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Review Article

Determinants of dietary patterns and diet quality during pregnancy: a systematic review with narrative synthesis

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Abstract

Objective: To identify determinants of diet in pregnancy, by detecting factors in our multiple-determinants life course framework that are associated with dietary patterns, quality or guideline adherence.

Design: A systematic review of observational studies, published in English or German, was conducted. Sociodemographic, lifestyle, environmental and pregnancy-related determinants were considered. Four electronic databases were searched in January 2015 and updated in April 2016 and a total of 4368 articles identified. Risk of bias was assessed using adapted Newcastle–Ottawa Scales.

Setting: High- and upper-middle-income countries.

Subjects: Pregnant or postpartum women reporting their dietary intake during pregnancy.

Results: Seventeen publications of twelve studies were included and compared narratively due to heterogeneity. Diet in pregnancy was patterned along a social gradient and aligned with other health behaviours before and during pregnancy. Few studies investigated the influence of the social and built environment and their findings were inconsistent. Except for parity, pregnancy determinants were rarely assessed even though pregnancy is a physiologically and psychologically unique period. Various less well-researched factors such as the role of ethnicity, pregnancy intendedness, pregnancy ailments and macro-level environment were identified that need to be studied in more detail.

Conclusions: The framework was supported by the literature identified, but more research of sound methodology is needed in order to conclusively disentangle the interplay of the different determinants. Practitioners should be aware that pregnant women who are young, have a low education or do not follow general health advice appear to be at higher risk of inadequate dietary intake.

Keywords
Dietary patterns
Dietary quality
Pregnancy
Determinants
Influences
Dietary behaviour
Systematic review

Diet during pregnancy is crucial for maternal and child health[1,2]. Energy and nutrient intakes must support growth of maternal and fetal tissues and accumulate reserves for lactation[3]. Inadequate nutrition (deficits and excesses) bears the risk of permanent consequences for the offspring[4]. Life course epidemiology frames pregnancy as a critical period[5]. Pregnancy has been identified as a period with great potential for change in dietary habits[6]. Heightened awareness of potential threats to own and child's health may motivate women to adapt health-promoting behaviours including nutritional changes[7].

Dietary assessment is complex; it involves recording and analysing a multitude of foods and drinks consumed every day and in varying quantities[8]. Due to this complexity, diet is methodologically difficult to capture and no gold-standard method exists to date[9]. Growing concerns about the limitations of examining single foods or nutrients in isolation[10] led to the development of the concept of dietary patterns (DP) 30 years ago[11].

Dietary quality (DQ) is another relatively new concept to capture diet as a whole by scoring adherence to (national) dietary guidelines, rating the diversity of food

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choice in key food groups, or scoring predefined food patterns known to protect or impair health[12].

Their definitions overlap. DP have been defined as 'the quantities, proportions, variety, or combination of different foods, drinks, and nutrients (when available) in diets, and the frequency with which they are habitually consumed' (p. 1)[13]. Similarly, DQ has been described as a 'relatively new concept [that] involves the assessment of both quality and variety of the entire diet, enabling examination of associations between whole foods and health status, rather than just nutrients' (p. 2473)[12].

A review of the health effects of gestational DP identified a range of health outcomes of mothers (e.g. infertility, gestational diabetes mellitus and depressive symptoms) and their children (e.g. fetal growth, preterm birth and risk of asthma)[14]. Likewise DQ was associated with blood TAG[15], pre-eclampsia[16] and fetal growth restriction[17].

Considering the importance of diet in pregnancy and the increase in studies assessing diet as patterns or quality, a systematic review of its determinants is necessary in order to assess the population needs and develop effective public health interventions.

Methods

Research question and concepts

We previously developed a conceptual framework of determinants of diet in pregnancy taking a multiple-determinants and life course view (described below). We conducted the present systematic review to test the 'fit' of our framework and summarise the available evidence.

Diet in this context was defined as a representation of overall diet, not merely single foods or nutrients, using DP, DQ or guideline compliance. We recognise that these are distinct entities, but they have the same underlying principle: to capture total dietary intake as best as possible.

We understood determinant according to Last's definition of 'any factor, whether event, characteristic, or other definable entity, that brings about change in a health condition, or other defined characteristic' (p. 37)[18]. In our case we considered factors which brought about change in diet (measured as DP, DQ or guideline adherence) of pregnant women.

Our conceptual framework (Fig. 1) is based on an initial literature scoping, the Conceptual Framework for Patterns of Determinants of Health[19] and the Perinatal Health Framework[20] (which built on the former but added the angle of time and adapted it for the case of perinatal health). The framework includes different determinants: environmental, sociodemographic and individual responses, these are not limited to the perinatal period, and pregnancy-related factors.

Determinants are positioned based on their distance to diet. As distal we classed environmental determinants. We expanded the meaning of environment beyond the physical environment to include the categories set out in the environmental research framework for weight-gain prevention[21] as consisting of physical, sociocultural, economic/financial and political factors. We amended this categorisation: the categories of political and economic determinants were merged and the category of medical environment was added. We hypothesised that the medical/health-care system

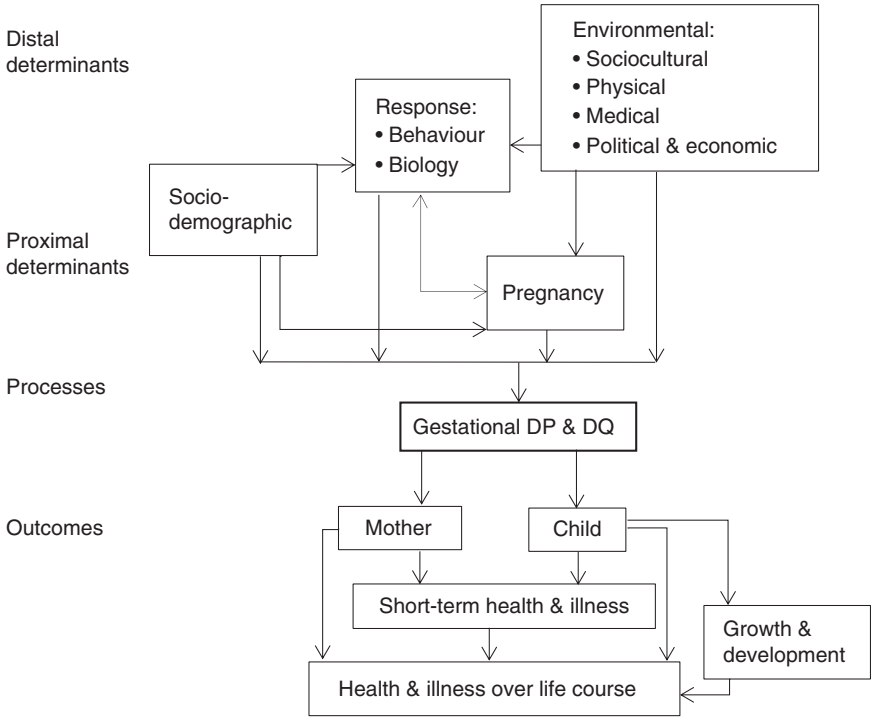

Fig. 1 Conceptual multiple-determinants life course framework of diet in pregnancy (DP, dietary pattern; DQ, dietary quality)

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plays a greater role in pregnancy due to more frequent contact with practitioners. For example, health-care practitioners may influence diet through information giving. Conversely, inadequate dietary intake may result in contacts with health-care providers to get treatment or advice for nutrition-related health problems such as anaemia.

As proximal determinants we defined the remaining categories. Sociodemographic factors include age, education, employment, ethnicity and other personal attributes like partnership. They may impact diet directly or indirectly via effects on individual response or pregnancy.

Evans and Stoddard argue that the social and physical environment can lead to individual differences in biological response (e.g. expression of genes) or behavioural response (e.g. engaging in health-risk behaviours in response to stress)[19]. Misra also outlined that negative health behaviour may occur in response to experiences such as discrimination[20]. The review of individual responses is relevant for the study of dietary intake as well. Research indicates that genetic differences may explain diverse biological responses to overfeeding[22] and individuals differ in their behavioural response to internal and external food cues[23]. We hypothesised individual responses to be influenced by both individual and environmental factors and thus positioned this category in between both these categories, distance wise.

Finally, pregnancy factors were defined as those determinants that relate to pregnancy, or only act during pregnancy, or mediate, or modify the influence of existing determinants during pregnancy. Pregnancy is known to influence dietary intake due to physical symptoms such as nausea and food aversions as well as psychological factors such as higher or lower restraint of eating in anticipation of gestational weight gain[24]. In distance terms pregnancy-related factors were placed closest to diet in pregnancy, since pregnancy is described as a unique period and was thus considered the most immediate influence.

Data sources and search strategy

Four databases were searched from the date of their inception to January 2015; searches were updated in April 2016 (see Appendix for search strategies). The search combined three concepts: 'determinants', 'dietary patterns' and 'pregnancy'. Search terms were amended slightly for each database. In addition, hand searches were performed (reference lists of all obtained articles, table of contents of key journals and conference abstracts). One publication had to be excluded from the review as crucial data were missing in the original publication[25] and could not be retrieved.

Study selection

Inclusion and exclusion criteria are assembled in Table 1. Briefly, studies had to be of observational design and published in English or German. Participants had to be from a high- or upper-middle-income country[26], i.e. countries with generally an abundance of food, where dietary intake is a reflection of food choice or access rather than availability. Participants had to be pregnant or in postpartum at the time of dietary assessment and the measurements had to refer to any time during pregnancy. The study's aim had to be the assessment of determinants of diet in pregnancy. Determinants of diet could be

Table 1 Inclusion and exclusion criteria

Aspect	Include	Exclude
Participants	Women who at the time of dietary assessment were: • pregnant or ≤8 weeks postpartum • apparently healthy/not requiring special diets • majority of sample aged ≥18 years	Children, men, women who were not pregnant/postpartum at the time of diet assessment. Pregnant women with inborn errors of metabolism (e.g. PKU), requiring specific diets, studies on teens or where majority of participants is <18 years
Independent variable(s)	Determinants of diet, sociodemographic/lifestyle/ environmental/pregnancy-related factors	Studies focusing solely on outcomes of diet
Dependent variable(s)	Diet quality or dietary pattern	Single/few nutrients or single/few aspects of entire dietary intake, studies where nutrients are assessed by blood or plasma markers only
Study type	Observational studies: • case–control studies • cross-sectional studies • cohort studiesthat use an analytical approach to assess diet relationship between independent and dependent variable(s)	Intervention studies, quasi-experimental studies, ecological studies, evaluation studies, case reports, case series, abstracts, letters to the editor, metabolic studies, endocrinologic studies, methodological studies (e.g. validation of questionnaires, diagnostic tools)
Languages	English, German	
Country	High-income countries and upper-middle-income countries[26]	
Quality	Studies reporting on the statistical association between independent and dependent variable(s) graphically or numerically	Studies that do not report statistical tests on the associations, studies that do not report coefficients or level of significance numerically or graphically, studies that do not report sufficient detail on data collection and analysis

PKU, phenylketonuria.

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sociodemographic, individual responses, environmental or pregnancy-related factors. Dietary intake had to be reported as DP or DQ, which included measurements of adherence to dietary guidelines.

Data extraction and analysis

Screening of articles and data extraction was conducted in two steps. First, relevant studies were identified based on title and abstract by one reviewer (I.-M.D.). All 130 articles that could not clearly be excluded beyond doubt were read in full by two reviewers (I.-M.D. and B.B. or A.G.), results were compared and disagreements resolved by discussion. A data extraction form was designed, piloted and adjusted. One reviewer (I.-M.D.) extracted data in consultation with the co-authors and a statistician if study reports were unclear.

Assessment of risk of bias

The Newcastle–Ottawa Scale (NOS) for assessing the quality of non-randomised studies in meta-analyses was used to assess the likelihood of bias in each publication included[27]. The NOS has been recommended for use in reviews of observational studies[28]. We adapted the NOS to fit the purpose of the current review (Table 2).

We use the terms 'risk of bias' and 'study quality' interchangeably and not as a judgement of the authors' methodological merits, but rather of how 'relevant' the study was for our review.

Statistical methods

The studies that were included were heterogeneous in sample size, population and methods used for assessing diet (Table 3). When studies show heterogeneity on so many levels a pooling of results (meta-analysis) is not appropriate but a narrative synthesis can be conducted, whereby studies are narratively described, trends explored and reasons for inconsistencies of findings discussed[29].

Results

A total of 4368 articles were identified, 4238 articles were excluded based on their title and abstract (Fig. 2). Accordingly, 130 full-text publications were read of which seventeen

Table 2 Adapted Newcastle–Ottawa Scale for assessing the quality of non-randomised studies

Study type	Quality aspect	Coding
Cohort		Maximum of 9 stars in total = lowest risk of bias
	Selection: 1. Representativeness of the sample 2. Selection of the non-exposed cohort 3. Ascertainment of the determinants of diet	Maximum of 3 stars in this section: 1. Representative of all pregnant women: yes/somewhat = * 2. Drawn from same community as exposed (i.e. women with low SES): yes = * 3. Secure record/structured interview: yes = *
	Comparability of cohorts: 1. Comparability for SES 2. Comparability for additional factors	Maximum of 2 stars in this section: 1. Study controls or adjusts for SES/income/education/occupation: yes = * 2. Study controls for additional factors: yes = *
	Outcome: 1. Represents usual diet 2. Assessment method 3. Assessment adequacy	Maximum of 4 stars in this section: 1. Diet assessment covers at least 2 d = * 2. Validated assessment method†: yes = *; yes in same population = additional * 3. Prospective assessment or retrospective covering ≤1 week = *
Cross-sectional		Maximum of 10 stars in total = lowest risk of bias
	Selection 1. Representativeness of the sample 2. Sample size 3. Non-respondents 4. Ascertainment of the determinants of diet	Maximum of 4 stars in this section 1. Representative of all pregnant women: yes/somewhat = * 2. Reported, justified and satisfactory: yes = * 3. Participation rate ≥50 % and characteristics of respondents and non-respondents satisfactory: yes = * 4. Secure record/structured interview: yes = *
	Comparability of cohorts: 1. Comparability for SES 2. Comparability for additional factors	Maximum of 2 stars in this section: 1. Study controls or adjusts for SES/income/education/occupation: yes = * 2. Study controls for additional factors: yes = *
	Outcome: 1. Represents usual diet 2. Assessment method 3. Assessment adequacy	Maximum of 4 stars in this section: 1. Diet assessment covers at least 2 d = * 2. Validated assessment method†: yes = *; yes in same population = additional * 3. Prospective assessment or retrospective covering ≤ 1 week = *

SES, socio-economic status.
†We awarded a * for ≥3 d dietary records if participants were trained in record keeping/records were interviewer-checked, or any method described as validated by the authors.

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Table 3 Characteristics of studies included in the present review

Study							Quality*			
ID	Name	Type	Place	Authors, year, reference	Sample size	Publication goal/objectives	Diet type	S	C	O/E
1	ALSPAC	CH	Europe, UK, Avon area	Northstone *et al.* (2008)[30]	12 053	To assess DP in 3rd trimester and to determine associations with sociodemographic and lifestyle factors	DP	2/3	2/2	2/4
2	CANDLE	CH	North America, USA, Memphis	Völgyi *et al.* (2013)[31]	1155	To identify distinct DP during pregnancy in the Mid-South, and to analyse the differences in food groups and nutrients among the different DP and how they relate to sociodemographic status of the study population	DP	2/3	0/2	2/4
3	Not reported	CH	Europe, Spain, City of Reus	Cucó *et al.* (2006)[32]†	80	To identify DP in preconception, GW 6, 10, 26 and 38, and at 6 months postpartum. To describe the association of lifestyle, sociodemographic factors and BMI with the DP	DP	2/3	2/2	4/4
4	DIPP	CH	Europe, Finland	Arkkola *et al.* (2008)[33]	3730	To identify and describe DP in the cohort and to examine the influence of sociodemographic factors and energy and nutrient intakes on DP	DP	2/3	2/2	1/4
5	ECCAGE	CH	South America, Brazil	Hoffmann *et al.* (2013)[6]	712	To examine DP in pregnant women and the association between DP and sociodemographic characteristics	DP	3/3	0/2	2/4
6	PHP	CH	North America, Canada, London	Fowler *et al.* (2012)[44]	2313	To assess participants' eating behaviours and correlates of adequate food consumption as defined by the CFG recommendations	CFG adh.	3/3	2/2	3/4
				Nash *et al.* (2013)[35]	2282	To assess the determinants of DQ in pregnancy by focusing on both personal characteristics and food environment	DQ	2/3	2/2	3/4
7	PIN	CH	North America, USA, North Carolina	Bodnar and Siega-Riz (2002)[36]	2063	To develop a DQ assessment tool specifically for pregnancy and to assess differences in DQ by sociodemographic factors	DQ	3/3	0/2	3/4
				Laraia *et al.* (2004)[38]	918	To examine the impact of the food environment on overall diet quality in pregnancy	DQ	3/3	2/2	3/4
				Laraia *et al.* (2007)[37]	2394	To investigate the association between pre-gravid weight status and diet quality	DQ	3/3	2/2	1/4
8	Project Viva	CH	North America, USA	Rifas-Shiman *et al.* (2009)[16]	1777	To assess relationships between maternal characteristics and DQ in 1st trimester and to examine associations with pregnancy outcomes	DQ	2/3	2/2	3/4
9	Rhea	CH	Europe, Greece	Kritsotakis *et al.* (2015)[34]	377	To assess the association of maternal social capital and its dimensions with adherence to the MD during pregnancy	MD adh.	2/3	2/2	1/4
10	Not reported	CS	North America, USA, Texas	Fowles *et al.* (2011)[39]	118	To develop a path model that shows the relationships between distress, social support and eating habits with DQ	DQ	1/4	2/2	4/4
				Fowles *et al.* (2012)[41]	71	To assess the relationship between diet quality in 1st trimester with stress, depression, social support and eating habits	DQ	0/4	0/2	4/4

Table 3 *Continued*

	Study							Quality*		
ID	Name	Type	Place	Authors, year, reference	Sample size	Publication goal/objectives	Diet type	S	C	O/E
				Fowles *et al.* (2011)[40]	50	To describe differences in contextual factors and food/nutrient intakes in low-income pregnant women with high/low frequency of fast-food consumption, in order to generate new research hypotheses	DQ	0/4	0/2	4/4
11	Not reported	CS	Europe, Greece, Athens	Tsigga *et al.* (2011)[42]	100	To assess differences in the HEI during pregnancy depending on weight status before and during pregnancy	DQ	1/4	0/2	4/4
12	Not reported	CS	North America, USA, North Dakota	Watts *et al.* (2007)[43]	5862	To assess DQ of pregnant WIC participants in North Dakota and to compare DQ of Native Americans and whites	DQ	2/4	0/2	3/4

S, selection; C, comparison; O, outcome (for cohort studies); E, exposure (for case–control studies); ALSPAC, Avon Longitudinal Study of Parents and Children; CANDLE, Conditions Affecting Neurocognitive Development and Learning in Early Childhood; DIPP, Type 1 Diabetes Prediction and Prevention Project; ECCAGE, Study of Food Intake and Eating Behavior during Pregnancy (Brazil); PHP, Prenatal Health Project; PIN, Pregnancy, Infection, and Nutrition Study; CH, cohort study; CS, cross-sectional study; DP, dietary pattern(s); GW, gestational week; CFG, Eating Well with Canada's Food Guide; DQ, dietary quality; MD, Mediterranean diet; HEI, Healthy Eating Index; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children; CFG adh., adherence to Eating Well with Canada's Food Guide; MD adh., Mediterranean diet adherence (score).
*Study quality aspects: Newcastle–Ottawa-Scale rating (actual score/maximum score).
†Diet measured at several time points over the course of pregnancy (all other studies: only one single measurement).

met all inclusion criteria. They presented results of twelve studies. All were written in English. No abstracts of unpublished studies were identified. Nine studies were published in the past 5 years, indicating that this is a new research area.

Most studies were from North America (*n* 6) or Europe (*n* 5), one was from South America. Eight were cohort studies and four were cross-sectional studies. Sizes ranged from fifty to 12 053 participants (Table 3).

Five of the seventeen publications assessed diet using DP[6,30–33]. A further publication assessed DP with adherence scores to the Mediterranean diet[34]. DQ was assessed in ten of the seventeen publications[16,35–43] using different DQ indices (Table 3); one publication assessed DQ using guideline adherence[44].

Different DQ tools were used but in all higher scores indicated higher quality. As anticipated, the assessment of DP was more diverse. Some studies used adherence scores where higher scores indicated higher adherence, some classed participants into mutually exclusive DP groups.

The NOS scores for cohort studies ranged from 5 to 8 (maximum 9). For publications of the three cross-sectional studies, NOS scores ranged from 5 to 7 (maximum: 10; Table 3).

Determinants of diet in pregnancy among reviewed publications (n 17)

Table 4 shows the different factors assessed in each study. The sociodemographic factor most frequently investigated was education[6,16,30–39,41,42,44], followed by age[6,16,30–34,36–39,42,43].

Other commonly measured sociodemographic determinants were ethnicity/birthplace/nationality[16,30,31,34–38,41,43,44], income/financial difficulty/Medicaid[30,31,36–38,41–44] and marital status/partnership/cohabitation[6,30,31,34,35,37,38,41,44]. Occupation/employment[6,30,44] was less commonly assessed.

The most frequently used individual response factors were pre-pregnancy BMI or weight category[6,16,30–32,37,40–42,44], smoking before[32,41,43] and during pregnancy[30,32–34,37,44], and physical activity/exercise before[34] and during pregnancy[30,32,35,37,41,41,41]. Other aspects of health behaviour were less commonly assessed such as supplement use[37,44], alcohol during pregnancy[44] and caffeine during pregnancy[44].

The most often assessed pregnancy-related determinant was parity[16,30,31,33–37,42,44]; studies also assessed the influence of nausea[35] and pregnancy body image[30].

The category of environmental factors was considered in only a few publications, which mainly looked at the living environment/place of residence[33,34,42,43], social environment (support)[34,35,39] and food environment[35].

The influence of depression[30,40] and stress/anxiety[30,35,39,40] also emerged as determinants. As these did not fit any of the four categories of determinants we grouped them into a new category, psychological health, which could be regarded as an individual psychological response.

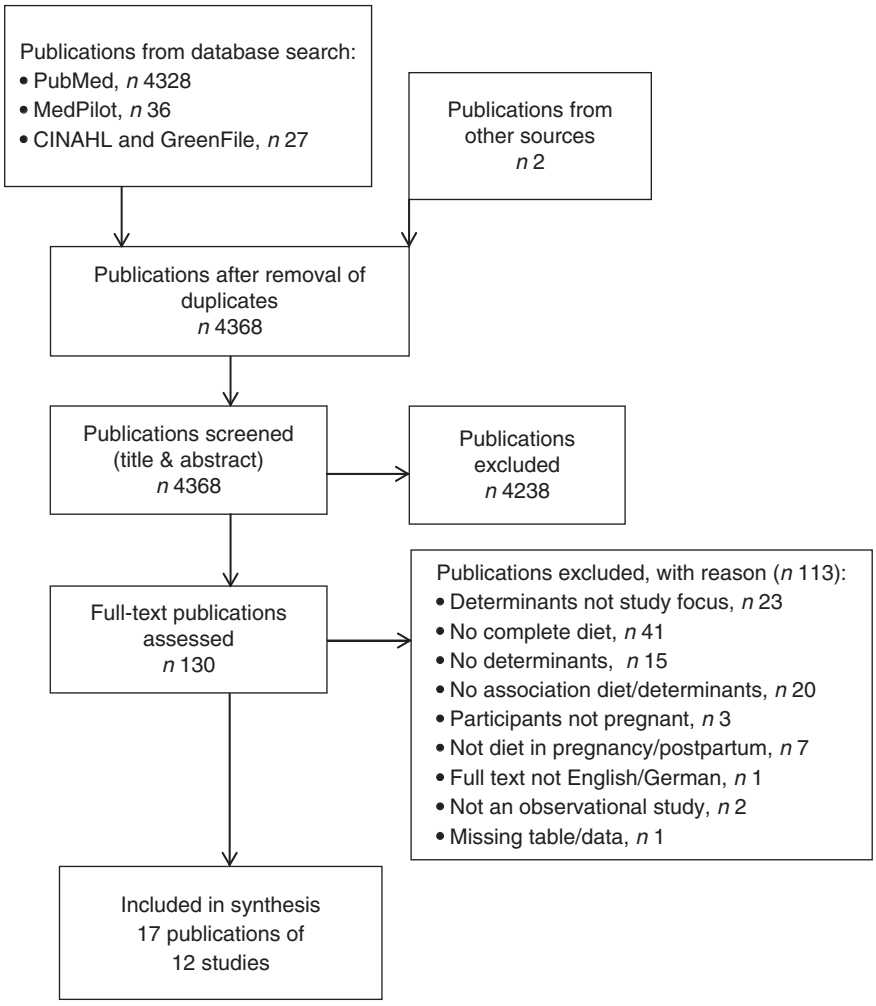

Fig. 2 Flowchart showing the selection of studies for the present review on determinants of dietary patterns and diet quality during pregnancy

Studies reviewed (n 12)

The ALSPAC (Avon Longitudinal Study of Parents and Children) cohort (UK) benefited from a large sample, the assessment of a multitude of determinants and the use of multivariable-adjusted analyses[30]. DP were derived using principal component analysis, a type of factor analysis which aims to reduce food variables to underlying factors (DP) that explain as much variation in the data as possible[45]. All five patterns combined explained only 31·3 % of variability, which may be a reflection of the number of variables analysed or an indication that further unidentified latent DP exist in that population[10].

The CANDLE (Conditions Affecting Neurocognitive Development and Learning in Early Childhood) cohort included predominantly African-American women from the southern USA[31]. A third of the sample was obese and a quarter overweight. The diet assessment covered a 3-month period making recall bias a possibility, although administering the FFQ by trained interviewers may have helped to overcome this issue. The associations between determinants and DP were not adjusted for potential confounders.

The study by Cucó *et al.* (Spain) was the only study with a longitudinal analysis[32]. Diet was measured using 7 d records assessed by trained interviewers; a method we considered would reduce bias from recall or under-reporting. The sample was small and consisted of women who were more educated than representative for that geographical area. The association between patterns and determinants was assessed by fitting multiple linear regression models. The explained variance for both patterns was low, at 11 to 15 % for 'Sweetened beverages and sugars' and 9 to 11 % for 'Vegetables and meat' across the different time points. This may be explained due to a large number of variables in relation to sample size or indicate the existence of further unidentified patterns[10]. Exploratory factor analysis tends to work better with larger sample sizes[46] and more heterogeneous samples[47]. Given the effort that went into that study and its longitudinal nature, it is a shame (for the aim of our review) that only four determinants made it into the final adjusted model: smoking, physical activity, age and BMI.

The DIPP (Type 1 Diabetes Prediction and Prevention Project) cohort benefited from a validated FFQ that was

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Table 4 Determinants of diet during pregnancy identified in the present review

ID	Name	Authors, year, reference	Assessment time	Methods	Diet type	Determinants of diet
1	ALSPAC	Northstone *et al.* (2008)[30]	GW 32	• Self-administered FFQ • DP by PCA with varimax rotation • ANOVA and *t* tests for univariate associations with DP • Independent associations were determined using the general linear model option • Multivariate analyses for adjusted regression coefficients and 95 % CI	Scores of five patterns: • **Health conscious DP:** high loadings for salad, fruit, rice, pasta, oat and bran-based breakfast cereals, fish, pulses, fruit juice and non-white bread • **Traditional DP:** high consumption of all types of vegetables, red meat and poultry • **Processed DP:** high intakes of high-fat processed foods, such as meat pies, pizza, burgers, fried foods, chips and baked beans • **Confectionary DP:** high intakes of high-sugar foods such as chocolate, sweets, biscuits and cakes • **Vegetarian DP:** high loadings for meat substitutes, pulses, nuts and herbal teas; high negative loadings for red meat and poultry	Independent predictors of maternal DP scores: • **Health conscious DP scores:** negatively associated with education level, age, financial difficulty and parity. Positively associated with activity level. Higher scores in those who were vegetarian, feeling energetic, dieted during pregnancy and reported weight/shape concern. Lower scores in those without a partner, with anxiety, who were overweight, who did not work in the final TM, were non-white or smoked • **Traditional DP scores:** strong independent association with age (negatively), physical activity, parity and feeling energetic (positively). Overweight women had higher scores as did women who dieted during pregnancy, had weight/shape concerns. Lower scores in women who were not house owners, without a partner, did not work in final TM, non-white or were depressed • **Processed DP scores:** scores inversely associated with education, age, degree of financial difficulty, parity. Women who smoked and those living in council housing were more likely to score high • **Confectionary DP:** higher scores in women who were younger, non-white, suffering from anxiety, did not feel energetic and lived in council or rented housing. Negative association with being overweight and dieting during pregnancy • **Vegetarian DP:** highly associated with classing oneself as vegetarian, also independently associated with age and education, but no linear trends evident. Women in rented or council housing, with financial difficulties, non-white and those not working in final TM scored higher. Score decreased with parity
2	CANDLE	Völgyi *et al.* (2013)[31]	GW 16–28	• Interviewer-administered 111-food-and-beverage-item FFQ • Interviewers trained and monitored by a registered dietitian • EFA analysis with principal component extraction and varimax rotation • Median test and Kruskal–Wallis ANOVA used to describe differences in demographics among DP	Seven mutually exclusive patterns: • **Healthy:** high loadings of vegetables, fruits, non-fried fish and chicken, water • **Processed:** processed meat, fast food items, snacks, sweets and soft drinks • **US Southern:** typical US Southern foods such as eggs, cooked cereals, peaches, corn, fried fish, beans, greens, cabbage, sweet potatoes, liver, pig's feet, neck bones, oxtails, tongue, pork and real fruit juices • **Healthy-Processed**	Women in the seven DP differed significantly in age, height, pre-pregnancy weight and BMI, race, education, marital status, HH size and Medicaid membership. Differences in ethnicity and parity were not significant. Women with the **Healthy** DP were significantly more likely to be older, higher educated, less likely to be a single mother, receive Medicaid or be obese pre-pregnancy, and had smaller HH sizes *v.* women in the **US-Southern**, **Processed** or **Mixed** DP

Table 4 *Continued*

ID	Name	Authors, year, reference	Assessment time	Methods	Diet type	Determinants of diet
					• **Healthy-Southern** • **Processed-Southern** • **Mixed**	DP aligned across race categories, such that Caucasians mainly classed as **Mixed** (35 %), **Healthy** (30 %) and **Healthy-Processed** (24 %) DP, while African Americans mainly categorised as **Mixed** (41 %), **Processed-Southern** (18 %) and **US Southern** (15 %)
3	Not reported	Cucó *et al.* (2006)[32]	Pre-conception, GW 6, 10, 26, 38, and 6 months postpartum	• Prospective at different times from preconception to postpartum • EFA (PCA) • Associations between lifestyle and sociodemographic variables and DP by fitted multiple linear regressions models	Two patterns: • **Sweetened beverages & sugars:** characterised by high intakes of sweetened beverages, sugars; low intakes of fresh fruit, vegetables, roots and tubers • **Vegetables and meat:** high intakes of vegetables, roots, tubers, red meat, cured cold meats, olive oil, eggs	In GW 6 and 10, smoking was positively associated with the **Sweetened beverages & sugars** DP, while mPAL (marker of physical activity) was negatively associated with it but only in GW 10. This pattern may be characteristic of sedentary women who smoke during family planning and in first TM, which could be regarded as less health conscious In GW 10 and 38, age was positively associated with the **Vegetables and meat** DP
4	DIPP	Arkkola *et al.* (2008)[33]	8th month	• Retrospective (after birth) • By validated FFQ with 181 food items in fifty-two food groups, designed to reflect Finnish food consumption habits • DP identified by PCA with varimax rotation • Multiple linear regression analysis was used to test how age, educational level, smoking during pregnancy, living area and the number of earlier deliveries explained the variance in pattern score	Seven patterns: • **Healthy:** high loadings of fruit, vegetables, roots, poultry, rice and pasta, nuts and seeds, and low-fat milk • **Fast food:** high loadings of sweets, fast foods, soft drinks, white bread, sausage and processed meats • **Traditional bread:** high loadings of roots, wholegrain breads, high-fat cheese and pastry and potatoes • **Traditional meat:** high loadings of processed vegetables, meat, sausage, potatoes and processed meat • **Low-fat foods:** high loadings of light soft drinks, wholegrain bread, low-fat milk and margarine • **Coffee:** high loadings of coffee, milk in coffee, low-fat pastry and sausages • **Alcohol & butter:** high loadings of butter, wine and liquor, beer; negative loadings for fruits, fruit juices and margarine	DP were differently associated with age, education level, smoking in pregnancy, living area and parity Age was positively associated with **Healthy** and **Alcohol & butter** DP, but negatively with **Fast food** and **Traditional meat** DP Education was positively associated with **Healthy**, **Alcohol & butter** and **Low-fat foods** DP Smoking during pregnancy was positively associated with **Fast foods**, **Traditional meat** and **Coffee** DP Parity was positively associated with **Traditional bread**, **Traditional meat**, **Coffee**, **Alcohol & butter** DP, while negatively associated with **Healthy**, **Fast food** and **Low-fat foods** DP
5	ECCAGE	Hoffmann *et al.* (2013)[6]	GW 16–36	• Retrospective (diet during pregnancy) • Semi-quantitative, validated, eighty-eight-item FFQ • DP identified using cluster analysis • Association between DP and sociodemographic variables was analysed using the χ^2 test and adjusted standardised residuals	Three patterns: • **Restricted:** cookies, whole milk, yoghurt, chips, finger foods, soft drinks, ice cream • **Varied:** grains/cereals/tubercles, bread/cakes/cookies, fruits, vegetables, cheese, pizza, mayonnaise, candies • **Common Brazilian:** rice/beans/pasta, French roll, margarine, boneless beef/chicken/eggs, coffee/artificial juices, sugar	• **Restricted** DP was associated with not cohabiting with a partner, age ≤19 years, being a non-working student and high daily energy intake (>19 129 kJ/>4572 kcal). It may therefore be characteristic of women who lack information, knowledge or social support • **Varied** DP was associated older age, cohabiting with a partner, being employed, high income (family income ≥3·01 minimum

Table 4 *Continued*

ID	Name	Authors, year, reference	Assessment time	Methods	Diet type	Determinants of diet
						wages) and high education (≥9 years). It may thus be characteristic of women who are more health conscious and have higher socio-economic resources • **Common Brazilian** DP was associated with lower family income (<3·01 minimum wages), low education level (≤4 years), being non-student and unemployed and lowest energy intake (<10 519 kJ/ < 2514 kcal). This pattern may be more appealing to people of low socio-economic status since it is largely made up of foods inexpensive in Brazil. The role of pre-pregnancy BMI was not statistically significant
6	PHP	Fowler *et al.* (2012)[44]	GW 10–22	• Retrospective (past months) • By self-administered, semi-quantitative, 106-food-item FFQ • Compliance with CFG recommended serving sizes of food groups • Binomial logistic regression to analyse the association between sociodemographic and lifestyle characteristics with consumption of minimum number of recommended servings of all food groups	**CFG compliance score:** Healthy eating pattern = daily servings of: • 8 × vegetables • fruits • 2 × meat & alternatives • 7 × grain products • 3 × milk & alternatives	Compliance was very low, only 3·5 % met all four food group recommendations. Women who met the CFG guidelines were significantly less likely primipara and more likely educated beyond high school; these variables were entered into logistic regression analysis where only primiparity remained significantly associated with not meeting CFG guidelines Marital status, HH income, employment status, birthplace, smoking and alcohol consumption during pregnancy, pre-pregnancy BMI, daily caffeine intake and supplement use were all not significantly associated with meeting guidelines
		Nash *et al.* (2013)[35]	Not reported	• Retrospective (past months) • FFQ, 106 food items, validated for use in pregnant women in the cohort • Univariate und multivariate linear regressions were performed with the predictor variables on DQ • Stepwise procedure was used with automated backwards elimination to create a parsimonious model with variables significant at $P < 0{\cdot}05$ • *A priori* interactions were assessed between presence of fast-food restaurants and marital status/income	**Canadian DQI-P score:** Modified version of the DQI-P, adapted for Canadians, based on the 2007 Canada's Food Guide Six components, intake of: • Folate • Fe • Ca • Energy intake from fat • Servings of grains • Servings of fruit and vegetables Total score 70, was converted into %	Using DQI-P score, 56 % were classed as having adequate diets. In univariate analysis, occupation was the only significant predictor or DQI-P score. Different multivariate linear regression models were fitted; in the final parsimonious model variables significantly associated with higher DQ were immigrant living in Canada for a maximum of 5 years, parity of at least 1, being married, exercising more, being a non-smoker, having low anxiety levels and greater social support from family. There were no significant associations for food environment variables. However, the presence of a fast-food restaurant within 500 m significantly decreased DQ in a previous model

Table 4 *Continued*

ID	Name	Authors, year, reference	Assessment time	Methods	Diet type	Determinants of diet
7	PIN	Bodnar and Siega-Riz (2002)[36]	GW 26–28	• Retrospective (covering past 3 months, entire 2nd TM) • Self-administered, 120-item modified NCI-Block FFQ • Student's *t* test and ANOVA to compare mean DQI-P scores across sociodemographic characteristics	**DQI-P scores and tertiles:** Eight components with maximum of 10 points; max. score 80, ≥70 indicates highest DQ % recommended daily servings for: • Grains • Vegetables • Fruits • Folate • Fe • Ca • Energy from fat • Meal pattern score Mean DQI-P score was 55·2 (SD 12·1)	Significant higher mean scores were observed in women who were more affluent (>350 % of poverty index), nulliparous and mean scores increased with age and education. Mean score was slightly higher in black women than whites, albeit not significantly
		Laraia *et al.* (2004)[38]	GW 26–28	• Retrospective (covering past 3 months, usual intake in 2nd TM) • Self-administered, 120-item modified NCI-Block FFQ • ANOVA for mean differences in DQI-P by socio-economic categories • Multinomial logistic regression to estimate the effect of food outlets on DQ (crude and adjusted)	**DQI-P scores and tertiles:** Eight components with maximum of 10 points; max. score 80, ≥70 indicates highest DQ % recommended daily servings for: • Grains • Vegetables • Fruits • Folate • Fe • Ca • Energy from fat • Meal pattern score Mean DQI-P score was 55·2 (SD 12·1)	Significant higher mean scores seen in women who were black (*v.* white), 31 years or older, had more than college education. Scores did not differ significantly depending on marital status or income Living further away from convenience stores and supermarkets, but not grocery stores, was significantly associated with decreased DQ Adjusted OR for falling into the lowest *v.* highest DQ tertile revealed that women living more than 4 miles (6·4 km) from a supermarket or convenience store had an increased chance of being in the lowest DQ tertile The influence of distance to convenience stores persisted even after controlling for several socio-economic factors and distance to grocery or convenience stores
		Laraia *et al.* (2007)[37]	GW 26–28	• Retrospective (past 3 months, entire 2nd TM) • Self-administered, 120-item modified NCI-Block FFQ • ANOVA with Bonferroni correction for mean differences in DQI-P scores across health behaviour characteristic • Multinomial logistic regression to estimate the association of pre-gravid BMI with DQ (crude and adjusted)	**DQI-P scores and tertiles:** Eight components with maximum of 10 points; max. score 80, ≥70 indicates highest DQ % recommended daily servings for: • Grains • Vegetables • Fruits • Folate • Fe • Ca • Energy from fat • Meal pattern score Mean DQI-P score was 55 (SD 11·6)	Non-white women had significantly higher mean scores as did more affluent women (>185 % of poverty), married women, primipara, non-smokers, those who had used any vitamins before pregnancy and women reporting vigorous pre-pregnancy leisure activity. Mean scores also rose with education. Obese women had significantly lower mean scores than normal or underweight women (preconception) Multinomial logistical regression showed that obese women had significantly higher odds of falling into the lowest *v.* highest DQ tertile compared with underweight women. A modest inverse association between pre-gravid obesity and low DQ remained after adjustment for several SES variables and smoking, even after controlling for pre-pregnancy vitamin use and physical activity

Table 4 *Continued*

ID	Name	Authors, year, reference	Assessment time	Methods	Diet type	Determinants of diet
8	Project Viva	Rifas-Shiman *et al.* (2009)[16]	GW 26–28	• Two retrospective dietary assessments (in early pregnancy, from last menstrual period until FFQ completion; in 2nd TM referring to previous 3 months) • Self-administered, validated, 166-item semi-quantitative FFQ (adapted Willett) • Crude and multivariate adjusted linear regression models were used to examine the relationship between maternal characteristics and diet intake	**DQ assessed by AHEI-P score:** AHEI-P, nine components, summed up to a maximum score 90: • Vegetables • Fruit • Ratio of white to red meat • Fibre • *Trans* fats • Ratio of PUFA to SFA • Folate • Fe • Ca intake from food In this publication, the 'nuts & soya' component was omitted, because women may avoid nuts during pregnancy due to allergy concerns for their offspring Mean AHEI-P score 61 (min. 33, max. 89)	After adjustment for all other characteristics, women who were older had significantly higher DQ, while women who had higher pre-pregnancy BMI, lower education and more children had lower AHEI-P scores. Before multivariate adjustment, African-American women had lower scores, but upon adjustment scores became more similar to those seen in white women; the initial observed difference came largely from confounding (age and education)
9	Rhea	Kritsotakis *et al.* (2015)[34]	GW 14–18	• Semi-quantitative FFQ, 250 items in seventeen groups • MD score calculated • Spearman's ρ correlation used to estimate the strength of association between social capital dimensions and MD adherence • Linear regression analyses to estimate association between social capital and MD score while adjusting for confounders	**MD adherence score:** Maximum 8 points = maximum adherence, based on at least median consumption of beneficial components: vegetables, legumes, fruits and nuts, cereals, fish & seafood, dairy products; and consumption below median of detrimental components meat, fat: MUFA to SFA ratio	Mean MD scores increased with education level, scores were slightly higher in those who were not married, of Greek origin, primiparous, residing in urban areas, non-smoker and physically active before pregnancy In univariate analysis MD scores increased with total social capital score. In adjusted analysis total social capital and tolerance of diversity scores were positively associated with MD score. Participation in the community was marginally significant. Multivariable linear regression models using MD score as a continuous outcome identified a dose–response effect for total maternal social capital (high scores associated with an increase of almost 1 point on the MD scale) and tolerance of diversity score There was a marginal effect for participation in the community while the dimensions feelings of safety and value of life and social agency did not emerge as significant determinants of MD
10	Not reported	Fowles *et al.* (2011)[39]	1st TM	• Retrospective, three 24 h dietary recalls • Pearson product-moment coefficients for correlations • Only variables with significant relationship with DQ were entered into prediction analysis	**DQI-P score:** Eight components with maximum of 10 points; max. score 80, $\geq$70 is highest DQ % recommended daily servings for • Grains • Vegetables	In correlational analysis a significant negative relationship emerged between DQ and eating habits and distress (marker of stress and depression) and a significant positive relationship with age, education and social support

Table 4 *Continued*

ID	Name	Authors, year, reference	Assessment time	Methods	Diet type	Determinants of diet
				• A path model was tested	• Fruits • Folate • Fe • Ca • Total fat • Meal pattern score	In a path model distress had a direct and indirect effect on DQ, poor eating habits had a direct effect on DQ, while social support had no effect. Age had an indirect effect on DQ
		Fowles *et al.* (2012)[41]	1st TM	• Retrospective, three 24 h dietary recalls • Comparative (χ^2 test) and correlational analyses	**DQI-P score:** Eight components with maximum of 10 points; max. score 80, ≥70 is highest DQ % recommended daily servings for: • Grains • Vegetables • Fruits • Folate • Fe • Ca • Total fat • Meal pattern score Median score was 53·3	Only 4 % of women had adequate DQ. In bivariate analysis women with DQ score below the median had significantly less control over meal preparation, less support from others but higher stress and depression scores than women with high scores DQ was negatively associated with meal skipping, low control over food preparation and stress. DQ was positively related to support from others, but not to support from one's partner
		Fowles *et al.* (2011)[40]	1st TM	• Retrospective: three 24 h dietary recalls conducted over 2 weeks (1st at clinic, 2nd and 3rd via telephone) • Nutrient and food groups were averaged over the 3 d. Nutrient values were adjusted for energy intake • Characteristics compared by *t* test	**DQI-P score:** Eight components with maximum of 10 points; max. score 80, ≥70 is highest DQ % recommended daily servings for: • Grains • Vegetables • Fruits • Folate • Fe • Ca • Total fat • Meal pattern score	DQ was negatively related to depression, overall stress and persistent stress. High frequency fast-food eaters had lower mean DQ scores but the difference was not significant
11	Not reported	Tsigga *et al.* (2011)[42]	Varied	• Retrospective (24 h dietary recalls) • On three consecutive days: 1st assessment at clinic visit (recruitment), next two days via phone interview by a dietitian • HEI score calculated from median intake of each participant • Multivariate statistical techniques and logistic regression were used to assess relationship between HEI and characteristic • SCA was conducted in MiniTab between HEI score categories and demographic characteristics	**HEI score:** Twelve components summing to a maximum score of 100: • Total fruit • Whole fruits • Total vegetables • Dark green and orange vegetables • Vegetables and legumes • Meat and beans • Total grains and whole grains • Milk • Oils	HEI scores were significantly higher in women who were normal weight before and normal- or underweight during pregnancy. Living in an urban area increased the odds of having low HEI score A simple correspondence symmetric plot showed that low HEI scores were associated with urban residence and overweight during and obesity both during and before pregnancy In contrast, high scores were associated with rural residence and gestational under- and normal weight

Table 4 *Continued*

ID	Name	Authors, year, reference	Assessment time	Methods	Diet type	Determinants of diet
					• Saturated fat • Na • Energy from solid fat, alcoholic beverages and added sugars HEI scores above 80 indicate high DQ, scores of 60 to 79·9 indicate average DQ, and below 60 low DQ Mean HEI score 66·9 (SD 0·6)	While there was a clear association with weight status and area of residence, education, age, income and gravidity did not appear to influence HEI scores
12	Not reported	Watts *et al.* (2007)[43]	Varied	• Retrospective • FFQ (HSFFQ, adapted from Willett's), validated in that population, 103 items, foods added that were typical for Native Americans in that area • DQI-P was calculated based on HSFFQ data • Differences in scores according to sociodemographic characteristics were calculated using *t* tests and ANOVA to test for differences	**DQI-P score:** Ten components with maximum of 10 points; max. score 100 % recommended daily servings for: • Grains • Vegetables • Fruits • Folate • Fe • Ca • Total fat • Saturated fat • Cholesterol • Dietary diversity Scores >80 indicate a 'good' diet, scores of 51–80 points indicate a diet that 'needs improvement' and scores ≤50 indicate a 'poor' diet' Mean DQI-P score 53·9	White women had significant higher DQ scores than Native Americans. Women who never smoked had significantly higher scores, while living in a town/city was significantly negatively associated with DQ. Scores did not vary significantly with age or poverty level

ALSPAC, Avon Longitudinal Study of Parents and Children; CANDLE, Conditions Affecting Neurocognitive Development and Learning in Early Childhood; DIPP, Type 1 Diabetes Prediction and Prevention Project; ECCAGE, Study of Food Intake and Eating Behavior during Pregnancy (Brazil); PHP, Prenatal Health Project; PIN, Pregnancy, Infection, and Nutrition Study; GW, gestational week; TM, trimester; DP, dietary pattern; PCA, principal component analysis; EFA, exploratory factor analysis; CFG, Eating Well with Canada's Food Guide; NCI, National Cancer Institute (USA); DQI-P, Diet Quality Index for Pregnancy; MD, Mediterranean diet; HEI, Healthy Eating Index; SCA, simple correspondence analysis; HSFFQ, Harvard Service Food Frequency Questionnaire; AHEI-P, Alternate Healthy Eating Index adapted for pregnancy; HH, household; mPAL, measured physical activity level.

adapted to fit the Finnish diet[33]. Women received the questionnaire after birth; this information was checked by an interviewer but only 3 months later. This could have led to recall bias. Non-response bias is also possible since women who did not complete dietary information had lower education but higher parity. Seven DP were identified through principal component analysis. Collectively these patterns explained 29·5 % of variance, therefore the variance explained by each individual pattern was low. Factor loadings of 0·2 or greater were considered in pattern derivation. This is lower than recommended[46] and may lead to DP that lack construct validity[48]. A pattern such as 'Alcohol and butter' is not intuitively understandable, and the presence of alcohol in the diet of pregnant women is startling. Interpretation of the 'Healthy' dietary pattern is more straightforward. As the multiple linear regression analysis was not adjusted, it is difficult to exclude the presence of confounding.

The Brazilian ECCAGE (Study of Food Intake and Eating Behavior during Pregnancy) Study was the only publication using cluster analysis[6]. This approach differs from the commonly used factor analyses as participants are 'clustered' in accordance with similarities in their dietary intake rather than foods being 'factored' that correlate greatly[45]. The study satisfied all requirements regarding sample selection and representativeness, but analyses were not adjusted for confounders. The FFQ was validated for use in pregnancy but validity was found to be low; dietary intake may thus not have been adequately captured.

Two publications from the Canadian PHP (Perinatal Health Project) assessed a range of determinants. In the first publication only parity was associated with meeting guidelines. Given that only 3·5 % of participants were classed as guideline compliant, the ability to assess differences between the compliant and non-compliant may have become impaired through lack of power[44]. The second publication identified more factors that were associated with the Diet Quality Index adapted for pregnancy (DQI-P)[35]. Overall the model had a low R^2, indicating that only a small proportion of variability in DQ was explained by the measured determinants[35].

The PIN (Pregnancy, Infection, and Nutrition) study was represented by three publications[36–38]. The FFQ used in PIN has been shown to underestimate grain servings, which may have biased the results[37]. Results on food environment are limited by the fact that distance to food retail is a rather crude measure of access[38] and factors besides access, such as income, may also influence food purchasing. In two publications analyses were adjusted for confounders[37,38].

The US Project Viva study used an FFQ specifically validated for use in pregnant women and both crude and adjusted analyses to assess the associations between determinants and diet[16]. However, generalisability from this cohort may be impaired due to higher than average socio-economic position and lower prevalence of overweight and obesity than the national average. Bias may have resulted from determinants being assessed by self-report rather than validated by interviewer assessment.

Women of Greek origin (rather than immigrants) and those with higher education were over-represented in the Rhea cohort, limiting generalisability of findings. The study benefited from established scales for assessing social capital and dietary intake, as well as analyses that were adjusted for a wide range of confounders[34].

Three publications of a US study of low-income women point to the involvement of stress, distress and anxiety on DQ. However, that study consisted of a convenience sample of women recruited through a small number of clinics offering free services to un- and underinsured pregnant women, deeming the sample not representative. Results are published on similar topics but corresponding to fifty[40], seventy-one[41] and 118[39] participants; it thus seems like data were analysed before participant recruitment was completed, which could have biased later analyses. The study includes the only publication reporting a sample size calculation; sample size was adequate for the latest publication.

When interpreting results from the studies by Tsigga *et al.*[42] and Watts *et al.*[43], readers must be aware that both are cross-sectional studies with rather low NOS rating. Potential sources of bias include not reporting sample size calculation[42], not reporting participation rate and analyses not being adjusted or stratified[42,43]. Also, Tsigga *et al.* used the Healthy Eating Index (HEI) without adaptations for pregnancy and Watts *et al.* adapted the DQI-P; in neither case is it clear if these modifications of instruments (or lack thereof) are appropriate to capture diet in the target population.

Determinants reviewed in seventeen publications

Pregnancy-related

Parity was the most commonly investigated pregnancy-related factor (ten publications). In the ALSPAC and DIPP studies, pattern scores were associated with parity[30,33]. In the PHP study, parity was associated with meeting guidelines[44] and DQ score[35]. In the US cohorts PIN[36] and Project Viva[16], parity was inversely associated with DQ. The same was observed for mean Mediterranean diet score in Rhea participants[34]. Another Greek study found that parity did not appear to influence HEI score[42]. Dieting during pregnancy was positively associated with the 'Healthy' and 'Traditional' DP and negatively with the 'Confectionary' DP. Body weight and shape concerns in pregnancy were associated with the 'Healthy' and 'Traditional' DP[30].

Sociodemographic

In the ALSPAC cohort, a 'Health conscious' DP (Table 4) was positively associated with education level and age, and was more commonly seen in women who were owner-occupiers rather than in rented accommodation[30].

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As in ALSPAC, in the CANDLE cohort women adhering to the 'Healthy' DP were more likely older, with higher education levels and cohabiting. With regard to ethnicity, clear patterning emerged such that the 'Processed', 'US Southern' and their mixed patterns 'Processed-Southern' and 'Healthy-Southern' were more commonly consumed by African Americans, while Caucasians and women of other ethnicities tended to consume the 'Healthy' or 'Healthy-Processed' pattern[31].

In the Spanish cohort assessing DP in weeks 6, 10, 26 and 38 of pregnancy, the 'Vegetable and meat' pattern was positively associated with age in weeks 10 and 38[32].

Results from multiple linear regression analysis showed positive associations for age and the 'Healthy' and the 'Alcohol and butter' patterns, but inverse associations for the 'Fast food' pattern and the 'Traditional meat' pattern in the DIPP study. Education was positively associated with the 'Healthy', 'Low-fat foods' and 'Alcohol and butter' patterns[33].

In the ECCAGE cohort the 'Varied' pattern, much like the 'Healthy' patterns in studies discussed above, was associated with being older and more educated. It was also associated with living with a partner, being employed and having a higher income[6].

Among PHP participants, dietary guideline compliance was low; only 3·5 % of participants met all recommendations. Meeting guidelines was not associated with education[44]. Using the DQI-P, 56 % were classed as having sufficient DQ. In the final parsimonious model, DQ score was predicted by being a recent immigrant and being married[35].

Three publications from the PIN cohort also found older age, higher education and greater income to be associated with higher DQ[36]. Mean DQI-P scores were higher in African-American women[36,38].

Another US cohort, Project Viva, assessed DQ using the Alternate Healthy Eating Index adapted for pregnancy (AHEI-P). In multivariate-adjusted models controlling for all maternal characteristics simultaneously, AHEI-P scores were positively associated with age and education. Scores initially appeared to differ by race; however, these differences disappeared upon adjustment and were found to largely stem from confounding by age and education[16].

Mean Mediterranean diet scores were higher in Rhea study participants who were older, more educated, married and Greek nationality[34]. Interestingly, in another Greek study, HEI scores did not appear to be influenced by maternal age, education or income[42].

Age and education were also positively associated with DQ in a sample of low-income, un- and underinsured US women[39].

A comparative study of Caucasian and Native American low-income women in recipients of federal supplemental nutrition programme assistance found no differences in DQ scores by age or income but lower mean scores in Native Americans (unadjusted for confounders)[43].

Individual response

In accordance with our framework, we regarded weight status before pregnancy as an individual biological and behavioural response to environmental cues. We also classed health behaviours such as smoking or physical activity as individual responses.

ALSPAC participants considering themselves 'more active' than their peers scored higher on the 'Health conscious' pattern[30].

CANDLE participants of normal pre-pregnancy weight more likely followed the 'Healthy' pattern, while overweight and obese more commonly followed the 'US-Southern', 'Processed' and their mixed patterns[31]. In the Spanish cohort, preconception BMI was negatively associated with the 'Vegetables and meat' pattern in week 38 of pregnancy, while smoking was positively and physical activity negatively associated with the 'Sweetened beverages and sugars' pattern[32]. Participants who were obese before pregnancy had 76 % greater odds of low DQ scores in the PIN cohort[37]. Likewise, in Project Viva, pre-pregnancy BMI was inversely associated with DQ[16]. Conversely, in the Brazilian ECCAGE study no association was seen between pre-pregnancy BMI and any DP[6]. HEI score was negatively associated with BMI in correlational but not regression analysis in a small Greek study[42].

Smoking in pregnancy was associated with the 'Fast foods', 'Traditional meat' and 'Coffee' patterns in the DIPP study[33]. In the PHP study, not smoking and exercising more predicted greater DQ[35] and greater mean Mediterranean diet scores in the Rhea cohort[34]. Frequent fast-food eaters exhibited lower DQ[40].

Environment

HEI scores were determined by place of residency; Greek women living in urban areas had increased odds of low DQ[42].

The food environment, specifically distance to outlets, emerged as a determinant. Living within 500 m of fast-food restaurants was associated with poorer DQ in univariate analysis and in the first multivariate linear regression model[35]. Likewise, women living 4 miles (6·4 km) or more away from supermarkets had twice the odds of low DQ[38].

Two studies investigated the social environment. After adjustment for confounders, total social capital and tolerance of diversity scores were positively associated with Mediterranean diet score. The authors offer the interpretation that social capital leads to feelings of obligation, reciprocity and self-control, which result in greater motivation to follow a healthy diet[34]. Social support from family and friends was positively associated with DQ[35].

Other factors

Anxiety was associated with the 'Confectionary' and depression with the 'Vegetarian' pattern[30] and inversely associated with DQ[35]. DQ was negatively associated with

depression, overall and persistent stress in low-income un- and underinsured women[40]. These factors were not represented in the conceptual framework; they could build a new category or could be grouped as individual psychological responses.

Discussion

The present systematic review has synthesised seventeen publications of twelve studies on determinants of diet during pregnancy in accordance with our framework.

Factors within the category of sociodemographic determinants have been most frequently studied. Evidence consistently points to a social gradient whereby women who are older, more educated, with higher incomes or other markers of affluence more likely followed a 'healthier' DP or scored higher on DQ scales. A social gradient in diet has been observed in different populations and settings[49] and in pregnant women[50]. However, pregnancy has been described as a period of greater motivation for behaviour change and great potential for health promotion[7]. The fact that the social gradient in diet persists in pregnancy indicates that the health promotion potential is not used to its fullest potential, women's motivation is not as great as expected, or that neither can overcome the wider social forces in play.

Findings regarding ethnicity are less consistent. As analyses were mostly not adjusted for confounders we find the evidence from the Project Viva cohort most convincing, where differences largely stemmed from confounding by age and education. Evidence from the reviewed studies also indicates that partnership and markers thereof such as cohabitation determine dietary intake.

Studies on individual response largely investigated health behaviours. Included studies paint a picture of a 'behavioural' gradient, whereby health-promoting behaviour such as adequate physical activity appears linked with higher DQ or adherence to 'health conscious' type patterns, whereas the opposite was seen for detrimental behaviours such as smoking. We interpret these as individual behavioural responses. The observation that diet in pregnancy 'parallels' other health-related behaviour before and during pregnancy corroborates with findings from different age groups and populations indicating that health-risk and health-protective behaviours 'cluster' together[51]. The relationship between pre-pregnancy weight and diet in pregnancy is more difficult to interpret. If body weight is interpreted as an outcome of diet this indicates that diet 'tracks' from preconception into pregnancy, rather than body weight being a determinant. This is supported by a prospective analysis of the Southampton Women's Survey where DP did not change substantially upon becoming pregnant[52].

Our review showed that pregnancy-related factors other than parity and environmental factors were less commonly investigated in studies.

The lack of studies investigating pregnancy determinants is in contrast with theoretical and empirical literature framing pregnancy as a physiologically and psychologically unique period important for health[7,53]. We would have expected studies to investigate a wide range of pregnancy factors such as pregnancy intendedness, pregnancy ailments, changes in appetite and pregnancy-induced health changes for their potential influence on diet. But this was not the case; studies investigated only a few pregnancy factors other than parity. Findings on parity were inconsistent. It is possible that this is due to confounding, i.e. parity acting as a marker of age, marital status and other sociodemographic determinants, or that the influence of parity is context specific, e.g. differences in resources and support allocated to women in their first pregnancy and women who already have children.

Environmental determinants were assessed in few of the included studies. Evidence points to social support and social capital as determinants. Evidence regarding the built and food environment stems from few studies with some inconsistencies. Other facets of the environment such as medical (e.g. antenatal care) or political and economic (e.g. food policies, advertisement) were not researched. This corroborates with findings of a series of systematic reviews of determinants of diet across different age groups which also identified a lack of studies investigating macro-level environmental determinants[54].

Psychological health emerged as a new category of determinants to add to the framework. Reviewed studies indicate that depression, stress and anxiety influence diet during pregnancy. However, we did not specifically search for these factors; these findings were thus not derived systematically. A review of psychological determinants should be conducted in order to identify where in the framework they should be placed, i.e. whether they should be regarded as a form of individual response or build an independent category.

The methodological quality of the reviewed studies raises concern. Sample size calculations were rarely reported and only nine adjusted for confounders[6,16,30,32–35,37,38]. The assessment of dietary patterns and quality is also problematic. The reviewed studies may not be capturing exactly the same outcome (diet). Particularly DP differ between populations, places and cultural contexts and are sometimes difficult to interpret[14]. DP are frequently derived using factor analysis, a method criticised for being based on subjective decisions[47] and because results can be influenced by choice of factor loading cut-offs and rotation methods[48]. Nutritional epidemiology has reacted to this by striving for new approaches for deriving DP such as exploratory structural equation modelling[48], simplified factor analyses approaches[55] and latent class modelling[56].

Our review benefited from an extensive literature search and quality assessment. The first step of screening and data extraction was conducted by only one reviewer. In order to counteract this potential source of bias, only articles that could be excluded without doubt (e.g. participants were not

pregnant or in postpartum) were excluded based on title/abstract. Therefore 130 articles entered the second stage of screening and were read in full by two reviewers. With data extraction, any lack of clarity was resolved by discussion among reviewers. We reviewed only observational studies, which are methodologically weaker than experimental studies, because we wanted to identify the drivers of diet when women are free to choose, i.e. in real-life settings rather than experiments. Language bias is possible because all included studies were in English. Restriction to high- and upper-middle-income countries limits the generalisability of our findings.

Our framework should be seen as work in progress as this is a new research area. We recommend that more studies be conducted, particularly assessing environmental factors and pregnancy itself as a potential unique determinant. Future studies should use sound statistical techniques to overcome the issues (e.g. use of factor analysis and principal component analysis, not adjusting for confounders, lack of sample size calculations) we outlined. Once a stronger evidence base is built, it can be translated into solid public health messages and interventions.

Conclusion

Diet in pregnancy appears socially patterned and aligns along other health behaviours. Practitioners should be aware that women who are young, less educated and less affluent or who show health-risk behaviours appear to be at higher risk of poor diet in pregnancy and may require closer monitoring and advice.

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Appendix

Search strategies

PubMed

Filters: Humans, Adult: 19+ years: ((((((((((((determin*(Text Word) OR correlat*(Text Word) OR predict*(Text Word) OR associat*(Text Word) OR socioeconomic*(Text Word) OR socio-economic*(Text Word) OR social*(Text Word) OR econom*(Text Word) OR incom(Text Word) OR famil*(Text Word) OR household(Text Word) OR employment(Text Word) OR occupation(Text Word) OR educat*(Text Word) OR cultur*(Text Word) OR rac*(Text Word) OR ethnic*(Text Word) OR religio*(Text Word) OR marital status(Text Word) OR age(Text Word))) OR socioeconomic factors(MeSH Terms)) OR socioeconomic status(MeSH Terms)) OR marital status(MeSH Terms)) OR age factors(MeSH Terms)) OR income(MeSH Terms)) OR family characteristics(MeSH

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Terms)) OR cultural background(MeSH Terms)) OR household(MeSH Terms)) OR employment(MeSH Terms)) OR epidemiologic determinants(MeSH Terms)) OR statistics as topic(MeSH Terms)) AND ((((((‘diet pattern’(Text Word) OR ‘dietary pattern’ (Text Word) OR ‘food pattern’(Text Word) OR ‘meal pattern’(Text Word) OR dietary habit*(Text Word) OR food habit*(Text Word) OR meal habit*(Text Word))) OR diets(MeSH Terms)) OR maternal nutrition physiology(MeSH Terms)) OR food habits(MeSH Terms)) OR food preferences (MeSH Terms)) AND ((((pregnant(Text Word) OR pregnancy(Text Word) OR gestation*(Text Word) OR mother (Text Word) OR maternal(Text Word) OR expecting(Text Word) OR expecting(Text Word) OR parous(Text Word) OR gravid*(Text Word))) OR pregnant women(MeSH Terms)) OR pregnancy maintenance(MeSH Terms))

CINAHL and GreenFILE Library via EBSCOHOST

(determinant OR socioeconomic factor OR association OR cause OR cultural OR religion OR family OR employ) AND TX (dietary pattern OR meal pattern OR food pattern OR nutrition pattern OR diet habit OR meal habit OR food habit OR nutrition habit) AND SU (pregnancy OR pregnant OR gestation OR gravid)

MedPilot, now LVIVO

TI = (determinant OR socioeconomic factor OR association OR cause OR cultural OR religion OR family OR employ) AND TI = (dietary pattern OR meal pattern OR food pattern OR nutrition pattern OR diet habit OR meal habit OR food habit OR nutrition habit) AND TI = (pregnancy OR pregnant OR gestation OR gravid)

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