REVIEW

Associations between Maternal Dietary Patterns and Perinatal Outcomes: A Systematic Review and Meta-Analysis of Cohort Studies

Shima Abdollahi,[1] Sepideh Soltani,[2] Russell J de Souza,[3,4] Scott C Forbes,[5] Omid Toupchian,[1] and Amin Salehi-Abargouei[6,7]

[1] School of Public Health, North Khorasan University of Medical Sciences, Bojnurd, Iran; [2] Yazd Cardiovascular Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran; [3] Department of Health Research Methods, Evidence, and Impact, McMaster University, Hamilton, Ontario, Canada; [4] Population Health Research Institute, Hamilton, Ontario, Canada; [5] Department of Physical Education, Faculty of Education, Brandon University, Brandon, Manitoba, Canada; [6] Nutrition and Food Security Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran; and [7] Department of Nutrition, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

ABSTRACT

The aim was to systematically review and meta-analyze prospective cohort studies investigating the relation between maternal dietary patterns during pregnancy with pregnancy and birth outcomes. PubMed, Scopus, and ISI Web of Science were searched from inception until October 2019 for eligible studies. Studies reporting relative risk, ORs, or incidences (for binary data) or means ± SDs or B-coefficients (for continuous outcomes) comparing the highest and lowest adherence with maternal dietary patterns were included. Dietary patterns were categorized as "healthy," "unhealthy," or "mixed." No language restrictions were applied. Study-specific effect sizes with SEs for outcomes of interest were pooled using a random-effects model. Quality of evidence was assessed using Grading of Recommendations Assessment, Development, and Evaluation (GRADE). Sixty-six relevant publications were included. A higher maternal adherence to a healthy diet was associated with a reduced risk of gestational hypertension (14%, $P < 0.001$), maternal depression (40%, $P = 0.004$), low birth weight (28%, $P = 0.001$), preterm birth (56%, $P < 0.001$), higher gestational weight gain (Hedges' g: 0.15; $P = 0.01$), and birth weight (Hedges' g: 0.19; $P = 0.007$). Higher maternal adherence to an unhealthy or a mixed diet was associated with higher odds of gestational hypertension (23%, $P < 0.001$ for unhealthy, and 8%, $P = 0.01$ for mixed diet). In stratified analyses, a higher healthy eating index was associated with reduced odds of being large based on gestational age (31%, $P = 0.02$) and a higher head circumference at birth (0.23 cm, $P = 0.02$). The Mediterranean and "prudent" dietary patterns were related to lower odds of being small based on gestational age (46%, $P = 0.04$) and preterm birth (52%, $P = 0.03$), respectively. The overall GRADE quality of the evidence for most associations was low or very low, indicating that future high-quality research is warranted. This study was registered at http://www.crd.york.ac.uk/PROSPERO as CRD42018089756. *Adv Nutr* 2021;12:1332–1352.

Keywords: dietary patterns, pregnancy outcomes, perinatal outcomes, systematic review, meta-analysis

Introduction

Modifiable factors such as smoking, weight gain, and diet affect pregnancy and neonatal outcomes (1–5). The "Barker hypothesis" proposed in 1990 by the British epidemiologist David Barker (1938–2013) posits that, in humans, intrauterine growth retardation, low birth weight (LBW), and premature birth have a causal relation to the origins of hypertension, cardiovascular disease, and type 2 diabetes in middle aged adults (6–8).

Several investigations have examined the relation between maternal intake of nutrients, foods, and food groups with pregnancy outcomes (9–13). An important conceptual shift in the field of nutrition has been a movement away from studies investigating single foods or nutrients in favor of studies examining the entire diet (14–17). Evaluating the entire diet is more informative since associations between individual foods or nutrients with diseases are difficult to detect due to small effect sizes and biological interactions (18, 19). Dietary pattern analyses overcome these limitations possibly by having larger effect sizes, absorbing interaction effects among nutrients, and importantly, reflecting "real world" eating habits (20). Moreover, dietary patterns can easily inform public health recommendations. Several approaches have been developed and used extensively to derive dietary patterns. These include a posteriori methods that benefit from the use of statistical analyses, such as factor analysis, cluster analysis, and reduced rank regression, and a priori approaches that evaluate overall diet quality compared

 Adv Nutr 2021;12:1332–1352; doi: https://doi.org/10.1093/advances/nmaa156.

with recommended diets [e.g., The Healthy Eating Index-2010, Dietary Approaches to Stop Hypertension (DASH) diet score, and Mediterranean diet score] (20, 21).

Several studies have attempted to establish associations between maternal dietary patterns and perinatal outcomes; however, results are inconsistent. For instance, in a Norwegian prospective cohort study, Brantsæter et al. (15) found that a "vegetable" dietary pattern (characterized by high intake of vegetables, plant foods, and vegetable oils) reduces the risk of pre-eclampsia, whereas adherence to a "Western" dietary pattern, characterized by a high consumption of processed meat, white bread, sugar-sweetened drinks, and salty snacks, increases the risk. In contrast, in the Generation R study (Netherlands), no associations were found between pregnancy dietary pattern and pre-eclampsia (22). Another prospective cohort study performed in Denmark showed that maternal adherence to a "Mediterranean-like" dietary pattern was associated with reduced risk of preterm delivery (23). In addition, several prospective cohort studies found that a healthier dietary pattern in pregnancy is associated with higher birth weight (24–26), whereas others found no association despite similar study methodology (27–31).

Previous meta-analyses have explored the associations between maternal diet and cognitive and behavioral outcomes in children (32), risk of allergic disease (33) or asthma (34), risk of hypospadias and birth weight (35), birth outcomes (36), glycemic outcomes, and other pregnancy outcomes (37). However, these studies assessed limited outcomes, were not exhaustive in their selection of diets, and had methodological limitations. Notably, in most of these syntheses, prospective and cross-sectional (34, 35, 37, 38) or interventional (39) associations were pooled together. Since, well-designed and conducted prospective cohort studies are the strongest observational methodological approach to examine the relation between diet and health (40), we conducted this systematic review to summarize the evidence from prospective cohort studies examining the associations between maternal dietary patterns and perinatal (maternal and neonatal) outcomes and synthesize these results, where appropriate, using meta-analytic techniques.

Methods

The current study is in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (41) and was registered in an international prospective registry of systematic reviews (http://www.crd.york.ac.uk/PROSPERO; registration no.: CRD42018089756).

Search strategy and selection criteria

A systematic search for relevant published articles was conducted using PubMed, Scopus, and ISI Web of Science databases from inception to 25 October 2019. There was no language restriction. A combination of keywords relevant to dietary patterns, pregnancy, and study design were used to identify potential studies. Furthermore, the reference lists of identified articles were reviewed manually to find any other related studies. Details about the search strategy are provided in **Supplemental Table 1**.

Titles and abstracts of all retrieved articles were evaluated independently by 2 reviewers (OT and SS), and potentially eligible studies underwent a full-text review for inclusion according to the following criteria: *1*) prospective cohort or nested case-control studies and *2*) assessment of the association between dietary patterns of adult mothers ($\geq$18 y) regardless of the methods used to define dietary patterns and all events that occur for the mother or offspring (perinatal outcomes). Cross-sectional, case-control, clinical trials, and review studies were excluded. We also excluded studies if they evaluated an individual nutrient or food group. Furthermore, studies that included women with pre-existing diseases, twins or higher-order multiple pregnancies, and induced pregnancy were also excluded. If duplicate publications of the same cohort were found, the most complete data were included in the meta-analysis. Discrepancies in the application of these criteria were resolved by discussion with another author (AS-A).

Definition of dietary patterns

For this review, we grouped the dietary patterns (or scores) into 3 categories based on constituent foods of each diet: healthy, unhealthy, and mixed patterns. Foods in each diet were selected based on the dietary recommendations for the prevention of chronic diseases (42, 43). Accordingly, a healthy diet was characterized by high intakes of fruits, vegetables, whole grains, low-fat dairy products, vegetable oils, and fish. An unhealthy diet was characterized by refined grains, foods high in saturated fats, red meat, processed meat, fast foods, and high sugary foods, which are related to a range of chronic diseases, such as cardiovascular diseases, cancer, and diabetes (44, 45). A combination of both healthy and unhealthy foods was labeled as mixed. If studies reported $\geq$2 healthy or unhealthy dietary patterns, we selected the pattern that most clearly fulfilled the predetermined healthy or unhealthy criteria. When both a priori and a posteriori dietary patterns were reported in the same population, the

Supported by the North Khorasan University of Medical Sciences, Bojnurd, Iran (grant number 98p1334).
Author disclosures: RJ de Souza has served as an external resource person to the World Health Organization's Nutrition Guidelines Advisory Group on *trans* fats, saturated fats, and polyunsaturated fats. The WHO paid for his travel and accommodation to attend meetings from 2012–2017 to present and discuss this work. He has also done contract research for the Canadian Institutes of Health Research's Institute of Nutrition, Metabolism, and Diabetes, Health Canada, and the World Health Organization for which he received remuneration. He has received speaker's fees from the University of Toronto, and McMaster Children's Hospital. He has held grants from the Canadian Institutes of Health Research, Canadian Foundation for Dietetic Research, Population Health Research Institute, and Hamilton Health Sciences Corporation as a principal investigator, and is a co-investigator on several funded team grants from Canadian Institutes of Health Research that examine maternal and infant health. He serves as an independent director of the Helderleigh Foundation (Canada). All the other authors report no conflicts of interest.
Supplemental Tables 1–25 and Supplemental Figures 1 and 2 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/advances.
Address correspondence to AS-A (e-mail: abargouei@ssu.ac.ir; abargouei@gmail.com).
Abbreviations used: DASH, Dietary Approaches to Stop Hypertension; FFQ, food-frequency questionnaire; FGR, fetal growth restriction; GDM, gestational diabetes mellitus; GRADE, Grading of Recommendations Assessment, Development, and Evaluation; IUGR, intrauterine growth restriction; LBW, low birth weight; LGA, large for gestational age; ROBINS-E, Risk of Bias IN observational Studies of Exposures; RR, risk ratio; SGA, small for gestational age; WMD, weighted mean difference.

priori dietary pattern was preferred, due to lower researcher involvement in diet identification. Any disagreements with respect to categorization were discussed and resolved by discussion with the senior author (AS-A).

Data extraction

The eligible studies were reviewed and the following information was extracted: first author's name, publication year, name of the cohort (or study), country, timing of dietary assessment (i.e., gestational week), total number of participants, dietary assessment tool, name of dietary pattern, outcome ascertainment, and variables that entered into the multivariable model as potential confounders. Effect sizes with 95% CIs were also extracted for the categories of diet adherence. When multiple estimates were reported in the article, we used the results with adjustment for the highest number of confounders (i.e., the "most" multivariable-adjusted model). Data extraction was completed by 2 separate authors, working independently (OT and SS), and entered in duplicate. Inconsistencies were resolved through discussion with a third author (AS-A).

Study quality assessment

Two researchers (SA and SS) independently assessed the methodological quality of included articles using the Risk Of Bias IN observational Studies of Exposures (ROBINS-E) tool (46). The articles were rated from low risk of bias to critical risk of bias based on 7 domains (confounding, selection bias, classification of interventions, deviations from intended interventions, missing data, measurement bias, and selection of reported results). Articles with low risk of bias for all criteria were judged as low risk of bias; if at least 1 criterion was moderate, serious, or critical risk of bias, the overall quality of study was regarded as moderate, serious, and critical risk of bias, respectively (47).

Quality of meta-evidence

We used the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system to assess certainty of evidence for each exposure–outcome association based on the major domains of study limitations (48, 49). The quality of evidence derived from prospective observational studies begins as low quality (50). Then, the quality was downgraded based on 5 criteria. Scores were downgraded for risk of bias (if most of the studies showed serious critical risk of bias) (46), inconsistency [serious ($I^2 = 50\%$ to 75%) or very serious ($I^2 = 75\%$ to 100%) heterogeneity] (51), indirectness (when the results of most studies were not generalizable or did not directly measure the exposure and outcome of interest) (52), imprecision (we did not downgrade for this factor because of the large sample sizes of the included studies) (53), and publication bias (as assessed by funnel plots and Egger's and Begg's tests) (54).

Data synthesis

We conducted meta-analyses when at least 3 studies provided data for a given outcome. The included studies reported a measure of association or difference along with an estimate of the variance (e.g., SE or CI). The effect size was the natural logarithm of the observed OR or risk ratio (RR) comparing the highest versus lowest exposure category (for binary outcomes) and the summary mean differences between the highest and lowest exposure category for continuous outcomes. All estimates were pooled as ORs. The few studies that reported RRs were treated as ORs, which resulted in a conservative estimate of the RR. When the number of events in each category was reported, the OR was calculated using events in the highest exposure versus reference level and the total number of participants in each category. The effect sizes were standardized using Hedges' g if all the studies in the meta-analysis did not use the same scale to assess the continuous outcomes (55), including gestational weight gain and birth weight. Associations were considered small if Hedges' g was ≤ 0.2, medium if Hedges' g was between 0.2 and 0.8, and large if Hedges' g was ≥ 0.8 (56). When studies reported data separately by ethnicity or BMI categories in the same population, we pooled the estimates using a fixed-effects meta-analysis before including the study estimate in the analysis. The overall associations were derived using the DerSimonian and Laird random-effects model. Statistical heterogeneity between studies was assessed using Cochran's Q test and quantified by the I^2 statistic (51). When eligible studies did not report data in a form that could be included in the meta-analysis, they were included in the systematic review and narratively summarized.

We performed subgroup analyses to compare the associations of dietary patterns with health outcomes based on the following classification: *1*) prudent dietary pattern, *2*) New Nordic diet, *3*) DASH diet, *4*) Mediterranean diet, *5*) Healthy Eating Index, *6*) diet diversity, *7*) plant-based diet, and *8*) other healthy diets. Our primary sensitivity analysis approach was to remove each single study from the meta-analyses and recalculate the summary effect (the "leave-one-out" approach). An influential outlier was considered a study whose removal either pushed the significance level of the overall effect from <0.05 to ≥ 0.05 (or vice versa) or altered the effect size by $\geq 10\%$. An additional sensitivity analysis was also conducted in which we removed unadjusted effect sizes and recalculated the summary estimate. Publication bias was evaluated when at least 10 studies were available for an outcome by inspection of Begg's funnel plots, and the statistical asymmetry was checked by using Egger's regression asymmetry test and Begg's adjusted rank correlation test. When there was evidence of publication bias, Duval and Tweedie's "trim and fill" method was used to correct funnel plot asymmetry (57). All data analyses were implemented using STATA version 11 (StataCorp), and P values <0.05 were considered statistically significant.

Results

Study search and characteristics of included studies

The flow of study selection is provided in **Figure 1**. The primary search identified 20,276 articles; 193 full-text articles were retrieved and assessed for eligibility. Finally, 113 publications from 51 cohort studies met the inclusion criteria

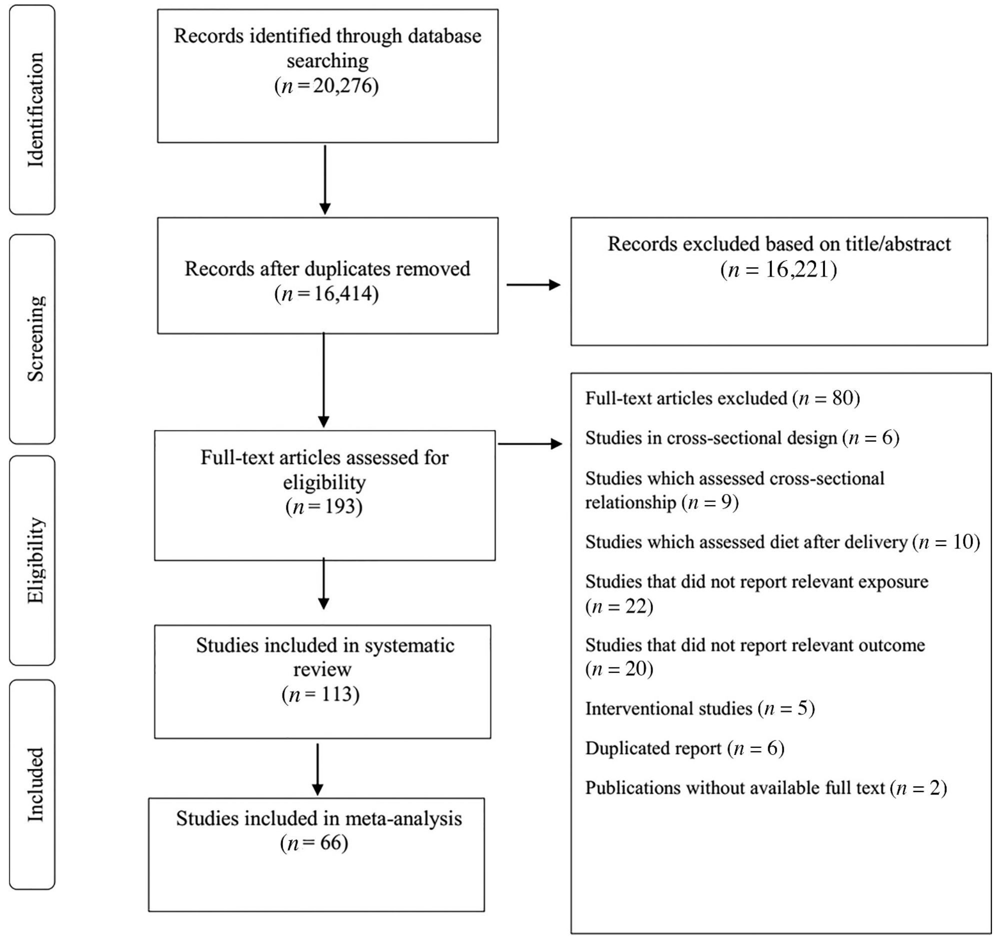

FIGURE 1 Flow diagram of study selection procedures.

and were included in the systematic review (15, 22–31, 58–159). The most common reasons for exclusion were related to failure to report relevant exposure or outcomes. The complete list of reasons for exclusion of articles is presented in **Supplemental Table 2**.

All publications assessed diet during pregnancy, except for 13 (6 cohort studies) which examined the prepregnancy diet (63, 74–76, 86, 88, 101, 105, 135, 136, 144, 145, 155). One study pooled the prepregnancy and pregnancy dietary data in the same analysis (90). The included studies were conducted in the United States (29 publications from 13 cohorts) (28, 29, 31, 61–63, 74, 78, 85, 86, 88, 89, 106, 113, 114, 118, 128–130, 132, 133, 137, 139, 141, 144, 145, 155, 157, 159), European countries (34 publications from 11 cohorts) (15, 22, 23, 25–27, 30, 58, 64–66, 79, 80, 94, 95, 97, 98, 103, 105, 107, 117, 120–122, 126, 127, 134, 138, 140, 142, 143, 147, 148, 151), Spain (10 publications from 4 cohorts) (24, 67, 70, 75, 76, 84, 87, 116, 131, 146), Canada (3 publications from 6 cohorts) (83, 99, 158), and Brazil (7 publications from 3 cohorts) (59, 60, 73, 81, 119, 149, 150). An additional 22 publications (13 cohorts) were from Asia (14, 71, 72, 77, 91–93, 96, 100, 102, 108–112, 115, 123, 124, 152, 156, 159), 3 from Australia (90, 135, 136), and 3 from Africa (68, 153, 154). Three publications pooled the data from different countries (69, 101, 125). The dietary patterns derived from the eligible studies as well as their categorization for the present study are provided in **Supplemental Table 3**.

In total, 66 publications were included in the analyses to assess the association of dietary patterns with maternal outcomes, including cesarean delivery (14, 59, 87, 91, 137, 139, 141), depression (68, 100, 123), gestational weight gain (14, 24, 26, 27, 31, 60, 61, 78, 81, 87, 113, 137, 139, 141, 142, 154, 157), gestational diabetes mellitus (GDM) (24, 62, 63, 75–77, 88, 90, 92, 93, 95, 96, 101, 112, 113, 119, 129, 133, 136, 137, 145, 148, 155–157), and gestational hypertensive disorders (14, 15, 22, 66, 69, 78, 88, 90, 92, 95, 97, 137, 144, 147, 157) or offspring outcomes, including LBW (26, 30, 78, 90, 91, 104, 154), preterm birth (23, 25, 29–31, 59, 78, 90, 91, 95, 154, 157), stillbirth (86, 91, 154), fetal growth restriction (FGR) (69, 131), obesity (24, 30, 58, 74), and birth-size parameters (24–28, 30, 31, 59, 66, 69, 71, 78, 87, 125, 128, 131, 137, 139, 143, 154, 157).

Risk of bias of included studies

The risk of bias of included studies was assessed using the ROBINS-E tool. **Supplemental Table 4** shows the details on the scores for each study. Most studies were at high risk of bias due to uncontrolled/residual confounding. Another source of bias was risk of bias due to outcome assessment methods, where studies mostly relied on medical record data or self-report, which might lead to measurement bias. Finally, a validated food-frequency questionnaire (FFQ) was the most common dietary measurement method (60/66; 90.9%), which, although economical for large-scale epidemiology studies, is known to be biased because responses are self-reported from memory and are often subject to individual variation in perception of portion sizes (160).

Most studies that examined the association between maternal diet and cesarean delivery (14, 87, 91, 92, 137, 139, 141), gestational hypertensive disorders (14, 66, 69, 88, 90, 97, 137, 144, 157), gestational weight gain (14, 24, 27, 31, 61, 81, 87, 113, 137, 141, 154, 157), GDM (24, 63, 75–77, 88, 90, 93, 95, 112, 113, 136, 137, 145, 157), birth weight (24–27, 31, 71, 87, 137, 139, 154), LBW (26, 90, 91, 104, 154), and stillbirth (91, 154) were at high risk of bias.

Association between maternal diet and maternal outcomes

Meta-analysis.

The meta-analysis of cohort studies investigating the association between dietary patterns and the odds of maternal outcomes is reported in **Table 1** and **Supplemental Figure 1**.

GDM.

Twenty-seven articles investigated the association between dietary pattern and GDM (**Supplemental Table 5**). Two publications could not be included in the quantitative synthesis because the data were not appropriate for the statistical approach (73, 135). We pooled the 17 studies that reported the association between a healthy dietary pattern and GDM (24, 62, 75–77, 92, 93, 95, 101, 112, 119, 129, 133, 136, 145, 148, 156, 157). We found no significant association between higher adherence to a healthy diet and odds of GDM (17 studies, 121,558 participants; OR: 0.89; 95% CI: 0.75, 1.06; $P = 0.2$). Similarly, higher adherence to an unhealthy (8 studies, 25,148 participants; OR: 1.08; 95% CI: 0.81, 1.43; $P = 0.59$) or a mixed (7 studies, 24,826 participants; OR: 1.17; 95% CI: 0.95, 1.44; $P = 0.13$) dietary pattern was not associated with the incidence of GDM (Table 1). The subgroup meta-analysis also found no significant association between types of healthy dietary patterns and odds of GDM (Table 1).

Gestational hypertensive disorders.

Fifteen articles investigated the association between dietary pattern and gestational hypertensive disorders (**Supplemental Table 6**) (14, 15, 22, 66, 69, 78, 88, 90, 92, 95, 97, 137, 144, 147, 157). Two articles were excluded from analyses because results were not presented as highest versus lowest categories of diet adherence (73, 99). We pooled the outcomes of gestational hypertension (14, 69, 88, 90, 97, 144, 157) and pre-eclampsia (15, 22, 66, 78, 92, 95, 147) in the same analysis. One study reported number of participants with gestational hypertension and also participants with pre-eclampsia in quartiles of the diet score (137). We estimated effect size using the sum of the 2 numbers.

Higher adherence to a healthy diet was associated with a 14% lower odds of hypertensive disorders during pregnancy (12 studies, 195,916 participants; OR: 0.86; 95% CI: 0.81, 0.91; $P < 0.001$). Higher adherence to an unhealthy diet was associated with a 23% higher odds of hypertensive disorders during pregnancy (5 studies, 81,144 participants; OR: 1.23; 95% CI: 1.14, 1.34; $P < 0.001$); and higher adherence to a mixed diet was associated with an 8% higher odds of these disorders (5 studies, 83,475 participants; OR: 1.08; 95% CI: 1.01, 1.16; $P = 0.01$) (Table 1). In stratified analyses, higher adherence to the Healthy Eating Index was associated with a reduced odds of gestational hypertensive disorders comparing with the lowest category (3 studies, 23,048 participants; OR: 0.85; 95% CI: 0.74, 0.99; $P = 0.03$) (Table 1).

Gestational weight gain.

Seventeen articles reported the association between dietary patterns and gestational weight gain, 10 of which were included in the meta-analysis (**Supplemental Table 7**) (24, 27, 31, 81, 87, 113, 137, 142, 154, 157).

The meta-analysis showed that the highest adherence to a healthy dietary pattern was significantly associated with more weight gain when compared with the lowest adherence; however, the association was weak (9 studies, 9803 participants; Hedges' *g*: 0.15; 95% CI: 0.03, 0.28; $P = 0.01$) (Table 1), although there was no significant association with the odds of excessive gestational weight gain (as a dichotomous outcome) comparing extreme categories of healthy dietary pattern (26, 61, 78, 139, 141, 142) (6 studies, 71,719 participants; OR: 0.87; 95% CI: 0.73, 1.04; $P = 0.13$) (**Supplemental Table 8**, Table 1).

Inadequate gestational weight gain in relation to maternal dietary pattern was reported in 9 articles, of which 5 were included in the meta-analysis (61, 78, 95, 139, 142) (**Supplemental Table 9**). These analyses revealed no significant association between healthy diet and the odds of inadequate gestational weight gain (5 studies, 71,390 participants; OR: 0.98; 95% CI: 0.83, 1.17; $P = 0.88$). In subgroup analyses, there was no significant association between healthy dietary patterns and the odds of inadequate gestational weight gain (Table 1). There were insufficient data to conduct analyses of unhealthy or mixed diets in this regard.

Maternal depression.

We pooled the results from 3 studies to evaluate the association between dietary pattern during pregnancy and maternal depression (**Supplemental Table 10**) (68, 100, 123). A higher adherence to a healthy dietary pattern was associated with a 40% reduced odds of maternal depression (3 studies, 5092 participants; OR: 0.60; 95% CI: 0.42, 0.85; $P = 0.004$) (Table 1).

Cesarean delivery.

Eight studies investigated the association between dietary pattern in pregnancy and cesarean delivery (14, 59, 73, 87, 91, 137, 139, 141), of which 5 were included in the meta-analysis (**Supplemental Table 11**) (14, 87, 91, 137, 139).

TABLE 1 Meta-analysis of dietary patterns in pregnancy and maternal outcomes by subgroups (all analyses were conducted using a random-effects model)[1]

			Meta-analysis		Heterogeneity			
Study group	Studies, *n* [reference(s)]	Participant, *n*	OR (95% CI)	*P*-effect	Q statistic	*P*-within group	I^2, %	*P*-between group
Gestational diabetes mellitus								
Healthy dietary pattern	17 (24, 62, 75, 77, 92, 93, 95, 101, 112, 119, 129, 133, 136, 145, 148, 156, 157)	121,558	0.89 (0.75, 1.06)	0.2	49.33	<0.001	67.6	0.001
Unhealthy dietary pattern	8 (75, 77, 92, 96, 112, 119, 136, 155)	25,148	1.08 (0.81, 1.43)	0.59	17.59	0.01	60.2	
Mixed dietary pattern	7 (63, 77, 92, 93, 112, 119, 156)	24,826	1.17 (0.95, 1.44)	0.13	13.05	0.04	54.0	
Healthy diet subgroups								
Prudent dietary pattern	6 (77, 92, 93, 129, 148, 155)	19,639	0.81 (0.59, 1.13)	0.22	13.38	0.02	62.6	<0.001
Mediterranean diet	6 (24, 75, 101, 113, 136, 145)	32,698	0.83 (0.64, 1.09)	0.19	14.71	0.01	66.0	
Healthy Eating Index	5 (62, 88, 133, 148, 157)	27,586	0.74 (0.51, 1.07)	0.11	14.62	0.006	72.6	
New Nordic diet score	1 (26)	72,072	1.43 (1.17, 1.77)	0.001	0.0	—	—	
DASH score	1 (145)	21,376	0.66 (0.53 0.82)	<0.001	0.0	—	—	
Diet quality	1 (88)	21,312	0.68 (0.53, 0.85)	0.001	0.0	—	—	
Dietary diversity	1 (88)	21,312	1.00 (0.78, 1.26)	1.00	0.0	—	—	
Plant-based foods	4 (63, 90, 136, 156)	23,210	0.91 (0.79, 1.05)	0.22	1.56	0.67	0.0	
The Australian recommended food score	1 (90)	1902	1.70 (0.71, 4.06)	0.23	0.0	—	—	
Other healthy diets	4 (76, 119, 136, 137)	9957	0.67 (0.41, 1.09)	0.11	0.01	0.01	72.5	
Gestational hypertensive disorders								
Healthy dietary pattern	12 (22, 69, 78, 90, 92, 95, 97, 137, 144, 157)	195,916	0.86 (0.81, 0.91)	<0.001	10.88	0.45	0.0	<0.001
Unhealthy dietary pattern	5 (15, 66, 72, 92, 97)	81,144	1.23 (1.14, 1.34)	<0.001	2.32	0.67	0.0	
Mixed dietary pattern	5 (15, 22, 72, 92, 97)	83,475	1.08 (1.01, 1.16)	0.01	1.37	0.84	0.0	
Healthy diet subgroups								
Prudent dietary pattern	2 (92, 147)	29,004	0.70 (0.53, 0.91)	0.01	1.24	0.26	19.4	0.009
Mediterranean diet	4 (22, 69)	6462	0.82 (0.50, 1.34)	0.65	0.65	0.88	0.0	
Healthy Eating Index	3 (78, 88, 157)	23,048	0.85 (0.74, 0.99)	0.03	0.86	0.64	0.0	
New Nordic diet score	2 (95, 97)	127,211	0.89 (0.83, 0.95)	0.003	1.00	0.31	0.0	
DASH score	1 (144)	54,588	0.83 (0.73, 0.93)	0.002	0.00	—	—	
Diet quality	1 (88)	19,917	0.82 (0.68, 0.98)	0.03	0.00	—	—	
Dietary diversity	1 (88)	19,917	0.87 (0.72, 1.05)	0.162	0.00	—	—	
Plant-based foods	2 (15, 97)	78,562	0.87 (0.60, 1.26)	0.48	17.73	<0.001	94.4	
The Australian recommended food score	1 (90)	1904	0.40 (0.19, 0.85)	0.01	0.00	—	—	
Other healthy diet	1 (137)	1808	1.02 (0.65, 1.61)	0.9	0.00	—	—	
Inadequate gestational weight gain								
Healthy dietary pattern	5 (26, 61, 78, 139, 142)	71,390	0.98 (0.83, 1.17)	0.88	8.3	0.08	51.8	0.84
Unhealthy dietary pattern	1 (142)	1917	0.98 (0.69, 1.40)	0.91	0.00	—	—	
Healthy diet subgroups								
Prudent dietary pattern	1 (142)	1917	0.84 (0.58, 1.22)	0.358	0.00	—	—	0.67
Healthy Eating Index	4 (61, 78, 139, 142)	4793	1.01 (0.75, 1.35)	0.180	7.44	0.05	59.7	
New Nordic diet score	1 (26)	66,597	0.94 (0.91, 0.98)	0.003	0.00	—	—	
Plant-based diet	1 (142)	1917	0.85 (0.58, 1.24)	0.4	0.0	—	—	

(*Continued*)

TABLE 1 (*Continued*)

Study group	Studies, *n* [reference(s)]	Participant, *n*	Meta-analysis: OR (95% CI)	Meta-analysis: *P*-effect	Heterogeneity: *Q* statistic	Heterogeneity: *P*-within group	Heterogeneity: I^2, %	Heterogeneity: *P*-between group
Excessive gestational weight gain								
Healthy dietary pattern	6 (26, 61, 78, 139, 141, 142)	71,719	0.87 (0.73, 1.04)	0.13	11.99	0.03	58.3	0.02
Unhealthy dietary pattern	2 (60, 142)	2076	1.43 (1.06, 1.92)	0.01	0.04	0.85	0.0	
Mixed dietary pattern	1 (60)	159	0.74 (0.31, 1.71)	0.48	0.0	—	—	
Healthy diet subgroups								
Prudent dietary pattern	1 (142)	1917	1.06 (0.76, 1.47)	0.73	0.0	0.0	0.0	0.15
Healthy Eating Index	5 (61, 78, 139, 141, 142)	5222	0.83 (0.66, 1.03)	0.1	7.59	0.1	47.3	
New Nordic diet score	1 (26)	66,597	0.97 (0.92, 1.03)	0.4	0.0	0.0	0.0	
Other healthy diets	1 (142)	1917	1.09 (0.77, 1.53)	0.62	0.0	0.0	0.0	
Maternal depression								
Healthy dietary pattern	3 (68, 100, 123)	5092	0.60 (0.42, 0.85)	0.004	3.54	0.171	43.4	0.04
Unhealthy dietary pattern	2 (68, 123)	1394	0.87 (0.57, 1.33)	0.515	1.01	0.315	1.0	
Healthy diet subgroups								
Prudent dietary pattern	2 (68, 123)	1394	0.72 (0.39, 1.30)	0.274	1.67	0.197	40.0	0.17
Dietary diversity	1 (100)	3698	0.52 (0.44, 0.62)	<0.001	0.0	—	—	
Cesarean delivery								
Healthy dietary pattern	5 (59, 87, 91, 137, 139)	3921	0.83 (0.68, 1.00)	0.06	0.86	0.93	0.0	0.26
Unhealthy dietary pattern	3 (14, 59, 91)	1922	1.16 (0.81, 1.67)	0.39	0.49	0.78	0.0	
Mixed dietary pattern	3 (14, 59, 91)	1922	0.91 (0.68, 1.22)	0.54	1.82	0.4	0.0	
Healthy diet subgroups								
Prudent dietary pattern	2 (59, 91)	999	0.80 (0.55, 1.18)	0.27	0.0	0.98	0.0	0.82
Mediterranean diet	1 (87)	35	0.18 (0.007, 4.89)	0.31	0.0	0.0	—	
Healthy Eating Index	2 (87, 139)	1114	0.86 (0.63, 1.17)	0.34	0.79	0.37	0.0	
Other healthy diet	1 (137)	1808	0.84 (0.61, 1.15)	0.29	0.0	0.0	—	
Gestational weight gain (Hedges' *g*)								
Healthy dietary pattern	9 (24, 27, 31, 81, 87, 113, 142, 154, 157)	9803	0.15 (0.03, 0.28)[2]	0.01	55.31	<0.001	85.5	0.09
Unhealthy dietary pattern	2 (81, 142)	3356	0.00 (−0.09, 0.09)[2]	0.99	0.74	0.39	0.0	
Mixed dietary pattern	1 (31)	764	0.19 (0.01, 0.36)[2]	0.03	0.0	—	—	
Healthy diet subgroups								
Prudent dietary pattern	3 (31, 81, 142)	4120	0.27 (−0.10, 0.65)[2]	0.15	26.72	<0.001	92.5	<0.001
Mediterranean diet	4 (24, 27, 87, 113)	3040	0.04 (−0.09, 0.17)[2]	0.32	5.61	0.13	46.5	
Healthy Eating Index	3 (87, 142, 157)	5462	− 0.002 (−0.08, 0.07)[2]	0.95	1.34	0.51	0.0	
Dietary diversity	1 (154)	374	0.26 (0.06, 0.46)[2]	0.001	0.00	0.00	—	
Other healthy diets	2 (137, 142)	4966	− 0.02 (−0.10, 0.05)[2]	0.49	1.41	0.23	28.8	

[1]DASH, Dietary Approaches to Stop Hypertension.
[2]Values are Hedges' *g* (95% CI).

A healthy diet tended to be associated with decreased odds of caesarean delivery (5 studies, 3921 participants; OR: 0.83; 95% CI: 0.68, 1.00; $P = 0.06$), but there were no associations between unhealthy (3 studies, 1922 participants; OR: 1.16; 95% CI: 0.81, 1.67; $P = 0.39$) or mixed (3 studies, 1922 participants; OR: 0.91; 95% CI: 0.68, 1.22; $P = 0.54$) dietary patterns (Table 1).

Association between maternal diet and offspring outcomes

The meta-analysis of cohort studies investigating the association between maternal dietary patterns and the odds of offspring outcomes is reported in **Table 2** and **Supplemental Figure 2**.

Birth weight.

Thirty-one eligible studies provided an estimate of the association between maternal diet and birth weight, of which 19 studies were included in the meta-analysis (24–28, 30, 31, 66, 69, 71, 78, 87, 125, 128, 131, 137, 139, 143, 154). Other studies were excluded from the analyses because data did not compare highest versus lowest adherence to diets (72, 73, 79, 83, 109, 111, 116, 122, 124, 141, 158, 159) (**Supplemental Table 12**).

A higher maternal adherence to a healthy diet was strongly associated with higher birth weights compared with lower adherence (15 studies, 75,041 participants; Hedges' g: 0.91; 95% CI: 0.05, 0.32; $P = 0.007$) (Table 2). There were no associations for unhealthy (2 studies, 1585 participants; Hedges' g: −0.10; 95% CI: −0.33, 0.11; $P = 0.35$) or mixed (3 studies, 2659 participants; Hedges' g: 0.37; 95% CI: −0.24, 0.99; $P = 0.24$) dietary patterns and birth weight. There were no significant subgroup findings (Table 2).

Birth length.

Thirteen studies explored the association between maternal dietary pattern and birth length (14, 27, 30, 64, 69, 72, 78, 87, 124, 131, 139, 141, 159) and 7 (9 effect sizes) were included in the quantitative syntheses (27, 30, 69, 78, 87, 131, 139). (**Supplemental Table 13**).

The meta-analysis revealed no significant associations between a healthy dietary pattern and birth length [9 effect sizes, 7227 participants; weighted mean difference (WMD): 0.08 cm; 95% CI: −0.06, 0.23; $P = 0.26$]. There were no significant subgroup findings (Table 2).

Head circumference.

Ten studies (12 effect sizes) examined the association between maternal healthy diet and head circumference at birth (27, 30, 69, 78, 83, 124, 131, 139, 143, 159). Three studies could not be included in the quantitative synthesis because of inappropriate data (83, 124, 159) (**Supplemental Table 14**).

There was no significant association between healthy diet and head circumference (9 effect sizes, 10,303 participants; WMD: 0.09 cm; 95% CI: −0.03, 0.22; $P = 0.14$). In subgroup analyses, infants born to mothers with higher adherence to the Healthy Eating Index during pregnancy had 0.23-cm higher birth head circumference compared with infants born to mothers with lower adherence (4 studies, 3810 participants; WMD: 0.23 cm; 95% CI: 0.03, 0.43; $P = 0.02$) (Table 2).

LBW.

Seven eligible studies reported the association between maternal diet and LBW (26, 30, 78, 90, 91, 104, 154) (**Supplemental Table 15**).

The meta-analysis indicated that higher maternal adherence to a healthy diet during pregnancy was associated with 28% lower odds of having an LBW infant (7 studies, 70,662 participants; OR: 0.72; 95% CI: 0.53, 0.97; $P = 0.001$) (Table 2).

Preterm birth.

Seventeen studies were identified that examined the association between maternal dietary pattern and odds of preterm birth, of which 12 contributed to the quantitative synthesis (23, 25, 29–31, 59, 80, 90, 91, 95, 154, 157) (**Supplemental Table 16**).

Mothers with the highest adherence to a healthy diet during pregnancy had a 56% lower odds of a preterm birth (10 studies, 39,415 participants; OR: 0.44; 95% CI: 0.31, 0.62; $P < 0.001$). In subgroup analysis, the prudent dietary pattern was associated with lower preterm birth incidence (5 studies, 71,554 participants; OR: 0.48; 95% CI: 0.25, 0.93; $P = 0.03$). No significant associations were found for unhealthy (4 studies, 70,144 participants; OR: 2.05; 95% CI: 0.85, 4.91; $P = 0.1$) and mixed (4 studies, 68,411 participants; OR: 0.67; 95% CI: 0.32, 1.39; $P = 0.28$) dietary patterns (Table 2).

Large for gestational age.

Results from 6 articles were used to evaluate the association of maternal diet and large for gestational age (LGA) (26, 59, 78, 128, 137, 157). Five studies were excluded from quantitative syntheses because of inappropriate data (14, 79, 109, 118, 158) (**Supplemental Table 17**).

There was no significant difference in odds of LGA among mothers who had the highest adherence to a healthy diet compared with lowest adherence (6 studies, 72,499 participants; OR: 0.89; 0.95% CI: 0.67, 1.19; $P = 0.45$). In subgroup analyses, there was a 31% lower odds of LGA in mothers with higher adherence to the Healthy Eating Index (3 studies, 3906 participants; OR: 0.69; 0.95% CI: 0.5, 0.94; $P = 0.02$) (Table 2).

Small for gestational age.

Fifteen articles investigated the association between maternal dietary pattern and small for gestational age (SGA), 8 of which were included in the meta-analysis (26, 59, 66, 78, 128, 137, 143, 157) (**Supplemental Table 18**).

There was no evidence of association between maternal healthy dietary patterns and incidence of SGA (7 studies, 75,706 participants; OR: 0.8; 0.95% CI: 0.57, 1.11; $P = 0.19$). Pooling the results of 3 studies, higher adherence to a

TABLE 2 Meta-analysis of maternal dietary patterns and offspring outcomes (all analyses were conducted using a random-effects model)[1]

Study group	Studies, *n* [reference(s)]	Participants, *n*	WMD (95% CI), cm	*P*-effect	*Q* statistic	*P*-within group	I^2, %	*P*-between group
Birth weight (Hedges' *g*)								
Healthy dietary pattern	15 (24, 26–28, 30, 69, 78, 87, 128, 137, 139, 143, 154)	75,041	0.19 (0.05, 0.32)	0.007	324.69	<0.001	95.7	<0.001
Unhealthy dietary pattern	2 (71, 125)	1585	−0.10 (−0.33, 0.11)	0.35	2.37	0.09	63.4	
Mixed dietary pattern	3 (31, 66, 71)	2659	0.37 (−0.24, 0.99)	0.24	76.31	<0.001	97.4	
Healthy diet subgroups								
Prudent dietary pattern	1 (31)	764	0.14 (−0.03, 0.31)	0.11	0.00	—	—	<0.001
Mediterranean diet	8 (24, 25, 27, 69, 87, 143)	35,345	0.04 (−0.03, 0.12)	0.24	11.27	—	—	
Healthy Eating Index	7 (28, 30, 78, 87, 128, 131, 139)	8271	0.25 (−0.08, 0.59)	0.11	188.19	—	—	
New Nordic diet score	1 (26)	56,629	0.06 (0.04, 0.08)	<0.001	0.00	—	—	
Dietary diversity	1 (154)	374	1.31 (1.09, 1.54)	<0.001	0.00	—	—	
Other healthy diet	1 (137)	1807	0.15 (0.02, 0.28)	0.01	0.00	—	—	
Birth length (cm)								
Healthy dietary pattern	9 (27, 30, 69, 78, 87, 131, 139)	7227	0.08 (−0.06, 0.23)	0.26	10.35	0.24	22.7	
Healthy diet subgroups								
Mediterranean diet	5 (27, 69, 87)	3382	0.10 (−0.15, 0.35)	0.43	5.48	0.24	27.1	0.7
Healthy Eating Index	5 (30, 78, 87, 131, 139)	3845	0.08 (−0.05, 0.22)	0.43	4.78	0.31	16.3	
Birth head circumference (cm)								
Healthy dietary pattern	9 (27, 30, 69, 78, 131, 139, 143)	10,303	0.09 (−0.03, 0.22)	0.14	18.21	0.02	56.1	
Healthy diet subgroups								
Mediterranean diet	5 (27, 69, 143)	6493	0.004 (−0.08, 0.09)	0.93	4.3	0.36	7.0	0.004
Healthy Eating Index	4 (30, 78, 131, 139)	3810	0.23 (0.03, 0.43)	0.02	5.69	0.12	47.3	
Low birth weight								
Healthy dietary pattern	7 (26, 30, 78, 90, 91, 104, 154)	70,662	0.72 (0.53, 0.97)[2]	0.001	4.09	0.66	0.0	0.04
Unhealthy dietary pattern	1 (91)	812	2.91 (0.97, 8.74)[2]	0.05	0.00	—	—	
Mixed dietary pattern	1 (91)	812	0.60 (0.27, 1.34)[2]	0.21	0.00	—	—	
Healthy diet subgroups								
Prudent dietary pattern	1 (91)	812	0.59 (0.19, 1.81)[2]	0.36	0.00	—	—	0.63
Healthy Eating Index	2 (30, 78)	1944	0.69 (0.32, 1.45)[2]	0.33	1.13	0.28	11.1	
New Nordic diet score	1 (26)	66,597	0.77 (0.62, 0.97)[2]	0.02	0.00	—	—	
Dietary diversity	2 (104, 154)	494	0.51 (0.26, 1.00)[2]	0.05	0.43	0.51	0.0	
The Australian recommended food score	1 (90)	1897	0.40 (0.12, 1.33)[2]	0.13	0.00	—	—	
Preterm birth								
Healthy dietary pattern	10 (23, 25, 29–31, 59, 90, 91, 154, 157)	39,415	0.44 (0.31, 0.62)[2]	<0.001	25.01	0.003	64.0	<0.001
Unhealthy dietary pattern	4 (29, 59, 80, 91)	70,144	2.05 (0.85, 4.91)[2]	0.1	60.28	<0.001	95.0	
Mixed dietary pattern	4 (31, 59, 80, 91)	68,411	0.67 (0.32, 1.39)[2]	0.28	23.05	<0.001	87.0	
Healthy diet subgroups								
Prudent dietary pattern	5 (29, 31, 59, 80, 91)	71,554	0.48 (0.25, 0.93)[2]	0.03	46.73	<0.001	93.1	<0.001
Mediterranean diet	2 (23, 25)	28,240	0.64 (0.40, 1.01)[2]	0.06	0.13	0.72	0.00	

(*Continued*)

TABLE 2 (*Continued*)

Study group	Studies, *n* [reference(s)]	Participants, *n*	WMD (95% CI), cm	*P*-effect	*Q* statistic	*P*-within group	I^2, %	*P*-between group
Healthy Eating Index	2 (30, 157)	3351	0.60 (0.40, 0.92)[2]	0.02	0.07	0.79	0.0	
New Nordic diet score	1 (95)	72,037	0.91 (0.80, 1.03)[2]	0.14	0.00	—	—	
DASH score	1 (29)	3143	0.59 (0.40, 0.86)[2]	0.006	0.00	—	—	
Dietary diversity	1 (154)	373	0.22 (0.11, 0.43)[2]	<0.001	0.00	—	—	
The Australian recommended food score	1 (90)	1897	0.50 (0.21, 1.17)[2]	0.11	0.00	—	—	
Large for gestational age								
Healthy dietary pattern	6 (26, 59, 78, 128, 137, 157)	72,499	0.89 (0.67, 1.19)[2]	0.45	13.13	0.02	61.9	
Unhealthy dietary pattern	1 (59)	188	4.13 (1.302, 13.14)[2]	0.01	0.00	—	—	
Healthy diet subgroups								
Prudent dietary pattern	1 (59)	188	1.84 (0.74, 4.53)[2]	0.18	0.0	—	—	0.007
Healthy Eating Index	3 (78, 128, 157)	3906	0.69 (0.50, 0.94)[2]	0.02	1.1	0.57	0.0	
New Nordic diet score	1 (26)	66,597	1.11 (1.05, 1.19)[2]	<0.001	0.0	—	—	
Other healthy diet	1 (137)	1808	0.81 (0.54, 1.21)[2]	0.3	0.0	—	—	
Small for gestational age								
Healthy dietary pattern	7 (26, 59, 78, 128, 137, 143, 157)	75,706	0.80 (0.57, 1.11)[2]	0.19	19.24	0.004	68.8	0.02
Unhealthy dietary pattern	2 (59, 66)	1035	0.83 (0.34, 2.02)[2]	0.69	1.29	0.25	22.2	
Mixed dietary pattern	2 (59, 66)	1035	0.31 (0.08, 1.14)[2]	0.08	3.45	0.06	71.0	
Healthy diet subgroups								
Prudent dietary pattern	1 (59)	188	0.23 (0.026, 2.14)[2]	0.19	0.00	—	—	
Mediterranean diet	3 (66, 128, 143)	4829	0.54 (0.29, 0.99)[2]	0.04	5.06	0.08	60.4	
Healthy Eating Index	3 (78, 128, 157)	3906	0.89 (0.52, 1.53)[2]	0.69	4.15	0.12	51.9	0.01
New Nordic diet score	1 (26)	66,597	0.92 (0.86, 0.99)[2]	0.02	0.00	—	—	
Other healthy diet	1 (137)	1808	1.24 (0.73, 2.09)[2]	0.42	0.00	—	—	
Fetal growth restriction in head circumference								
Healthy dietary pattern	4 (69, 131)	4071	0.96 (0.57, 1.61)[2]	0.89	6.31	0.09	52.4	
Healthy diet subgroups								
Mediterranean diet	3 (69)	3284	1.19 (0.81. 1.74)[2]	0.36	0.83	0.66	0.00	0.01
Healthy Eating Index	1 (131)	787	0.4 (0.17, 0.92)[2]	0.03	0.00	—	—	
Fetal growth restriction in length								
Healthy dietary pattern	4 (69, 131)	4071	0.85 (0.58, 1.24)[2]	0.41	0.55	0.9	0.00	
Healthy diet subgroups								
Mediterranean diet	3 (69)	3284	0.87 (0.57, 1.33)[2]	0.53	0.49	0.78	0.00	0.81
Healthy Eating Index	1 (131)	787	0.78 (0.33, 1.79)[2]	0.55	0	—	—	
Fetal growth restriction in weight								
Healthy dietary pattern	4 (69, 131)	4071	0.69 (0.3, 1.58)[2]	0.38	14.63	0.002	79.5	
Healthy diet subgroups								
Mediterranean diet	3 (69)	3284	0.95 (0.41, 2.18)[2]	0.91	7.72	0.02	74.1	0.009
Healthy Eating Index	1 (131)	787	0.24 (0.1, 0.56)[2]	0.001	0.00	—	—	

(*Continued*)

TABLE 2 (*Continued*)

Study group	Studies, *n* [reference(s)]	Participants, *n*	WMD (95% CI), cm	*P*-effect	*Q* statistic	*P*-within group	I^2, %	*P*-between group
Stillbirth								
Healthy dietary pattern	3 (86, 91, 154)	17,135	0.74 (0.29, 1.85)[2]	0.52	11.71	0.003	82.9	
Unhealthy dietary pattern	1 (91)	812	57.97 (3.52, 955.99)[2]	0.005	0.00	—	—	
Mixed dietary pattern	1 (91)	812	0.33 (0.22, 0.50)[2]	<0.001	0.00	—	—	
Obesity in offspring								
Healthy dietary pattern	4 (30, 58, 74, 84)	39,436	0.96 (0.83, 1.12)[2]	0.65	0.53	0.91	0.0	
Macrosomia								
Healthy dietary pattern	3 (26, 30, 78)	68,541	1.67 (0.46, 5.98)[2]	0.42	48.67	<0.001	95.9	

[1]DASH, Dietary Approaches to Stop Hypertension; WMD, weighted mean difference.
[2]Values are ORs (95% CIs).

Mediterranean diet was associated with a 46% reduction in the odds of SGA (3 studies, 4829 participants; OR: 0.54; 0.95% CI: 0.29, 0.99; $P = 0.04$) (Table 2).

FGR in weight, height, and head circumference.
Two articles reported the association between a healthy diet and FGR in offspring (69, 131) (**Supplemental Table 19**). These studies reported the results of the INfancia y Medio Ambiente—(Environment and Childhood) Project (INMA) cohort consortium in the Atlantic, Mediterranean (69), and Valencia areas of Spain (131), and the Rhea mother–child study in Crete, Greece (69). The study by Saunders et al. (134) could not be included in the analyses because linear associations were presented.

There was no significant association when considering the extreme categories of a healthy diet for FGR in weight, height, and head circumference (4 studies, 4071 participants; OR: 0.69, 0.95% CI: 0.3, 1.58; $P = 0.38$, for FGR in weight; OR: 0.85, 0.95% CI: 0.58, 1.24; $P = 0.41$, for FGR in length; OR: 0.96, CI: 0.57, 1.61; $P = 0.89$, for FGR in head circumference). There were no significant subgroup findings (Table 2).

Stillbirth.
Meta-analysis based on 3 studies (86, 91, 154) (**Supplemental Table 20**) showed no evidence of an association between higher maternal adherence to a healthy diet and stillbirth (3 studies, 17,135 participants; OR: 0.74; 0.95% CI: 0.29, 1.85; $P = 0.52$) (Table 2).

Obesity in offspring.
Five studies investigated the association between maternal diet and obesity in offspring (30, 58, 74, 84, 114) (**Supplemental Table 21**). One study was not included in the analysis because it did not present a suitable association measure (114). There was no evidence of an association between maternal diet and obesity in offspring (4 studies, 39,436 participants; OR: 0.96; 0.95% CI: 0.83, 1.12; $P = 0.65$).

Macrosomia.
Three studies explored the association of maternal diet during pregnancy and odds of fetal macrosomia (26, 30, 78) (**Supplemental Table 22**). No significant association was observed (3 studies, 68,541 participants; OR: 1.67; 0.95% CI: 0.46, 5.98; $P = 0.42$).

Narrative syntheses

Supplemental Table 23 shows the characteristics of studies that were not suitable for quantitative synthesis.

Allergic disease in offspring.
Six studies (n = 12,311 participants) evaluated the association of maternal diet with allergic diseases in offspring (70, 102, 108, 117, 120, 138) (Supplemental Table 23). Chatzi et al. (70) reported that a high Mediterranean diet score was associated with reduced odds of atopy at age 6.5 y (OR: 0.55; 95% CI: 0.31, 0.97). Loo et al. (108) reported similar results for a "seafood and noodles" dietary pattern (characterized

by higher intakes of noodles, seafood, and soya sauce–based gravies and low intakes of curry and ethnic bread) (OR: 0.7; 95% CI: 0.5, 0.9). Another study showed that diet with higher intakes of baked and sugary products during pregnancy was associated with a higher prevalence of food allergies in the offspring (OR: 1.51; 95% CI: 1.01, 2.14) (102). An additional 3 studies, however, found no significant association between maternal diet and allergic diseases in offspring (117, 120, 138).

Asthma in offspring.
Three studies (n = 10,421 participants) examined linear associations of maternal diet and asthma in the offspring (Supplemental Table 23) (106, 120, 138). No evidence of an association between maternal diet and asthma symptoms in offspring was observed in any study.

Eczema in offspring.
Six studies (n = 13,960 participants) investigated the association between maternal dietary patterns and eczema in the offspring (67, 106, 108, 115, 120, 138) (Supplemental Table 23). No significant associations were observed in any study.

Wheeze in offspring.
Five studies (n = 11,362 participants) measured the association of maternal dietary pattern with wheezing in the offspring (67, 106, 108, 115, 138) (Supplemental Table 23). All but one study found no significant association. Miyake et al. (115) found that higher adherence to a Western dietary pattern was associated with reduced odds of wheezing in childhood (OR: 0.59; 95% CI: 0.35, 0.98).

Pregnancy loss.
Two studies (n = 11,884 participants) investigated the associations between maternal diet and pregnancy loss (86, 91). Neither reported significant associations between maternal diet and the odds of pregnancy loss.

Maternal anxiety.
Two studies (n = 3883 participants) investigated the association between maternal diet and anxiety symptoms (Supplemental Table 23). In one study, a high maternal dietary diversity score was negatively associated with anxiety status (OR: 0.75, 95% CI: 0.62, 0.91) (100). In another study, the common Brazilian diet (characterized by higher intake of rice, beans, meats and eggs, and vegetable spices) (β: −1.2; 95% CI: −2.22, −0.18) and a healthy dietary pattern (β: −1.2; 95% CI: −2.43, −0.13) were associated with fewer anxiety symptoms (150).

Difficulty conceiving.
One study (n = 458 participants) reported that higher adherence to a Mediterranean diet was associated with a lower risk of difficulty getting pregnant (i.e., improved fertility; OR: 0.56, 95% CI: 0.35, 0.95) (Supplemental Table 23) (146).

Postpartum overweight.
One study (n = 186 participants) observed no significant association between maternal diet and being overweight during postpartum (Supplemental Table 23) (60).

Postpartum weight retention.
Two studies (n = 47,197 participants) measured the association between maternal diet and postpartum weight retention. One study suggested no significant association (60). Another study found that a higher Healthy Eating Index score was inversely associated with weight retention 6 mo after delivery (OR: 0.94; 95% CI: 0.91, 0.96) (Supplemental Table 23) (151).

Child emotional dysregulation.
One study (n = 7814 participants) found that a maternal unhealthy dietary pattern was associated with child emotional dysregulation at 2 y of age (correlation coefficient: 0.024; $P \leq 0.05$) (Supplemental Table 23) (127).

Forearm fracture in offspring.
One study (n = 53,922 participants) found no association between maternal dietary pattern in pregnancy and first forearm fracture in offspring (Supplemental Table 23) (126).

Hypospadias.
One study (n = 7928 participants) found that women who identified as vegetarian were more likely to give birth to a boy with hypospadias compared with omnivores (OR: 4.99; 95% CI: 2.10, 11.88) (Supplemental Table 23) (121).

Internalizing and externalizing problems in offspring.
Three studies (n = 53,653 participants) investigated the associations between maternal diet and internalizing and externalizing problems in the offspring (Supplemental Table 23). One study (n = 23,020 participants) indicated that higher intake of unhealthy foods during pregnancy was associated with increased child externalizing behaviors (intercept factor: 0.03, slope factor: −0.002; $P < 0.01$) (98). In another study (n = 3104 participants), maternal Mediterranean diet was negatively associated (OR: 0.90; 95% CI: 0.83, 0.97) and the traditional Dutch diet was positively associated (OR: 1.11; 95% CI: 1.03, 1.21) with child externalizing problems (140). Finally, Borge et al. (65) (n = 27,529 participants) reported that higher maternal diet quality score was inversely associated with child developmental outcomes.

Intrauterine growth restriction.
Two studies (n = 4019 participants) examined the association between maternal diet and intrauterine growth restriction (IUGR) (Supplemental Table 23). Hajianfar et al. (91) reported that higher adherence to a healthy dietary pattern (OR: 2.35; 95% CI: 1.54, 3.6) and Western dietary pattern (OR: 0.18; 95% CI: 0.11, 0.29) was associated with higher and lower incidences of IUGR, respectively. Timmermans et al. (143) reported that higher maternal adherence to a Mediterranean diet was associated with lower incidences of IUGR (OR: 0.34; 95% CI: 0.2, 0.6).

Low birth length and low birth head circumference.
One study ($n = 812$ participants) reported no association between maternal diet pattern (Western, traditional, and healthy) and low birth length and low birth head circumference (Supplemental Table 23) (91).

Neurodevelopmental disorders in offspring.
One study ($n = 80,743$ participants) found no association of maternal vegetarian diet during pregnancy and risk of neurodevelopmental disorders in the offspring (Supplemental Table 23) (107).

Rhinitis in offspring.
One study ($n = 622$ participants) found no association between maternal dietary pattern during pregnancy and odds of rhinitis in the offspring (Supplemental Table 23) (108).

Respiratory infection in offspring.
One study ($n = 1376$ participants) found no significant association between maternal diet during pregnancy and risk of respiratory infections in the offspring at age 3 (Supplemental Table 23) (106).

Substance-use disorders among adolescent offspring.
One study ($n = 5228$ participants) found that a "health conscious" diet during pregnancy was associated with increased risk of cannabis use (OR: 1.29; 95% CI: 1.14, 1.47), and a maternal vegetarian diet was associated with increased risk of alcohol (OR: 1.28; 95% CI: 1.17, 1.41), cannabis (OR: 1.42; 95% CI: 1.3, 1.55), and tobacco use (OR: 1.21; 95% CI: 1.1, 1.33) in offspring at the age of 15 years old (Supplemental Table 23) (94).

Publication bias and sensitivity analysis
Funnel plots were suggestive of publication bias in the analyses of dietary pattern and GDM, which was confirmed by Egger's test ($P = 0.03$). However, the trim-and-fill method was applied and results remained stable (OR: 0.51; 95% CI: 0.82, 1.23).

The sensitivity analysis revealed that the study by Tielemans et al. (142) was responsible for the heterogeneity for inadequate gestational weight gain ($I^2 = 51.8\%$) and removal of this study changed the estimates from nonsignificant to significant for the association between maternal healthy dietary pattern and lower risk of inadequate gestational weight gain (OR: 0.94, 95% CI: 0.9, 0.98; $P = 0.003$; $I^2 = 0.0\%$, P-heterogeneity = 0.48). Exclusion of studies by Zerfu et al. (154) and Navarro et al. (30) for the association between maternal healthy dietary pattern and birth weight in the offspring reduced heterogeneity (I^2 = from 95.7% to 40.0%, P-heterogeneity = 0.06), with stability in the significance of pooled estimates; however, the association was weak (Hedges' g: 0.05, 95% CI: 0.01, 0.09).

Additionally, the results for preterm birth and hypertensive disorders of pregnancy were consistently significant when we restricted the meta-analysis to adjusted effect sizes only. The association between higher adherence to a healthy diet and risk of GDM became significant in the most-adjusted models (13 studies; OR: 0.80; 0.95% CI: 0.67, 0.95; $P = 0.01$). The associations for LBW and birth weight were significant in the less-adjusted models but became nonsignificant when fully adjusted models were used (**Supplemental Tables 24–25**). We were unable to conduct sensitivity analysis for gestational weight gain, cesarean delivery, maternal depression, FGR, and stillbirth due to insufficient data.

Certainty of evidence
The GRADE certainty of evidence was moderate for obesity in offspring (⊕⊕⊕◯); low (⊕⊕◯◯) for cesarean delivery, excessive and inadequate gestational weight gain, maternal hypertensive disorders, maternal depression, and FGR in length; and very low (⊕◯◯◯) for all others (**Table 3**).

Discussion
In this comprehensive systematic review of prospective observational studies, we have summarized the evidence for associations between dietary patterns in pregnancy and adverse outcomes in mothers and offspring. Significant associations were found between higher adherence to a healthy diet and reduced risk of gestational hypertensive disorders, maternal depression, LBW, preterm birth, and higher gestational weight gain and birth weight. Higher maternal adherence to an unhealthy and a mixed diet was associated with a higher risk of gestational hypertension. The stratified analyses based on the types of healthy diet revealed that a higher Healthy Eating Index score was associated with a greater head circumference and reduced odds of LGA. Mediterranean and prudent dietary patterns were also associated with a reduced risk of SGA and preterm birth, respectively.

There have been previous meta-analyses investigating the effects of maternal diet in pregnancy and related outcomes (13, 32–37). A meta-analysis (2016) of 21 studies concluded that adherence to a healthy diet during pregnancy is significantly associated with a 22% lower odds of preeclampsia and GDM and a 25% lower risk of preterm birth (37). A meta-analysis (2017) of 25 studies showed that a healthy maternal diet is associated with higher birth weight and lower risk of preterm birth, while unhealthy diets were associated with lower birth weight (36). A recent meta-analysis showed that vegan mothers were more likely to give birth to LBW infants compared with omnivorous mothers (35). A vegetarian diet may not provide some of the nutrients, such as vitamin B-12 and zinc, that are associated with LBW infants (161), although most of the included studies were from low-income countries, which may impact diet quality. Furthermore, gestational weight gain and maternal BMI are important predictors of birth weight and were not considered in the study. Our meta-analysis extends these findings to synthesize prospective associations of both maternal diet and maternal and offspring outcomes. The importance of dietary exposures in early pregnancy for maternal and fetal health is generally well accepted (162,

TABLE 3 GRADE evidence profile for prospective cohort studies of maternal dietary pattern and perinatal outcomes[1]

Outcome	Studies, *n* (reference)	Risk of bias[2]	Inconsistency[3]	Indirectness[4]	Imprecision[5]	Publication bias	Certainty[5]
Maternal outcomes							
Cesarean delivery	7 (14, 59, 87, 91, 137, 139, 141)	Very serious	Not serious	Not serious	Not serious	Not assessed[6]	⊕⊕◯◯ Low
Excessive gestational weight gain	7 (26, 60, 61, 78, 139, 141, 142)	Serious	Serious[4]	Not serious	Not serious	Not assessed[6]	⊕⊕◯◯ Low
Gestational diabetes mellitus	25 (24, 62, 63, 75–77, 87, 90, 92, 93, 95, 96, 101, 112, 113, 119, 129, 133, 136, 137, 145, 148, 155–157)	Very serious	Very serious	Serious	Not serious	Serious[7]	⊕◯◯◯ Very low
Gestational hypertensive disorders	17 (14, 15, 22, 66, 69, 78, 88, 90, 92, 95, 97, 137, 144, 147, 157)	Serious	Not serious	Serious	Not serious	Not serious	⊕⊕◯◯ Low
Gestational weight gain	10 (24, 27, 31, 82, 87, 113, 137, 142, 154, 157)	Very serious	Very serious[4]	Not serious	Not serious	Not serious	⊕◯◯◯ Very low
Inadequate gestational weight gain	5 (26, 61, 78, 139, 142)	Serious	Serious	Not serious	Not serious	Not assessed[6]	⊕⊕◯◯ Low
Maternal depression	3 (68, 100, 123)	Serious	Serious	Not serious	Not serious	Not assessed[6]	⊕⊕◯◯ Low
Offspring outcomes							
Birth weight	21 (24–28, 30, 31, 66, 69, 71, 78, 87, 125, 128, 131, 137, 139, 143, 154)	Very serious	Serious[4]	Serious	Not Serious	Not serious	⊕◯◯◯ Very low
Birth length	9 (27, 30, 69, 78, 87, 131, 139)	Serious	Serious	Serious	Not serious	Not assessed[6]	⊕◯◯◯ Very low
Birth head circumference	9 (27, 30, 69, 78, 131, 139, 143)	Serious	Serious	Serious	Not serious	Not assessed[6]	⊕◯◯◯ Very low
Fetal growth restriction in weight	3 (69, 131)	Serious	Very serious	Serious	Not serious	Not assessed[6]	⊕◯◯◯ Very low
Fetal growth restriction in length	3 (69, 131)	Serious	Not serious	Serious	Not serious	Not assessed[6]	⊕⊕◯◯ Low
Fetal growth restriction in head circumference	3 (69, 131)	Serious	Serious	Serious	Not serious	Not assessed[6]	⊕◯◯◯ Very low
Large for gestational age	6 (26, 59, 78, 128, 137, 157)	Serious	Very serious	Serious	Not serious	Not assessed[6]	⊕◯◯◯ Very low
Preterm birth	12 (23, 25, 29–31, 59, 80, 90, 91, 95, 154, 157)	Serious	Very serious	Not serious	Not serious	Not serious	⊕◯◯◯ Very low
Low birth weight	7 (26, 30, 78, 90, 91, 104, 154)	Very serious	Not serious	Serious	Not serious	Not assessed[6]	⊕◯◯◯ Very low
Small for gestational age	8 (26, 59, 66, 78, 128, 137, 143, 157)	Serious	Very serious	Serious	Not serious	Not assessed[6]	⊕◯◯◯ Very low
Stillbirth	3 (86, 91, 154)	Very serious	Very serious	Serious	Not serious	Not assessed[6]	⊕◯◯◯ Very low
Obesity in offspring	4 (30, 58, 74, 84)	Serious	Not serious	Not serious	Not serious	Not assessed[6]	⊕⊕⊕◯ Moderate

[1]Moderate quality: We are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low quality: Our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low quality: We have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect. GRADE, Grading of Recommendations Assessment, Development and Evaluation; ROBINS-E, Risk Of Bias IN observational Studies of Exposures.

[2]Risk of bias assessed using ROBINS-E tool. Possibility of residual confounding always must be considered in observational studies. Main study limitations included incomplete adjustment for confounders and measurement bias related to outcome assessment. Downgrade 2 levels when >75% of included studies for each outcome rated serious risk of bias, and 1 level when 50–75% of included studies for each outcome rated serious risk of bias.

[3]Downgrade 1 level if I^2 was 50% to 75%, and 2 levels if I^2 was 75% to 100%.

[4]Downgrade 1 level when most of the studies did not directly measure the outcomes.

[5]No downgrade for imprecision because of >2000 participants for each outcome.

[6]No downgrade for publication bias, as publication bias could not be assessed due to lack of power for assessing funnel plot asymmetry and small study effects (<10 cohorts included in our meta-analysis).

[7]Downgrade 1 level for publication bias ($P = 0.03$).

163). Maternal dietary pattern, an overall measurement of food and nutrient intake, influences the health of offspring (162). It is well documented that dietary patterns emphasizing higher amounts of fruits, vegetables, whole grains, and fish and de-emphasizing intakes of processed foods and high-fat and high sugary foods are associated with lower incidences of chronic diseases, inflammation, and cardiovascular diseases (164, 165). A diet rich in antioxidants is associated with lower homocysteine concentrations, which is a known risk factor for pre-eclampsia (166). Furthermore, dietary patterns rich in vitamins and antioxidants may protect against postpartum depression through attenuating inflammatory markers in the brain (68). Such anti-inflammatory diets can also improve blood glucose control and antioxidant capacity (167) that are related to preterm birth (168, 169).

Our results revealed that high adherence to a healthy diet is associated with greater gestational weight gain and lower risk for both excessive and inadequate gestational weight gain. This result is in contrast with some previous findings (24, 142, 157, 170). We interpret this finding to mean that healthy diets likely promote gestational weight gain within recommended ranges. Alternatively, prepregnancy BMI was lower among those women with the highest adherence to a healthy diet (31, 113, 157). Therefore, it is plausible that women who eat healthier are leaner, and although they gain more absolute weight during pregnancy, their gestational weight gain remains within Institute of Medicine recommendations.

High adherence to healthy diets during pregnancy was associated with higher birth weights, which may be due to higher fat-free mass accrual (171–174). Previous studies have shown that poor diet quality during pregnancy is associated with higher neonatal adiposity, independent of maternal weight and energy intake (132, 139). Although we could not specify if this higher birth weight would consistently result in a classification of LGA, the lack of association with macrosomia or LGA suggests that the infants' mass accrual is within the normal range. However, more research is needed to fully understand these results.

As with any review of observational studies, an important issue in our study is separating associations of diet from those induced by residual confounders. In our sensitivity analysis, which only included the most-adjusted models (13 studies), the associations between maternal healthy diet and risk of GDM were stronger. Maternal age, BMI, physical activity, and familial history of diabetes are known risk factors for GDM (175, 176). These factors were taken into account in most studies that reported adjusted effect sizes. The results of the sensitivity analysis for gestational hypertensive disorders and preterm birth were the same as those without adjustments, which indicates that maternal diet is associated with these events independent of measured confounders.

Our review has several strengths. First, we have evaluated the methodological quality of the studies and assessed the certainty of evidence for these associations using GRADE. Second, we have limited this review to prospective studies, which ensures that diet reporting is not influenced by adverse events, therefore minimizing recall bias. Third, a comprehensive search strategy was developed; thus, we are confident that we captured all relevant studies. Fourth, the wide range of ethnicities with large sample sizes increases the generalizability of our results.

Our study also has some limitations. First, diet is a set of several exposures that are strongly intercorrelated. For instance, individuals who adhere to a healthy diet are typically more active, leaner, and engage in several healthy behaviors, which makes it difficult to ascribe an effect to a specific behavior. Second, we were limited by the handful of dietary patterns described/derived by the included studies. Thus, we must acknowledge that what is defined as a "healthy" or "prudent" pattern based on current knowledge is likely to evolve as knowledge of nutrition and health expands. Thus, these labels are subjective. Third, we can never rule out that our findings are due to residual confounders measured or unmeasured. However, we were unable to directly adjust our complete set of analyses for a standard set of confounders, which would have been an approach to deal with this limitation. Moreover, it should be noted that, although adjustment for multiple tests are not routinely used in systematic reviews and not recommended in general, issues of multiplicity might be important in systematic reviews as much as other research types. It is recommended that planning of the statistical testing of hypotheses (including any adjustments for multiple testing) should be done at the design stage of original articles. However, this is difficult for systematic reviews when it is not clear which outcomes and which measures will be available from eligible studies, such as the present review. It is important to note that one in 20 independent statistical tests will be statistically significant at the 5% significance level. Therefore, the statistically significant findings should be interpreted with caution. A fourth major limitation of the present study is that we subjectively categorized diet as "healthy," "unhealthy," and "mixed" dietary patterns, as described and presented by the primary study. Since this classification is highly researcher-specific, variability in classification of diets may lead to misclassification, thus biasing our results towards the null. Finally, in dietary pattern analyses, the names chosen for the diet are user-generated and may not be comparable from study to study. Although a diet is judged by the degree of adherence to the overall diet, not a specific food, loading unhealthy foods into a healthy diet can also alter the findings.

Although observational studies cannot provide high-quality evidence for a causal relation, we used the GRADE framework to assess our confidence in the evidence for a causal relation between exposures of an outcome. Overall, 5% of associations were rated as moderate confidence, 31.5% as low, and 63% as very low. A common limitation that lowered our confidence in findings due to comparability issues included failure to account for demographic factors as potential confounders. It is well established that sociodemographic and other behavioral factors, such as physical activity, smoking, and maternal obesity, among others, are associated with adverse events of pregnancy (177–179). Some studies controlled for several confounders using regression-based approaches, whereas others simply counted the number of events or means in categories of the diet adherence, without adjustment. In addition, exposure measurement bias—derived from imprecise exposure measurement tools—may be present. Most of the reviewed studies relied on FFQs to assess the dietary intakes (60 out of 66 studies). The FFQ has been extensively used in nutrition epidemiology studies and has been shown to be a reliable and valid tool in general adult populations (180). However, this tool is subject to measurement error because it fails to collect detailed information about food preparation and cooking methods and is dependent on memory-based recall (181), which reduced the overall quality of studies. Novel technology methods such as web-based dietary assessment tools (182) or image-based dietary food records may provide more detailed information and have advantages over the traditional methods (183).

We observed high between-studies heterogeneity for many analyses, which remained after sensitivity analysis. We acknowledge that some degree of heterogeneity is to be expected because of diverse baseline characteristics of the participants, various approaches of dietary pattern identification, varying outcome assessment methods (self-reported or medical records, and/or measured), and different cutoffs for definition of outcomes, such as GDM, gestational hypertension, and preterm birth. However, we were not able to perform subgroup analyses based on several prespecified effect modifiers, some of which may have influenced the estimates of association (e.g., maternal age, ethnicity, and prepregnancy weight) and downgrade the evidence for inconsistency. Serious indirectness was observed in some analyses because the outcome was measured indirectly in most of the studies, although we did not downgrade the evidence for imprecision due to the large number of included participants. All of these limitations led to a moderate to very low certainty of evidence; this means that the observed associations may differ if high-quality studies were included in the analysis.

Conclusions

Overall, a healthy maternal diet was associated with a lower incidence of gestational hypertension, maternal depression, LBW, preterm birth, and with increased gestational weight gain and birth weight. A maternal unhealthy diet was associated with increased risk of gestational hypertension. As the quality of evidence was low or very low for all outcomes, it is recommended that future studies examine the effect of maternal dietary patterns on adverse events using rigorous methodological approaches.

Acknowledgments

The authors' responsibilities were as follows—AS-A and SS: conceived the study idea; SA, SS, and OT: conducted the literature search and performed data extraction and quality assessment; SA and AS-A: analyzed the data; SA: wrote the first draft of the manuscript; RJdS and SCF: provided critical review; AS-A: had primary responsibility for final content; and all authors: read and approved the final manuscript.

References

1. Di Cintio E, Parazzini F, Chatenoud L, Surace M, Benzi G, Zanconato G, La Vecchia C. Dietary factors and risk of spontaneous abortion. Eur J Obstet Gynecol Reprod Biol 2001;95:132–6.
2. Hossein-Nezhad A, Maghbooli Z, Vassigh A-R, Larijani B. Prevalence of gestational diabetes mellitus and pregnancy outcomes in Iranian women. Taiwanese J Obstet Gynecol 2007;46:236–41.
3. Metzger B, Coustan D, Trimble E. Hyperglycemia and adverse pregnancy outcomes. Clin Chem 2019;65:937–8.
4. Cnattingius S. The epidemiology of smoking during pregnancy: smoking prevalence, maternal characteristics, and pregnancy outcomes. Nicotine Tobacco Res 2004;6:S125–S40.
5. Viswanathan M, Siega-Riz AM, Moos M-K, Deierlein A, Mumford S, Knaack J, Thieda P, Lux LJ, Lohr KN. Outcomes of maternal weight gain, Evid Rep Technol Assess (Full Rep) 2008; 168:1–223.
6. Barker DJ. Maternal nutrition, fetal nutrition, and disease in later life. Nutrition 1997;13:807–13.
7. Kind KL, Moore VM, Davies MJ. Diet around conception and during pregnancy—effects on fetal and neonatal outcomes. Reprod Biomed Online 2006;12:532–41.
8. Godfrey KM, Barker DJ. Fetal programming and adult health. Public Health Nutr 2001;4:611–24.
9. Saldana TM, Siega-Riz AM, Adair LS. Effect of macronutrient intake on the development of glucose intolerance during pregnancy. Am J Clin Nutr 2004;79:479–86.
10. Chen L, Hu FB, Yeung E, Willett W, Zhang C. Prospective study of pre-gravid sugar-sweetened beverage consumption and the risk of gestational diabetes mellitus. Diabetes Care 2009;32:2236–41.
11. Ley SH, Hanley AJ, Retnakaran R, Sermer M, Zinman B, O'Connor DL. Effect of macronutrient intake during the second trimester on glucose metabolism later in pregnancy. Am J Clin Nutr 2011;94:1232–40.
12. Ying H, Wang D. Effects of dietary fat on onset of gestational diabetes mellitus. Zhonghua Fu Chan Ke Za Zhi 2006;41:729–31.
13. Ha V, Bonner AJ, Jadoo JK, Beyene J, Anand SS, de Souza RJ. The effects of various diets on glycemic outcomes during pregnancy: a systematic review and network meta-analysis. PLoS One 2017;12.
14. Chia A-R, de Seymour JV, Colega M, Chen L-W, Chan Y-H, Aris IM, Tint M-T, Quah PL, Godfrey KM, Yap F. A vegetable, fruit, and white rice dietary pattern during pregnancy is associated with a lower risk of preterm birth and larger birth size in a multiethnic Asian cohort: the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohort study. Am J Clin Nutr 2016;104:1416–23.
15. Brantsæter AL, Haugen M, Samuelsen SO, Torjusen H, Trogstad L, Alexander J, Magnus P, Meltzer HM. A dietary pattern characterized by high intake of vegetables, fruits, and vegetable oils is associated with reduced risk of preeclampsia in nulliparous pregnant Norwegian women. J Nutr 2009;139:1162–8.
16. Cole ZA, Gale CR, Javaid MK, Robinson SM, Law C, Boucher BJ, Crozier SR, Godfrey KM, Dennison EM, Cooper C. Maternal dietary patterns during pregnancy and childhood bone mass: a longitudinal study. J Bone Miner Res 2009;24:663–8.
17. Thompson JM, Wall C, Becroft DM, Robinson E, Wild CJ, Mitchell EA. Maternal dietary patterns in pregnancy and the association with small-for-gestational-age infants. Br J Nutr 2010;103:1665–73.
18. Hu FB, Rimm EB, Stampfer MJ, Ascherio A, Spiegelman D, Willett WC. Prospective study of major dietary patterns and risk of coronary heart disease in men. Am J Clin Nutr 2000;72:912–21.
19. Schulze MB, Hoffmann K. Methodological approaches to study dietary patterns in relation to risk of coronary heart disease and stroke. Br J Nutr 2006;95:860–9.

20. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol 2002;13:3–9.
21. Reedy J, Wirfält E, Flood A, Mitrou PN, Krebs-Smith SM, Kipnis V, Midthune D, Leitzmann M, Hollenbeck A, Schatzkin A. Comparing 3 dietary pattern methods—cluster analysis, factor analysis, and index analysis—with colorectal cancer risk: the NIH–AARP Diet and Health Study. Am J Epidemiol 2010;171:479–87.
22. Timmermans S, Steegers-Theunissen RP, Vujkovic M, Bakker R, den Breeijen H, Raat H, Russcher H, Lindemans J, Hofman A, Jaddoe VW, et al. Major dietary patterns and blood pressure patterns during pregnancy: the Generation R Study. Am J Obstet Gynecol 2011;205:337.e1.
23. Mikkelsen TB, Østerdal ML, Knudsen VK, Haugen M, Meltzer HM, Bakketeig L, Olsen SF. Association between a Mediterranean-type diet and risk of preterm birth among Danish women: a prospective cohort study. Acta Obstet Gynecol Scand 2008;87:325–30.
24. Fernandez-Barres S, Vrijheid M, Manzano-Salgado CB, Valvi D, Martinez D, Iniguez C, Jimenez-Zabala A, Riano-Galan I, Navarrete-Munoz EM, Santa-Marina L, et al. The association of Mediterranean diet during pregnancy with longitudinal body mass index trajectories and cardiometabolic risk in early childhood. J Pediatr 2019;206:119–27.e6.
25. Haugen M, Meltzer HM, Brantsæter AL, Mikkelsen T, Østerdal ML, Alexander J, Olsen SF, Bakketeig L. Mediterranean-type diet and risk of preterm birth among women in the Norwegian Mother and Child Cohort Study (MoBa): a prospective cohort study. Acta Obstet Gynecol Scand 2008;87:319–24.
26. Hillesund ER, Bere E, Haugen M, Overby NC. Development of a New Nordic Diet score and its association with gestational weight gain and fetal growth—a study performed in the Norwegian Mother and Child Cohort Study (MoBa). Public Health Nutr 2014;17:1909–18.
27. Abreu S, Santos PC, Montenegro N, Mota J. Relationship between dairy product intake during pregnancy and neonatal and maternal outcomes among Portuguese women. Obes Res Clin Pract 2017;11:276–86.
28. Badon SE, Miller RS, Qiu C, Sorensen TK, Williams MA, Enquobahrie DA. Maternal healthy lifestyle during early pregnancy and offspring birthweight: differences by offspring sex. J Matern Fetal Neonatal Med 2018;31:1111–7.
29. Martin CL, Sotres-Alvarez D, Siega-Riz AM. Maternal dietary patterns during the second trimester are associated with preterm birth. J Nutr 2015;145:1857–64.
30. Navarro P, Mehegan J, Murrin CM, Kelleher CC, Phillips CM. Adherence to the Healthy Eating Index-2015 across generations is associated with birth outcomes and weight status at age 5 in the Lifeways Cross-Generation Cohort Study. Nutrients 2019;11:928–46.
31. Starling AP, Sauder KA, Kaar JL, Shapiro AL, Siega-Riz AM, Dabelea D. Maternal dietary patterns during pregnancy are associated with newborn body composition. J Nutr 2017;147:1334–9.
32. Borge TC, Aase H, Brantsæter AL, Biele G. The importance of maternal diet quality during pregnancy on cognitive and behavioural outcomes in children: a systematic review and meta-analysis. BMJ Open 2017;7:e016777.
33. Garcia-Larsen V, Ierodiakonou D, Jarrold K, Cunha S, Chivinge J, Robinson Z, Geoghegan N, Ruparelia A, Devani P, Trivella M. Diet during pregnancy and infancy and risk of allergic or autoimmune disease: a systematic review and meta-analysis. PLoS Med 2018;15:e1002507.
34. Zhang Y, Lin J, Fu W, Liu S, Gong C, Dai J. Mediterranean diet during pregnancy and childhood for asthma in children: a systematic review and meta-analysis of observational studies. Pediatr Pulmonol 2019.54949
35. Tan C, Zhao Y, Wang S. Is a vegetarian diet safe to follow during pregnancy? A systematic review and meta-analysis of observational studies. Crit Rev Food Sci Nutr 2019;59:2586–96.
36. Chia A-R, Chen L-W, Lai JS, Wong CH, Neelakantan N, van Dam RM, Chong MF-F. Maternal dietary patterns and birth outcomes: a systematic review and meta-analysis. Adv Nutr 2019;10:685–95.10685
37. Kibret KT, Chojenta C, Gresham E, Tegegne TK, Loxton D. 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. Public Health Nutr 2019;22:506–20.
38. Schoenaker DA, Mishra GD, Callaway LK, Soedamah-Muthu SS. The role of energy, nutrients, foods, and dietary patterns in the development of gestational diabetes mellitus: a systematic review of observational studies. Diabetes Care 2016;39:16–23.
39. Raghavan R, Dreibelbis C, Kingshipp BL, Wong YP, Abrams B, Gernand AD, Rasmussen KM, Siega-Riz AM, Stang J, Casavale KO. Dietary patterns before and during pregnancy and birth outcomes: a systematic review. Am J Clin Nutr 2019;109:729S–56S.
40. Goldacre M. The role of cohort studies in medical research. Pharmacoepidem Drug Safe 2001;10:5–11.
41. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement. Int J Surg 2010;8:336–41.
42. World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013–2020, Geneva (Switzerland): WHO; 2013.
43. World Health Organization. Comprehensive implementation plan on maternal, infant and young child nutrition. Geneva (Switzerland): World Health Organization; 2014.
44. World Health Organization. Diet, nutrition, and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation. Geneva (Switzerland): WHO; 2003.
45. World Health Organization. Guidelines: saturated fatty acid and trans–fatty acid intake for adults and children. Geneva (Switzerland): WHO; 2018.
46. Bero L, Chartres N, Diong J, Fabbri A, Ghersi D, Lam J, Lau A, McDonald S, Mintzes B, Sutton P. The risk of bias in observational studies of exposures (ROBINS-E) tool: concerns arising from application to observational studies of exposures. Syst Rev 2018;7: 242.
47. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, Henry D, Altman DG, Ansari MT, Boutron I. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;355:i4919.
48. Guyatt GH, Oxman AD, Schünemann HJ, Tugwell P, Knottnerus A. GRADE guidelines: a new series of articles in the Journal of Clinical Epidemiology. J Clin Epidemiol 2011;64:380–2.
49. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schünemann HJ. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 2008;336:924–6.
50. Balshem H, Helfand M, Schünemann HJ, Oxman AD, Kunz R, Brozek J, Vist GE, Falck-Ytter Y, Meerpohl J, Norris S. GRADE guidelines: 3. Rating the quality of evidence. J Clin Epidemiol 2011;64: 401–6.
51. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557–60.
52. Guyatt GH, Oxman AD, Kunz R, Woodcock J, Brozek J, Helfand M, Alonso-Coello P, Falck-Ytter Y, Jaeschke R, Vist G. GRADE guidelines: 8. Rating the quality of evidence—indirectness. J Clin Epidemiol 2011;64:1303–10.
53. Guyatt GH, Oxman AD, Kunz R, Brozek J, Alonso-Coello P, Rind D, Devereaux P, Montori VM, Freyschuss B, Vist G. GRADE guidelines 6. Rating the quality of evidence—imprecision. J Clin Epidemiol 2011;64:1283–93.
54. Guyatt GH, Oxman AD, Montori V, Vist G, Kunz R, Brozek J, Alonso-Coello P, Djulbegovic B, Atkins D, Falck-Ytter Y. GRADE guidelines: 5. Rating the quality of evidence—publication bias. J Clin Epidemiol 2011;64:1277–82.
55. Borenstein M, Hedges LV, Higgins JP, Rothstein HR. Introduction to meta-analysis. United Kingdom: John Wiley & Sons; 2011.
56. Cohen J. Statistical power analysis for the behavioral sciences. New York: Lawrence Erlbaum Associates. Academic Press; 2013.

57. Duval S, Tweedie R. Trim and fill: a simple funnel-plot–based method of testing and adjusting for publication bias in meta-analysis. Biometrics 2000;56:455–63.
58. Ahrendt Bjerregaard A, Halldorsson TI, Tetens I, Frodi Olsen S. Mother's dietary quality during pregnancy and offspring's dietary quality in adolescence: follow-up from a national birth cohort study of 19,582 mother-offspring pairs. PLoS Med 2019;16:e1002911.
59. Alves-Santos NH, Cocate PG, Benaim C, Farias DR, Emmett PM, Kac G. Prepregnancy dietary patterns and their association with perinatal outcomes: a prospective cohort study. J Acad Nutr Diet 2019;119:1439–51.
60. Alves-Santos NH, Cocate PG, Eshriqui I, Benaim C, Barros EG, Emmett PM, Kac G. Dietary patterns and their association with adiponectin and leptin concentrations throughout pregnancy: a prospective cohort. Br J Nutr 2018;119:320–9.
61. Ancira-Moreno M, Vadillo-Ortega F, JÁ R-D, Sánchez BN, Pasteris J, Batis C, Castillo-Castrejón M, O'Neill MS. Gestational weight gain trajectories over pregnancy and their association with maternal diet quality: results from the PRINCESA cohort. Nutrition 2019;65:158–66.
62. Badon SE, Enquobahrie DA, Wartko PD, Miller RS, Qiu C, Gelaye B, Sorensen TK, Williams MA. Healthy lifestyle during early pregnancy and risk of gestational diabetes mellitus. Am J Epidemiol 2017;186:326–33.
63. Bao W, Bowers K, Tobias DK, Olsen SF, Chavarro J, Vaag A, Kiely M, Zhang C. Prepregnancy low-carbohydrate dietary pattern and risk of gestational diabetes mellitus: a prospective cohort study. Am J Clin Nutr 2014;99:1378–84.
64. Bienertova-Vasku J, Zlamal F, Prusa T, Novak J, Mikes O, Cupr P, Pohorala A, Svancara J, Andryskova L, Pikhart H. Parental heights and maternal education as predictors of length/height of children at birth, age 3 and 19 years, independently on diet: the ELSPA C study. Eur J Clin Nutr 2017; 71:1193–9.
65. Borge TC, Brantsaeter AL, Caspersen IH, Meltzer HM, Brandlistuen RE, Aase H, Biele G. Estimating strength of associations between prenatal diet quality and child developmental outcomes—results from a large prospective pregnancy cohort. Am J Epidemiol 2019;188:1902–12.
66. Bouwland-Both MI, Steegers-Theunissen RP, Vujkovic M, Lesaffre EM, Mook-Kanamori DO, Hofman A, Lindemans J, Russcher H, Jaddoe VW, Steegers EA. A periconceptional energy-rich dietary pattern is associated with early fetal growth: the Generation R study. BJOG 2013;120:435–45.
67. Chatzi L, Garcia R, Roumeliotaki T, Basterrechea M, Begiristain H, Iñiguez C, Vioque J, Kogevinas M, Sunyer J. Mediterranean diet adherence during pregnancy and risk of wheeze and eczema in the first year of life: INMA (Spain) and RHEA (Greece) mother-child cohort studies. Br J Nutr 2013;110:2058–68.
68. Chatzi L, Melaki V, Sarri K, Apostolaki I, Roumeliotaki T, Georgiou V, Vassilaki M, Koutis A, Bitsios P, Kogevinas M. Dietary patterns during pregnancy and the risk of postpartum depression: the mother-child "Rhea" cohort in Crete, Greece. Public Health Nutr 2011;14:1663–70.
69. Chatzi L, Mendez M, Garcia R, Roumeliotaki T, Ibarluzea J, Tardón A, Amiano P, Lertxundi A, Iñiguez C, Vioque J, et al. Mediterranean diet adherence during pregnancy and fetal growth: INMA (Spain) and RHEA (Greece) mother-child cohort studies. Br J Nutr 2012;107:135–45.
70. Chatzi L, Torrent M, Romieu I, Garcia-Esteban R, Ferrer C, Vioque J, Kogevinas M, Sunyer J. Mediterranean diet in pregnancy is protective for wheeze and atopy in childhood. Thorax 2008;63:507–13.
71. Chen LW, Aris IM, Bernard JY, Tint MT, Chia A, Colega M, Gluckman PD, Shek LPC, Saw SM, Chong YS, et al. Associations of maternal dietary patterns during pregnancy with offspring adiposity from birth until 54 months of age. Nutrients 2017;9:2–19.
72. Chia AR, Tint MT, Han CY, Chen LW, Colega M, Aris IM, Chua MC, Tan KH, Yap F, Shek LPC, et al. Adherence to a healthy eating index for pregnant women is associated with lower neonatal adiposity in a multiethnic Asian cohort: the Growing Up in Singapore Towards healthy Outcomes (GUSTO) Study. Am J Clin Nutr 2018;107:71–9.
73. Coelho Nde L, Cunha DB, Esteves AP, Lacerda EM, Theme Filha MM. Dietary patterns in pregnancy and birth weight. Rev Saude Publica 2015;49:62–72.
74. Dhana K, Haines J, Liu G, Zhang C, Wang X, Field AE, Chavarro JE, Sun Q. Association between maternal adherence to healthy lifestyle practices and risk of obesity in offspring: results from two prospective cohort studies of mother-child pairs in the United States. BMJ 2018;362:362.
75. Donazar-Ezcurra M, Lopez-del Burgo C, Martinez-Gonzalez MA, Basterra-Gortari FJ, de Irala J, Bes-Rastrollo M. Pre-pregnancy adherences to empirically derived dietary patterns and gestational diabetes risk in a Mediterranean cohort: the Seguimiento Universidad de Navarra (SUN) project. Br J Nutr 2017; 118:1–7.
76. Donazar-Ezcurra M, Lopez-Del Burgo C, Martinez-Gonzalez MA, Dominguez LJ, Basterra-Gortari FJ, de Irala J, Bes-Rastrollo M. Association of the Dietary-Based Diabetes-Risk Score (DDS) with the risk of gestational diabetes mellitus in the Seguimiento Universidad de Navarra (SUN) project. Br J Nutr 2019; 122:800–7.
77. Du H, Jiang H, Chen B, Xu L, Liu S, Yi J, He G, Qian X. Association of dietary pattern during pregnancy and gestational diabetes mellitus: a prospective cohort study in northern China. Biomed Environ Sci 2017;30:887–97.
78. Emond JA, Karagas MR, Baker ER, Gilbert-Diamond D. Better diet quality during pregnancy is associated with a reduced likelihood of an infant born small for gestational age: an analysis of the prospective New Hampshire Birth Cohort Study. J Nutr 2018;148:22–30.
79. Englund-Ögge L, Brantsæter AL, Juodakis J, Haugen M, Meltzer HM, Jacobsson B, Sengpiel V. Associations between maternal dietary patterns and infant birth weight, small and large for gestational age in the Norwegian Mother and Child Cohort Study. Eur J Clin Nutr 2019;73:1270–82.
80. Englund-Ogge L, Brantsaeter AL, Sengpiel V, Haugen M, Birgisdottir BE, Myhre R, Meltzer HM, Jacobsson B. Maternal dietary patterns and preterm delivery: results from large prospective cohort study. BMJ 2014;348:g1446.
81. Eshriqui I, Franco-Sena AB, Farias DR, Freitas-Vilela AA, Cunha DB, Barros EG, Emmett PM, Kac G. Prepregnancy dietary patterns are associated with blood lipid level changes during pregnancy: a prospective cohort study in Rio de Janeiro, Brazil. J Acad Nutr Diet 2016;117:1066–79.
82. Eshriqui I, Vilela AAF, Rebelo F, Farias DR, Castro MBT, Kac G. Gestational dietary patterns are not associated with blood pressure changes during pregnancy and early postpartum in a Brazilian prospective cohort. Eur J Nutr 2016;55:21–32.
83. Ferland S, O'Brien HT. Maternal dietary intake and pregnancy outcome. J Reprod Med 2003;48:86–94.
84. Fernández-Barrés S, Romaguera D, Valvi D, Martínez D, Vioque J, Navarrete-Muñoz EM, Amiano P, Gonzalez-Palacios S, Guxens M, Pereda E, et al. Mediterranean dietary pattern in pregnant women and offspring risk of overweight and abdominal obesity in early childhood: the INMA birth cohort study. Pediatr Obesity 2016;11: 491–9.
85. Fulay AP, Rifas-Shiman SL, Oken E, Perng W. Associations of the Dietary Approaches to Stop Hypertension (DASH) diet with pregnancy complications in Project Viva. Eur J Clin Nutr 2018; 72:1385–95.
86. Gaskins AJ, Rich-Edwards JW, Hauser R, Williams PL, Gillman MW, Penzias A, Missmer SA, Chavarro JE. Prepregnancy dietary patterns and risk of pregnancy loss. Am J Clin Nutr 2014;100:1166–72.
87. Gesteiro E, Bernal BR, Bastida S, Sánchez-Muniz F. Maternal diets with low healthy eating index or Mediterranean diet adherence scores are associated with high cord-blood insulin levels and insulin resistance markers at birth. Eur J Clin Nutr 2012;66:1008.
88. Gicevic S, Gaskins AJ, Fung TT, Rosner B, Tobias DK, Isanaka S, Willett WC. Evaluating pre-pregnancy dietary diversity vs. dietary

quality scores as predictors of gestational diabetes and hypertensive disorders of pregnancy. PLoS One 2018;13:e0195103.
89. Grandy M, Snowden JM, Boone-Heinonen J, Purnell JQ, Thornburg KL, Marshall NE. Poorer maternal diet quality and increased birth weight. J Matern Fetal Neonatal Med 2018;31:1613–9.
90. Gresham E, Collins CE, Mishra GD, Byles JE, Hure AJ. Diet quality before or during pregnancy and the relationship with pregnancy and birth outcomes: the Australian Longitudinal Study on Women's Health. Public Health Nutr 2016;19:2975–83.
91. Hajianfar H, Esmaillzadeh A, Feizi A, Shahshahan Z, Azadbakht L. Major maternal dietary patterns during early pregnancy and their association with neonatal anthropometric measurement. Biomed Res Int 2018;10:1–11.
92. Hajianfar H, Esmaillzadeh A, Feizi 101A, Shahshahan Z, Azadbakht L. The association between major dietary patterns and pregnancy-related complications. Arch Iranian Med 2018;21:443–51.
93. He JR, Yuan MY, Chen NN, Lu JH, Hu CY, Mai WB, Zhang RF, Pan YH, Qiu L, Wu YF, et al. Maternal dietary patterns and gestational diabetes mellitus: a large prospective cohort study in China. Br J Nutr 2015;113:1292–300.
94. Hibbeln JR, SanGiovanni JP, Golding J, Emmett PM, Northstone K, Davis JM, Schuckit M, Heron J. Meat consumption during pregnancy and substance misuse among adolescent offspring: stratification of TCN2 genetic variants. Alcohol Clin Exp Res 2017;41:1928–37.
95. Hillesund ER, Overby NC, Engel SM, Klungsoyr K, Harmon QE, Haugen M, Bere E. Associations of adherence to the New Nordic Diet with risk of preeclampsia and preterm delivery in the Norwegian Mother and Child Cohort Study (MoBa). Eur J Epidemiol 2014;29:753–65.
96. Hu J, Oken E, Aris IM, Lin PID, Ma Y, Ding N, Gao M, Wei X, Wen D. Dietary patterns during pregnancy are associated with the risk of gestational diabetes mellitus: evidence from a Chinese prospective birth cohort study. Nutrients 2019;11:405–20.
97. Ikem E, Halldorsson TI, Birgisdóttir BE, Rasmussen MA, Olsen SF, Maslova E. Dietary patterns and the risk of pregnancy-associated hypertension in the Danish National Birth Cohort: a prospective longitudinal study. BJOG 2019;126:663–73.
98. Jacka FN, Ystrom E, Brantsaeter AL, Karevold E, Roth C, Haugen M, Meltzer HM, Schjolberg S, Berk M. Maternal and early postnatal nutrition and mental health of offspring by age 5 years: a prospective cohort study. J Am Acad Child Adolesc Psychiatry 2013;52: 1038–47.
99. Jarman M, Mathe N, Ramazani F, Pakseresht M, Robson P, Johnson S, Bell R. Dietary patterns prior to pregnancy and associations with pregnancy complications. Nutrients 2018;10:914–29.
100. Jiang W, Mo M, Li M, Wang S, Muyiduli X, Shao B, Jiang S, Yu Y. The relationship of dietary diversity score with depression and anxiety among prenatal and post-partum women. J Obstet Gynaecol Res 2018;44:1929–36.
101. Karamanos B, Thanopoulou A, Anastasiou E, Assaad-Khalil S, Albache N, Bachaoui M, Slama CB, El Ghomari H, Jotic A, Lalic N, et al. Relation of the Mediterranean diet with the incidence of gestational diabetes. Eur J Clin Nutr 2014;68:8–13.
102. Kim YH, Kim KW, Lee SY, Koo KO, Kwon SO, Seo JH, Suh DI, Shin YH, Ahn K, Oh SY, et al. Maternal perinatal dietary patterns affect food allergy development in susceptible infants. J Allergy Clin Immunol Pract 2019;7:2337–47, e7.
103. Knudsen V, Orozova-Bekkevold I, Mikkelsen TB, Wolff S, Olsen S. Major dietary patterns in pregnancy and fetal growth. Eur J Clin Nutr 2008;62:463–70.
104. Komal Manerkar DG. Effect of maternal diet diversity and physical activity on neonatal birth weight: a study from urban slums of Mumbai. J Clin Diagn Res 2017;11:7–11.
105. Koutelidakis AE, Alexatou O, Kousaiti S, Gkretsi E, Vasios G, Sampani A, Tolia M, Kiortsis DN, Giaginis C. Higher adherence to Mediterranean diet prior to pregnancy is associated with decreased risk for deviation from the maternal recommended gestational weight gain. Int J Food Sci Nutr 2018;69:84–92.
106. Lange NE, Rifas-Shiman SL, Camargo CA, Jr, Gold DR, Gillman MW, Litonjua AA. Maternal dietary pattern during pregnancy is not associated with recurrent wheeze in children. J Allergy Clin Immunol 2010;126:250.
107. Larsen PS, Nybo Andersen AM, Uldall P, Bech BH, Olsen J, Hansen AV, Strandberg-Larsen K. Maternal vegetarianism and neurodevelopment of children enrolled in the Danish National Birth Cohort. Acta Paediatr 2014;103:e507–9.
108. Loo EXL, Ong L, Goh A, Chia AR, Teoh OH, Colega MT, Chan YH, Saw SM, Kwek K, Gluckman PD, et al. Effect of maternal dietary patterns during pregnancy on self-reported allergic diseases in the first 3 years of life: results from the GUSTO Study. Int Arch Allergy Immunol 2017;173:105–13.
109. Lu MS, Chen QZ, He JR, Wei XL, Lu JH, Li SH, Wen XX, Chan FF, Chen NN, Qiu L, et al. Maternal dietary patterns and fetal growth: a large prospective cohort study in China. Nutrients 2016;8:71–81.
110. Lu M-S, He J-R, Chen Q, Lu J, Wei X, Zhou Q, Chan F, Zhang L, Chen N, Qiu L. Maternal dietary patterns during pregnancy and preterm delivery: a large prospective cohort study in China. Nutr J 2018;17:71.
111. Ma L, Lu Q, Ouyang J, Huang J, Huang S, Jiao C, Zhang Z, Mao L. How are maternal dietary patterns and maternal/fetal cytokines associated with birth weight? A path analysis. Br J Nutr 2019;121:1178–87.
112. Mak JKL, Pham NM, Lee AH, Tang L, Pan XF, Binns CW, Sun X. Dietary patterns during pregnancy and risk of gestational diabetes: a prospective cohort study in Western China. Nutr J 2018;17:107.
113. Mantzoros CS, Sweeney L, Williams CJ, Oken E, Kelesidis T, Rifas-Shiman SL, Gillman MW. Maternal diet and cord blood leptin and adiponectin concentrations at birth. Clin Nutr 2010;29:622–6.
114. Martin CL, Siega-Riz AM, Sotres-Alvarez D, Robinson WR, Daniels JL, Perrin EM, Stuebe AM. Maternal dietary patterns during pregnancy are associated with child growth in the first 3 years of life. J Nutr 2016;146:2281–8.
115. Miyake Y, Okubo H, Sasaki S, Tanaka K, Hirota Y. Maternal dietary patterns during pregnancy and risk of wheeze and eczema in Japanese infants aged 16–24 months: the Osaka Maternal and Child Health Study. Pediatr Allergy Immunol 2011;22:734–41.
116. Monteagudo C, Mariscal-Arcas M, Heras-Gonzalez L, Ibanez-Peinado D, Rivas A, Olea-Serrano F. Effects of maternal diet and environmental exposure to organochlorine pesticides on newborn weight in southern Spain. Chemosphere 2016;156:135–42.
117. Moonesinghe H, Patil VK, Dean T, Arshad SH, Glasbey G, Grundy J, Venter C. Association between healthy eating in pregnancy and allergic status of the offspring in childhood. Ann Allergy Asthma Immunol 2016;116:163–5.
118. Moore BF, Sauder KA, Starling AP, Hebert JR, Shivappa N, Ringham BM, Glueck DH, Dabelea D. Proinflammatory diets during pregnancy and neonatal adiposity in the Healthy Start Study. J Pediatr 2017;195:121–7.
119. Nascimento GR, Alves LV, Fonseca CL, Figueiroa JN, Alves JG. Dietary patterns and gestational diabetes mellitus in a low income pregnant women population in Brazil—a cohort study. Arch Latinoam Nutr 2016;66:301–8.
120. Nguyen AN, Elbert NJ, Pasmans S, Kiefte-de Jong JC, de Jong NW, Moll HA, Jaddoe VWV, de Jongste JC, Franco OH, Duijts L, et al. Diet quality throughout early life in relation to allergic sensitization and atopic diseases in childhood. Nutrients 2017;9:841–54.
121. North K, Golding J. A maternal vegetarian diet in pregnancy is associated with hypospadias. BJU Int 2000;85:107–13.
122. Northstone K, Ness AR, Emmett PM, Rogers IS. Adjusting for energy intake in dietary pattern investigations using principal components analysis. Eur J Clin Nutr 2008;62:931–8.
123. Okubo H, Miyake Y, Sasaki S, Tanaka K, Murakami K, Hirota Y. Dietary patterns during pregnancy and the risk of postpartum depression in Japan: the Osaka Maternal and Child Health Study. Br J Nutr 2011;105:1251–7.
124. Okubo H, Miyake Y, Sasaki S, Tanaka K, Murakami K, Hirota Y. Maternal dietary patterns in pregnancy and fetal growth in Japan: the Osaka Maternal and Child Health Study. Br J Nutr 2012;107:1526–33.

125. Papadopoulou E, Kogevinas M, Botsivali M, Pedersen M, Besselink H, Mendez MA, Fleming S, Hardie LJ, Knudsen LE, Wright J, et al. Maternal diet, prenatal exposure to dioxin-like compounds and birth outcomes in a European prospective mother-child study (NewGeneris). Sci Total Environ 2014;484:121–8.
126. Petersen SB, Rasmussen MA, Olsen SF, Vestergaard P, Mølgaard C, Halldorsson TI, Strøm M. Maternal dietary patterns during pregnancy in relation to offspring forearm fractures: prospective study from the Danish National Birth Cohort. Nutrients 2015;7:2382–400.
127. Pina-Camacho L, Jensen SK, Gaysina D, Barker ED. Maternal depression symptoms, unhealthy diet and child emotional-behavioural dysregulation. Psychol Med 2015;45:1851–60.
128. Poon AK, Yeung E, Boghossian N, Albert PS, Zhang C. Maternal dietary patterns during third trimester in association with birthweight characteristics and early infant growth. Scientifica 2013;2013:1–7.
129. Radesky JS, Oken E, Rifas-Shiman SL, Kleinman KP, Rich-Edwards JW, Gillman MW. Diet during early pregnancy and development of gestational diabetes. Paediatr Perinat Epidemiol 2007;22:47–59.
130. Rifas-Shiman SL, Rich-Edwards JW, Kleinman KP, Oken E, Gillman MW. Dietary quality during pregnancy varies by maternal characteristics in Project Viva: a US cohort. J Am Diet Assoc 2009;109:1004–11.
131. Rodriguez-Bernal CL, Rebagliato M, Iniguez C, Vioque J, Navarrete-Munoz EM, Murcia M, Bolumar F, Marco A, Ballester F. Diet quality in early pregnancy and its effects on fetal growth outcomes: the Infancia y Medio Ambiente (Childhood and Environment) Mother and Child Cohort Study in Spain. Am J Clin Nutr 2010;91:1659–66.
132. Rohatgi KW, Tinius RA, Cade WT, Steele EM, Cahill AG, Parra DC. Relationships between consumption of ultra-processed foods, gestational weight gain and neonatal outcomes in a sample of US pregnant women. Peer J 2017;5:e4091.
133. Sauder KA, Starling AP, Shapiro AL, Kaar JL, Ringham BM, Glueck DH, Leiferman JA, Siega-Riz AM, Dabelea D. Diet, physical activity and mental health status are associated with dysglycaemia in pregnancy: the Healthy Start Study. Diabet Med 2016;33: 663–7.
134. Saunders L, Guldner L, Costet N, Kadhel P, Rouget F, Monfort C, Thomé JP, Multigner L, Cordier S. Effect of a Mediterranean diet during pregnancy on fetal growth and preterm delivery: results from a French Caribbean mother–child cohort study (TIMOUN). Paediatr Perinat Epidemiol 2014;28:235–44.
135. Schoenaker D, Vergouwe Y, Soedamah-Muthu SS, Callaway LK, Mishra GD. Preconception risk of gestational diabetes: development of a prediction model in nulliparous Australian women. Diabetes Res Clin Pract 2018;146:48–57.
136. Schoenaker D, Soedamah-Muthu SS, Callaway LK, Mishra GD. Pre-pregnancy dietary patterns and risk of gestational diabetes mellitus: results from an Australian population-based prospective cohort study. Diabetologia 2015;58:2726–35.
137. Sen S, Rifas-Shiman SL, Shivappa N, Wirth MD, Hébert JR, Gold DR, Gillman MW, Oken E. Dietary inflammatory potential during pregnancy is associated with lower fetal growth and breastfeeding failure: results from Project Viva. J Nutr 2015;146:728–36.
138. Shaheen SO, Northstone K, Newson RB, Emmett PM, Sherriff A, Henderson AJ. Dietary patterns in pregnancy and respiratory and atopic outcomes in childhood. Thorax 2009;64:411–7.
139. Shapiro AL, Kaar JL, Crume TL, Starling AP, Siega-Riz AM, Ringham BM, Glueck DH, Norris JM, Barbour LA, Friedman JE, et al. Maternal diet quality in pregnancy and neonatal adiposity: the Healthy Start Study. Int J Obes 2016;40:1056–62.
140. Steenweg-de Graaff J, Tiemeier H, Steegers-Theunissen RPM, Hofman A, Jaddoe VWV, Verhulst FC, Roza SJ. Maternal dietary patterns during pregnancy and child internalising and externalising problems. Clin Nutr 2014;33:115–21.
141. Tahir MJ, Haapala JL, Foster LP, Duncan KM, Teague AM, Kharbanda EO, McGovern PM, Whitaker KM, Rasmussen KM, Fields DA, et al. Higher maternal diet quality during pregnancy and lactation is associated with lower infant weight-for-length, body fat percent, and fat mass in early postnatal life. Nutrients 2019;11:632–46.
142. Tielemans MJ, Erler NS, Leermakers ETM, van den Broek M, Jaddoe VWV, Steegers EAP, Kiefte-de Jong JC, Franco OH. A priori and a posteriori dietary patterns during pregnancy and gestational weight gain: the Generation R Study. Nutrients 2015;7:9383–99.
143. Timmermans S, Steegers-Theunissen RP, Vujkovic M, den Breeijen H, Russcher H, Lindemans J, Mackenbach J, Hofman A, Lesaffre EE, Jaddoe VV, et al. The Mediterranean diet and fetal size parameters: the Generation R Study. Br J Nutr 2012;108:1399–409.
144. Timpka S, Stuart JJ, Tanz LJ, Rimm EB, Franks PW, Rich-Edwards JW. Lifestyle in progression from hypertensive disorders of pregnancy to chronic hypertension in Nurses' Health Study II: observational cohort study. BMJ 2017;358:j3024.
145. Tobias DK, Zhang C, Chavarro J, Bowers K, Rich-Edwards J, Rosner B, Mozaffarian D, Hu FB. Prepregnancy adherence to dietary patterns and lower risk of gestational diabetes mellitus. Am J Clin Nutr 2012;96:289–95.
146. Toledo E, Lopez-del Burgo C, Ruiz-Zambrana A, Donazar M, Navarro-Blasco I, Martinez-Gonzalez MA, de Irala J. Dietary patterns and difficulty conceiving: a nested case-control study. Fertil Steril 2011;96:1149–53.
147. Torjusen H, Brantsaeter AL, Haugen M, Alexander J, Bakketeig LS, Lieblein G, Stigum H, Naes T, Swartz J, Holmboe-Ottesen G, et al. Reduced risk of pre-eclampsia with organic vegetable consumption: results from the prospective Norwegian Mother and Child Cohort Study. BMJ Open 2014;4:e006143.
148. Tryggvadottir EA, Medek H, Birgisdottir BE, Geirsson RT, Gunnarsdottir I. Association between healthy maternal dietary pattern and risk for gestational diabetes mellitus. Eur J Clin Nutr 2016;70:237–42.
149. Vilela AA, Farias DR, Eshriqui I, Vaz Jdos S, Franco-Sena AB, Castro MB, Olinto MT, Machado SP, Moura da Silva AA, Kac G. Prepregnancy healthy dietary pattern is inversely associated with depressive symptoms among pregnant Brazilian women. J Nutr 2014;144:1612–8.
150. Vilela AA, Pinto Tde J, Rebelo F, Benaim C, Lepsch J, Dias-Silva CH, Castro MB, Kac G. Association of prepregnancy dietary patterns and anxiety symptoms from midpregnancy to early postpartum in a prospective cohort of Brazilian women. J Acad Nutr Diet 2015;115:1626–35.
151. Von Ruesten A, Brantsæter AL, Haugen M, Meltzer HM, Mehlig K, Winkvist A, Lissner L. Adherence of pregnant women to Nordic dietary guidelines in relation to postpartum weight retention: results from the Norwegian Mother and Child Cohort Study. BMC Public Health 2014;14:75–87.
152. Wei X, He JR, Lin Y, Lu M, Zhou Q, Li S, Lu J, Yuan M, Chen N, Zhang L, et al. The influence of maternal dietary patterns on gestational weight gain: a large prospective cohort study in China. Nutrition 2019;59:90–5.
153. Wrottesley SV, Pisa PT, Norris SA. The influence of maternal dietary patterns on body mass index and gestational weight gain in urban Black South African women. Nutrients 2017;9:732–46.
154. Zerfu TA, Umeta M, Baye K. 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 2016;103:1482–8.
155. Zhang C, Schulze MB, Solomon CG, Hu FB. A prospective study of dietary patterns, meat intake and the risk of gestational diabetes mellitus. Diabetologia 2006;49:2604–13.
156. Zhou X, Chen R, Zhong C, Wu J, Li X, Li Q, Cui W, Yi N, Xiao M, Yin H, et al. Maternal dietary pattern characterised by high protein and low carbohydrate intake in pregnancy is associated with a higher risk of gestational diabetes mellitus in Chinese women: a prospective cohort study. Br J Nutr 2018;120:1045–55.
157. Zhu Y, Hedderson MM, Sridhar S, Xu F, Feng J, Ferrara A. Poor diet quality in pregnancy is associated with increased risk of excess fetal

growth: a prospective multi-racial/ethnic cohort study. Int J Epidemiol 2019;48:423–32.
158. Zulyniak MA, de Souza RJ, Shaikh M, Desai D, Lefebvre DL, Gupta M, Wilson J, Wahi G, Subbarao P, Becker AB, et al. Does the impact of a plant-based diet during pregnancy on birth weight differ by ethnicity? A dietary pattern analysis from a prospective Canadian birth cohort alliance. BMJ Open 2017;7:e017753.
159. Colón-Ramos U, Racette SB, Ganiban J, Nguyen TG, Kocak M, Carroll KN, Völgyi E, Tylavsky FA. Association between dietary patterns during pregnancy and birth size measures in a diverse population in southern US. Nutrients 2015;7:1318–32.
160. Cade J, Thompson R, Burley V, Warm D. Development, validation and utilisation of food-frequency questionnaires—a review. Public Health Nutr 2002;5:567–87.
161. Foster M, Herulah UN, Prasad A, Petocz P, Samman SJN. Zinc status of vegetarians during pregnancy: a systematic review of observational studies and meta-analysis of zinc intake. Nutrients 2015;7:4512–25.
162. Kunz LH, King JC. Impact of maternal nutrition and metabolism on health of the offspring. Semin Fetal Neonatal Med 2007; 12:71–7.
163. Brenseke B, Prater MR, Bahamonde J, Gutierrez JC. Current thoughts on maternal nutrition and fetal programming of the metabolic syndrome. J Pregnancy 2013;2013:368–461.
164. Boeing H, Bechthold A, Bub A, Ellinger S, Haller D, Kroke A, Leschik-Bonnet E, Müller MJ, Oberritter H, Schulze M. Critical review: vegetables and fruit in the prevention of chronic diseases. Eur J Nutr 2012;51:637–63.
165. Canella DS, Levy RB, Martins APB, Claro RM, Moubarac J-C, Baraldi LG, Cannon G, Monteiro CA. Ultra-processed food products and obesity in Brazilian households (2008–2009). PLoS One 2014;9:e92752.
166. Hasanzadeh M, Ayatollahi H, Farzadnia M, Ayati S, Khoob MK. Elevated plasma total homocysteine in preeclampsia. Saudi Med J 2008;29:875–8.
167. Fargnoli JL, Fung TT, Olenczuk DM, Chamberland JP, Hu FB, Mantzoros CS. Adherence to healthy eating patterns is associated with higher circulating total and high-molecular-weight adiponectin and lower resistin concentrations in women from the Nurses' Health Study. Am J Clin Nutr 2008;88:1213–24.
168. Romero R, Chaiworapongsa T, Espinoza J. Micronutrients and intrauterine infection, preterm birth and the fetal inflammatory response syndrome. J Nutr 2003;133:1668S–73S.
169. Casanueva E, Ripoll C, Tolentino M, Morales RM, Pfeffer F, Vilchis P, Vadillo-Ortega F. Vitamin C supplementation to prevent premature rupture of the chorioamniotic membranes: a randomized trial. Am J Clin Nutr 2005;81:859–63.
170. Uusitalo U, Arkkola T, Ovaskainen M-L, Kronberg-Kippilä C, Kenward MG, Veijola R, Simell O, Knip M, Virtanen SM. Unhealthy dietary patterns are associated with weight gain during pregnancy among Finnish women. Public Health Nutr 2009;12: 2392–9.
171. Lederman SA, Paxton A, Heymsfield SB, Wang J, Thornton J, Pierson Jr RN. Maternal body fat and water during pregnancy: do they raise infant birth weight? Am J Obstet Gynecol 1999;180:235–40.
172. Larciprete G, Valensise H, Vasapollo B, Di Pierro G, Menghini S, Magnani F, De Lorenzo A, Arduini D. Maternal body composition at term gestation and birth weight: is there a link? Acta Diabetol 2003;40:s222–s4.
173. Farah N, Stuart B, Donnelly V, Kennelly MM, Turner MJ. The influence of maternal body composition on birth weight. Eur J Obstet Gynecol Reprod Biol 2011;157:14–7.
174. Kulkarni B, Shatrugna V, Balakrishna N. Maternal lean body mass may be the major determinant of birth weight: a study from India. Eur J Clin Nutr 2006;60:1341–4.
175. Egbe TO, Tsaku ES, Tchounzou R, Ngowe MN. Prevalence and risk factors of gestational diabetes mellitus in a population of pregnant women attending three health facilities in Limbe, Cameroon: a cross-sectional study. Pan Afr Med J 2018;31:195–208.
176. Pons RS, Rockett FC, de Almeida Rubin B, Oppermann MLR, Bosa VL. Risk factors for gestational diabetes mellitus in a sample of pregnant women diagnosed with the disease. Diabetol Metab 2015;7.
177. Pang MW, Law LW, Leung TY, Lai PY, La TK. Sociodemographic factors and pregnancy events associated with women who declined vaginal birth after cesarean section. Eur J Obstet Gynecol Reprod Biol 2009;143:24–8.
178. Boudet-Berquier J, Salanave B, Desenclos J-C, Castetbon K. Sociodemographic factors and pregnancy outcomes associated with prepregnancy obesity: effect modification of parity in the nationwide Epifane birth-cohort. BMC Pregnancy Childbirth 2017;17:273.
179. Koné S, Hürlimann E, Baikoro N, Dao D, Bonfoh B, N'Goran EK, Utzinger J, Jaeger FN. Pregnancy-related morbidity and risk factors for fatal foetal outcomes in the Taabo health and demographic surveillance system, Côte d'Ivoire. BMC Pregnancy Childbirth 2018;18:216–30.
180. Shim J-S, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. Epidemiol Health 2014;22:36–44.
181. Yang YJ, Kim MK, Hwang SH, Ahn Y, Shim JE, Kim DH. Relative validities of 3-day food records and the food frequency questionnaire. Nutr Res Pract 2010;4:142–8.
182. Mensink G, Haftenberger M, Thamm M. Validity of DISHES 98, a computerised dietary history interview: energy and macronutrient intake. Eur J Clin Nutr 2001;55:409–17.
183. Benedik E, Seljak BK, Hribar M, Rogelj I, Bratanič B, Orel R, Fidler Mis N. Comparison of a web-based dietary assessment tool with software for the evaluation of dietary records. SJPH 2015;54:91–7.