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Original Article

Habitual micronutrient intake during and after pregnancy in Caucasian Londoners

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Abstract

Micronutrient status is of fundamental importance both upon conception and throughout pregnancy. There is an abundance of literature investigating nutrient intakes during individual trimesters of pregnancy but few studies have investigated baseline intakes of nutrients throughout gestation as a continuum. The current investigation set out to measure habitual micronutrient intakes at weeks 13, 25, 35 of pregnancy and 6 weeks postpartum using a prospective background information questionnaire, 4–7-day weighed food diary and postnatal questionnaire. Seventy-two primiparous, Caucasian Londoners were recruited at the study start with 42 completing the first, second, third trimester and postpartum study stages respectively. Study findings indicated that sodium intakes were significantly higher than UK guidelines throughout and after pregnancy ($P < 0.001$). Intakes of folate, iron, vitamin D, potassium, iodine and selenium were lower than UK recommendations during and after pregnancy, but to varying levels of statistical significance ($P < 0.05$). Only 23–38% of women met UK recommendations for folate (300 μg day^{-1}) through dietary sources. Similarly, only a small percentage of women met dietary guidelines for iron (19–28%). The findings from the current study indicate that public health interventions may be required to help expectant mothers achieve an optimal diet, particularly after birth when dietary recommendations increase for some micronutrients.

Keywords: pregnancy, postpartum, micronutrients, dietary guidelines.

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Introduction

Adequate intakes of vitamins and minerals are fundamental to fetal health and development (Allen 2005). An insufficient supply of micronutrients can result in a state of biological competition between the mother and conceptus, which may subsequently affect the health status of the mother and child (King 2003). Micronutrients deficiencies may result in poor pregnancy outcomes, including: intrauterine growth retardation (Fall *et al.* 2003), impaired postnatal growth and immune function (Barker & Fall 2000) and an increased risk of diseases in adulthood, including cardiovascular disease and type 2 diabetes (Barker 2003). Furthermore, an inadequate intake of micronutrients during and after pregnancy can result in low levels of secretion into breast milk, forming a cycle that may result in micronutrient depletion in infancy (Allen 2005).

A few studies have investigated maternal micronutrient intakes in the UK, at varying phases of pregnancy. Mouratidou *et al.* (2006) assessed dietary intakes of 250 pregnant women from Sheffield, UK, using a semi-quantified food frequency questionnaire (FFQ) between weeks 14 and 18 of pregnancy. It was reported that 40% of the study population did not meet the Estimated Average Requirement (EAR) for calcium, 67% of iron and 69% for folate. A prospective cohort undertaken by Langley Evans & Langley-Evans (2003) in the East Midlands measured micronutrient intakes of 204 women in the first trimester and 176 in the third trimester of pregnancy using 5-day food diaries. Birthweight and infant head circumference at birth were unrelated to micronutrient intakes in the first or third trimester of pregnancy. Although this study accounted for micronutrients from supplements, iron intake remained below UK recommendations, mean intake 11.4 mg day^{-1} (Langley-Evans & Langley-Evans 2003). Rogers & Emmett (1998) undertook one of the largest studies investigating the diet of 11 923 pregnant women living in the Southwest of England using an unquantified FFQ. When nutrients intakes were compared with UK dietary requirements, energy, iron, magnesium, potassium and folate fell below recommended levels.

Rees *et al.* (2005) studied nutrient intakes of mothers that delivered low-birthweight babies and were living in East London between weeks 8 and 12 postpartum using a 7-day food diary. It was reported that Caucasians and Asians had some of the lowest vitamin D intakes (2.4 µg day^{-1}) and Africans had some of the lowest calcium intakes (565 mg day^{-1}) in the puerperium. As nutrient intakes can fall short during pregnancy, it has been recommended that supplements are taken to complement the diet, but not replace it. It is generally recommended that single vitamin or mineral supplements are not taken in higher than normal doses unless recommended by a health specialist (Schweitzer 2006).

The aims of this observational study were: (1) to collect detailed prospective data identifying baseline dietary micronutrient intakes (excluding supplements) through the entire gestation period and puerperium as a continuum; and (2) to compare maternal micronutrient intakes with UK dietary recommendations.

Materials and methods

Ethical approval was given by St Georges' Hospital, King's College Hospital and London South Bank University (August 2002). Participants were recruited from St Georges' Hospital Early Pregnancy Unit and through King's College Medical School Ante-natal Department.

During the process of recruitment, individuals were informed that the study aimed to observe patterns of dietary intake throughout pregnancy but specific aims were not stated, to limit any bias. Subjects included in the present study were 18–40 years, Caucasian, non-smokers, not taking medications known to influence the appetite and able to give voluntary, written informed consent to participate in the study. Caucasian subjects were recruited to control for different dietary habits of other cultures (Rees *et al.* 2005). At the initial meeting, the study requirements were clearly explained to participants and volunteers were given an information sheet and asked to sign a consent form. At the same meeting, participants were provided with a food diary and electronic, calibrated scales to avoid the measurement error ±5 g associated with spring balances (Bingham 1987). If more than one item of food was eaten from the same plate, the method of cumulative weighing was used. This was considered to be comparatively quick and easy for the participant and involved recording the weight of the plate, bowl, glass or cup and its subsequent weight as the relative constituents was added. Where composite dishes, e.g. mixed salads, casseroles or stews, were eaten, subjects were asked to record and weigh the ingredients and estimate the proportion of the whole meal eaten herself. In the present study, it was decided that we would aim to use the 7-day weighed inventory, but when women were experiencing difficulties, such as severe nausea and vomiting, 4-day records were acceptable (providing these included a weekend day). Gay (2000) found that increasing the recording period from 4 to 7 days gains only a small increase in the precision with which mean intakes are estimated, yet has a desirable impact on the response rate.

When food diaries were returned to the research centre, the study investigator checked portion sizes against the Ministry of Agriculture Fisheries and Food' *Food Portion Sizes* (1994) and coded the foods for analysis. Food diaries were then analysed and a mean intake calculated using Dietplan (version 5). Food diaries were excluded when they were not fully completed, volunteers did not include a weekend day, food weight was not sufficiently recorded, or the diary appeared to have been completed retrospectively. Two volunteers were excluded from pregnancy data analysis for each trimester because they were expecting twin births.

Finally, a post natal questionnaire was sent to all study participants after their expected-date-of-delivery. This provided information about perinatal outcome, including: length of labour, method of delivery, infant birthweight, length and head circumference.

Statistical analyses

Statistical analyses were conducted using SPSS/PC version 12.0. Descriptive statistics were used to calculate the mean, standard deviations and range of variables. Micronutrient intakes were expressed as a percentage of participants that met UK dietary requirements (DoH 1991). Mean micronutrient intakes were also compared against dietary recommendations using one-sample *t*-tests. As data were collected from the same individuals over several time periods, micronutrient intakes were compared between study stages for the 42 individuals, using repeated measures analysis of variance (one factor time with four levels).

Validity of food diaries

The validity of food diaries was monitored using the Goldberg energy intake (EI) : basal metabolic rate (BMR) ratio (estimated), (EI : BMRest) (Goldberg *et al.* 1991), as recommended by Rutishauser (2005). Pre-pregnancy BMR was calculated using weight (kg), height (m) and age (years) using the traditional Schofield equations (Schofield Schofield *et al.* 1985). Metabolic increments were then added for each trimester of pregnancy, as suggested by Prentice *et al.* (1996). The EI of subjects were obtained from individual dietary analyses using the software programme Dietplan 5 (Forestfield Software Ltd., West Sussex, UK) and divided by the relevant BMR. Goldberg *et al.* (1991) EI : BMRest cut-off points for energy were applied; a cut-off of 1.2 or below was indicative of under-reporting. Subjects meeting or falling below this ratio were excluded.

Results

Seventy-two volunteers were recruited at the study start, with 42 participants completing all study stages. Subjects that met or fell below the Goldberg *et al.* (1991) EI : BMRest cut-off points were excluded ($n = 16$) and five participants were excluded because food diaries were completed inadequately. Remaining participants withdrew for personal reasons ($n = 9$) which included: miscarriage or stillbirth ($n = 4$), being too busy, misplacing the study pack or moving house ($n = 5$).

When background characteristics were compared between participants that completed all study phases and those that withdrew, few differences were identified (Tables 1 and 2). Mean age, pre-pregnancy weight, body mass index were all similar, as was the social classification group. The mean age of study participants completing all study stages was 33.2 years (range 19–40) (Table 1). Although all mothers were Caucasian, the ethnicities of fathers varied. Four (6%) were mixed race, one Black/Caribbean and one was Fijian.

The weighed inventory was completed at the following phases of gestation (mean value): weeks 12.6, 25.0, 35.1 and 7.6 weeks after birth. Eighty-eight per cent of subjects were within National Statistics Socio-

Table 1. Characteristics of the study population ($n = 42$ throughout the study)

Characteristic	Mean (standard deviation)	Range
Background information		
Age (years)	33.2 (4.55)	19.0–40.0
Pre-pregnancy weight (kg)	65.9 (12.4)	47.7–105
Pre-pregnancy height (m)	1.67 (0.06)	1.54–1.83
Pre-pregnancy body mass index	23.5 (3.99)	17.4–32.0
First trimester weight (kg)	67.6 (12.6)	48.5–108
Second trimester weight (kg)	72.0 (12.6)	55.0–111
Third trimester weight (kg)	77.8 (13.4)	59.1–118
Postpartum weight (kg)	70.8 (12.4)	53.6–108
Social classification	88% participants were in Social Classification groups I–III*	
Week of study completion		
First trimester	12.6 (1.63)	9.10–15.3
Second trimester	25.0 (1.08)	23.1–27.1
Third trimester	35.1 (1.57)	32.1–38.1
After birth	7.62 (6.05)	5.00–34.0

*Office for National Statistics Classification Scale (2002).

Table 2. Baseline characteristics of excluded participants ($n = 30$)

Characteristic	Mean (standard deviation)	Range
Background information		
Age (years)	33.1 (4.73)	20.0–39.0
Pre-pregnancy weight (kg)	66.6 (7.17)	51.0–84.5
Pre-pregnancy height (m)	1.67 (0.07)	1.50–1.80
Pre-pregnancy body mass index	23.9 (2.33)	19.7–29.9
Social classification	87% participants were in Social Classification groups I–III*	

*Office for National Statistics Classification Scale (2002).

Economic Classification Scales groups 1–3 (Office for National Statistics 2002). All participants were non-smokers. The mean pre-pregnancy height of volunteers was 1.69 m (range 1.54–1.83), weight 70 kg (range 48–105) and body mass index 24.7 kg m^{-2} (range 17.4–32.0).

Dietary intakes of all micronutrients remained relatively constant throughout gestation. There were no statistically significant differences when mean micronutrient intakes were compared between each of the three trimesters of gestation and after parturition. Only vitamin C was of near statistical significance ($P = 0.065$) when vitamin C intakes were compared between the first trimester and after birth. At 101 mg day^{-1} (standard deviation = 55.2) vitamin C intake after birth was somewhat lower (but not significantly) than levels consumed in the first trimester (130 mg day^{-1}, standard deviation = 67.9).

When mean micronutrient intakes were compared with Department of Health UK Dietary Guidelines (DoH 1991), sodium intakes were significantly higher than recommended levels of 1600 mg day^{-1} throughout the study entirety ($P < 0.001$). Mean intakes of vitamin D, potassium and iodine were significantly lower than UK recommendations ($P < 0.001$) for all three trimesters of pregnancy and after birth. Iron intakes were significantly lower than UK 14.8 mg day^{-1} recommendations in the first, second and postpartum study stages ($P < 0.001$) and somewhat lower in the third trimester ($P = 0.03$). Selenium followed a similar trend and mean intakes were significantly lower that UK guidelines in the first, third and post-partum study phases ($P < 0.001$) and marginally lower in the second trimester ($P = 0.03$).

In percentage terms, a high proportion of women (75% of the study population or more) met UK dietary guidelines for thiamine, niacin, biotin, phosphorus, sodium, chloride and vitamins B6, B12, A and C. However, only 23–38% of women met UK recommendations for folate (300 µg day^{-1}) through dietary sources. Similarly, only a small percentage of women met dietary recommendations for iron (19–28%). Less than 50% of participants met intakes of riboflavin, vitamin D calcium, magnesium, potassium, zinc, copper, selenium and iodine throughout and after pregnancy. Furthermore, it is important to note that a high percentage of mothers failed to meet calcium requirements after birth when dietary requirements increase. Only 17% of women met UK calcium guidelines of 1250 mg day^{-1} from dietary sources.

Discussion

In the present study, mean intakes of the B vitamins, antioxidant vitamins C, vitamin A and vitamin E, minerals calcium, magnesium, chloride, zinc and copper were consumed in proportions that met government recommendations (DoH 1991) for the three trimesters of pregnancy, and were supplied at this level from food sources alone (Table 2). However, it is of great concern that intakes of some micronutrients were consumed in excess, or at the other end of the spectrum, fell significantly below UK dietary recommendations. Mean dietary intakes of sodium exceeded recommended levels of 1600 mg day^{-1} (DoH 1991) by 1000 mg day^{-1}. Although, further investigation is required, it is has been reported that reducing sodium intake from dietary sources may reduce the risk of developing pre-eclampsia during pregnancy (Duley *et al.* 2005). It has been reported that as many as 20 000 UK women suffer from pre-eclampsia each year (Department of Health 1999).

In terms of dietary inadequacies, the present study identified that food intakes of folate, vitamin D, potassium, iron, selenium and iodine were not sufficient. Black (2003) confirmed associations between folic acid and congenital malformations, iron deficiency and anaemia during pregnancy. Low plasma 25-hydroxyvitamin D has been associated with poor fetal and infant skeletal growth and tooth mineralization (Zeghoud *et al.* 1997). Although large randomized studies are required to evaluate associations between selenium intake and pregnancy outcome, research indicates that a selenium-rich diet may reduce the risk of pregnancy loss (Kumar Kumar *et al.* 2002). Iodine deficiency during pregnancy may inhibit fetal mental development and result in cognitive impairment (Ohara *et al.* 2004). An informative article by Ashworth & Antipatis (2001) explained that micronutrient deficiencies can, through the actions of enzymes and transcription factors, have a profound effect on the development of fetal tissues and organs and affect health status of infants in the long-term.

Overall, the results from the present study indicate that pregnant women may not be obtaining sufficient levels of key micronutrients from their diet, particularly with regard to folate and iron. When dietary recommendations are not met, it may be beneficial for women to consume additional supplements. It has been suggested that as much as 200 µg day^{-1} of synthetic folic acid should be taken post-fortification to prevent deaths from anencephaly or paralysis through spina bifida (Brent & Oakley 2006). In addition, a low daily dose of iron (30 mg day^{-1}) may improve birthweight and protect against iron-deficiency anaemia in both the mother and child (Rioux & LeBlanc 2007). Multiple-micronutrient supplementation has been associated with the delivery of fewer low-birthweight and small-for-gestational age babies but further investigation is required to study the adverse effects of multiple-micronutrient supplementation (Haider & Bhutta 2006).

Postnatally, this study identified that women failed to meet dietary requirements for several important micronutrients (Table 3), particularly, those associated with bone health (calcium, magnesium and vitamin D). Bearing in mind that the Organisation of World Health (2001) is now promoting the consumption of breast milk *per se* for at least 6 months after birth, it is imperative that an optimal diet is consumed. It has been widely documented that the

Table 3. Daily habitual micronutrient intakes throughout and after pregnancy ($n = 42$)

	First Trimester Mean (SD)	RNI (%)	Second trimester mean (SD)	RNI (%)	Third trimester mean (SD)	RNI (%)	Postpartum mean (SD)	RNI (%)	DoH (1991) RNI recommendations	
									Pregnancy	Postpartum
Thiamin (mg)	1.52 (0.43)	95.2	1.49 (0.30)	97.6	1.61 (0.49)	97.6	1.59 (0.89)	92.9	0.9	1.1
Riboflavin (mg)	1.70 (0.63)	66.7	1.76 (0.55)	73.8	1.86 (0.66)	81.0	1.77 (0.73)	57.1	1.4	1.6
Niacin (mg)	18.4 (6.20)	81.0	19.1 (5.03)	88.1	19.9 (5.73)	92.9	19.8 (6.79)	85.7	13	15
B_6 (mg)	1.80 (0.54)	90.5	1.91 (0.52)	97.6	1.94 (0.50)	95.2	1.85 (0.59)	90.5	1.2	1.2
B_{12} (µg)	3.35 (1.47)	92.9	3.90 (2.26)	88.1	3.46 (1.20)	97.6	3.46 (1.74)	88.1	1.5	2.0
Folate (µg)	262 (92.0)	23.8	273 (68.4)	26.2	265 (85.5)	38.1	244 (85.2)	38.1	300	360
Pantothenic acid (mg)	3.66 (1.22)	69.0	3.87 (1.18)	69.0	3.88 (0.99)	78.6	3.64 (1.14)	78.6	3–7 mg day^{-1}	3–7 mg day^{-1}
Biotin (µg)	25.4 (10.6)	97.6	24.2 (9.17)	97.6	24.3 (8.52)	97.6	22.8 (7.75)	95.2	10–200	10–200
Vitamin C (mg)	130 (67.9)	90.5	130 (58.0)	95.2	136 (75.9)	95.2	101 (55.2)	66.7	50	70
Total vitamin A (µg)	2596 (1295)	90.5	2644 (1832)	97.6	2164 (1348)	95.2	1454 (1385)	85.7	700	950
Vitamin D (µg)	1.86 (0.93)	0.00	2.59 (1.74)	0.00	2.18 (1.31)	0.00	2.31 (1.75)	0.00	10	10
Vitamin E (mg)	6.78 (3.66)	90.5	5.70 (2.30)	92.9	5.54 (2.23)	85.7	5.37 (2.09)	90.5	3	3
Calcium (mg)	913 (332)	69.0	883 (265)	73.8	945 (283)	76.2	882 (277)	16.7	700	1250
Phosphorus (mg)	1249 (359)	100.0	1230 (307)	97.6	2807 (639)	100.0	1241 (335)	83.3	550	990
Magnesium (mg)	277 (84)	52.4	268 (66.2)	54.8	273 (75.7)	45.2	2.59 (1.03)	19.0	270	320
Sodium (mg)	2802 (841)	95.2	2764 (1106)	97.6	2735 (681)	97.6	2729 (871)	92.9	1600	1600
Potassium (mg)	2849 (702)	16.7	2821 (588)	9.5	2807 (639)	11.9	2565 (670)	4.8	3500	3500
Chloride (mg)	4266 (1663)	92.9	3961 (982)	97.6	4070 (967)	97.6	4032 (1223)	90.5	2500	2500
Iron (mg)	12.3 (4.57)	28.6	12.1 (3.50)	21.4	13.0 (5.25)	33.3	12.3 (4.54)	19.0	14.8	14.8
Zinc (mg)	7.74 (2.17)	57.1	7.67 (2.96)	54.8	7.69 (1.78)	66.7	7.59 (2.18)	2.4	7.0	13.0
Copper (mg)	1.21 (0.48)	42.9	1.15 (0.41)	54.8	1.16 (0.43)	47.6	1.09 (0.36)	21.4	1.2	1.5
Selenium (µg)	51.5 (34.0)	26.2	50.2 (28.9)	19.0	49.4 (20.6)	23.8	53.7 (35.0)	4.8	60	75
Iodine (µg)	103.3 (53.3)	21.4	107 (49.7)	14.3	110 (47.6)	21.4	100 (41.5)	9.5	140	140

RNI, reference nutrient intakes; SD, standard deviation.

quality of the maternal diet is reflected in the breast milk, particularly with reference to maternal intakes of water-soluble vitamins (Allen 1994). Chierici *et al.* (1999) undertook a supplementation trial with lactating mothers ($n = 32$). This study found that micronutrient intakes were only found to be beneficial in women whose diets were already deficient in micronutrients (Chierici *et al.* 1999). Findings from this study demonstrate that women from the present study may have benefited from dietary supplements, but only those with a poor quality diet.

Although this study has identified that woman do not consume enough folate and iron during pregnancy and calcium and magnesium after birth (among other nutrients, Tables 2 and 3), we can also question the dietary recommendations to which habitual intakes are compared. British recommendations are rather out of date (DoH 1991), when compared with American Guidelines (Food & Nutrition Board 2004). There is a clear need to update British guidelines with revised figures based on recent research which may affect data interpretations. Furthermore, the guidelines that currently exist are not specific to pregnancy, or the individual trimesters within gestation. Micronutrient requirements may vary markedly between trimesters and ideally should be specific to each distinct gestative phase.

This investigation was subject to research limitations, enrolment of volunteers in the first trimester meant that some women miscarried prior to the completion of the first study pack. Such misfortunes unfortunately resulted in participant withdrawal. As this was a long-term follow-through study, only 42 participants completed every study stage. Although an analysis of participant characteristics identified that characteristics were similar between individuals completing and failing to complete all study stages, it could be speculated that this was not an entirely representative study sample. Furthermore, volunteers that came forward to participate were generally older and from higher sectors of the National Statistics Socio-Economic Classification (Office for National Statistics 2002). While the present study population was not representative of the entire UK pregnant population, it appeared to be representative of London (Office for National Statistics 2004). It is, therefore, a limitation of the study that subject numbers were not evenly distributed for lower social groups and age. Had this been so, it is possible that study findings may have been quite different. In terms of dietary intake measurements, the 7-day weight inventory is generally highly regarded and accounts for day-to-day variation (Bingham 1987). However, the 'truth' of food records is somewhat questionable as subjects may under-report foods with a low nutrient density and over-report healthful food groups. Such discrepancies, together with the large number of tests carried out, may have resulted in Type I error and findings that may not be entirely true to a representative population (Rutishauser 2005).

In light of these findings, the present results confirm the importance of providing dietary information to women during pregnancy, particularly information about how to increase intakes of iron and folate (during pregnancy) and calcium (post-pregnancy) to recommended levels. The fact that the intakes of lactating women fell below recommended intakes is of some concern, particularly in the case of calcium. It is possible that today's generation of pregnant women has become reliant upon supplementary sources of micronutrients and that dietary sources are being replaced by these synthetic alternatives. Also when comparing data between studies, it is important to note that different intakes of micronutrients may depend on season, year, economic status and variation between individuals in the same community, all of which may have impact upon dietary intakes in the present study Black (2003). In addition, some studies have added supplement sources to their published analyses, which may account for higher intakes (Langley-Evans & Langley-Evans 2003).

Overall, it can be concluded that poor quality diets in this study resulted in inadequate micronutrient intakes, both throughout and after pregnancy. Further research is now required to study patterns of micronutrient intakes throughout the entire gestative period, including before and after pregnancy. Investigations also need to be established to focus on the micronutrients that are frequently overlooked, such as B vitamins, copper, selenium, iodine and their role in relation to perinatal outcome and to use biomarkers to validate dietary intakes. Until further research has been undertaken in the UK, the DoH (1991) dietary recommendations cannot be revised with the accuracy and detail, i.e. required for such important phase of the life-cycle.

Key messages

- While an adequate diet should be consumed and encouraged to meet recommended nutrient intakes, supplementation may be required in some cases.
- Women should make sure that any salt that they purchase is iodized and that any dietary supplements contain iodine.
- For some women, supplementation may be required during pregnancy (particularly in the case of folate and iron) and in the puerperium (particularly in the case of calcium).
- While many women are aware that supplementation is beneficial prior to and during the early phases of pregnancy, women do not appear to be aware of the benefits of postpartum supplementation. This information needs to be conveyed to the public domain.

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Conflicts of interest

None declared.

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