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A systematic review of dietary assessments of pregnant adolescents in industrialised countries

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Adolescent pregnancy is a major public health challenge for many industrialised countries and is associated with significant medical, nutritional, social and economic risk for mothers and their infants. Despite this, relatively little is known about the nutrient intakes of adolescents during pregnancy. The aim of this study is to review the current evidence relating to the dietary assessment of pregnant adolescents living in industrialised countries. Nine papers were identified that fulfilled the inclusion criteria, seven of which were conducted in the USA. Mean nutrient intakes were compared with the most recent US dietary reference intakes (DRI) for pregnant adolescents. Despite the poor quality of the majority of studies, there appeared to be some consensus to suggest that the nutrient intakes of pregnant adolescents were below the DRI for energy, iron, folate, calcium, vitamin E and magnesium, nutrients which are recognised to be vital for fetal growth and development during pregnancy. Modest differences were observed in nutrient intake between trimesters and age groups. Current research is limited by sampling and measurement bias, and research is urgently required to address these limitations. Further consideration should also be made of the influence of age and of role of socio-economic support on pregnant adolescents' nutrient intake. The achievement of improved nutrition in pregnancy among adolescents requires multidisciplinary collaborations of adolescent health care providers, academics, professional organisations, policy makers, industry and service users. Only once this is achieved can adolescent nutrition, and adolescent nutrition in pregnancy, be significantly and sustainably optimised.

Dietary assessment: Pregnancy: Adolescent: Systematic review

'In the world's rich nations, more than three quarters of a million teenagers will become mothers in the next twelve months' (UNICEF, 2001, p. 3)

Adolescent pregnancy is a major public health challenge for many industrialised countries. In the most up-to-date and comprehensive survey of adolescent birth rates in the industrialised world, it was reported in 1998 that the USA had the highest adolescent birth rate, whilst the UK had the highest adolescent birth rate in Europe. Rates of adolescent births (the number of births per 1000 adolescents aged 15–19 years) in the USA were 52·1 per 1000 births – about four times the European Union average. Adolescent birth rates in the UK were 30·8 per 1000 births – approximately five times those of The Netherlands, three times those of France and twice those of Germany (UNICEF, 2001). Although there is some evidence to suggest that these rates have fallen in recent years, for example the under 18 and under 16 conception rates in England have decreased by 9·8 and 9·9 % respectively since 1998 (Office for National Statistics, 2005), adolescent pregnancy rates remain high.

Adolescent pregnancy is associated with significant medical, nutritional, social and economic risk for mothers and their infants. There is evidence to suggest that the medical risk is particularly severe for young adolescents. Infants born to young adolescents (< 15 years) are twice as likely to be low birth weight (LBW) (< 2500 g) and three times as likely not to survive the neonatal period compared with infants born to adult mothers (Lenders *et al.* 2000). Recent UK data confirm that children born to adolescent mothers have the highest infant mortality rate of 7·9 per 1000 live births. This contrasts with a rate of 4·3 per 1000 live births in women aged 30–34 years (the lowest risk group) (Office for National Statistics, 2004). Rates of spontaneous miscarriage and of very preterm birth (< 32 weeks) are highest in those aged 13–15 years (Olausson *et al.* 1999). Young adolescent mothers are at higher risk for maternal complications than adult mothers, e.g. abnormally high maternal weight gains, pregnancy-induced hypertension, pre-eclampsia, anaemia and renal disease (Hediger *et al.* 1990; Story & Alton, 1995; Lenders *et al.* 2000; Umans & Lindheimer, 2001).

The cause of adverse pregnancy outcome in the adolescent has been debated. Some attribute the poor outcomes to various factors associated with being young, e.g. poor socio-economic status, lifestyle and adequacy of prenatal care, factors which are risk factors for poor birth outcomes in their own right.

Abbreviations: AI, adequate intake; DRI, dietary reference intakes; EAR, estimated average requirements; EER, estimated energy requirement; LBW, low birth weight.

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For example, it has been reported that, in the UK, adolescent mothers are more likely than older mothers to come from unskilled manual backgrounds or live in areas with higher social deprivation; have mother's who were adolescent mothers themselves; have low self-esteem; have low educational achievement (Teenage Pregnancy Unit, 2004); and are more likely than older mothers to smoke during pregnancy (Hamlyn *et al.* 2002). Pregnant adolescents are also more likely to enter prenatal care late and less likely to obtain an adequate quantity of care compared with adults (Stevens-Simon *et al.* 1992). Casanueva and colleagues (1991) investigated the effect of late prenatal care on the nutritional status of 163 pregnant adolescents aged 11–17 years (mean age 15 years (SD 1)) and found that late prenatal care (accessed when $\geq$ 25 weeks pregnant) was associated with increased risk of maternal anaemia, iron deficiency and zinc deficiency.

Other researchers have attributed the poor pregnancy outcomes of adolescent mothers to an independent factor related to some aspect of the woman's physiology, such as gynaecological immaturity, competition for nutrients, or the growth and nutritional status of the mother (King, 2003). A plausible explanation for the negative effect of young gynaecological age on pregnancy outcome is the competition for nutrients between the mother and fetus. The competition for nutrients hypothesis was first proposed by Naeye (1981). Further support for the hypothesis was provided by a study that reported that infants born to young, growing mothers were smaller than those born to adult women (Frisancho *et al.* 1983). In more recent research, Scholl *et al.* (1990, 1994) reported that many pregnant adolescents continue to grow during gestation, as assessed by measuring knee height length, and that these adolescents give birth to smaller infants (about 155 g less) despite a tendency to gain more weight during pregnancy and retain more weight postpartum than non-growing adolescents. In their subsequent research, Scholl *et al.* (2000) found that growing adolescents have a surge in maternal leptin concentrations during the last trimester, which may reduce the rate of maternal fat breakdown during late pregnancy and thereby increase the mother's use of glucose for energy. This would result in less energy being available for fetal growth. Therefore, it looks possible that the still-growing pregnant adolescent partitions metabolic fuels to enable more energy to become available for maternal growth (and therefore higher maternal fat gains) at the expense of that available for fetal growth (resulting in lower birth weights).

Adolescence is a critical period during which lifetime habits are established (Cavadini *et al.* 2000) and, as adolescents are particularly susceptible to certain risk behaviours, including unhealthy eating, the impact that their eating behaviour has on both their short- and long-term nutritional status is considerable. Nutritional surveys have shown that the highest prevalence of nutritional deficiencies occurs in adolescence, with the most commonly noted deficiencies in calcium, iron, zinc, riboflavin, folate and vitamins A and D (e.g. Gregory *et al.* 2000). The dietary habits acquired during adolescence have the potential to enhance or undermine health throughout life. For example, high fat intake during adolescence and into adulthood is associated with an increased risk of heart disease, and low calcium intake during adolescence is associated with low bone density and an increased risk of osteoporosis in later life (Lytle, 2002). Adequate nutrition in adolescent pregnancy therefore presents many challenges for health professionals and policy makers alike. Despite this, relatively little is known about the nutrient intakes of adolescents during pregnancy. The aim of this study is to review the current evidence relating to the dietary assessment of pregnant adolescents living in industrialised countries.

'Adolescence' can be described as the transitional stage of development between childhood and adulthood. It is a cultural and social phenomenon and therefore its end points are not easily defined. *Stedman's Medical Dictionary* defines an adolescent as: 'a young person who has undergone puberty but who has not reached full maturity; a teenager' (2004). For reasons of clarity, here 'adolescence' refers to the ages 13–19 years inclusive (unless otherwise stated).

Methods

The research question applied to the systematic review was 'what is the nature of the nutrient intakes of pregnant adolescents living in industrialised countries?' Papers that focused on adolescents living in non-industrialised countries were not included in this review due to the cultural and socio-economic disparities between the industrialised and non-industrialised world, making synthesis of findings impractical. The systematic review protocol broadly followed the NHS Centre for Reviews and Dissemination guidelines (2001). The main stages of the review are illustrated in Fig. 1.

Stage 1 of the review involved searching for publications using electronic databases, websites and citations, hand searching relevant journals and contacts with experts. The search terms used in the electronic databases were: pregnant, pregnancy, maternal, mother, nutrition, nutrient, food, adolescent, adolescence, teenager, teenage, teen, young, child, girl. The databases searched were: Ovid Medline, CINAHL, British Nursing Index, Proquest Nursing Journals, The Cochrane Library and EBSCO Host Electronic Journals Service. The *Journal of the American Dietetic Association* and the *British Journal of Nutrition* were hand searched. Studies published between 1980 and 2006 were included in the review.

At stage 2 of the review, the title and abstracts were analysed for relevance to the research question and the inclusion and exclusion criteria were applied (see Table 1). Primary papers were then obtained and further scrutinised against the inclusion and exclusion criteria (stage 3). Studies that fulfilled the inclusion criteria were then assessed for quality (stage 4) using quality criteria for quantitative studies (CASP, 2004).

Analysis

Given the methodological variation in the included papers, the papers were tabulated and summarised narratively. Mean nutrient intake data were compared with the most recent US dietary reference intakes (DRI) for pregnant adolescents, as published by the Institute of Medicine, Food and Nutrition Board (1997, 1998, 2000*a*,*b*, 2005). US recommendations were used for purposes of clarity and consistency of comparison, as all but one of the studies was conducted in the USA or US territories. When available, mean nutrient values were compared with the estimated average requirements (EAR). The EAR is defined as 'the average daily nutrient intake level estimated to meet the requirement of half the healthy

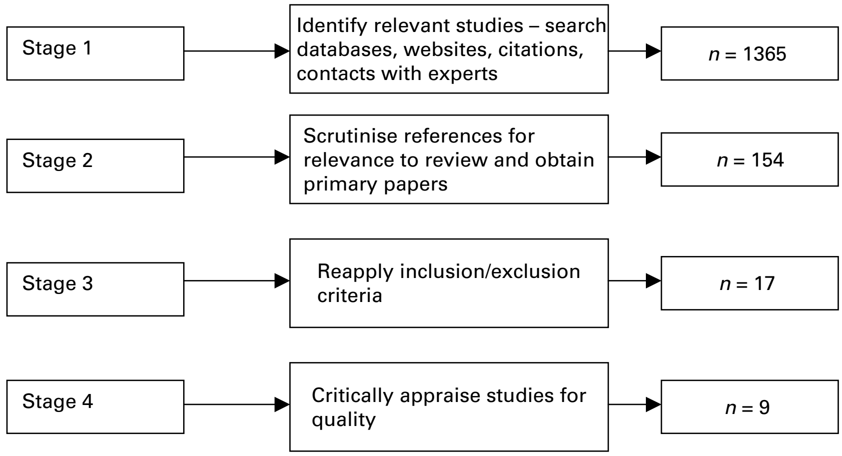

Fig. 1. Main stages of the systematic review process.

individuals in a particular life stage and gender group' (Institute of Medicine, Food & Nutrition Board, 2005, p. 3). Intakes were compared with the EAR in preference to the RDA because, even when the mean nutrient intake of a group is found to equal the RDA, a proportion of persons in the group will still have usual intakes below the EAR due to the large between-subject variation in nutrient intakes. To ensure a low prevalence of intakes below the EAR, the mean intake of a group should exceed the RDA, often by a considerable amount (Gibson, personal communication, 2005). Ideally, the proportion of adolescents meeting or failing to meet the reference standard would be provided in order to evaluate the adequacy of nutrient intakes of a population group. As information on the number of adolescents whose intake falls below the reference standard is unavailable in the majority of studies, the group mean will be compared with the reference standard. For nutrients that do not yet have a defined EAR, the AI (adequate intakes) or RDA were used as reference values. Energy intakes were compared with the estimated energy requirement (EER). In pregnant and lactating women, the EER incorporates 'the needs associated with the deposition of tissues or the secretion of milk at

Table 1. Inclusion and exclusion criteria

Aspect	Inclusion criteria	Exclusion criteria
Types of study	Research papers using any methods	Opinion papers Letters to editor Foreign language
Focus of study	Studies designed to assess the nutrient intakes of pregnant adolescents Studies with emergent findings relating to nutrient intakes of pregnant adolescents	
Participants	Healthy pregnant human adolescents living in industrialised countries	Non-human studies Pregnant adults Non-pregnant or unwell adolescents Adolescents living in non-industrialised countries
Presentation and analysis of data	Papers presenting nutrient intakes as absolute values	Nutrient intakes expressed as the number of participants who consumed more or less than the recommended intakes* Papers that analysed dietary intake by a secondary factor (e.g. high *v.* low sugar consumers)†‡§¶ Papers where dietary intake were presented as % RDA or as nutrient densities (per 1000 kcal) only‖** Duplication of data††

* Burchett & Seely (2003).
† Lenders *et al.* (1994).
‡ Lenders *et al.* (1997).
§ Chang *et al.* (2003).
¶ Carruth (1981).
‖ Endres *et al.* (1987).
** Pope *et al.* (1997).
†† Skinner & Carruth (1991).

rates consistent with good health' (Institute of Medicine, Food & Nutrition Board, 2005, p 3).

Findings

Nine papers were identified that fulfilled the inclusion criteria (see Table 2). Seven of the papers were conducted in the USA, one was conducted in a US territory (Guam, an island located in the western North Pacific Ocean) and one was carried out in Australia. In all but three of the papers, the nutrient intake of adolescents was the primary outcome of interest. Gutierrez's (1999) main outcome measures were maternal weight gain and infant birth weight, whereas Job & Capra (1995) and Giddens *et al.* (2000) conducted a comparative evaluation of the nutrient intakes of pregnant adolescents and pregnant adults. Job & Capra (1995) also compared the intakes of pregnant adolescents and non-pregnant adolescents. Three papers conducted secondary statistical analyses on nutrient intakes at different stages of pregnancy (Job & Capra, 1995; Giddens *et al.* 2000; Pobocik *et al.* 2003), whilst another compared the intake in two trimesters descriptively (Gutierrez, 1999). One paper compared nutrient intakes of pregnant adolescents before and during participation in a supplemental food programme (Endres *et al.* 1985) and two sought to determine whether differences were present among various age groups of adolescents (Job & Capra, 1995; Pobocik *et al.* 2003).

Participants

Participants were aged 13–20 years, with a mean age of between 16 and 17 years. Only one study randomly selected their participants (Giddens *et al.* 2000); the rest used convenience samples. Eligibility criteria for participation were often limited, with only two studies employing exclusion criteria. Gutierrez (1999) excluded multigravida adolescents and those with a history of miscarriage or health problems (e.g. diabetes, kidney or heart problems) and competitive athletes or heavy exercisers, and Job & Capra (1995) excluded adolescents with gestational diabetes. Few of the studies provided clear or detailed information regarding the socio-economic status of the participants in their study. In some studies socio-economic status was implied, whether it was a mix of low and high socio-economic groups (Loris *et al.* 1985) or predominantly a low socio-economic group (Carruth & Skinner, 1991; Giddens *et al.* 2000; Pobocik *et al.* 2003). Two studies provided more detailed information, indicating that their sample consisted of low socio-economic group participants (Endres *et al.* 1985, Skinner *et al.* 1992). Two of the studies related to very specific populations, i.e. Mexican American (Gutierrez, 1999) and Guamananian adolescents (Pobocik *et al.* 2003), both of whom are subject to specific cultural influences limiting the generalisability of these studies to different populations.

Data collection

Data collection methods varied widely between studies, ranging from single 24 h recalls to 7 d estimated food records, as described in Table 2. The measures utilised to ensure the validity of the data collection methods were diverse and often inadequate. Only three studies specified whether the data collector was trained and/or appropriately qualified (Endres *et al.* 1985; Skinner *et al.* 1992; Giddens *et al.* 2000), two trained their participants in the data collection method used (Skinner *et al.* 1992; Giddens *et al.* 2000) and five used models, photographs and/or household measures to aid the estimation of portion sizes (Loris *et al.* 1985; Skinner *et al.* 1992; Job & Capra, 1995; Giddens *et al.* 2000; Pobocik *et al.* 2003). Although some did not specify clearly, it appeared that no studies included the contribution of supplemental vitamins or minerals in their nutrient calculations. Five studies conducted both weekday and weekend assessment of dietary intake (Carruth & Skinner, 1991; Skinner *et al.* 1992; Job & Capra, 1995; Gutierrez, 1999; Giddens *et al.* 2000) and two carried out measurements during different seasons (Job & Capra, 1995; Giddens *et al.* 2000). Only one study collected data regarding the nutritional status of pregnant adolescents. Endres *et al.* (1985) reported Hb and haematocrit values, but provided no methodological detail about the measurements. Pregnancy outcomes were described in three studies: namely infant birth weight (Loris *et al.* 1985; Gutierrez, 1999) and maternal weight gain (Loris *et al.* 1985; Gutierrez, 1999; Giddens *et al.* 2000). Mean infant birth weight ranged from 3288 g (Gutierrez, 1999) to 3377 g (Loris *et al.* 1985), comparing well with reported norms. The WHO Collaborative Study on Maternal Anthropometry and Pregnancy Outcomes showed that birth weights between 3·1 and 3·6 kg, with a mean of 3·3 kg, were associated with the optimal ratio of good fetal and maternal outcomes (WHO, 1995; Kelly *et al.* 1996). Gutierrez (1999) reported that 45 of the 46 births resulted in healthy term infants, whereas eight of 135 infants in Loris and colleagues' study were born preterm and five were small for gestational age (< 2500 g). Mean total maternal weight gains were 14·2 kg (Giddens *et al.* 2000), 14·4 kg (Gutierrez, 1999) and 16·8 kg (Loris *et al.* 1985). These average weight gains were somewhat higher than recent recommendations that healthy, well-nourished women should gain 10–14 kg during pregnancy, with an average of 12 kg, in order to increase the probability of delivering full-term infants with an average birth weight of 3·3 kg, and to reduce the risk of fetal and maternal complications (FAO/WHO/UNU, 2004). All studies, however, were limited by the lack of knowledge of pre-pregnancy BMI, relying instead on use of weight at the first prenatal visit or maternal recollection.

Nutrient intake

Mean nutrient intake data were compared with current US DRI. The nutrient intakes that fell most frequently below the DRI were energy, iron, folate, calcium, vitamin E and magnesium (Table 3).

All nine studies reported that iron intakes of pregnant adolescents fell below the EAR of 23 mg/d. Mean iron intakes were found to be lower in the second than the third trimester of pregnancy ($P < 0·05$, Pobocik *et al.* 2003), although Job & Capra (1995) and Giddens *et al.* (2000) failed to find any statistical difference. Eight studies found that energy intakes were below the EER. Gutierrez (1999) reported that adolescents tended to consume approximately 300 calories more during the third trimester compared with the second trimester, but no statistically significant differences were observed. All of

Table 2. Characteristics of included studies

	Participants		Methods	Results		
Author and country	Age/number	Inclusion criteria	Data collection	Participants	Dietary intake	Quality
Endres *et al.* (1985) USA	Forty-six WIC pregnant adolescents and ninety-one pre-WIC pregnant adolescents aged 15–18 years	All participants met the criteria for the WIC programme (185 % of poverty)	24 h recall Energy and thirteen nutrients assessed	WIC adolescents had received supplemental food for average of 4 months	Nutrient intakes below US DRI: energy, calcium, iron, folate, vitamin E, vitamin B_6	Data collection: data collected by trained interviewers; no details of day of week data collected; unclear whether data included nutrient intake from supplements
		No exclusions	Data collected at 26 weeks (WIC) and 20 weeks (pre-WIC) (means)			Participants: mean age not given; convenience sample; low socio-economic group; no exclusion criteria utilised
Loris *et al.* (1985) USA	Fifty-seven pregnant adolescents aged 13–19 years	Singleton births, recruited from two areas: one predominantly low-income, one middle-/upper-income	24 h recall and FFQ Energy and ten nutrients assessed	27 % of participants received food stamps; 23 % enrolled in WIC	Nutrient intakes below US DRI: iron	Data collection: portions estimated using household measures; no training provided; no details of day of week data collected; unclear whether data included nutrient intake from supplements
		No exclusions	Data collected in second or third trimester			Participants: mean age not given; convenience sample; range of socio-economic groups suggested; limited exclusion criteria utilised
Carruth & Skinner (1991) USA	Thirty-four pregnant adolescents aged 13–18 years	No exclusions	24 h recall and dietary records of two weekdays and one weekend day	Mean age at conception 16·6 years; mean gynaecological age 4·0 + 1·9 years.	Nutrient intakes below US DRI: energy, calcium, iron	Data collection: no details of measures used to ensure validity of data collection tools (no models used, no training, etc.); both weekday and weekend days assessed; nutrient intake from food sources only
			Energy and nine nutrients assessed	Twenty-seven white, seven black; nine lived with both parents, remainder lived with single parents/husbands; three-quarters single; twenty received welfare, one-third of their families received financial assistance		Participants: standard deviation of age not given; convenience sample; some detail of socio-economic grouping; no exclusion criteria utilised
Skinner *et al.* (1992) USA	115 pregnant adolescents aged 13–18 years	White pregnant adolescents; < 18 years old at conception	Data collected at 28–36 weeks Two 24 h recalls and 2 d dietary records, including one weekend day	Mean age 16·3 + 1·2 years; mean Hollingshead index score 26·4 + 9·6 (of a maximum of 66)	Nutrient intakes below US DRI: energy. iron, folate, magnesium	Data collection: food models and measuring utensils used, data taken by registered dietitian, training in food records given, food records checked for accuracy; both weekday and weekend days assessed; unclear if data included nutrient intake from supplements
		No exclusions	Energy and thirteen nutrients assessed			Participants: convenience sample; Hollingshead score of socio-economic status reported, limited exclusion criteria utilised
			Data collected in third trimester			

Table 2. *Continued*

	Participants		Methods	Results		
Author and country	Age/number	Inclusion criteria	Data collection	Participants	Dietary intake	Quality
Dunn *et al.* (1994) USA	Thirty pregnant ‘teenagers’	Participants from a rural southern community	24 h recall Energy and twenty-seven nutrients assessed	Mean age 16 years (three < 14 years); twenty-one black, eight white, one Hispanic; mean age at menarche 11 years; mean gravida one; mean parity zero; mean gynaecological age 6 years	Nutrient intakes below US DRI: energy, dietary fibre, calcium, iron, folate, vitamin E, magnesium, potassium	Data collection: no details of measures used to ensure validity of data collection tools (no models used, no training, etc.); no details of day of week data collected; nutrient intake from food sources only; no details of stage of pregnancy
		No exclusions	No details of stage of pregnancy data given			Participants: range and standard deviation of age not given; convenience sample; no socio-economic data given; no exclusion criteria
Job & Capra (1995) Australia	Thirty-five pregnant adolescents aged 15–18 years	Age ≤ 18 years Exclusions: gestational diabetes	Between one and three 24 h recalls. FFQ used to help validate 24 h recall	Mean age 17 years (range 15–18 years); ‘generally single and supported by families’; ‘majority’ not completed nor intended to complete tertiary education; most Australian born	Nutrient intakes below US DRI: energy, calcium, iron, zinc	Data collection: probing and life-size colour photographs used to estimate portion sizes; no training given; interviews sometimes by telephone; interviews conducted on different days of week and in different seasons; FFQ used to validate 24 h recall data; nutrient intake from food sources only; data collected in three trimesters of pregnancy
					No significant differences were observed between trimesters	Participants: standard deviation of age not given; convenience sample; no socio-economic data given; limited exclusion criteria
			Energy and six nutrients assessed Data collected in first, second and/or third trimester*			Data analysis: statistical comparison of stage of pregnancy
Gutierrez (1999) USA	Forty-six pregnant adolescents aged 13–18 years	Inclusions: primigradida; Mexican American; aged 13–18 years	Two 24 h recalls Energy and eleven nutrients assessed	Mean age 16·34 + 1·56 years (13–18 years); ten US-born, thirty-six Mexican-born; forty-five healthy full-term infants and one preterm; details of living arrangements, income, employment status, financial resources/services accessed provided	Nutrient intakes below US DRI†: energy, iron, folate, vitamin E	Data collection: no details of measures used to ensure validity of data collection tools (no models used, no training, etc.); interviews conducted by bilingual graduate students; data collected on all days of the week; data collected over 18-month period; unclear whether data included nutrient intake from supplements; data collected in two trimesters of pregnancy

Table 2. *Continued*

Author and country	Participants: Age/number	Participants: Inclusion criteria	Methods: Data collection	Results: Participants	Results: Dietary intake	Quality
		Exclusions: history of miscarriage, health problems (e.g. diabetes, kidney or heart problems), competitive athletes, heavy exercisers	Data collected in second trimester (18–22 weeks) and third trimester (30–34 weeks)			Participants: convenience sample; socio-economic data provided; exclusion criteria applied
						Data analysis: descriptive comparison of stage of pregnancy
Giddens *et al.* (2000) USA	Fifty-nine pregnant adolescents aged 13–18 years	Inclusions: all subjects participating in a larger RCT on calcium intake; singleton pregnancy; any ethnicity; 13–19 weeks gestation; all prescribed standard multivitamin/mineral prenatal supplement	Two 7 d food records	Mean age 16·9 + 1·3 yeard (range 14–18 years); 73 % African American, 27 % white; 10 % smokers; none married; mean height 161·6 + 3·9 cm; approximately 95 % of those attending the prenatal recruitment clinics had household income at or below 185 % poverty level	Nutrient intakes below US DRI: energy, dietary fibre, calcium, iron, folate, vitamin E, magnesium	Data collection: 2-D models, measuring utensils and food record guide used; training by an RD and written instructions given; participants telephoned and written to during recording periods; food record checked by RD for accuracy and completeness; weekdays and weekend days recorded; nutrient intake from food sources only; data collected in two trimesters of pregnancy
		No exclusions	Energy and twenty-two nutrients assessed		No statistical difference in mean nutrient intakes between second and third trimesters	Participants: random sample; low socio-economic grouping suggested; no exclusion criteria
			Data collected at 19–21 weeks and 29–31 weeks‡			Data analysis: statistical comparison of second and third trimesters
Pobocik *et al.* (2003) Guam (a US territory)	434 pregnant adolescents aged 14–20 years	No exclusions	24 h recall	14 % aged 14–15 years, 47 % 16–17 years, 39 % 18–20 years; 71 % Chamorro (indigenous Western Pacific Islanders), 17 % Filipino, 3 % white; 65 % enrolled in WIC	Nutrient intakes below US DRI: energy, calcium, iron, folate, vitamin E, magnesium	Data collection: dishes and food models used; use of salt and high-sodium condiments added at table not measured; nutrient intake from food sources only; research assistants used ‘culturally appropriate (data collection) methods’; no details of day of week data collected; data collected in three trimesters of pregnancy

Table 2. *Continued*

Author and country	Participants		Methods	Results		Quality
	Age/number	Inclusion criteria	Data collection	Participants	Dietary intake	
			Energy and fifteen nutrients assessed		Iron lower in second and third trimester ($P<0·05$). Differences also existed for thiamin, riboflavin and phosphorus, but no details given as intakes above RDA.	Participants: convenience sample; majority low socio-economic grouping suggested; no exclusion criteria
			Data collected in first trimester (*n* 77), second trimester (*n* 177) and third trimester (*n* 180)§		Calcium intake declined with increasing age ($P<0·0001$). Phosphorus also varied by age, but no details given as intakes above RDA.	Data analysis: Statistical comparison of three trimesters and age groups 14–15, 16–17 and 18–20 years

WIC, special supplementary nutrition programme for women, infants and children; RD, registered dietician; RCT, randomised controlled trial.
* As no significant differences were found to exist between the first, second and third trimesters, the mean nutrient intakes for the three trimesters (as calculated by the authors) is used.
† In both the second and third trimester. Adolescents tended to consume approximately 300 calories more during the third compared with the second trimester
‡ As no differences were found in mean nutrient values between food records collected during the second and third trimesters, the two sets of food records were combined by the authors.
§ The authors combined the data from three trimesters to provide one nutrient intake record.

the studies that assessed folate intake (*n* 6) found that intakes fell well below the EAR of 520 μg/d during pregnancy. Calcium intakes were below the AI in six of the nine studies, and Pobocik *et al.* (2003) found that calcium intake declined with increasing age ($P<0·0001$). Each of the studies that measured vitamin E (Endres *et al.* 1985; Dunn *et al.* 1994; Giddens *et al.* 2000; Pobocik *et al.* 2003) and dietary fibre (Dunn *et al.* 1994; Giddens *et al.* 2000) recorded mean intakes that were below the DRI. Mean magnesium intakes were below the EAR in four of the five studies included in the review (Skinner *et al.* 1992; Gutierrez, 1999; Giddens *et al.* 2000; Pobocik *et al.* 2003).

Discussion

This systematic review focused only on the dietary assessment of pregnant adolescents living in industrialised countries, as cultural and socio-economic disparities between the industrialised and non-industrialised world would limit the meaningfulness of any synthesis of findings. It is likely for example, that well-nourished women raised in affluent or economically developed societies will have different nutrient needs in pregnancy from those of women from low-income developing societies (FAO/WHO/UNU, 2004). Future systematic reviews should focus on the particular nutrient intakes of pregnant adolescents living in non-industrialised countries. It is possible that the generalisability of the findings presented in this review may be limited because seven of the nine included studies were conducted in the USA. There is no *a priori* reason, however, why these findings would not apply to countries with similar ethnic and socio-economic demographics. The review does highlight the urgent need for further primary studies in non-US settings.

The quality of the studies included in the review was generally poor and all were limited by sampling and/or measurement bias. However, there does appear to be some consensus amongst the studies to suggest that the nutrient intakes of pregnant adolescents were low in a number of nutrients recognised to be vital for fetal growth and development during pregnancy. Crude estimates indicate that, as a percentage of the DRI, mean intakes of energy were 67–105 % of the EER, intakes of iron were 49–99 % of the EAR, calcium intakes were 57–167 % of the AI, folate intakes were 47–86 % of the EAR, intakes of vitamin E were 53–93 % of the EAR and magnesium intakes were 75–106 % of the EAR (percentages dependent on the age of the adolescent).

The Institute of Medicine, Food and Nutrition Board recommends that adolescent and adult women require an additional 1424 kJ/d in the second trimester and an extra 1892 kJ/d in the third trimester compared with the first trimester of pregnancy (Institute of Medicine, Food & Nutrition Board, 2005). Many of the studies included in the review reported that the energy intakes of pregnant adolescents fell below the EER. Studies of energy balance during pregnancy have found that although energy expenditure increases, energy intake does not increase proportionally, yet weight gain remains normal (Prentice *et al.* 1989, 1996). Therefore, it is possible that the DRI overestimates the energy needs of most women during pregnancy (King, 2000). Alternatively, this incongruence could be explained by under-reporting of food intake by participants in dietary studies. It has been

Table 3. Comparison of studies that have investigated the nutrient intakes of pregnant adolescents with US dietary reference intakes (Mean values and standard deviations or standard errors of the mean)

	Endres *et al.* (1985)				Carruth & Skinner (1991)		Loris *et al.* (1985)		Skinner *et al.* (1992)		Dunn *et al.* (1994)	
	WIC		Pre-WIC									
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Energy (kJ)	7988	3136	8068	3747	11 815	4333	9416	2395	10 480	3408	11 572	3827
Total protein (g)	80·3	32·8	76·7	35·0	110	48	88	25	90	30	109·5	43
Total fat (g)											118	56
Cholesterol (mg)											469·7	258
Total carbohydrate (g)											324·5	95
Dietary fibre (g)											13·3	6
Vitamin A (μg RE)	1169*	1313	1169*	1904	1440*	1254	1258*	989	1038*	589		
Vitamin C (mg)	85·5	94·1	99·0	86·8	133	104	121	78	104	80	111	95
Vitamin E (mg α-tocopherol)	8·6†	13·9	6·4†	9·8							11	8
Vitamin D (μg)	5·2‡	4·7	5·2‡	6·2					8·1‡	5·5		
Folate (μg)	243·1	324·5	242·7	240·8					275	150	248	112
Calcium (mg)	918·7	572·6	943·3	644·9	1670	961	1263	478	1317	669	1188	762
Iron (mg)	16·0	12·7	15·1	13·6	16·6	9·5	13·6	4	14·7	6·1	16	8
Zinc (mg)									11·2	4·8	14	6
Copper (mg)											1·3	0·7
Selenium (μg)											133	61
Thiamin (mg)	1·6	1·3	1·5	1·1	1·86	1·11	1·63	0·50	1·9	0·7	2·2	1·1
Riboflavin (mg)	2·4	1·6	2·3	2·0	3·20	2·05	2·46	0·76	2·6	1·1	2·5	1·1
Vitamin B_6 (mg)	1·1	1·3	1·0	1·2					1·7	0·8	2·0	0·9
Vitamin B_{12} (μg)											5·1	2·2
Phosphorus (mg)	1333	612	1311	644	2049	906	1621	512			1744	815
Magnesium (mg)									264	106	307	165
Potassium (mg)					4050	1953					3484	1957
Sodium (mg)											3896	1643
Niacin (mg NE)	18·5	15·4	19·3	14·4	21·5	10·8	19·4	6·5	22·0	7·5	28	9
Pantothenic acid (mg)											6	3

Table 3. *Continued*

	Job & Capra (1995)		Gutierrez (1999) 18–22 weeks gestation		Gutierrez (1999) 30–34 weeks gestation		Giddens *et al.* (2000)		Pobocik *et al.* (2003)		US DRI§ for pregnant adolescents
	Mean	SEM	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Energy (kJ)	8930	398	10 006	3475	10 969	3341	9805	2550	10 413	4425	First trimester 9914–10 061 Second trimester 11 338–11 484 Third trimester 11 807–11 953¶ ‖
Total protein (g)	73	3·4	111·2	45·1	117·7	42·7	82	20	99·0	44·7	46/71**
Total fat (g)							97	28			Not determined
Cholesterol (mg)			324·5	202·9	413·4	249·9	299	89			Not determined
Total carbohydrate (g)							291	82			135
Dietary fibre (g)							14	5			28††
Vitamin A (μg RE)	973	87	2492	3550	1978	1888	1053	572	1093	1579	530–550‖
Vitamin C (mg)	135	22	252·0	152·4	230·7	140·1	128	62	167	183	66–70‖
Vitamin E (mg α-tocopherol)			10·72	11·39	11·15	10·38	9·0	3·5	8	8	12
Vitamin D (μg)							6·4	2·6			5·0††
Folate (μg)			447·4	319·9	392·5	181·1	312	138	292	242	520
Calcium (mg)	923	85	1561	187	1655	800	989	332	743	575	1300–1000‖††
Iron (mg)	11·2	0·5	17·69	8·20	22·72	19·62	16·0	5·7	20	11	23–22‖
Zinc (mg)	9·5	0·5	14·51	6·53	15·29	6·51	11·6	4·2	13	8	10–9·5‖
Copper (mg)							1·2	0·4			0·785–0·8‖
Selenium (μg)							116	29			49
Thiamin (mg)							2·1	0·6	2·4	1·2	1·2
Riboflavin (mg)							2·3	0·7	2·1	1·2	1·2
Vitamin B_6 (mg)							1·9	0·6	2·0	1·2	1·6
Vitamin B_{12} (μg)							5·3	2·8	5·5	7·6	2·2
Phosphorus (mg)							1340	359	1338	632	1055–580‖
Magnesium (mg)							252	72	270	131	335–290‖
Potassium (mg)											4700††
Sodium (mg)											1500††
Niacin (mg NE)							24·1	6·8	30	14	14
Pantothenic acid (mg)											6††

WIC, special supplementary nutrition program for women, infants and children; RE, retinol equivalents; NE, niacin equivalents.
* Converted to μg retinol equivalents (IU/5 = μg RE) for comparison of dietary data.
† Converted to mg α-tocopherol (I IU = 0·67 mg α-tocopherol) for comparison of dietary data.
‡ Converted to μg (I IU = 0·025 μg vitamin D) for comparison of dietary data
§ US dietary reference intakes (DRI) for pregnant adolescents. Unless stated otherwise, the estimated average requirements (EARs) are given.
¶ EER, estimated energy requirement in first/second/third trimester.
‖ Range denotes levels for pregnant adolescents aged 14–18 years and 19 years.
** RDA in first/second half of pregnancy.
†† Adequate intake.

observed that some participants provide diet records that are biased to the underestimation of their true habitual intake, despite appearing highly motivated (Goldberg *et al.* 1993, Smithers *et al.* 2000, Black & Cole, 2001). Such findings provide evidence of the need for very cautious interpretation of food-intake data. Goldberg *et al.* (1993) suggested that measures of energy expenditure were a more credible measure of the daily energy budget throughout gestation. In their longitudinal study of twelve women before and during pregnancy, Goldberg *et al.* (1993) found that there was a substantial inter-individual variation in response to pregnancy, highlighting further difficulties of making prescriptive recommendations for individuals as there is no way of predicting how they will respond (metabolically and behaviourally) to pregnancy.

Iron is needed for the rapid expansion of maternal blood volume and the deposition of iron in fetal tissues. Iron-deficiency anaemia is the most common nutrient deficiency in pregnancy and has also been reported to be at its peak incidence between the ages of 15 and 19 years in non-pregnant girls (Wahl, 1999), related in part to the rapid growth associated with adolescence (Lifshitz *et al.* 1993). The pregnant adolescent is at particular risk of developing iron-deficiency anaemia. Indeed, previous research has reported a high prevalence of anaemia (Schneck *et al.* 1990; Gadowsky *et al.* 1995) and depleted iron stores (Gadowsky *et al.* 1995) in pregnant adolescents. Low iron status in the pregnant adolescent has been associated with reduced fetal oxygenation (Reifsnider & Gill, 2000) and poor birth outcomes, such as a greater risk of LBW, prematurity and an increased risk of stillbirth (Ward, 2000; Tomashek *et al.* 2006).

During growth calcium intake is an important determinant of bone mineralisation and thus bone density. In a still growing adolescent calcium intake during pregnancy may be limited by poor maternal diet and by the need to retain enough calcium to mineralise two skeletons. Magnesium is also vital to bone quality by controlling hydroxyapatite crystal growth to prevent formation of brittle bone. However, our knowledge base to determine magnesium as opposed to calcium requirements is very weak and, without reliable magnesium status indicators, it is difficult to determine whether current intakes are adequate for optimal bone health (Weaver, 2000). Calcium also plays an important role in influencing the contractility of smooth muscle, both in the vasculature and in the uterus. It has been shown that calcium supplementation during pregnancy is associated with a reduced risk of gestational hypertension, pre-term delivery and possibly pre-eclampsia (Repke & Villar, 1991), although the beneficial effects on hypertension and pre-term delivery may be confined to high-risk populations or those who have a high demand for calcium (of which pregnant adolescents are an example) (Lenders *et al.* 2000).

According to US recommendations, pregnant adolescents aged 14–18 years should consume 1300 mg of calcium/d throughout pregnancy (Institute of Medicine, Food & Nutrition Board, 1997). Those aged 19 years and above should consume 1000 mg calcium/d. The majority of studies in the review reported that pregnant adolescents' consumption of calcium was below the recommended amount, and that intake significantly declined with increasing age (Pobocik *et al.* 2003). It is possible that this suboptimal intake could be due, in part, to the preferential consumption of low-calcium beverages such as soft drinks that serve to displace calcium-rich milk drinks (Harnack *et al.* 1999), a phenomenon which has been shown to be generally more prevalent among adolescents of lower parental occupational status compared with those with higher family affluence (Vereecken *et al.* 2005). The decline in calcium intake over the course of adolescence has been reported in previous studies (Gregory *et al.* 2000) and may be related to a decline in milk intake, which has also been observed to decline during adolescence (Harnack *et al.* 1999; Bowman, 2002; Striegel-Moore *et al.* 2006). This could reflect a decrease in breakfast consumption (Bowman, 2002; Lee & Reicks, 2003) or increased intake of meals away from home (Bowman *et al.* 2004) in this population. Clearly, the low calcium intake that was observed in many adolescents could have a serious impact on the health and development of the pregnant adolescent and her fetus. Indeed, recent research has suggested that the consumption of fewer than two servings of dairy products per day by pregnant adolescents could negatively affect fetal bone development by limiting the amount of calcium provided to the fetus (Chang *et al.* 2003).

The consensus amongst the studies was that adolescents' folate intake did not meet the increased requirements of pregnancy. Insufficient intake of folate in the periconceptional period is linked to increased risk of neural tube defects in infants. Evidence from randomised controlled trials that supplementing with folic acid reduces the risk of neural tube defects (MRC Vitamin Study Research Group, 1991) has prompted governments around the world to advise women who could become pregnant to take folic acid supplements (400 μg/d), in addition to ensuring their diet is rich in foods providing folates and folic acid. However, whilst it has been demonstrated that folic acid supplementation is highly effective in optimising folate status in both adults (McNulty *et al.* 2000) and adolescents (Gadowsky *et al.* 1995), nationwide campaigns have been shown to have had limited impact in the primary target group, namely women and adolescents around the time of conception and in the early weeks of pregnancy (Buttriss, 2004). Surveys conducted in the UK, Australia, the USA and Puerto Rico indicate that only around 30 % of the pregnant population use folic acid correctly, i.e. periconceptionally (Wild *et al.* 1997; Miller *et al.* 2000; Honein *et al.* 2001; De La Vega *et al.* 2002). This figure could be even lower in the pregnant adolescent population, with only 14 % of 16–19 year olds reporting being aware of the need to increase folate intake before conception (Wild *et al.* 1996).

The vitamin E intakes of the pregnant adolescents were below the recommended intake amounts. These estimates of intake may be artificially low, however, as the dietary supply of vitamin E is difficult to assess. Food composition data are poor and reported intake of fat and oil, the major sources of vitamin E in the diet, may be underestimated (Gutierrez & King, 1993). Biochemical or clinical evidence of vitamin E deficiency in industrialised countries is rare.

There was limited evidence to suggest that adolescents' nutrient intakes varied according to the stage of pregnancy. Job & Capra (1995), Gutierrez (1999) and Giddens *et al.* (2000) failed to find a significant difference in intakes between trimesters. However, Pobocik and colleagues' (2003) study of 434 adolescents reported that iron intakes were lower in the second compared with the third trimester ($P < 0.05$). Differences also existed for thiamin, riboflavin and phosphorus, but no further details were provided as intakes of these nutrients were above the recommended intake amounts. It is possible that the absence of significant differences observed in the majority of the studies was due to their small sample size, and further large-scale studies are necessary in order to elucidate this.

There were a number of methodological limitations in the studies that should be considered when interpreting these results. The application of exclusion criteria and control of potential confounding variables was limited in most studies, thereby limiting the reliability of the data. All of the studies were subject to sampling bias, with most utilising convenience sampling methods. Only one study used random sampling (Giddens *et al.* 2000). This study, however, was part of a larger randomised controlled trial on calcium intake where participants were prescribed multivitamin/mineral supplements and, consequently, reported a high use of nutrient supplementation (79 % reported a high compliance in taking the supplement). This is in contrast to an earlier study that reported limited use of supplements by pregnant adolescents (Skinner & Carruth, 1991). It is likely that this relatively highly motivated sample of adolescents had dietary habits that differ from those of pregnant adolescents who do not take supplements. Previous research has confirmed that young people who consume dietary supplements tend to have higher intakes of vitamins from food sources than non-supplement users (Gregory *et al.* 2000). Unfortunately, Giddens *et al.* did not examine the dietary differences between supplement users and non-users, and therefore potential differences in nutrient intake cannot be ascertained.

The participants in the included studies tended to be older adolescents, with a mean age of between 16 and 17 years. It is likely that the nutritional requirements of a younger adolescent group (which are needed to sustain their own growth, as well as the growth of their fetus) are different from those of an older adolescent group. Only two studies conducted comparisons of the nutrient intakes of older *v.* younger pregnant adolescents. Job & Capra (1995) compared two groups of adolescents; one aged 15–16 years (*n* 23) and another aged 17–18 years (*n* 47), and found no significant differences between age groups, possibly due to the relatively small sample sizes of the groups. In a larger study, Pobocik *et al.* (2003) found two differences when comparing the nutrient intakes of adolescents aged 14–15 years (*n* 61), 16–17 years (*n* 203) and 18–20 years (*n* 170). They found that calcium intake significantly declined with increasing age, and phosphorus 'varied' with age (but with no further detail provided). Again, due to the lack of available data, conclusions cannot be drawn and further large-scale studies are necessary.

Socio-economic factors are known to exert a strong influence on nutrient intake. Low-income groups are less likely to eat sufficient quantities of fruit and vegetables (Henderson *et al.* 2003) and are more likely to consume whole milk, table sugar and sugar confectionary than higher income groups (Gregory *et al.* 2000). Barriers to good nutritional practices of women living in conditions of material deprivation include problems with access, cost and storage of food (Reid & Adamson, 1997). It has been reported that a high proportion of low-income pregnant adolescents miss meals and resort to buying less healthy 'cheap filler' foods when money runs out (Burchett & Seely, 2003). Over time, such ways of 'managing' poverty can become second nature, despite the potential costs to the adolescents' physical and emotional well-being (Attree, 2005). In addition, whilst peer influences may become more dominant as adolescents get older (Buttriss, 2002), the influence of the family on their food choices and eating behaviours should not be overlooked. A recent study has shown, for example, that parental presence at the evening meal has been positively associated with adolescents' higher consumption of fruit, vegetables and dairy foods (Videon & Manning, 2003). Few of the studies in this review provided sufficient amount of detail regarding the socio-economic and living circumstances of their participants. Without this information, it is not possible to identify accurately adolescents who are in need of specific nutritional intervention.

The majority of studies used data collection methods that were subject to measurement bias. Five studies used 24 h recall to collect dietary data, and three of those took measurements on a single day only. It is widely acknowledged that the 24 h recall method of nutrient intake assessment suffers from many limitations. The success of this method depends on the degree of motivation of the respondent, the persistence of the interviewer, and the participants' memory and their ability to estimate portion sizes. The 24 h recall is also subject to errors brought about by alterations in the food habits of participants. In addition, the 24 h recall method is not indicative of an individual's overall diet, as recording may not take place on a 'typical' day and therefore substantial error may be introduced when assessing a single day's diet (Nelson & Bingham, 1997). The size of the group required for a single 24 h recall to determine the mean usual nutrient intake of a group depends on the day-to-day variation in food intake between participants (i.e. between-subject variation), which is, in turn, affected by the nutrient under study. Generally, for example, for nutrients found in high concentrations in only a few foods, such as vitamin A, vitamin D and cholesterol, the number of records needed is much greater than for those found in a wide range of foods (e.g. protein) (Gibson, 2005). Indeed, large standard deviations can be observed in the included studies for many of the vitamins and minerals, indicating the presence of considerable between-subject variation as well as being reflective of those nutrients found in high amounts in relatively few foods. In addition, many studies failed to take account of weekend and seasonal variations in nutrient intake. Group mean nutrient intakes can vary according to the day of the week and the season in which they were consumed, although this effect is not exhibited by all nutrients (Gibson *et al.* 1985).

Thus, it is clear that, at present, there is a paucity of high-quality research that uses adequate methodological techniques to provide us with a clear description of pregnant adolescents' nutrient intake. Further well-designed and controlled studies are needed which take into account the influence of adolescent age, the stage of pregnancy, and weekly and seasonal variations in nutrient intake. In order to assess the effect of pregnant adolescent's nutrient intakes and the interactions of different nutrients on nutritional status, studies should also include biochemical indices of nutritional status and follow-up studies on maternal and neonatal outcomes. The various socio-cultural influences affecting the pregnant adolescent's nutrient intake should also be investigated further.

The nutritional challenges that face the pregnant adolescent are unique. The increased nutrient demands of pregnancy, together with the increased nutrient demands of the still-growing adolescent, may generate competition for nutrients between mother and fetus. Although relatively limited, the current research seems to suggest that pregnant adolescents' diets are suboptimal, particularly with regards to energy, iron, folate, calcium, vitamin E and magnesium. As up to 75 % of adolescents do not plan pregnancy (Goldberg, 2002), the issue of periconceptional nutrition is problematic. A UK survey of 674 adolescents (aged 14–15 years) on their perceptions of what constitutes a healthy pregnancy revealed that 70 % of respondents thought that the optimum time to initiate changes in what a woman eats and drinks to ensure a healthy pregnancy was when pregnancy had been confirmed (Edwards *et al.* 1997). This suggests that the benefits of pre-conceptual nutrition are not well understood by this population. A further complication is that many adolescents may be unaware of their pregnancy or may not have accessed services in their first trimester, so providing the appropriate support to these individuals may be difficult.

Nutrition in adolescent pregnancy must be viewed within a biopsychosocial context, since it has consistently been shown that there are multiple influencing factors that play a role in the eating behaviour and subsequent nutritional status of the pregnant adolescent. Eating behaviours are likely to be related to other, often 'risky', behaviours displayed in adolescents and should not be viewed in isolation (Irwin *et al.* 1997). Achieving dietary change in this particularly vulnerable section of the population, many of who are from disadvantaged backgrounds (Social Exclusion Unit, 1999), presents a major public health challenge. Biopsychosocial factors often experienced by such groups, including low levels of disposable income, unemployment, poor housing, suboptimal mental and physical health and limited access to a wide variety of reasonably priced foods, all contribute to difficulties in tackling behavioural change (Symon & Wrieden, 2003). These factors, in turn, lead to increasing health inequalities (Acheson, 1998). An important factor that should be considered when developing appropriate and effective strategies to promote healthy eating in pregnant adolescents is the heterogeneity of the group. Factors affecting food choices vary considerably, depending on the individual's particular circumstances. Family and peers are likely to have a strong influence on the eating habits of most pregnant adolescents. Poverty is a significant factor that limits the ability of some pregnant adolescents to eat a healthy diet, even in those who aspire to it.

There are numerous barriers to optimal nutrition in adolescent pregnancy, and any intervention should consider these carefully. Overcoming the barriers in order to achieve improved nutrition in pregnancy among adolescents requires multidisciplinary collaborations of adolescent health care providers, academics, professional organisations, policy makers, industry and service users. Certainly, more needs to be done at a policy level, both with regards to enabling adolescents' access to optimal nutrition and in modifying the nutrition message that adolescents receive. Governments around the world should ensure that there is consistency of food and nutrition messages in schools, for example, to include the curriculum, food provision in the canteen, vending machine policies, breakfast clubs, snacking and lunchbox policies. Any intervention that aims to encourage changes in lifestyle should be multifactorial and incorporate measures to improve the socio-economic circumstances of adolescents and their families. Only once this is achieved can adolescent nutrition, and adolescent nutrition in pregnancy, be significantly and sustainably optimised.

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