preterm birth.

periods, main outcomes (HDP, GDM, LBW and PTB) and adjustment for confounding factors.

Quality assessments

The quality of selected full-text articles was rated by two reviewers independently (K.T.K., T.K.T.) using the Academy of Nutrition and Dietetics quality appraisal tool[28]. This tool has four relevance questions and ten validity questions. The validity questions appraise the selection, comparability of groups, assessment of exposures or outcomes and statistical analysis for each study separately[28]. The validity of a study is assessed as the responses to all relevant questions being 'yes'. The response for all validity questions is 'yes' if the criterion was fulfilled, 'no' if not fulfilled, 'unclear' if not precisely stated and 'N/A' (not applicable) if the criterion does not apply to the articles[28]. The rating scores of studies were positive (+) if the responses to the validity questions were 'yes' for six or more responses (including all four relevance questions). If the articles did not fulfil the relevance criterion of selection, comparability of groups and measurement of exposures or outcomes, the rating score was neutral (Ø) and if the responses for the validity questions are 'no' or 'unclear' for six or more responses, a negative (–) rating score was given[28].

Statistical analysis

The data were entered into a Microsoft® Excel spreadsheet version 16 and exported to the statistical software package Stata version 13 for analysis. The OR was used as a measure of effect estimate. If an incidence of outcome variable was less than or equal to 20 %, the risk ratio (RR) and OR were pooled together in the meta-analysis; otherwise RR was converted to OR using the proposed methods of Zhang and Yu[29] and Cochrane[30]. If the studies did not report OR/RR but reported the coefficient (β) of the regression, it was converted into OR/RR by exponentiation of the coefficient (i.e. OR = exp(β))[31].

Some articles reported OR/RR based on different references. Some used lower adherence to dietary patterns, while some used good adherence. To make this consistent and unify all results using either the higher or lower group as reference, the new OR/RR was calculated by taking the reciprocal of the reported OR/RR. The lower limit of the new OR/RR is the reciprocal of the upper limit of the old OR/RR and the upper limit of the new OR/RR is reciprocal of the lower limit of the old OR/RR[32].

The random-effects model was used for calculating pooled estimates. Statistical heterogeneity was evaluated by Cochran's Q test (I^2), which shows the amount of heterogeneity between studies. An I^2 value reflects between-study variation (values of 25, 50 and 75 % refer to low, medium and high variation, respectively)[33].

Subgroup analyses were conducted to detect potential sources of heterogeneity. The possible effects of between-study variance of dietary assessment methods (dietary diversity score (DDS), Mediterranean diet score (MDS), PCA) and dietary assessment periods/trimesters (first trimester (1st–12th weeks), second trimester (13th–27th weeks), third trimester (28th–40th weeks)) were assessed.

Dietary patterns detected in each study were different regarding to the country of origin and the approaches used for identifying dietary patterns; however, they had similarities among commonly consumed food items. For instance, most articles identified a prudent, traditional, Mediterranean or healthy dietary pattern which commonly consisted of whole grains, nuts legumes/pulses, vegetables/fruits and fish. These studies were grouped together and analysed by labelling them as 'healthy dietary pattern'.

Similarly, those patterns comprised mostly of refined grains, processed meats or snacks, high-sugar and high-fat dairy products, eggs and white potatoes were grouped together, labelled as the 'Western dietary pattern' and then analysed.

Using the available articles, pooled estimates were determined for the effect of the healthy pattern on HDP, GDM, PTB and LBW. Likewise, meta-analysis was performed for a Western dietary pattern and GDM, HDP and PTB.

Results

Identified studies

Our search identified 6291 records after removal of duplicates. One hundred articles were identified for full-text review, with twenty-one articles incorporated in the systematic review and meta-analysis (Fig. 1).

Study characteristics

Of the twenty-one articles included, the majority (n 15) were conducted in developed countries, with the

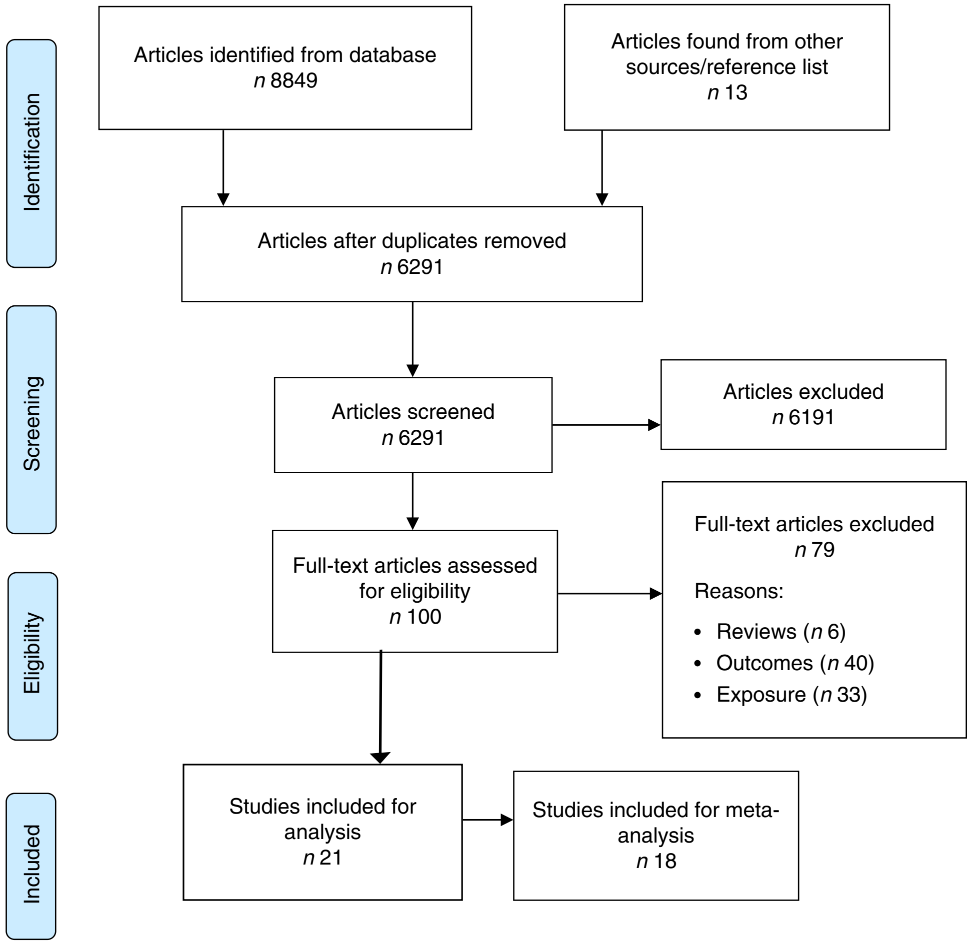

Fig. 1 (colour online) Flowchart of the study selection process for the current systematic review and meta-analysis on maternal dietary patterns and risk of adverse pregnancy and birth outcomes

remainder in developing countries. Out of all included articles, eighteen were cohort studies and three were cross-sectional studies. The articles were published between 2008 and 2016. The sample in each study ranged from 168[34] to 66 000[9] with 302 450 pregnant women in total. In the included articles, six reported the effect of dietary patterns on HDP[10,25,35–38], six reported on GDM[18,19,34,39–41], nine reported on PTB[9,20,21,36,42–46] and two reported on LBW[46,47] (Table 2).

Most of the articles (*n* 15) used an FFQ[9,10,19–21,25,35,36,38,40,41,43–45,47] as the method of dietary assessment, five studies used a 24 h recall[18,37,39,42,46], and one used a four-day food record[34] to assess the dietary intake. Various types of approaches were used to identify dietary patterns. Most studies applied the *a posteriori* approach (PCA; *n* 13)[9,10,18,19,21,25,34,35,38,41–43,47]; seven studies used the *a priori* method, DDS[37,46] or MDS[20,40,44,45] or New Nordic Diet (NND)[36]; and one study used the rank reduced regression method[39] to identify the dietary pattern of the women (Table 2). All studies had a positive score for the quality assessment.

The association of dietary patterns with adverse pregnancy outcomes (hypertensive disorders of pregnancy and gestational diabetes mellitus)

Dietary pattern and hypertensive disorders of pregnancy
Six articles[10,25,35–38] assessed the association between dietary pattern and HDP. These articles identified a range of different dietary patterns like healthy, traditional, Mediterranean and Western patterns, and therefore the results could not be pooled in meta-analysis except the healthy dietary pattern.

Healthy dietary pattern. Four studies[10,25,36,38] were available for meta-analysis that reported the association between a healthy dietary pattern with a high intake of fruits, vegetables, whole-grain foods, fish and poultry and HDP. Based on this pooled analysis, study participants who adhered to a healthy dietary pattern were shown to have significantly lower odds of pre-eclampsia (OR = 0·78, 95 % CI 0·70, 0·86; $I^2 = 39·0\,\%$, $P = 0·178$; Fig. 2).

However, one[37] cross-sectional study in Tanzania indicated that having a high DDS (OR = 5·84; 95 % CI 2·11, 16·15) or a medium DDS (OR = 2·54; 95 % CI 1·04, 6·16) was associated with increased odds of gestational hypertension. On the contrary, in a cohort study, no association

Table 2 Characteristics of the articles included in the current systematic review and meta-analysis on maternal dietary patterns and risk of adverse pregnancy and birth outcomes

Study	Study design; period; country	Sample (*n*)	Dietary assessment: Methods	Dietary assessment: Trimester (period)	Methods of defining dietary pattern	Dietary patterns identified	Main findings	Outcomes	Confounding factors
Brantsaeter *et al.* (2009)[10]	Cohort; 2002–2006; Norway	23 423	255-item FFQ*	2nd (17–22 weeks)	PCA	Vegetable; potato and fish; cakes and sweets; processed food	Vegetable (tertile 3 *v.* tertile 1): OR = 0·72 (95 % CI 0·62, 0·85) Processed food (tertile 3 *v.* tertile 1): OR = 1·21 (95 % CI 1·03, 1·42) Potato and fish (tertile 3 *v.* tertile 1): OR = 1·00 (95 % CI 0·84, 1·18)	PE	BMI, education, age, smoking, height, education status, hypertension prior to pregnancy, TEI, dietary supplement use
Eshriqui *et al.* (2016)[35]	Cohort; 2009–2012; Brazil	299	Eighty-two item FFQ*	3rd (28–38 weeks)	PCA	Healthy; processed; common Brazilian	Mixed-effect regression with SBP: Healthy: β = −0·199 (95 % CI − 1·28, 0·88); OR = 0·82 (95 % CI 0·28, 2·10). Processed: β = −0·268 (95 % CI −1·67, 1·14); OR = 0·76 (95 % CI 0·19, 3·13) Mixed-effect regression with DBP: Healthy: β = −0·670 (95 % CI −1·573, 0·232); OR = 0·51 (95 % CI 0·21, 1·26). Processed: β = −0·032 (95 % CI −1·202, 1·138); OR = 0·97 (95 % CI 0·30, 3·12)	Blood pressure (SBP & DBP)	Age, BMI, education, parity, TEI
Mwanri *et al.* (2015)[37]	Cross-sectional; 2011–2012; Tanzania	910	Sixteen-food-group 24 h recall*	2nd & 3rd (20–36 weeks)	DDS	Sixteen food groups	Medium DDS: OR = 2·54 (95 % CI 1·04, 6·16) High DDS: OR = 5·84 (95 % CI 2·11, 16·15)	Hypertension during pregnancy	Residence, age, gestational age, MUAC, parity, GDM, education, PA
Timmermans *et al.* (2011)[25]	Prospective cohort; the Netherlands	3187	293-item FFQ*	All (median 13·5 weeks)	PCA	Mediterranean diet pattern (MDP); traditional dietary pattern	For PE: Low adherence to MDP: OR = 1·2 (95 % CI 0·6, 2·3); adherence to MDP: OR = 0·83 (95 % CI 0·43, 1·60); adherence to traditional: OR = 1·1 (0·6, 2·1) For GHTN: Low adherence to MDP: OR = 1·3 (95 % CI 0·9, 1·9); adherence to MDP: OR = 0·77 (95 % CI 0·53, 1·11); adherence to traditional: OR = 1·3 (95 % CI 0·9, 1·9)	PE & GHTN	Maternal BMI, maternal age, parity, educational level, smoking, vomiting, preconception folic acid use
Torjusen *et al.* (2014)[38]	Cohort; 2002–2008; Norway	28 192	Six-food-group FFQ	2nd (17–22 weeks)	PCA	Healthy pattern; organic vegetables pattern	Healthy pattern, tertile 3 *v.* tertile 1: OR = 0·74 (95 % CI 0·64, 0·85) Organic vegetables, tertile 3 *v.* tertile 1: OR = 0·79 (95 % CI 0·62, 0·99)	PE	Hypertension prior to pregnancy, pre-pregnant BMI, height, age, education, household income, smoking in pregnancy, TEI, gestational weight gain

Table 2 *Continued*

Study	Study design; period; country	Sample (*n*)	Dietary assessment: Methods	Dietary assessment: Trimester (period)	Methods of defining dietary pattern	Dietary patterns identified	Main findings	Outcomes	Confounding factors
Hillesund *et al.* (2014)[36]	Cohort; Norway	72 072	255-item FFQ*	25 weeks	NND score	New Nordic dietary index (NND)	With high NND score: Risk of PE: OR = 0·86 (95 % CI 0·78, 0·95); risk of early PE: OR = 0·71 (95 % CI 0·52, 0·96); risk of PTB: OR = 0·91 (95 % CI 0·80, 1·30)	PE & PTB	Maternal age, height, pre-pregnancy BMI, parity, education, smoking status, exercise during pregnancy, chronic hypertension, diabetes, marital status, energy intake
Dayeon *et al.* (2015)[39]	Cross-sectional; USA	253	Eight-food-group 24 h recall	All (avg. 20 weeks)	RRR	'High refined grains', 'high nuts, seeds, fat and soyabeans, low milk', 'high added sugar and organ meats', 'low fruits, vegetables and seafood'	'High refined grains' pattern: OR = 4·9 (95 % CI 1·4, 17·0) 'High nuts, seeds, fat and soyabeans, low milk' pattern: OR = 7·5 (95 % CI 1·8, 32·3) 'High added sugar and organ meats' pattern: OR = 22·3 (95 % CI 3·9, 127·4)	GDM	Age, race/ethnicity, family poverty income ratio, education, marital status, energy intake, pre-pregnancy BMI, gestational weight gain, log-transformed CRP
De Seymour *et al.* (2016)[18]	Multi-ethnic Asian cohort; Singapore	909	Sixty-eight-food-group 24 h recall*	2nd & 3rd (26–28 weeks)	PCA	Three patterns: vegetable–fruit–rice-based-diet; seafood–noodle-based-diet; pasta–cheese–processed-meat diet	Vegetable–fruit–rice-based-diet: OR = 1·10 (95 % CI 0·90, 1·35) Seafood–noodle-based-diet: OR = 0·74 (95 % CI 0·59, 0·93) Pasta–cheese–processed-meat diet: OR = 0·96 (95 % CI 0·79, 1·17)	GDM	Energy intake, pregnancy BMI, birth order, smoking, alcohol intake, age, ethnicity, education, previous GDM, family history of diabetes, household monthly income, other dietary patterns
He *et al.* (2015)[19]	Prospective cohort, China	3063	Sixty-four-item FFQ*	2nd (24–27 weeks)	PCA	Four dietary patterns: vegetable pattern; protein-rich food pattern; prudent pattern; sweets and seafood pattern	Vegetable pattern: RR = 0·79 (95 % CI 0·64, 0·97) Sweets and seafood pattern: RR = 1·23 (95 % CI 1·02, 1·49) Protein-rich food pattern: RR = 0·95 (95 % CI 0·78, 1·16) Prudent pattern: RR = 1·00 (95 % CI 0·82, 1·22)	GDM	Maternal age, education level, monthly income, parity, pre-pregnancy BMI, family history of diabetes
Karamanos *et al.* (2014)[40]	Prospective cohort; Jan 2010–Jul 2011; ten Mediterranean countries	1076	Seventy-eight-item FFQ*	2nd & 3rd (24–32 weeks)	MDS	Mediterranean diet index	Mediterranean diet: OR = 0·618 (95 % CI 0·401, 0·950)	GDM	Age, BMI, diabetes in the family, weight gain, energy intake
Nascimento *et al.* (2016)[41]	Prospective cohort; Nov 2011–Feb 2014; Spain	841	Eighty-one-item FFQ*	2nd (15–20 weeks)	PCA	Three patterns: traditional pattern; vegetable and Western pattern; mixed pattern	High tertile *v.* low tertile (3 *v.* 1): Traditional pattern: RR = 0·88 (95 % CI 0·49, 1·58) Mixed pattern: RR = 0·93 (95 % CI 0·51, 1·71) Vegetable and Western pattern: RR = 0·78 (95 % CI 0·43, 1·43)	GDM	BMI, age, education, monthly income, family history of diabetes, parity

Table 2 *Continued*

Study	Study design; period; country	Sample (*n*)	Dietary assessment: Methods	Dietary assessment: Trimester (period)	Methods of defining dietary pattern	Dietary patterns identified	Main findings	Outcomes	Confounding factors
Tryggvadottir *et al.* (2016)[34]	Prospective cohort; Apr 2012–Oct 2013; Iceland	168	Eighteen-food-group & 4 d weighed food record	2nd (19–24 weeks)	PCA	Prudent pattern	Adhering to the prudent pattern: OR = 0·44 (95 % 0·21, 0·90)	GDM	Age, parity, pre-pregnancy weight, energy intake, weekly weight gain, total metabolic equivalents of task
Chia *et al.* (2016)[42]	Cohort study; 2009–2010; Singapore	923	Sixty-eight-food-group 24 h recalls and 3 d food diaries	2nd & 3rd (26–28 weeks)	PCA	Vegetable, fruit and white rice; seafood and noodle; pasta, cheese and processed meat	Adherence to vegetable, fruit and white rice pattern: OR = 0·67 (95 % CI 0·50, 0·91) Adherence to seafood and noodle pattern: OR = 1·27 (95 % CI 0·93, 1·74) Adherence to pasta, cheese and processed meat pattern: OR = 0·79 (95 % CI 0·55, 1·12)	PTB	Infant sex, birth order, maternal TEI, maternal age, ethnicity, pre-pregnancy BMI, weight gain until 26–28 week of gestation, height, GDM status, educational status, alcohol use, smoking during pregnancy, other dietary patterns
Englund-Ogge *et al.* (2014)[9]	Prospective cohort; 2002–2008; Norway	66 000	255-item FFQ*	2nd (17–22 weeks)	PCA	'Prudent'; 'Western'; 'traditional'	Prudent: RR = 0·88 (95 % CI 0·80, 0·97) Western: RR = 1·02 (95 % CI 0·92, 1·13) Traditional: RR = 0·91 (95 % CI 0·83, 0·99)	PTB	Maternal age, pre-pregnancy BMI, height, parity, TEI, maternal education, marital status, smoking, previous preterm delivery, household income, other dietary patterns
Haugen *et al.* (2008)[20]	Cohort; Norway	569	255-item FFQ*	2nd (18–22 weeks)	MDS	Mediterranean diet criteria	Mediterranean diet criteria 5 *v.* 0: OR = 0·73 (95 % CI 0·32, 1·68)	PTB	Parity, BMI, maternal height, SES; cohabitant status
Martin *et al.* (2015)[43]	Prospective cohort; USA	3143	Ninety-five-item FFQ	2nd & 3rd (26–29 weeks)	PCA and DASH	Factor 1; Factor 2; Factor 3; Factor 4	Factor 1: OR = 0·87 (95 % CI 0·60, 1·27) Factor 2: OR = 1·53 (95 % CI 1·02, 2·30) Factor 3: OR = 1·55 (95 % CI 1·07, 2·24) Adherence to DASH diet: OR = 0·59 (95 % CI 0·40, 0·85)	PTB	Maternal age, race, maternal pre-pregnancy BMI status, educational level, household income, parity, marital status, smoking status, energy intake
Rasmussen *et al.* (2014)[21]	Longitudinal cohort; Denmark	59 949	360-item FFQ*	2nd & 3rd (avg. 25 weeks)	PCA	Vegetable/prudent; Western; Seafood	Western pattern: OR = 1·30 (95 % CI 1·13, 1·49) Vegetable/prudent pattern: OR = 1·40 (95 % CI 0·80, 1·62) Seafood pattern: OR = 0·90 (95 % CI 0·72, 1·11)	PTB	Maternal age, maternal height, pre-pregnancy BMI, parity, civil status, SES, smoking during pregnancy
Zerfu *et al.* (2016)[46]	Prospective cohort; Ethiopia	432	Nine-food-group 24 h WDDS	2nd & 3rd (24–28 weeks)	DDS	Nine food groups	Low DDS: RR = 4·61 (95 % CI 2·31, 9·19) High DDS: RR = 0·21 (95 % CI 0·11, 0·43)	PTB	Age, height, MUAC, education, Hb level

Table 2 *Continued*

Study	Study design; period; country	Sample (*n*)	Dietary assessment: Methods	Dietary assessment: Trimester (period)	Methods of defining dietary pattern	Dietary patterns identified	Main findings	Outcomes	Confounding factors
Mikkelsen *et al.* (2008)(44)	Cohort; Denmark	35 530	360-item FFQ	2nd & 3rd (avg. 25 weeks)	MDS	Mediterranean diet criteria: consumption of fish twice/week; intake of olive or rapeseed oil; high consumption of fruits & vegetables (5/d or more); meat (other than poultry and fish) at most twice/week	Mediterranean diet criteria 5 *v.* 0: OR = 0·61 (95 % CI 0·35, 1·05) Mediterranean diet criteria 5 *v.* 1–4: OR = 0·92 (95 % CI 0·69, 1·24) Note: 5 *v.* 0 means fulfilled ≥5 *v.* no fulfilled criteria	PTB	Parity, BMI, maternal height, SES, cohabitant status
Saunders *et al.* (2014)(45)	Cohort; 2004–2007; French Caribbean island	728 (710 with complete data)	214-item FFQ	Days following delivery	MDS	Nine categories of the Mediterranean diet scale (vegetables, legumes, fruits and nuts, cereals, fish, meat and poultry, dairy products, alcohol, fat)	Adherence to Mediterranean diet: OR = 0·9 (95 % CI 0·8, 1·0)	PTB	Maternal place of birth, marital status, pre-pregnancy BMI, maternal education, enrolment site, weight gain during pregnancy, energy intake, maternal smoking during pregnancy
Abubakari and Jahn (2016)(47)	Cross-sectional; Ghana	578	Fifty-five-item FFQ*	2nd trimester and 0–1 month post-birth	PCA	Non-health conscious; health conscious	Health conscious diet: OR = 0·23 (95 % CI 0·12, 0·45) Non-health conscious diet: OR = 1·04 (95 % CI 0·65, 1·67) High DDS: OR = 0·10 (95 % CI 0·04, 0·13)	LBW	Gestational age
Zerfu *et al.*(46)	Cohort; Ethiopia	432	Nine-food-group 24 h WDDS	2nd & 3rd (24–28 weeks)	DDS	Nine food groups	High DDS: RR = 2·06 (95 % CI 1·03, 4·11)	LBW	Education, age, height, MUAC, and Hb level

WDDS, Women Dietary Diversity Score; avg., average; PCA, principal component analysis; DDS, dietary diversity score; RRR, reduced rank regression; MDS, Mediterranean diet score; DASH, Dietary Approaches to Stop Hypertension; SBP, systolic blood pressure; β, regression coefficient; DBP, diastolic blood pressure; PE, pre-eclampsia; GHTN, gestational hypertension; RR, risk ratio; PTB, preterm birth; GDM, gestational diabetes mellitus; LBW, low birth weight; TEI, total energy intake; MUAC, mid-upper arm circumference; PA, physical activity; CPR, C-reactive protein; SES, socio-economic status.
*Validated FFQ or recall was used.

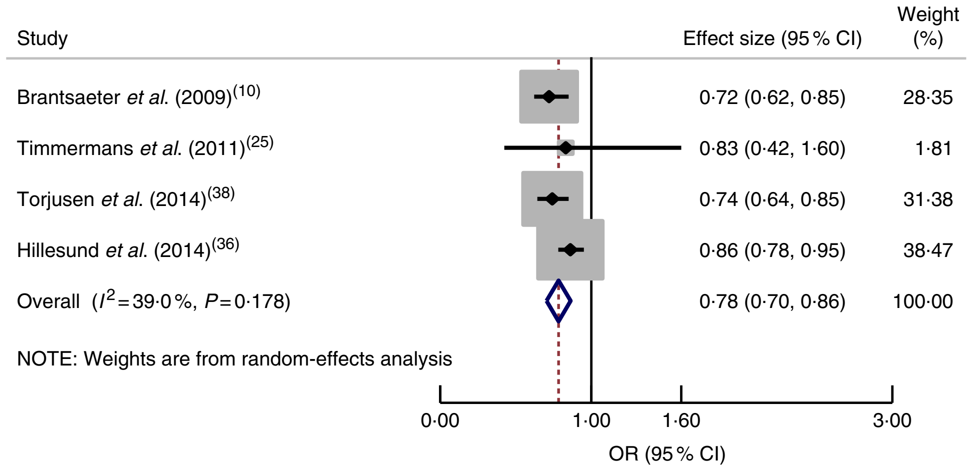

Fig. 2 (colour online) Forest plot for the pooled OR of the association between a healthy dietary pattern and pre-eclampsia. The study-specific OR and 95 % CI are represented by the black diamond and the horizontal line, respectively; the area of the grey square is proportional to the specific-study weight to the overall meta-analysis. The centre of the blue open diamond and the red dashed vertical line represent the pooled OR; and the width of the blue open diamond represents the pooled 95 % CI

was observed between gestational hypertension and adherence to a Mediterranean pattern (OR = 0·77; 95 % CI 0·53, 1·11) or a traditional pattern (OR = 1·3; 95 % CI 0·9, 1·9)[25]. Likewise, a cohort study from Brazil[35] revealed that adherence to a healthy dietary pattern did not have an effect on systolic blood pressure (OR = 0·82; 95 % CI 0·28, 2·21) or diastolic blood pressure (OR = 0·94; 95 % CI 0·18, 1·28).

Western dietary pattern. In a cohort study in Norway[10], a potato and fish dietary pattern (lean fish, cooked potatoes, processed fish; fish burgers, margarine, fish soufflé, meat spread, lean fish and poultry) was not associated with pre-eclampsia (OR = 1·00: 95 % CI 0·84, 1·18). Likewise, a cohort study in Brazil[35] reported that adherence to a processed food pattern was not significantly associated with the change in systolic blood pressure (OR = 0·76; 95 % CI 0·19, 3·13) and diastolic blood pressure (OR = 0·97; 95 % CI 0·30, 3·10) during pregnancy.

Dietary pattern and gestational diabetes mellitus

Healthy dietary pattern. Six studies[18,19,34,39–41] assessed the effect of dietary patterns on GDM. A cohort study in Singapore[18] indicated that a seafood–noodle-based diet was related with lower odds of GDM (OR = 0·74; 95 % CI 0·59, 0·93). However, higher *v.* lower adherence to a vegetable–fruit–rice-based diet (OR = 1·10; 95 % CI 0·90, 1·35) and a pasta–cheese–processed-meat diet (OR = 0·96; 95 % CI 0·79, 1·17) was not associated with GDM. Similarly, adherence to a traditional pattern (RR = 0·88; 95 % CI 0·49, 1·58) as well as adherence to a mixed pattern (RR = 0·93; 95 % CI 0·51, 1·71) was not associated with the incidence of GDM among Brazilian women[41].

The pooled estimate of a healthy dietary pattern on GDM was determined by using five studies[18,19,34,40,41]. Based on this estimate, women who had higher adherence to a healthy dietary pattern had lower odds of GDM (OR = 0·78; 95 % CI 0·56, 0·99), with significant heterogeneity detected between studies (I^2 = 68·6 %, P = 0·013; Fig. 3(a)).

Western dietary pattern. Four studies[18,19,39,41] were combined, showing no relationship between adherence to a Western dietary pattern and odds of GDM (OR = 0·94; 95 % CI 0·81, 1·07) and no heterogeneity between studies (I^2 = 0·0 %, P = 0·825; Fig. 3(b)).

A cross-sectional survey in the USA[39] and a prospective cohort study in China[19] reported that adherence to dietary patterns of refined grains (OR = 4·9; 95 % CI 1·4, 17·0), high nuts, seeds, fat and soyabeans, low milk (OR = 7·5; 95 % CI 1·8, 32·3), and sweets and seafood (RR = 1·23; 95 % CI 1·02, 1·49) during pregnancy was associated with an increased likelihood of GDM.

The association between dietary patterns and adverse birth outcomes (preterm birth and low birth weight)

Dietary pattern and preterm birth

Based on a meta-analysis of nine studies[9,20,21,36,42–46], women who had good adherence to a healthy dietary pattern were shown to have reduced odds of PTB (OR = 0·75; 95 % CI 0·57, 0·93), although significant heterogeneity was observed (I^2 = 89·6 %, P = 0·0001; Fig. 4(a)). Further subgroup analysis indicated a difference in relation to dietary pattern assessment method (MDS, DDS or PCA; P = 0·001). There was also a significant subgroup difference regarding dietary assessment period (second trimester or both second and third trimesters; P = 0·001; Fig. 4(b)).

On the other hand, the pooled estimate of four studies[9,21,42,43] showed that a Western dietary pattern did not increase the odds of PTB (OR = 1·11; 95 % CI 0·87, 1·34; I^2 = 77·8 %, P = 0·004; Fig. 4(c)). There were

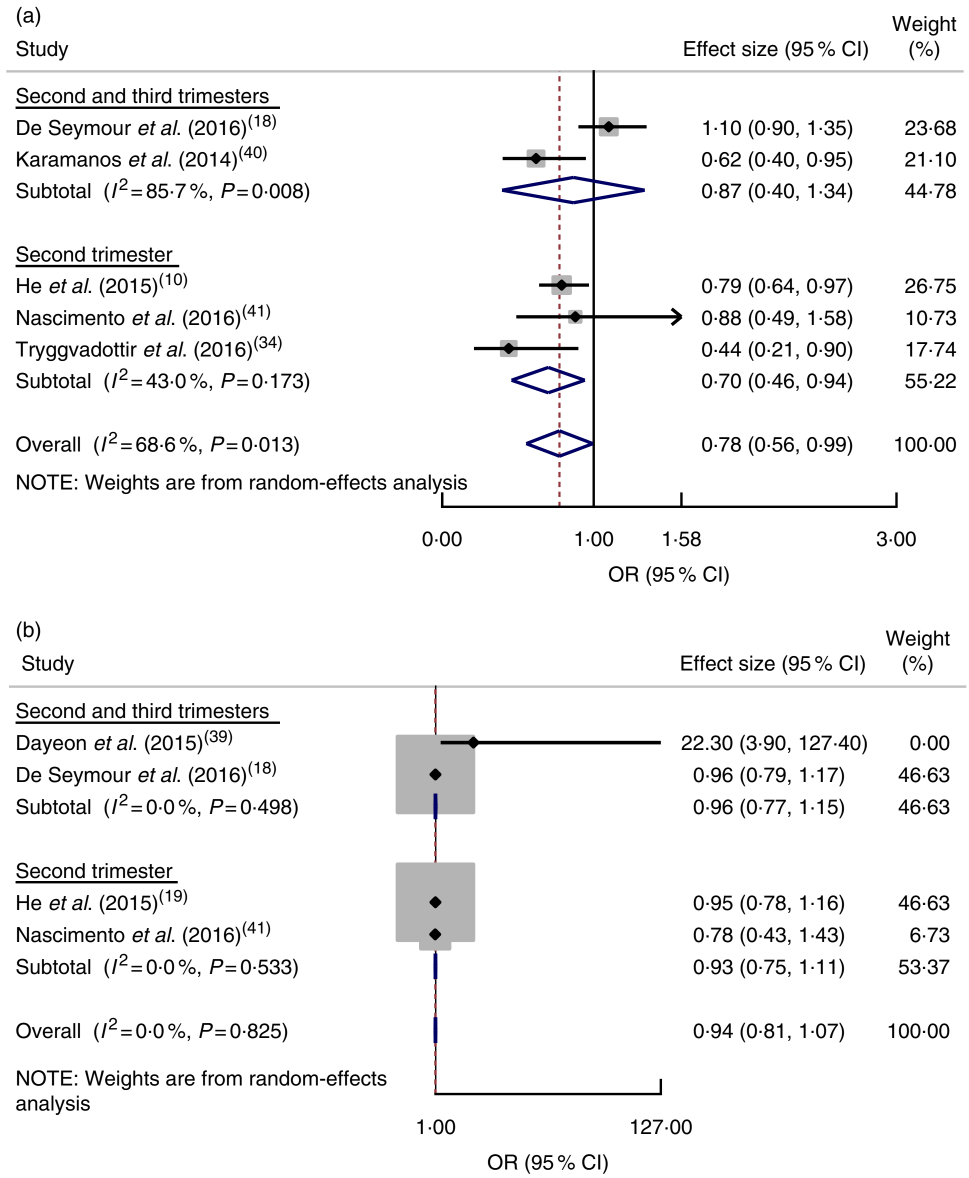

Fig. 3 (colour online) Forest plot for the pooled OR of the association between gestational diabetes mellitus (GDM) and different dietary patterns, with subgroup analysis regarding period of dietary assessment (second trimester *v.* both second and third trimesters): (a) association between GDM and healthy dietary pattern; (b) association between GDM and Western dietary pattern. The study-specific OR and 95 % CI are represented by the black diamond and the horizontal line, respectively; the area of the grey square is proportional to the specific-study weight to the overall meta-analysis. The centre of the blue open diamond and the red dashed vertical line represent the pooled OR; and the width of the blue open diamond represents the pooled 95 % CI

subgroup differences between assessing diet in the second trimester and in both the second and third trimesters with respect to risk of PTB ($P = 0·001$). We did not undertake a subgroup analysis regarding study design, as all studies had the same design (cohort).

Dietary patterns and low birth weight

Two studies assessed the effect of dietary pattern during gestation on LBW. A study in Ghana[47] reported that a 'health conscious' dietary pattern with a high intake of corn, rice, cassava, yam, fruits, vegetables (carrots, tomatoes, dark green leafy vegetables, cabbage, salad, cucumber), meat and eggs reduced the odds of LBW (OR = 0·23; 95 % CI 0·12, 0·45). Similarly, that study reported that women who had a higher DDS were less likely to deliver an LBW baby *v.* those who had a lower DDS (OR = 0·10; 95 % CI 0·04, 0·13). However, a high consumption of sweetened beverages, ice cream, chocolate, energy drinks, milk and local soft drinks, which was labelled the 'non-health conscious' dietary pattern, was not significantly associated with LBW (OR = 1·04; 95 % CI 0·65, 1·67). Another study in Ethiopia[46] showed that women who had an adequate DDS were less likely to deliver an LBW baby (OR = 0·49; 95 % CI 0·24, 0·97).

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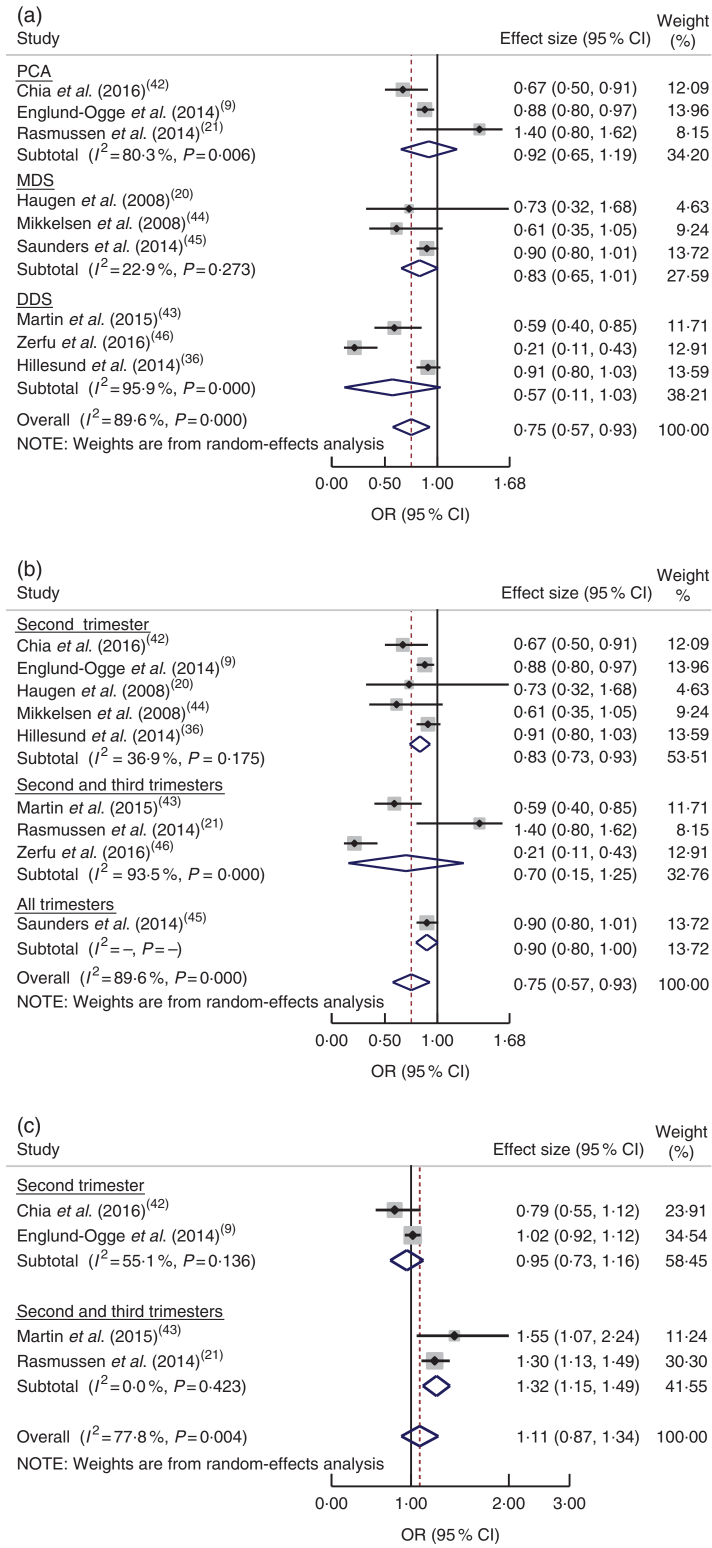

Fig. 4 (colour online) Forest plot for the pooled OR of the association between preterm birth (PTB) and different dietary patterns: (a) association between healthy dietary pattern and PTB, with subgroup analysis in relation to dietary pattern assessment methods (Mediterranean diet score (MDS) v. dietary diversity score (DDS) *v.* principal component analysis (PCA)); (b) association between healthy dietary pattern and PTB, with subgroup analysis regarding period of dietary assessment (second trimester *v.* both second and third trimesters *v.* all trimesters); and (c) association between Western pattern and PTB, with subgroup analysis regarding period of dietary assessment (second trimester *v.* both second and third trimesters). The study-specific OR and 95 % CI are represented by the black diamond and the horizontal line, respectively; the area of the grey square is proportional to the specific-study weight to the overall meta-analysis. The centre of the blue open diamond and the red dashed vertical line represent the pooled OR; and the width of the blue open diamond represents the pooled 95 % CI

Discussion

The current systematic review and meta-analysis summarizes evidence focusing on the effects of different dietary patterns during pregnancy on adverse pregnancy (HDP and GDM) and birth (PTB and LBW) outcomes. Globally, adverse pregnancy outcomes and nutritional insufficiencies still remain public health problems[48]. Sufficient consumption of energy, protein and micronutrients continues to be essential throughout pregnancy[49].

Hypertensive disorders of pregnancy

The meta-analysis of four studies assessing the healthy diet pattern resulted in pooled estimates suggesting decreased odds of pre-eclampsia. However, other studies reported inconsistent findings on the association between adherence to a healthy dietary pattern and the likelihood of HDP occurrence. A cohort study in the Netherlands[25] revealed that adherence to a Mediterranean diet pattern (vegetables, vegetable oils, pasta, fish, legumes and rice) or a traditional pattern (meat and potatoes) was not associated with gestational hypertension. A cohort study in Brazil[35] revealed that adherence to healthy dietary patterns with high intakes of dairy products, fruit, green vegetables, legumes, fish, cakes, cookies–crackers and tea was not associated with a change in systolic or diastolic blood pressure. On the contrary, a cross-sectional study in Tanzania[37] reported that, compared with a lower score, having a high and medium DDS were associated with increased odds of gestational hypertension.

These inconsistencies might be due to the differences in method and population characteristics. The Tanzanian study was cross-sectional[37] and conducted in a resource-limited setting; however, the other studies were cohort studies conducted in well-resourced settings, except the Brazilian study[35]. These studies also assessed dietary intake using a different number of food items and methods. The Tanzanian study applied a 24 h recall method using sixteen food groups, while the studies from Brazil[35] and the Netherlands[25] assessed dietary intake using an eighty-two-item and a 293-item FFQ, respectively.

The healthy diet pattern is in line with dietary guidelines, which suggest consumption of whole grains, vegetables, fruits, potatoes, pasta, cereals, beans, lentils and fish[50]. Similarly, the beneficiary influence of diets high in fibre, K, fruits, vegetables, cereals, dark bread and low-fat dairy products was reported as decreasing the odds of pre-eclampsia[51]. It was also reported that a lower likelihood of pregnancy-induced hypertension or pre-eclampsia is observed with a diet comprising intake of plant-derived foodstuffs and vegetables[52]. The risk of pregnancy complications like pre-eclampsia and LBW has been linked with maternal oxidative stress in the middle of pregnancy[53]. Evidence indicates that oxidative stress during pregnancy could be reduced by antioxidant compounds from fruit and vegetables[54]. The findings of a multicentre study indicate that oxidative stress could be reduced by sufficient intakes of fruit, vegetables and vitamin C[54]. A combination of vitamin C and E might lower the risk of pre-eclampsia[55] through removal of free radicals which may cause oxidative stress in pregnancy[56]. Therefore, it could be the cumulative effect of nutrients and their biochemical properties that influence pre-eclampsia risk.

Gestational diabetes mellitus

The meta-analyses of five studies assessing the healthy diet pattern resulted in pooled estimates that indicated reduced odds of GDM, but this was not statistically significant, most likely due to insufficient power, since few articles were included. Additionally, there were inconsistent findings among included studies for meta-analysis regarding the healthy dietary patterns and GDM; three studies showed decreased odds of GDM while the remainder reported no association. This might result from unmeasured factors due to the majority of studies not controlling for all possible confounding factors. For instance, He *et al.*[19] could not control for parity, energy intake, blood pressure and family history of type 2 diabetes mellitus. Likewise, parity, energy intake and blood pressure were not adjusted for in the other two studies[40,41]. There was also a difference in assessing dietary intake across these studies, with four studies[18,19,40,41] using a validated FFQ and the other an unvalidated FFQ[34]. The dietary intake was assessed at different trimesters of pregnancy, even though there was no significant difference in subgroup analysis based on dietary intake assessment period. This could be a possible explanation for the variations across different studies.

Evidence indicates that pre-pregnancy adherence to a Mediterranean pattern style, with intake of fruit, vegetables, legumes, nuts, fish and cereals, and to the Dietary Approaches to Stop Hypertension (DASH) diet decreases the odds of GDM[57,58]. Similarly, a clinical trial reported that adhering to the DASH diet, which is high in fruits, vegetables, whole grains and low-fat dairy products, with low amounts of saturated fats, cholesterol and refined grains, reduced the need for insulin treatment[59]. Intake of fibre, fruits and cereals reduced the odds of GDM[60].

A cohort study reported that higher odds of GDM was observed with adherence to a Western dietary pattern, which contained higher intake of refined-grain products, processed meat, red meat, French fries and pizza, sweets and desserts[26]. However, our pooled estimate of four studies did not show a significant relationship between the Western pattern and GDM occurrence. The possible explanation may be the difference in the dietary pattern investigation methods (two studies used FFQ[19,41] and two studies used 24 h recall methods[18,39]) and population (one study was conducted in a Western population[39] and three studies were done in an Asian population[18,19,41]).

Preterm birth

In the current systematic review, a pooled estimate of nine studies indicated that compared with low adherence, higher adherence to a healthy dietary pattern significantly decreased the odds of PTB. Likewise, the pooled estimates of four studies on vegetable pattern and three studies on the Mediterranean diet indicated decreased odds of PTB, but this was not statistically significant. However, the meta-analysis result of four studies assessing the Western pattern and PTB showed that adherence to the Western pattern was not significantly associated with PTB. There were significant differences in subgroup analysis based on dietary intake assessment period. In two articles, the dietary intake was assessed in the second (13–27 weeks) and third (28–40 weeks) trimesters and reported that the Western dietary pattern significantly increased the odds of PTB. Nevertheless, the other two studies assessed the dietary intake in the second trimester (13–27 weeks) and the Western dietary pattern did not significantly increase the odds of PTB. A previous systematic review of randomized controlled trials revealed that macronutrient dietary interventions have reduced PTB[61].

Low birth weight

Two articles assessed the effect of dietary patterns on LBW. A dietary pattern labelled as 'health conscious', characterized by intake of local dishes made from corn flour, vegetables (carrot, tomatoes, dark green leafy vegetables, cabbage, salad, cucumber), rice, meat, a mixture of corn and cassava dough, yam, fruits, water and eggs, was associated with reduced odds of LBW[47]. Similarly, women who had a higher DDS were less likely to deliver an LBW baby[46,47]. However, high consumption of sweetened beverages, ice cream, chocolate, energy drinks, milk and local soft drinks, which was labelled as a 'non-health conscious' dietary pattern, showed a significant effect on risk of LBW[47]. This is in line with the evidence that suggests the occurrence of LBW has decreased through the consumption of foods and fortified foodstuffs[62].

It is suggested that pregnant women should be advised to eat a diet rich in fruits and vegetables, whole grains, beans, lean meats and fish/seafood, and low in added sugar, red meat and processed foods[63]. Intake of vegetables, fruits and legumes improves micronutrient and antioxidant intakes, which could improve pregnancy and birth outcomes[63], particularly at the second trimester since oxidative stress has been shown to reach high levels mid-pregnancy[64]. Pregnancy complications and adverse outcomes like pre-eclampsia and PTB have been related to oxidative stress and associated inflammation[53]. Antioxidant vitamins (C and E) and essential trace elements (Cu and Zn) through dietary intake of legumes and fruits, which are rich in these nutrients, could decrease this risk[65–67]. Oxidative stress-linked adverse pregnancy outcomes could be reduced by antioxidants through an intake of vegetables and fruits[68].

Study limitations

The limitations of the present systematic review must be acknowledged. To acquire complete dietary data, most of the articles reviewed applied FFQ followed by diet scores. Nevertheless, there are unavoidable dietary intake misclassifications, which probably bias the degree of detecting real effects. Furthermore, problems of recall bias are also unavoidable because dietary information is dependent on memory. Including articles written only in the English language is another shortcoming of the systematic review. Due to the nature of nutritional research, it is difficult to make all dietary exposures similar for all study subjects. Heterogeneity among studies is a further issue; however, meta-analysis permits the inconsistent findings among studies to be evaluated, even with heterogeneity[69]. As all included studies were observational epidemiological studies, the effect of confounders may be another limitation of the current review, despite controlling for some possible confounding factors. Publication bias is always a concern in any review. Reviewed studies that had negative results might not have been submitted for publication, and thus are less likely to have been published.

Conclusion

The evidence presented in the current systematic review indicates the inconsistent associations between different dietary patterns and pregnancy and birth outcomes. Some results in the systemic review show the importance of healthy dietary intake during gestation to improve pregnancy and birth outcomes for the mother and infant, even though inconsistencies have been observed among studies. Essentially, the review suggests that dietary patterns with higher intake of whole grains, vegetables/fruits, legumes and fish are associated with lower likelihood of adverse pregnancy and birth outcomes. However, as the evidence presented herein is inconsistent regarding the association between dietary intake and pregnancy and birth outcomes, caution should be given during advising pregnant women about diet. Since most of the articles included in the review were conducted in resource-rich settings, additional studies need to be done in resource-limited settings to elucidate the impact of limited resources on dietary intake and adverse pregnancy and birth outcomes.

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