Title: Women's dietary changes before and during pregnancy: a systematic review

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Abstract

Background

Dietary intake before and during pregnancy has significant health outcomes for both mother and child, including a healthy gestational weight gain. To ensure effective interventions are successfully developed to improve dietary intake during pregnancy, it is important to understand what dietary changes pregnant women make without intervention.

Aims

To systematically identify and review studies examining women's dietary changes before and during pregnancy and to identify characteristics of the women making these changes.

Methods

A systematic search strategy was employed using three databases (Web of Science, CINAHL and PubMed) in May 2016. Search terms included those relating to preconception, pregnancy and diet. All papers were quality assessed using the Scottish Intercollegiate Guidelines Network methodology checklist for cohort studies.The search revealed 898 articles narrowed to full-text review of 23 studies. In total, 11 research articles were included in the review, describing nine different studies. The findings were narratively summarized in line with the aims of the review.

Findings

The included studies showed marked heterogeneity, which impacts on the findings. However, the majority report an increase in energy intake (kcal or kJ) during pregnancy. Of the studies that reported changes through food group comparisons, a majority reported a significant increase in fruit and vegetable consumption, a decrease in egg consumption, a decrease in fried and fast food consumption and a decrease in coffee and tea consumption from before to during pregnancy. The characteristics of the women participating in these studies, suggest that age, education and pregnancy intention are associated with healthier dietary changes; however these factors were only assessed in a small number of studies.

Key conclusions

The 11 included articles show varied results in dietary intake during pregnancy as compared to before. More research is needed regarding who makes these healthy changes, this includes consistency regarding measurement tools, outcomes and time points.

Implications for practice

Midwives as well as intervention developers need to be aware of the dietary changes women may spontaneously engage in when becoming pregnant, so that care and interventions can build on these.

Keywords: Pre-conception, pregnancy, dietary intake, caffeine, systematic review.

Introduction

Pregnancy is a time when many women gain weight they subsequently retain post pregnancy. Almost 30% of pregnant women gain more weight than is recommended by the American Institute of Medicine guidelines (IOM, 2009) and previous evidence from a range of countries suggests a mean weight gain between 0.4kg to 3.8 Kg as a result of pregnancy up to 2.5 years postpartum (Linne et al., 2002). Increased weight post-natal was also found to be a strong indicator of being overweight 15 years later (Linne et al., 2004). The more weight gained during pregnancy, the more likely that it may be retained postpartum (Johnson et al., 2013) and women who enter a subsequent pregnancy overweight or obese also have a higher risk of adverse outcomes for themselves and/or their infants (Kuhlmann et al., 2008 and Marchi et al., 2015).

Numerous interventions have targeted weight gain in pregnancy, including both physical activity and dietary components. A recent review suggests that interventions with dietary aspects may be most effective in helping women gain a healthy weight in pregnancy (Thangaratinam et al., 2012). Adequate nutritional intake during pregnancy is vitally important to ensure appropriate fetal growth both physically and mentally (Anderson et al., 2001) and poor maternal nutritional status is well reported to not only affect pregnancy outcomes (Osrin and de L Costello, 2000 and Keen et al., 2003), but may also be related to the risk of developing several non-communicable diseases in the adult child (Barker et al, 2013). As such dietary intake both before and during pregnancy is a major public health issue (Barker et al., 2013).

Pregnancy is a period where women are particularly concerned with their dietary intake (Pinto et al., 2008) and are considered highly motivated for dietary improvements (Szwajcer et al., 2008 and Phelan, 2010). For example, when pregnant women have been asked for the behaviours they do to keep healthy in pregnancy, healthy eating is the most commonly mentioned health behaviour (Lewallen, 2004). To ensure appropriate and effective interventions are successfully developed to improve dietary intake during pregnancy, the dietary changes women make when they become pregnant are important to understand (Skreden et al., 2014). The primary aim of this systematic review was therefore to review the existing literature on dietary intake change before and during pregnancy. In addition to knowing *what* dietary changes women make when becoming pregnant, it is also important to understand *who* makes these changes. Thus, our secondary review aim was to identify the key characteristics of the women who report changing their dietary intake from before to during pregnancy.

Methods

A systematic literature review was conducted to identify the changes in women's dietary intake before and during pregnancy and to identify which women may make these changes. Three databases (Web of Science, CINAHL and PubMed) were systematically searched in May, 2016. Search terms included preconception, pre-pregnancy, pregnancy, gestation, dietary intake, food intake, beverages, caffeine, fruit and vegetables. Scopus was used for forward searching (May 2016). Studies were included if they measured women's dietary intake before and during pregnancy, either prospectively or retrospectively. For the purpose of this review, dietary intake included food groups as well as energy and macronutrients. Notably, drinking alcohol was not included in this review despite being part of a woman's energy intake. There are two reasons for omitting alcohol from this review, firstly not all women drink alcohol when not pregnant (Petherick et al., 2010). Secondly, drinking alcohol is consistently reported to decrease before and during to pregnancy (Crozier et al., 2009a; Aden et al., 2007; Pinto et al., 2008).

In addition, to be included studies had to use a within-participants design to limit the bias and individual variance associated with dietary intake. Lastly, to be included, articles had to be in English and in peer-reviewed journals. Screening of titles and abstracts and decision on final inclusion of articles was done by both authors.

Analysis

All papers were quality assessed using the Scottish Intercollegiate Guidelines Network methodology checklist for cohort studies (Scottish Intercollegiate Guidelines Network, 2016). This checklist was chosen as it differentiates between prospective and retrospective cohort studies, of which both were included in this review. Both authors scored the studies independently and scoring discrepancies were resolved via discussion. Inter-rater reliability was calculated using percentage agreement.

For all studies, study population, study design, diet measurement, type and timing of measurement and study findings were extracted. Due to the heterogeneity of the studies identified it was inappropriate to conduct a meta-analysis and a narrative method of synthesis analysis was conducted. This method has been used previously when the experimental studies included are not sufficiently similar for a meta-analysis to be appropriate (Mays et al., 2005) Ethical approval was not required for this systematic review.

Results

The literature search yielded 898 articles including one article found by a hand search, of which 468 were screened by title and abstract and 23 were full text screened (see Figure 1). Details of study exclusion are detailed in Table 2 in supplementary material. Forward searching identified two additional articles (Aden et al., 2007 and Crozier et al., 2009a). In total, 11 research articles were included in the review, describing nine different studies.

Study characteristics

The included studies heralded from all over the world, published between 1998 and 2014 (see Table 1). The majority of studies used a prospective design (n= 6) with three studies (reported in five articles) using a retrospective design. Study sample size varied from 10 (Kopp-Hoolihan et al., 1999) to 7174 (Hellerstedt et al., 1998). The included studies varied greatly regarding the information authors reported regarding participant characteristics in terms of age, ethnicity, parity and weight status (see Table 1). Variations in measurement time points were also noticed with the prospective studies measuring pre-conception dietary intake within a few months of a confirmed pregnancy. The retrospective studies measured dietary intake at different time points during pregnancy or postpartum to gather information of dietary intake before and during pregnancy. Dietary intake was either measured through interview (face-to-face or by phone) or self-administered questionnaire. In total, seven articles provided data on changes in food groups and three articles reported findings in terms of energy and macronutrients, with one reporting both methods. Four articles provided data on characteristics of the women who report changing their dietary intake before and during pregnancy.

Quality assessment

Inter-rater reliability, assessed through percentage agreement was 77.8%. Whilst the prospective studies were deemed marginally stronger compared to the retrospective studies, all articles were found to be of acceptable quality. See Table 1 in supplementary material for full breakdown of quality assessment.

The results of the review are presented under two headings, dietary intake changes and characteristics of women making dietary changes. Changes in dietary intake will be clustered using the sub-headings of food groups or energy and macronutrient intake to complement the individual study reporting and to allow comparisons between studies to be made more easily.

Dietary intake change from preconception to pregnancy

Food Groups - Fruits and vegetables

Six articles reported data on fruit and vegetable intake with inconsistent findings (Cuco et al., 2006a; Pinto et al., 2008; Crozier et al., 2009a; Crozier et al., 2009b; Paulik et al., 2009; Smedley et al., 2014). Paulik et al. (2009) reported an increase in the percentage of women consuming both fruits and vegetables (more than 4 times per week) in pregnancy (85.7% vs 94.8% fruit and 67.6% vs 75.4% vegetables). This is further supported by Smedley et al. (2014), who reports a significant increase in the number of women 'always' consuming fruit and vegetables during pregnancy (65% vs 78% fruit and 61% vs 77% vegetables). Crozier et al. (2009a) reports an increase in citrus fruit and fruit juice intake during pregnancy compared to before pregnancy (52% vs. 64%). In contrast, Pinto et al. (2008) reported no significant change in median daily vegetable consumption (grams) between preconception and pregnancy, but did report a significant increase in fruit consumption during pregnancy (+21.5 grams). This was also supported by Cuco et al. (2006a) who reports no significant differences in mean consumption of fruit or vegetable intakes. In addition, portions of fruit and vegetables per day did not significantly differ between pre-conception and during pregnancy (5.2 vs. 5.35 portions) as reported by Crozier et al., (2009b).

Dairy

Three studies reported data on dairy intake and the results varied greatly between studies (Pinto et al., 2008; Crozier et al., 2009a; Smedley et al., 2014). Pinto et al. (2008) reported a significant increase in milk and dairy products between pre-conception and during pregnancy (387.5g vs 691.8g), and a significant decrease in egg consumption between pre-conception and during pregnancy (22.2g vs 11.1g). In addition, Crozier et al. (2009a) reported an increased intake in a number of dairy products including cream and milk as well as reporting an increase in the consumption of cheese and cottage cheese during both early (3.0 portions) and late (4.5 portions) pregnancy when compare to pre-conception (1.8 portions). However Smedley et al. (2014) reported no significant difference in dairy intake in all categories between pre-conception and during pregnancy

Meat and meat products

Two studies reported data on meat and meat products and the results varied greatly between studies (Pinto et al., 2008; Crozier et al., 2009a). Crozier et al. (2009a) reported an increase in processed meat consumption during early and late pregnancy, but reported no change in red meat, chicken, turkey or fish consumption during pregnancy. Crozier et al. (2009a) also reported that the proportion of women consuming meat such as liver and kidneys was 48% during pre-conception,

and decreased to 22% in early pregnancy and 16% in late pregnancy. This contrasts with evidence reported by Pinto et al. (2008) who reported a significant decrease in red meat consumption during pregnancy (-4.7g) but who also found no significant difference in fish consumption.

Starchy Carbohydrates (CHO)

Two studies reported data on starchy carbohydrates and the results varied greatly between studies (Pinto et al., 2008, Crozier et al., 2009a). Pinto et al. (2008) reported a significant increase in bread consumption but a decrease in rice, pasta and potato consumption during pregnancy. Crozier et al. (2009a) reported that rice and pasta consumption was lower during early and late pregnancy with an increase in weekly consumption of breakfast cereals during late pregnancy (7 portions) compared to pre-conception (4.5 portions) and early pregnancy (4.5 portions) also reported. However Crozier et al. (2009a) also reported no changes in intake of wholemeal bread, quiche, pizza and pancakes.

Sweet foods

Three studies reported data on sweet foods and the results varied greatly between studies (Pinto et al., 2008; Crozier et al., 2009a; Smedley et al., 2014). Smedley et al. (2014) and Pinto et al. (2008) reported no change in sweet bakery food or sweets consumption between pre-conception and during pregnancy, whereas Crozier et al. (2009a) reported an increase in portion consumption of sweet spreads, confectionary, cakes and biscuits during both early and late pregnancy, whereas puddings only increased during late pregnancy.

Fast and Fried Food

Two articles reported data on fried and fast food (Pinto et al, 2008; Smedley et al, 2014). Fried food intake was not significantly different before and during pregnancy (Smedley et al., 2014). However fast food intake did decrease during pregnancy, with a greater number of women reporting that they 'never' consumed this food (56% vs 67%) (Smedley et al., 2014). Similarly, Pinto et al. (2008) reported a decrease in the consumption of fast food during pregnancy compared to pre-conception intake (25.1g vs 17.1g)

Beverages

Five articles reported data on beverage intake and the results varied greatly between studies (Hellerstedt et al., 1998; Cuco et al. 2006a; Pinto et al., 2008; Crozier et al., 2009b; Skreden et al., 2014). Coffee and tea was the most commonly reported beverage, and consumption was found to decrease from before to during pregnancy in four studies (Hellerstedt et al., 1998; Pinto et al., 2008;

Crozier et al., 2009b; Skreden et al., 2014). Paulik et al. (2009, n=349) reports a decrease in drinking one cup of coffee per day from 56.2% to 33.2%. Milk was assessed in three articles; Skreden et al. (2014) reported an increase in milk intake and Pinto et al. (2008) reported an increase in daily intake of milk and dairy products. Whereas Paulik et al. (2009) reported a decrease from 66.8% vs 60.2%.

Regarding sugar sweetened beverages and fruit juices, both Pinto et al. (2008) and Cuco et al. (2006a) reported no significant differences from before to during pregnancy, whilst Crozier et al. (2009a) and Skreden et al. (2014) found an increase in fruit juice consumption. Moreover, a decrease in sugar-sweetened beverages and artificially sweetened beverages was found in both studies (Crozier et al., 2009a and Skreden et al., 2014). Cuco et al. (2006a) also reported that participants who had high scores of sweetened beverages and sugar during both pre-conception and during pregnancy tended to consume less fresh fruit, vegetables, roots and tubers. Lastly, the percentage of women who reported at least daily consumption of water increased from before to during pregnancy (Skreden et al., 2014).

Energy and Macronutrients

Total energy intake (kcal, kJ or MJ) was measured in five studies (Koop-Hoolihan, 1999; Pinto et al., 2008; Cuco et al., 2006a and 2006b and Aden et al., 2007), with four studies (Koop-Hoolihan, 1999; Cuco et al., 2006a and 2006b and Aden et al., 2007) recording an increase in energy intake during pregnancy and one reporting no significant change (Pinto et al., 2008).

Kopp-Hoolihan et al. (1999) reported energy intake using three day food diaries from 10 women during pre-conception (T1) and three trimesters during pregnancy (T1, T2, and T3). The results show a 9% increase (775kJ/day) in total energy intake between T1 and T3. Similarly, Aden et al. (2007) reported an increase in energy intake between pre-conception (1852 ± 751 kcal/day) and during pregnancy (2104 ± 583 kcal/day) using a Food Frequency Questionnaire (FFQ) and a 24hr dietary recall, although there was no indication if this was a statistically significant increase. Cuco et al. (2006a and 2006b) reported changes in energy intake between pre-conception and four different weeks during pregnancy. The authors in both articles report an increase in energy intake between preconception and the 10^{th} and 26^{th} week of pregnancy but a decrease during the 6^{th} and 38^{th} week. However, Pinto et al. (2008) reported no significantly difference between pre-conception (2393 kcal/day) and during pregnancy (2423 kcal/day).

Macronutrient intake was also reported in 3 studies (Cuco et al., 2006b; Aden et al., 2007 and Pinto et al., 2008), with no consistent changes in intake reported in studies. Cuco et al. (2006b) reported macronutrient intake using a 7 day consecutive food diary. Protein intake did not differ between pre-conception and during pregnancy; however the proportion of animal to vegetable protein increased in favour of vegetable protein during pregnancy compared to pre-conception. CHO and fat intake increased during the 10^{th}, 26^{th} and 38^{th} week (182.2g preconception vs 199.4g; 206.7g; 191.8g respectively CHO and 91.6g preconception vs 98.0g, 97.3g, 92.9g respectively Fat). Cuco et al. (2006b) also reported changes in maternal consumption of protein, fat, CHO and suggests that an increase of only 1 gram of these during preconception, 6^{th}, 10^{th}, 26th and 38^{th} week of pregnancy can cause significant changes in child birth weight (7.8 – 11.4 grams)

Aden et al. (2007) reported an increase in CHO and protein intake with a decrease in fat intake recorded during pregnancy. However, Pinto et al. (2008) reported no significant differences between CHO and total fat intake as a percentage of total energy intakes (%TEI) between pre-conception and during pregnancy. However the results do indicate a significant increase in %TEI saturated fat (SFA) and protein during pregnancy compared to pre-conception.

Characteristics of the women who report changing their dietary intake from before to during pregnancy

Four studies reported characteristics of the women who made dietary changes from before to during pregnancy. Crozier et al. (2009b) explored what variables may predict daily fruit and vegetable intake. They found that both at pre-conception and during pregnancy, younger women ate less than five portions of fruit and vegetables a day compared to older women. Cuco et al. (2006a) also reports a positive association between the consumption of vegetables and meat with age. Whilst Skreden et al. (2014) found that women over 25 years reported larger decreases in artificially sweetened beverages and increased their fruit juice consumption more compared to women less than 25 years old. The women over 25 years also reported a larger intake in milk compared to younger women from pre-conception to during pregnancy. The same study found no relationship between pre-pregnancy BMI (>25 vs. <25) and changes in drinking habits or beverage consumption. Skreden and colleagues (2014) also found that higher education was associated with more reduction in coffee consumption. Lastly, Hellerstedt et al. (1998) examined daily caffeine use and pregnancy intention. They found that women with intended pregnancies, compared to those who reported the pregnancy was unintended, were more likely to report decreased consumption of caffeine from before to during pregnancy.

Discussion

The aims of this review were to evaluate the evidence relating to what changes in dietary intake women make when becoming pregnant, and secondly identify any characteristics of the women making these changes. The included studies are heterogeneous, specifically in relation to outcome measures and time frames in which data collection occurred; as such the findings should be interpreted with caution. Overall, the review findings suggest that some changes regarding dietary intake are made during pregnancy and these are in line with studies that have compared dietary intake between pregnant women and non-pregnant women (Anderson et al, 1993; Verbeke et al, 2007 and Inskip et al, 2009). The majority of studies report an increase in energy intake (kcal or kJ) during pregnancy, but failed to consistently report changes in different macronutrient intake (Cuco et al., 2006a and 2006b; Aden et al., 2007 and Pinto et al., 2008). Of the studies that reported changes through food group comparisons, a majority reported a significant increase in fruit and vegetable consumption, a decrease in egg consumption, a decrease in fried and fast food consumption and a decrease in coffee and tea consumption from pre-conception to during pregnancy (Helderstedt et al., 1998; Cuco et al., 2006a; Pinto et al., 2008; Crozier et al., 2009a and 2009b; Paulik et al., 2009; Skreden et al., 2014; Smedley et al., 2014). There was no consistency in starch carbohydrate consumption, meat, fish or sweets/sweet food consumption. Regarding the characteristics of the women making these dietary changes, only three studies provided information and as such no conclusions can be drawn.

Dietary intake change before and during pregnancy

Changes in energy intake were found to vary considerably between studies, with several papers reporting a significant increase and others reporting no significant change. Despite the general trend towards an increase in overall energy intake there were no consistent differences reported in specific macronutrient intake from before and during pregnancy. However one author (Aden et al., 2007) did report a large range in energy intake between both stages, with pre-conception intake ranging between 1116 kcal/day to 6087 kcal/day and during pregnancy ranging between 945 kcal/day and 3627 kcal/day. This indicates that although average intake may not change, there are likely to be large inter-individual variations in the overall energy and macronutrient intake between pregnant women which could have significant health and weight implications.

In terms of food group consumption, the most consistent findings are an increase in fruit and vegetable intake as well as an increase in dairy and a decrease in caffeine intake. An increase in fruit intake has also been reported in studies comparing pregnant to non-pregnant women (Anderson et

al, 1993; Verbeke et al, 2007), although one study found little difference between these groups (Inskip et al., 2009). Although fruit and vegetable intake was widely reported to increase during pregnancy, it cannot be assumed that all women adequately consumed the national recommendations for fruit and vegetable consumption per day. Smedley et al. (2014) reported that although fruit and vegetable consumption increased during pregnancy, only two thirds of participants reported consuming the recommend quantities of fruit and vegetable as suggested by the Australian public health guidelines (National Health and Medical Research Council, 2003). As fruit and vegetable intake is recommended as part of a healthy balanced diet, and their increased consumption is linked with a number of positive health outcomes (Slavin and Lloyd, 2012), the results indicate that more information should be provided to women before and during pregnancy on the importance of not only increased fruit and vegetable consumption but to ensure they reach the correct public health recommendations for their country.

Two studies found an increase in milk and dairy consumption (Pinto et al. 2008 and Crozier et al., 2009a). This is in line with other research findings where pregnant women report higher dairy intake compared to non-pregnant women (Anderson et al, 1993; Verbeke et al, 2007). This increase is positive as the recommended intake of calcium increases during pregnancy and studies reporting micronutrient intake only indicate that calcium intake increases during pregnancy (Aden et al., 2007) which could further explain the reported increase in dairy consumption (Crozier et al., 2009a and Pinto et al., 2008). The increase in dairy consumption could also account for the increase in energy intake recorded (Koop-Hoolihan, 1999; Cuco et al., 2006a and 2006b and Aden et al., 2007), particularly as the types of products consumed may correspond to more energy-dense foods such as full-fat milk and cheese (Crozier et al., 2009a).

In terms of beverages, there was encouraging findings that women decrease their coffee intake when pregnant and increase their milk intake. A decrease in daily caffeine intake has also been found in women attempting pregnancy (Lum et al., 2011), this suggests it is a component of healthy eating some women are aware of. In terms of fruit juices and sugar-sweetened drinks, two studies reported inconsistent findings, and more research is needed. Fruit juices and sugar-sweetened drinks are both important to target for weight-management as they are often high in calories.

In addition, the proportion of women consuming liver and kidneys was 48% pre-conception, 22% in early pregnancy and 16% in late pregnancy (Crozier et al., 2009a); this change in consumption is consistent with previous public health messages in pregnancy relating to the harmful effects of

362 excess vitamin A consumption through liver consumption (NHS Choices, 2015), despite little
363 scientific evidence to support this (Strobel et al., 2007). Similarly the decrease of consumption in fast
364 food reported (Smedley et al., 2014) could be due to public health education programmes in
365 Australia relating to foods not to eat to avoid Listeria (Anderson, 2001). Indeed, previous research
366 has suggested that health education around effective weight management can affect weight gain
367 during pregnancy (Wilkinson et al., 2009), with further evidence to suggest that pre-conception
368 interventions can improve both the intention and self-efficacy of healthy eating behaviours during
369 pregnancy (Hillemeier et al., 2008). There is also emerging evidence to suggest that women start
370 eating healthily in preparation for pregnancy (Ramage et al, 2015).
371
372 The variation in dietary intake changes reported before and during pregnancy in the reviewed
373 studies, may be due to the disparity of nutritional and lifestyle advice given by different countries
374 (Shawe et al., 2015). A recent publication by Shawe et al. (2015) reviewed the pre-conception care
375 policy, guidelines and recommendations of six European countries (Belgium, Denmark, Italy,
376 Netherlands, Sweden and UK) and reported that there were large variations between countries
377 particularly in relation to fish, caffeine and alcohol consumption. This could account for some of the
378 inconsistent results reported by the current studies reviewed.
379
380 *Characteristics of the women who report changing their dietary intake from before to during*
381 *pregnancy*
382 Only four studies reported characteristics of the women making dietary changes. Findings suggest
383 that education and age may be linked to dietary intake (Crozier et al. 2009b; Cuco et al. 2006a;
384 Skreden et al., 2014) where older and more educated women tend to make healthier dietary
385 changes. Findings from one study suggest that pregnancy intention may be associated with coffee
386 intake (Hellerstedt et al., 1998). Since our search, a recent study fitting the scope of our review has
387 been published where older pregnant women were more likely to decrease their intake of processed
388 foods compared to younger pregnant women (Alves-Santos et al, 2016). Thus, whilst it is
389 disappointing that so few studies examined the demographic and pregnancy factors that may be
390 associated with dietary changes, our findings suggest that age, education and pregnancy intention
391 may be factors worthy further examination. For example, nutrition awareness has been found to be
392 higher in women trying to conceive compared to those women not trying to conceive (Szwajcer et al,
393 2012). This information is likely to be important for targeting the right population of women with
394 interventions and support.
395

Strengths and limitations

There are a number of strengths and limitations relating to the evidence presented in this review. Quality assessment of the 11 studies included using the SIGN checklist, reported the studies to be acceptable or highly acceptable in quality (Scottish Intercollegiate Guidelines Network, 2016). This indicates that despite the relatively low number of articles meeting the inclusion criteria (n=11) they were overall of good quality. Another strength was the range of countries in which the data was collected from, showing consistency in dietary change across different cultures although only English language articles were included.

One limitation of the literature included in the review is the different methods used to measure dietary intake. Ranging from food frequency questionnaires (FFQ), food diaries (FD; 3 and 7 day; weighed and unweighed) as well 24 hour dietary recall methods. Pinto et al. (2008) justified the use of an FFQ in their study as it allowed for retrospective estimation of dietary intake to be collected. However they also recorded intake with a 3 day food diary during pregnancy (Pinto et al., 2008) and reported that differences in intake recorded between the methods may be due to previous evidence indicating that the FFQ tends to overestimate intake whereas FD tends to underestimate (Cade et al., 2002). In addition, the longer the period of dietary recording, the greater likelihood of participant fatigue and therefore potential under or overestimation of dietary intake (Buzzard, 1998).

Studies included in this review were both prospective and retrospective in nature. Retrospective studies are limited in quality as they are subject to participant recall bias and potentially the prior knowledge of pregnancy outcomes could have affected the outcome of dietary intake recall (Pinto et al., 2008). In addition, recall bias may have been greater in women who experienced nausea and vomiting in early pregnancy and this may have affected dietary intake patterns when comparing pre-conception to during pregnancy (Pinto et al., 2008). Furthermore, the diversity of time points used by researchers is problematic, as women may change their eating throughout pregnancy. That said, those studies that measured diet at different time points in pregnancy report inconsistent findings regarding whether diet changes or not (Pinto et al., 2008; Cuco et al., 2006a). Clearly more research is needed. Not all included papers in this review reported changes in dietary intake as a primary objective and thus not conducting significance testing. These papers were still included due the authors to wanting to include all identified evidence in the review.

In addition, this review only included studies if they used a within-group study design. It must be acknowledged that studies using this design are subject to a number of limitations including practice

effects and fatigue, with participants potentially becoming more attuned to detailing their dietary intake practices, increasing the likelihood of miss-reporting. As such, this needs to be considered when interpreting the results. It must also be acknowledged that the review question could have been answered using other research designs such as comparisons between groups of pregnant and non-pregnant women. We have compared our review findings with evidence from such studies in the Discussion section, and shown that our findings are in line with these studies.

Implications and future directions

This review provides implications for both healthcare professionals, such as midwives, and intervention developers. Women often report wanting information early in their pregnancy about healthy eating (Olander et al., 2012). Healthcare professionals are consistently identified as the key source of information regarding healthy diet in pregnancy (Olander et al., 2012 and Smedley et al., 2014) and thus it is important for midwives and others to be aware of the dietary changes women may make when becoming pregnant, so that positive changes can be supported and built upon. It is also important to be mindful that a planned pregnancy may not necessarily mean women are healthier in preconception, and thus are likely to need the same advice as those women who have an unplanned pregnancy.

For intervention developers, these review findings are important to consider when targeting dietary intake in pregnancy. This review has identified food groups and characteristics of women that may confound intervention results. The review identifies that future studies should develop an agreed set of measures (timeframes, dietary recording techniques) for use across studies on this topic to reduce the problem of heterogeneity in this area. A successful intervention must be able to identify what behaviours women may change spontaneously when becoming pregnant and what behaviours they need support with.

Conclusion

Dietary intake before and during pregnancy has significant implications for the mother and unborn child with a number of health outcomes related to poor dietary intake. The current literature available on women's change in dietary intake, using within-subject design, from before to during pregnancy is limited to a handful of studies using a variety of dietary intake recording methods on a wide range of dietary variables to collect data both prospectively and retrospectively and whose overall quality is acceptable or highly acceptable. The evidence suggests that a number of changes in dietary intake may take place during pregnancy (such as an increase in fruit and vegetable intake),

but that a number of other key components relating to high energy dense foods are inconsistent which could have far reaching implications in terms of energy balance and excess weight gain during pregnancy. Further research needs to be conducted investigating the changes in dietary intake before and during pregnancy prospectively, using this alongside records of weight gain and pregnancy outcomes in both mother and child to determine the longer term health implications of poor dietary intake.

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591

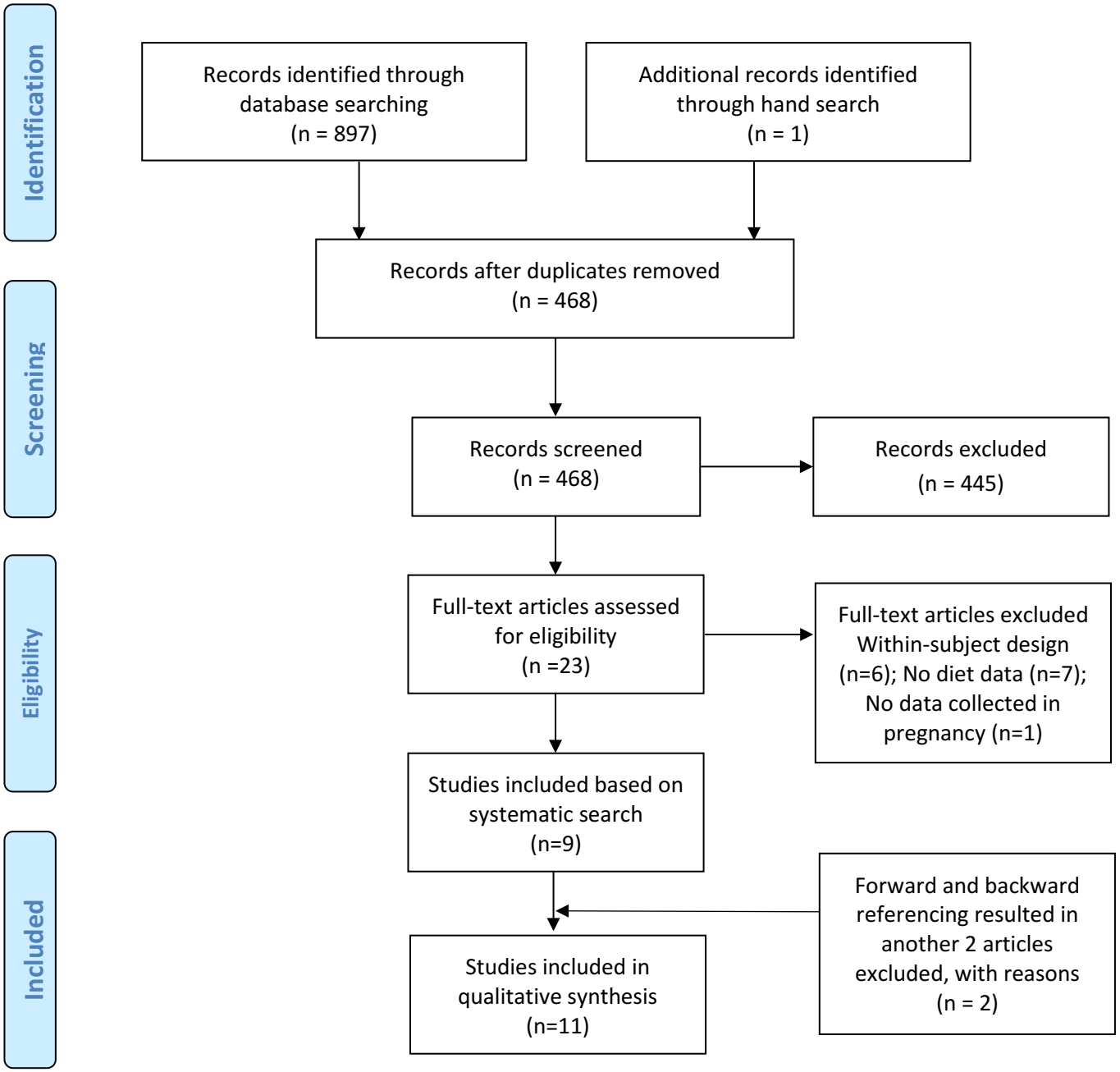
Acknowledgements:

We are very grateful for the comments made by two anonymous reviewers on our submitted manuscript. These comments helped strengthen the manuscript.

595 **Figure 1.** Flowchart describing the number of articles retrieved, and included and excluded at each

596 stage of the review process

597



598 **Table 1.** Summary of studies included in review.

Study authors, year (country)	Sample characteristics	Study design (prospective / retrospective)	When was diet measured?	What was measured?	How was diet measured?	Change in diet	Women's characteristics
Aden et al, 2007 (Sweden)	**Sample size:** 50 **Age:** 30 years (SD 4.6; range 18-40 years) **Gestation weeks:** 18.1 (SD 1.1; range 15-21) weeks **Weight category:** Pre-pregnant BMI mean 23.2 (SD3.1, 17.1-32.4) **SES or similar:** Before pregnancy FT working 52% Student 20% PT working 16% Unemployed/sick leave 4% Other 8% **Education:** Not reported **Ethnicity:** Swedish 92% Asian 6%, Persian 2% **Smoking:** Pre-pregnancy 16%, during pregnancy 6% **NCD's:** Not reported **Parity:** 62% first time mothers 38% one or more children	Retrospective	18 weeks gestation	Energy and nutrient intake	Self-administered, validated FFQ (84 items)	Intake mean (no p-values reported) **Energy (kcal)** Pre-pregnancy 1852 (SD 751) Pregnancy 2104 (SD 583) **Energy (MJ)** Pre-pregnancy 7.75 (SD 3.14) Pregnancy 8.81 (SD 2.44) **Carbohydrates (E%)** Pre-pregnancy 48.1 (SD 5.3) Pregnancy 51.1 (SD 6.6) **Protein (E%)** Pre-pregnancy 14.6 (SD 2.1) Pregnancy 16.8 (SD 2.4) **Fat (E%)** Pre-pregnancy 35.9 (5.4) Pregnancy 32.1 (SD 6.4)	None Reported.
Crozier et al, 2009a (United Kingdom)	**Sample size:** 2057 **Age:** Not reported **Gestation weeks:** N/A **Weight category:** Not reported **SES or similar:** Not reported **Education:** Not reported **Ethnicity:** Not reported	Prospective	Pre-pregnancy, 11 and 34 weeks gestation. Conception was on average 1.8 years after pre-pregnancy data collection	White bread, breakfast cereals, cakes and biscuits, processed meat, crisps, fruit and fruit juices, dried fruit, sweet	Validated interviewer-administered FFQ	Intake of white bread, breakfast cereals, cakes and biscuits, processed meat, crisps, fruit and fruit juices, dried fruit, sweet spreads, confectionery, and hot chocolate drinks increased from pre-pregnancy to pregnancy (all $p<0.0001$). Consumption of breakfast cereals, cakes	None Reported.

	Smoking: Not reported **NCD's:** Not reported **Parity:** Not reported			spreads, confectionery, and hot chocolate drinks, fruit, sweet spreads, puddings, cream, milk, cheese, full-fat spread, cooking fats and salad oils, red meat, soft drinks, rice and pasta, liver and kidney, vegetables, vegetable dishes, nuts, tea, coffee, boiled potatoes, crackers.		and biscuits, processed meat, non-citrus fruit, sweet spreads, and hot chocolate drinks increased further in late pregnancy (all p<0.0001). Puddings, cream, milk, cheese, full-fat spread, cooking fats and salad oils, red meat, and soft drinks did not change in early pregnancy, they increased in late pregnancy (all p<0.001). Intakes of 10 foods or food groups decreased in pregnancy. These were consumption of rice and pasta, liver and kidney, salad vegetables, other vegetables, vegetable dishes, nuts, diet cola, tea, and coffee were lower in pregnancy than before pregnancy (all p<0.0001). Compared to early pregnancy, consumption of rice, pasta, liver, and kidney were lower again in late pregnancy (p<0.001). Consumption of green vegetables, boiled potatoes, and crackers did not change in early pregnancy but decreased in late pregnancy.	
Crozier et al, 2009b (United Kingdom)	**Sample size:** 1490 **Age:** 28.2 years **Gestation weeks:** N/A **Weight category:** Non-pregnant BMI mean 24.3 **SES or similar:**	Prospective	Pre-pregnancy, 11 and 34 weeks gestation	Portions of fruit and vegetables per day Caffeinated drinks/day (i.e. coffee,	Interviewer-administered 100-item food frequency questionnaire	Fruit and vegetable median scores 5.2 (IQR 3.7-7.0) pre-pregnancy, 5.3 (IQR 3.7-7.0) 11 weeks gestation, 5.4 (IQR 3.9-7.2) 34 weeks gestation. Eating <5 portions of fruit and	None Reported.

	Education: None 2.3% GCSE grade D or below 10.3% GCSE graded C or above 28.4% A level or equivalent 29.3% HND or equivalent 7.8% Degree 21.9% **Ethnicity:** 96.2% White 3.8% Non-white **Smoking:** 26.6% yes pre-pregnancy **NCD's:** Not reported **Parity:** Not reported			caffeinated tea and cola)		vegetables a day: 47% pre-pregnancy, 46% 11 weeks gestation, 44% 34 weeks gestation (NS change btw time points) Caffeinated drinks median scores: 4.1 (IQR 2-6) pre-pregnancy, 2.0 (IQR 0.6-4.1) 11 weeks gestation, 2.3 (IQR 0.9-4.3) 34 weeks gestation. Drinking >300mg of caffeine in drinks per day: 39% before pregnancy, 16% 11 weeks gestation, 20% 34 weeks gestation. All changes significant. P < 0.05	
Cuco et al, 2006a (Spain)	**Sample size:** 80 **Age:** 29 years (24-35 years) **Gestation weeks:** Not reported **Weight category:** 6.3% below BMI 20 70% BMI 20-25 20% BMI 25-30 3.8% above 30 BMI **SES or similar:** Not reported **Education:** Only primary education 22.5% Secondary education and vocational training 40% University education 37.5% **Ethnicity:** Not reported **Smoking:** Not reported **NCD's:** Not reported **Parity:** Not reported	Prospective	Pre-pregnancy, 6, 10, 26 and 38 weeks gestation and 6 months postpartum	Energy intake (kcal)	7 consecutive day dietary record	Data reported as 50th percentile (25th-75th percentile) No p-values reported. **Energy intake (kcal)** Preconception 1910 (1730-2237) 6 weeks 1896 (1664-2076) 10 weeks 2017 (1743-2231) 26 weeks 2032 (1794-2251) 38 weeks 1899 (1680-2157) 6 months postpartum 1767 (1536-1957)	None Reported.
Cuco et al, 2006b(Spain)	**Sample size:** 77 **Age: 27.3%** 24-27 years 50.6% 28-31 years	Prospective	Pre-pregnancy, 6, 10, 26 and 38 weeks gestation	Energy intake (kcal), protein (g), carbohydrates	7 consecutive day dietary record	Data reported as 50th percentile (25th-75th percentile) No p-values reported. **Energy intake (kcal)**	None Reported.

	22.1% ≥32 years **Gestation weeks:** N/A **Weight category:** pre-pregnancy: 6.5% <BMI 20 71.4% BMI 20-25 18.2% BMI >25-30 3.9% BMI >30 **SES or similar:** Not reported **Education:** Not reported **Ethnicity:** Not reported **Smoking:** 48.1% never 14.3% ex-smokers 13% pre-pregnancy **NCD's:** Not reported **Parity:** 67.5% primiparae			(g), fats (g), animal proteins (g) vegetable proteins (g)		Preconception 1940 (1743-2311) 6 weeks 1908 (1667-2084) 10 weeks 2037 (1742-2258) 26 weeks 2035 (1813-2299) 38 weeks 1904 (1688-2169) **Proteins (g)** Preconception 80 (71.5-91.9) 6 weeks 76.4 (68.8-86) 10 weeks 79.9 (67.3-87.6) 26 weeks 80.5 (70.6-93) 38 weeks 79.9 (68.4-87.5) **Carbohydrates (g)** Preconception 182.2 (157.3-226.4) 6 weeks 182.9 (163.1-212) 10 weeks 199.4 (178.9-230.2) 26 weeks 206.7 (175-239.9) 38 weeks 191.8 (165-223.4) **Fats (g)** Preconception 91.6 (82-118.2) 6 weeks 91.9 (79.8-103.6) 10 weeks 98 (79.8-110.1) 26 weeks 97.3 (83.8-111) 38 weeks 92.9 (75.6-104.6) **Animal proteins (g)** Preconception 54.7 (46.7-62.8) 6 weeks 51.7 (43.6-58.7) 10 weeks 48.5 (40.6-58.2) 26 weeks 50.9 (42.9-64.3) 38 weeks 52.9 (43.6-65.1) **Vegetables proteins (g)** Preconception 17.7 (14.6-22.9) 6 weeks 19.1 (15.5-22.7) 10 weeks 21.3 (16.6-25.5) 26 weeks 20.5 (17.4-24.9) 38 weeks 18.6 (15.9-22.2)	
Hellerstedt et	**Sample size**: 8827 (7174)	Retrospective	1-20 weeks	Daily Caffeine	Telephone	Caffeine:	Pregnancy intention:

al, 1997 (USA)	**Age**: 18-48yr **Gestation weeks**: Mean 8 weeks (1-20 weeks) **Weight category**: Not reported **SES or similar**: Employed - (82.7, 79.1, 68.8%) **Education**: 37% college degrees 12% graduate education **Ethnicity:** White – (89.1, 82.6, 77.7%) **Smoking**: Not reported **NCD's:** Not reported **Parity**: 65.5-94.9%		gestation		survey (yes/no, categorical questions)	*Preconception* (67.5, 69.8, 73.8) *Pregnancy* (26.0,28.6, 38.7) All changes are P <.01.	Women with intended pregnancies, compared to those who reported the pregnancy was unintended, were more likely to report decreased consumption of caffeine in pregnancy.
Kopp-Hoolihan et al, 1999 (USA)	**Sample size:** 10 **Age:** 29.1 ± 5 (21-36 yrs) **Gestation weeks: n/a** **Weight category:** 23.1 ± 2.1 (19-26 kg/m2) **SES or similar:** Not stated **Education:** Not stated **Ethnicity:** Not reported **Smoking:** Not reported **NCD's:** Not reported **Parity:** 2nd or 3rd child	Prospective	T0 - Preconception (within 3months of pregnancy) T1, 2, 3 – Wk 8-10, 24-26, 34-36) TPost- 4-6 wk postpartum	RMR, DIT, TEE (active EE), EI and Body composition	3 day weighed food diary at each time point EI and Macronutrient content estimated at each time point from the 3d averaged values	**Energy Intake only:** 9% increase from T0 – T3 T0 – 8569 ± 1842 T1 – 8488 ± 1624 T2 – 8496 ± 1654 T3 – 9344 ± 2170 TPost – 8367 ± 2624 Large inter-individual variation	None reported

Paulik et al, 2009 (Hungary)	**Sample size:** 349 **Age:** 16-45 years Mean = 29.94 years **Gestation weeks:** 28.7 ± 0.7 weeks **Weight category:** not stated **SES or similar:** 7.4% Single **Education:** 37.5% secondary education 37.2% higher education **Ethnicity:** Not reported **Smoking:** Not reported **NCD's:** 78.7% in good or very good health **Parity:** 56.4% primiparae	Retrospective	During pregnancy (average 28.7 weeks gestation)	Fruit, vegetables, milk, coffee	Questionnaire	P-values not reported **Fruit** (85.7% vs 94.8%) **Vegetables** (67.6% vs 75.4%) **Milk** (66.8% vs 60.2%) **Coffee** (56.2% vs 33.2%)	None Reported
Pinto et al, 2008 Portugal	**Sample size:** 249 **Age:** 29 years (SD5.8) **Gestation weeks:** First trimester **Weight category:** 57% normal weight before pregnancy Pre-Preg BMI <18.5 = 3.4% 18.5-24 = 57.4% 25-30 = 28.4% >30 = 10.5% **SES or similar:** Employment- Student = 19.8%; employed = 59.5%; unemployed = 20.7%	Prospective	FFQ1 – first antenatal visit in trimester 1 (preconception) FFQ2 – After delivery (for whole pregnancy)	Energy (kcal) CHO (%TEI) Fat (%TEI) SFA (%TEI) Protein (%TEI) Caffeine (mg)	Semi-Quantitative FFQ with pre-specified portion sizes	**Preconception vs pregnancy** Energy (kcal) 2393 vs 2423 CHO (%TEI) 49.5% vs 50.3% Fat (%TEI) 31% vs 30.6% SFA (%TEI) 10% vs 10.5 Protein (%TEI) 17.6% vs 18.4% Caffeine (mg) 64.8 vs 34.4	None reported

	Education: <6yr = 31.7% 7-9yr = 29.3% 10-12yr = 26.1% >12 = 12.9% **Ethnicity:** Not stated **Smoking:** (1st, 2nd, 3rd tri) (25%, 15.3%, 13.4%) **NCD's:** Not reported **Parity:** 0 = 62.7%; +1 = 37.3%)						
Skreden et al, 2014 (Norway)	**Sample size: 575** **Age:** 28.1 years (SD 4.35) **Gestation weeks:** 15 weeks gestation (range 5-20 weeks) **Weight category:** healthy weight (70.2%), overweight category (21.9%), obese category (7.5%) **Mean BMI:** 23.9 (SD 3.83) **SES or similar:** Not reported **Education:** 7-10 years 1.6% 10-12 years 12.9% Completed high school 16.9% < 4 years university/college 33.1% ≥ 4 yeayrs, 35.5% **Ethnicity:** Not reported **Smoking:** Not reported **NCD's:** Not reported **Parity:** Not reported	Retrospective	15 weeks gestation (range 5-20 weeks) And 'before they got pregnant'	Milk, water, coffee, sugar-sweetened beverages (SSB), artificially sweetened beverages (ASB), fruit juice	Food frequency questionnaire (0-never, 10-several times daily)	From pre-pregnancy to early pregnancy: the percentage of women drinking coffee decreased (38 % v. 10%, p<0·001), SSB decreased (10 % v. 6%, p=0·011) and ASB (12 % v. 9%, P =0·001) decreased of those reporting drinking it daily. Percentage of women who reported at least daily consumption of water (85 % v. 92%, P<0·001), fruit juice (14 % v. 20%, P=0·001) and milk (37 % v. 42%, P=0·001) increased.	**Education:** Women with higher educational attainment reduced their frequency of at least daily coffee consumption (46% v. 12%) more than women with lower educational attainment (31% v. 9 %; interaction time×education, P=0·005). **Age (≥25 yrs vs <25yrs):** Older women reported a larger decrease in at least daily consumption of artificially sweetened beverages (17% v. 11%) compared with younger women (7% v. 7 %; interaction timexage, (P=0.045).

							Older women increased their frequency of at least daily consumption of fruit juice (17 % v. 27%) and daily intake of milk (35% v. 43%) from pre-pregnancy to early pregnancy more than younger women (fruit juice: 11% v. 13%; interaction time×age, P=0·029; milk; (39 % v. 40%; interaction time×age, P=0·041). **BMI:** No significant interactions found between BMI and changes in drinking habits from prepregnancy to pregnancy.
Smedley et al, 2014 (Australia)	**Sample size:** 100 **Age:** 18 – 24 years = 11 >25 years = 89 **Gestation weeks:** Postnatal (up to 12 months) **Weight category:** BMI: 18.5-25 = 69 25-30 = 20 30+ = 11 **SES or similar:**	Retrospective	12 months post birth (retrospective pre-conception and during pregnancy)	Dietary intake	Self-complete questionnaire (5-point Likert scale)	**Fruit (p 0.002)** Never (10 v 5) Sometimes (25 v 17) Always (65 v 78) **Veg (p 0.001)** Never (10 v 5) Sometimes (29 v 18) Always (61 v 77) **Fibre (p 0.001)** Never (22 v 8) Sometimes (23 v 16)	None reported

	Employed = 91 Unemployed = 9 **Education:** High school = 20 Tech college = 22 University = 58 **Ethnicity: n/a** Country of Birth Oz = 70 Other = 30 **Smoking:** Non= 68 Ex = 18 Current = 4 **NCD's:** Not reported None **Parity:** 1 child = 88 1 + = 12					Always (55 v 76) **Fried Food (NS)** Never (56 v 67) Sometimes (34 v 28) Always (10 v 5) **Fast Food (P0.017)** Never (56 v 67) Sometimes (34 v 28) Always (10 v 5) **Sweet Bakery (NS)** Never (38 v 40) Sometimes (47 v 40) Always (10 v 20) **Sweet Dairy (NS)** Never (25 v 27) Sometimes (41 v 32) Always (34 v 41)	

599

600 (SD=standard deviation, FFQ=food frequency questionnaire, NCD=Non-communicable diseases, RMR=Resting Metabolic Rate, DIT=Diet Induced Thermogenesis, TEE=Total
601 Energy Expenditure, EI= Energy intake

602 **Supplementary Table 1**: Quality assessment of included studies

Author (year) / Checklist item	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	1.13	1.14	2.1
Aden et al, 2007	Yes	DNA	Yes	DNA	DNA	DNA	Yes	DNA	Can't Say	Yes	Yes	DNA	No	Yes	Acceptable
Crozier et al, 2009a	Yes	DNA	Yes	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Can't Say	No	Acceptable
Crozier et al, 2009b	Yes	DNA	Yes	No	DNA	DNA	Yes	No	No	Yes	Yes	Yes	Can't Say	Yes	High quality
Cuco et al, 2006a	Yes	DNA	Yes	DNA	DNA	DNA	Yes	No	Can't Say	Yes	Can't Say	Yes	Yes	Yes	Acceptable
Cuco et al, 2005b	Yes	DNA	Yes	DNA	DNA	DNA	Yes	No	Can't Say	Yes	Can't Say	Yes	Yes	Yes	Acceptable
Hellerstedt et al, 1997	Yes	DNA	Yes	DNA	DNA	DNA	Yes	DNA	Can't Say	Yes	No	No	No	Yes	Acceptable
Kopp-Hoolihan et al, 1999	Yes	DNA	Yes	DNA	DNA	DNA	Yes	No	No	Yes	Can’t say	Yes	Can't Say	No	Acceptable
Paulik et al, 2009	Yes	DNA	Yes	DNA	DNA	DNA	Can't Say	DNA	Can't Say	Can't Say	No	Yes	No	No	Acceptable
Pinto et al, 2009	Yes	DNA	Yes	DNA	DNA	DNA	Yes	DNA	Can't Say	Yes	Can't Say	DNA	No	Yes	Acceptable
Skreden et al, 2015	Yes	DNA	Yes	DNA	DNA	DNA	Yes	DNA	No	Yes	Can’t say	DNA	Can't Say	Yes	Acceptable
Smedley et al, 2014	Yes	DNA	Yes	DNA	DNA	DNA	Yes	DNA	No	Can't Say	Can't Say	DNA	Can't Say	No	Acceptable

603 DNA – does not apply

604

Checklist items

1.1 The study addresses an appropriate and clearly focused question

1.2 The two groups being studied are selected from source populations that are comparable in all respects other than the factor under investigation. (Deemed not applicable in this review)

1.3 The study indicates how many of the people asked to take part did so, in each of the groups being studied

1.4 The likelihood that some eligible subjects might have the outcome at the time of enrolment is assessed and taken into account in the analysis.

1.5 What percentage of individuals or clusters recruited into each arm of the study dropped out before the study was completed? (Applies to prospective studies only)

1.6 Comparison is made between full participants and those lost to follow up, by exposure status. (Applies to prospective studies only)

1.7 The outcomes are clearly defined.

1.8 The assessment of outcome is made blind to exposure status. If the study is retrospective this may not be applicable.

1.9 Where blinding was not possible, there is some recognition that knowledge of exposure status could have influenced the assessment of outcome

1.10 The method of assessment of exposure is reliable

1.11 Evidence from other sources is used to demonstrate that the method of outcome assessment is valid and reliable

1.12 Exposure level or prognostic factor is assessed more than once (In this review – has dietary intake been assessed more than once in pregnancy/postpartum?)

1.13 The main potential confounders are identified and taken into account in the design and analysis.

1.14 Have confidence intervals been provided?

2.1 How well has the study done to minimise the risk of bias or confounding?

625 **Supplementary Table 2:** Details of studies excluded from systematic review and reason for exclusion.

Author	Year	Title and Journal	Reason for exclusion
Ådén et al.	2007	Energy and nutrients in self-reported diet before and at week 18-22 of pregnancy. *Scandinavian Journal of Food and Nutrition* 51(2): 67-73.	No diet data
Anderson et al.	2006	Prevalence of risk factors for adverse pregnancy outcomes during pregnancy and the preconception period -- United States, 2002-2004. *Maternal & Child Health Journal* 10(5): S101-106 101p.	No diet data
Arija et al.	2004	Food consumption, dietary habits and nutritional status of the population of Reus: Follow-up from preconception throughout pregnancy and after birth." *Medicina Clinica* 123(1): 5-11.	Manuscript not in English
Backhausen et al.	2014	Pregnancy planning and lifestyle prior to conception and during early pregnancy among Danish women. *European Journal of Contraception & Reproductive Health Care* 2014; **19**(1): 57-65.	No diet data
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