Public Health Nutrition: 12(7), 922–931 doi:10.1017/S1368980008003595

Dietary intake and nutritional adequacy prior to conception and during pregnancy: a follow-up study in the north of Portugal

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Submitted 29 January 2008: Accepted 16 July 2008: First published online 27 August 2008

Abstract

Objective: To assess maternal diet and nutritional adequacy prior to conception and during pregnancy.
Design: Follow-up of a cohort of pregnant women with collection of questionnaire data throughout pregnancy and after delivery.
Setting: Antenatal clinics at two public hospitals in Porto, Portugal.
Subjects: Two hundred and forty-nine pregnant women who reported a gestational age below 13 weeks at the time they attended their first antenatal visit.
Results: Intakes of energy and macronutrients were within recommended levels for most women. Pregnancy was accompanied by increases in the dietary intake of vitamins A and E, riboflavin, folate, Ca and Mg, but declines in the intake of alcohol and caffeine. The micronutrients with higher inadequacy prevalences prior to pregnancy were vitamin E (83 %), folate (58 %) and Mg (19 %). These three micronutrients, together with Fe, were also those with the highest inadequacy prevalences during pregnancy (91 %, 88 %, 73 % and 21 %, respectively, for folate, Fe, vitamin E and Mg). Ninety-seven per cent of the women reported taking supplements of folic acid during the first trimester, but the median gestational age at initiation was 6·5 (interquartile range 5, 9) weeks. Self-reported prevalences of Fe and Mg supplementation were high, and increased throughout pregnancy.
Conclusion: The study identified low dietary intakes of vitamin E, folate and Mg both in the preconceptional period and during pregnancy, and low intake of Fe during pregnancy only. The low dietary intake of folate and the late initiation of supplementation indicate that current national guidelines are unlikely to be effective in preventing neural tube defects.

Keywords
Diet
Maternal nutrition
Preconception care
Prenatal care
Dietary supplementation

Maternal nutrition during pregnancy has been linked to birth outcomes[1–7] (e.g. fetal growth[1,3,8], gestation length[7,9] and birth defects[10]) and long-term health of the offspring through intra-uterine programming in early fetal life and its impact on the susceptibility to CVD and type 2 diabetes mellitus[11]. A woman's diet during pregnancy has also been associated with her risk of developing hypertensive disorders during pregnancy[4,12] and obesity later in life[13].

Less is known about the impact of diet prior to and around conception on pregnancy outcomes as research has focused mainly on diet during mid to late pregnancy. Animal studies suggest that nutrition may influence oocyte and embryo quality, and thereby the proficiency of the fetus, fetal development and adult health outcomes[3]. In human subjects, pre-pregnancy maternal obesity, a broad indicator of energy intake prior to conception, is associated with size at birth and adverse pregnancy outcomes[14]. Intake of micronutrients prior to and around conception may also affect maternal health and pregnancy outcomes. Periconceptional folic acid supplementation protects against neural tube defects[15]. Physiological adaptive processes ensure that the higher Ca needs for fetal growth are met without requiring an increase in maternal intake[16], but it is not known whether low Ca intake prior to conception, or during pregnancy, affects the long-term health of the mother and her offspring[16].

Pregnancy is a period in which women are particularly concerned with their diet and health, and frequently change their habits even if only temporarily. There are no Portuguese nutritional guidelines for pregnant women, so health professionals base their recommendations on the Dietary

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Reference Intakes (DRI) developed for the US population[17,18]. The objectives of the present study were to assess dietary intake among Portuguese women prior to conception and during pregnancy, and to evaluate their adequacy.

Subjects and methods

Subjects

This study was nested within Geração XXI, a birth cohort assembled in Porto, Portugal. All mothers resident in the metropolitan area of Porto who delivered a live-born baby between 1 May 2005 and 31 August 2006 in the maternity clinics of the five public hospitals were invited to participate in Geração XXI. These hospitals are responsible for 91·6 % of the deliveries in the whole catchment population, with the remaining occurring in private hospitals/clinics. A total of 8654 babies were enrolled into the study. The present study is based on a sub-sample of mothers in this cohort who were followed up throughout pregnancy. All pregnant women who attended their first antenatal visit at Júlio Dinis Maternity Hospital or S. João Hospital between 1 December 2004 and 31 December 2005 were invited to participate if they reported a gestational age below 13 weeks. The invitations were made consecutively until the final size of the sub-sample was reached. Those who agreed to participate were interviewed in each trimester of pregnancy and in the immediate postpartum period. A sample size of 250 women will allow precise estimation of the true prevalence of intake inadequacy (i.e. 95 % confidence intervals around the point estimate with a width of ±5 % for true prevalence of ≤20 % or ≥80 %, and a maximum of ±7 % for true prevalence between 20 % and 80 %).

A total of 430 pregnant women were initially enrolled in the two participating hospitals (participation rate 96·2 %), with 249 completing the whole study. Forty-eight were excluded because of incorrect reporting of gestational age (as assessed by ultrasound) and thirty-one due to miscarriages, fetal deaths, stillbirths or very preterm deliveries (gestational age <32 weeks). A further ninety-nine women were excluded because, for logistic reasons, they were unable to complete both of the two FFQ (described later) and a further three because they provided unreliable dietary data (i.e. total energy intake outside mean ± 3SD). Although the 249 participating women were a subset of the 430 initially enrolled, the two groups had similar baseline characteristics: there were no differences between those who participated and all those who were initially enrolled in terms of their age (mean (SD): 28·9 (5·8) *v.* 29·2 (6·6) years, respectively; $P = 0·54$), number of completed years of schooling (mean (SD): 9·2 (4·1) *v.* 9·4 (3·6) years, respectively; $P = 0·39$) or marital status (86·3 % *v.* 86·1 % were married, respectively; $P = 0·53$), but those who participated were more likely to be primiparous (62·7 % *v.* 54·8 %, respectively; $P = 0·07$).

Ethical approval for the study was obtained from relevant institutional ethics committees. All participants provided written informed consent.

Data collection

Data were collected in each trimester of pregnancy and in the postpartum by trained interviewers using a structured questionnaire to obtain information on demographic and lifestyle variables, past medical history, health status during pregnancy, and use of vitamin and mineral supplements (including details on type of supplements and timing of their initiation and cessation). Education was recorded as the number of completed years of schooling and categorized as ≤6, 7–9, 10–12 and >12. Women were asked to estimate their monthly household income in 500€ categories. Height and weight were measured at each follow-up visit. Pre-pregnancy BMI was estimated from self-reported pre-pregnancy weight or, if this was not known (14·5 % of women), the weight measured at the first visit. BMI was analysed according to WHO categories (underweight: <18·5 kg/m^2; normal weight: 18·5–24·9 kg/m^2; overweight: 25·0–29·9 kg/m^2; obesity: ≥30·0 kg/m^2)[19].

Dietary and nutrient intake estimates

Dietary intake was assessed by a semi-quantitative FFQ, comprising eighty-six food or food group items. Frequency of consumption was recorded into nine pre-specified categories from ‘never or less than once per month’ to ‘six or more times per day’. Pre-specified portion sizes were allocated to each food item. Dietary intake was estimated by multiplying the frequency of intake for any given item by its respective portion size, in grams, and by a seasonal variation factor for foods consumed only in some seasons. The FFQ had been specially developed and validated for use among the Portuguese adult population[20] and, more recently, for use among pregnant women to estimate their dietary intake during the whole pregnancy (paper in preparation). The reference method for the latter was the average of three 3 d food diaries (FD), one from each trimester of pregnancy, collected from a subset of 101 pregnant women who participated in the present study. The percentage of pregnant women classified into the same or an adjacent quintile by the two methods was 60 % for total energy and 60 %, 58 % and 55 % for protein, carbohydrates and total fat, respectively. The corresponding percentages for selected micronutrients were 60 % for vitamin E, 66 % for folate, 69 % for Mg and 73 % for Fe. Extreme disagreement between the two methods (i.e. classification into opposite quintiles) was ≤5 % for all nutrients. Bland–Altman plots showed no evidence of biases.

The FFQ was administered twice. The first administration (FFQ1) occurred at the time of the first antenatal visit in the first trimester of pregnancy, and aimed to estimate usual dietary intake in the year preceding the current pregnancy. The second FFQ (FFQ2) was administered a few days after delivery to estimate usual dietary intake during the whole pregnancy.

The Food Processor Plus® program version SQL (ESHA Research, Salem, OR, USA) was used to convert food intakes into nutrient intakes. This database was supplemented with the nutritional composition of Portuguese foods and recipes, using data from Portuguese food composition databases(21,22) and national(23–26) and international(27–30) publications. If the nutrient composition of a dish was unknown, this was estimated on the basis of its culinary recipe and the nutrient composition of its ingredients.

Estimated Energy Requirements (EER) were calculated using the equation(31): $EER = 354 - 6{\cdot}9 \times \text{age (years)} + PAL[9{\cdot}36 \times \text{weight (kg)} + 726 \times \text{height (m)}]$, with physical activity level (PAL) assumed to be low active ($PAL = 1{\cdot}12$) as this is compatible with the activity level of the majority of Portuguese women(32). The average EER for the whole pregnancy was calculated by adding a further 1185 kJ (283 kcal) to the previous calculation, as daily energy requirements increase, on average, by 0 kJ (0 kcal) in the first trimester, 1465 kJ (350 kcal) in the second and 2093 kJ (500 kcal) in the third (daily mean for the whole pregnancy = 1185 kJ (283 kcal))(33). Inadequacy in nutrient intake was calculated by taking as cut-off points the Acceptable Macronutrient Distribution Ranges (AMDR) for macronutrients and the Estimated Average Requirements (EAR) for micronutrients, according to recommendations for the DRI of the US population(17,18,34,35). Inadequacies of Ca and vitamin D intakes were estimated on the basis of Adequate Intakes (AI) as there is no EAR for these micronutrients. Recommended levels were defined as those appropriate for non-pregnant and pregnant women aged 19–50 years. Prevalence of intake inadequacy was estimated as the percentage of participants whose intake was outside (for macronutrients) or below (for micronutrients) recommended levels.

Statistical analysis

The Kolmogorov–Smirnoff test was used to assess the assumption of normality. Only total energy intake had a normal distribution and, hence, the paired *t* test was used to compare mean differences in its intake between the two time periods. For all other nutrients and foods, the Wilcoxon signed-rank test was used to compare median differences in intake between paired observations. Prevalences in the inadequacy of intake of specific nutrients (with 95 % confidence intervals) were estimated, and logistic regression analyses conducted to identify potential socio-economic and behavioural determinants. Likelihood ratio tests and Wald tests were used to examine heterogeneity and linear trend, respectively, in the prevalence of intake inadequacy(36). All statistical analyses were performed with the Statistical Package for the Social Sciences version 14·0 (SPSS Inc., Chicago, IL, USA) and Epi Info™ version 6·0 (Centers for Disease Control and Prevention, Atlanta, GA, USA) statistical software packages.

Results

Participants' characteristics

The baseline characteristics of the study subjects are shown in Table 1. Participants had a mean age of 29 (SD 5·8) years at entry into the study. The median number of completed years of schooling was 9 (interquartile range (IQR) 6, 12); 86·3 % were married, 59·5 % were in active employment and 43·5 % had family monthly income below 1000€, a figure equivalent to 2·5 times the national minimum wage. Fifty-seven per cent of women were of normal weight prior to becoming pregnant. The pregnancy was unplanned for 43·4 % of women, and it was the first delivery for 62·7 %. Over half of participants experienced nausea and/or vomiting in the first trimester, but this percentage decreased with increasing gestational length. A quarter of the women reported smoking in the first trimester of pregnancy, but this percentage fell to 15·3 % and 13·4 % in the second and third trimesters,

Table 1 Characteristics of the study participants: sub-sample (*n* 249) of mothers in the Geração XXI birth cohort, Porto, Portugal, December 2004 to December 2005

	n†	%
Maternal age (years) at entry into the study		
≤20	29	11·6
21–30	124	49·8
31–40	96	38·6
Maternal education (years of schooling)		
≤6	79	31·7
7–9	73	29·3
10–12	65	26·1
>12	32	12·9
Current marital status		
Married	215	86·3
Not married	34	13·7
Current employment status		
Student	49	19·8
Employed	147	59·5
Unemployed	51	20·7
Current aggregate family income (€/month)		
<500	16	7·4
500–1000	78	36·1
1001–1500	80	37·0
>1500	42	19·4
Maternal pre-pregnancy BMI (kg/m^2)		
<18·5	8	3·4
18·5–24·9	136	57·4
25·0–29·9	68	28·4
≥30·0	25	10·5
Parity		
0	156	62·7
≥1	93	37·3
Assisted reproduction	13	5·2
Planned pregnancy	141	56·6
Nausea and/or vomiting during pregnancy		
1st trimester	133	54·5
2nd trimester	71	33·3
3rd trimester	42	19·6
Smoking during pregnancy		
1st trimester	62	25·0
2nd trimester	38	15·3
3rd trimester	33	13·4
Use of illicit drugs during pregnancy	8	3·2

†Totals do not always add up to 249 due to missing values.

respectively. Only 3·2 % reported to have ever used illicit drugs during pregnancy.

Food consumption

Table 2 shows usual daily food consumption prior to and during pregnancy. Average daily consumption of milk and dairy products during pregnancy was almost twice that in the preceding year. Intake of fats, bread, fruits and soup also increased significantly with pregnancy whereas intake of eggs, red meat, rice, pasta and potatoes, fast food, alcoholic beverages, and coffee and tea decreased significantly. There were no statistically significant differences in the consumption of fish, vegetables, sweets, soft drinks and fruit juices between the two periods. The daily number of meals increased throughout pregnancy, with the percentage of women who had more than 5 meals/d rising from 54·3 % in the first trimester to 71·5 % in the third (*P* for linear trend <0·001).

Nutrient intakes and their adequacy

The daily intake of total energy during pregnancy was not statistically significantly different from that in the preceding year, but the percentage of energy derived from protein and saturated fat increased slightly with pregnancy (Table 3). Pregnancy was also accompanied by statistically significant increases in the intake of vitamins A and E, riboflavin, folate, Ca and Mg (Table 3). In contrast, the percentage of women who reported ever drinking alcoholic beverages fell from 36·3 % prior to pregnancy to only 13·3 % during it, with the median intake among drinkers declining from 3·7 g to 0·9 g between the two time periods. Almost all women consumed caffeine prior to and during pregnancy, but the median daily intake was reduced from 65 mg to 34 mg between the two periods (Table 3).

Daily mean energy intake was higher than EER both prior to (10 157 kJ (2426 kcal) *v.* 8252 kJ (1971 kcal), respectively; $P<0·001$) and during pregnancy (10 429 kJ (2491 kcal) *v.* 9437 kJ (2254 kcal), respectively; $P<0·001$). However, the mean difference between reported and recommended levels was much higher prior to pregnancy than during it (1905 kJ (455 kcal) *v.* 992 kJ (237 kcal), respectively). The reported intakes of total fat and carbohydrates prior to pregnancy were outside the AMDR for respectively 20·6 % and 13·7 % of the participating women, reflecting mainly under-consumption of carbohydrates and over-consumption of total fat. These levels of inadequacy were little affected by pregnancy.

Overall, the prevalence of micronutrient inadequacy was higher during pregnancy than prior to it. The nutrients with higher inadequacy prevalences prior to pregnancy were vitamin E (83·1 %), folate (58·2 %) and Mg (18·5 %; Table 3). These three nutrients, together with Fe, were also those with the highest inadequacy prevalences during pregnancy (90·8 % for folate, 88·0 % for Fe, 73·1 % for vitamin E and 21·3 % for Mg; Table 3). As average levels of Ca intake were above recommendations in both periods, it is likely that the prevalence of inadequacy for this nutrient was rather low. In contrast, the intake of vitamin D was below recommended levels in both periods, but this inadequacy is of little concern to the Portuguese population given its high levels of exposure to sunlight.

The FFQ2 estimates of prevalence of inadequacy for the subset of 101 subjects who also completed a 3 d FD in each trimester of pregnancy were similar to those found for the whole sample of 249 women (Tables 3 and 4). The estimates of prevalence of inadequacy provided by the average of the three FD were similar to those provided by FFQ2 in this subset of women, except that the FD yielded

Table 2 Median daily consumption of foods (in grams) among the study population in the year preceding pregnancy and during pregnancy: sub-sample (*n* 249) of mothers in the Geração XXI birth cohort, Porto, Portugal, December 2004 to December 2005

	Preconceptional food intake (FFQ1)		Food intake during pregnancy (FFQ2)		Difference		
Food group†	Median	IQR	Median	IQR	Median	IQR	*P*‡
Milk and dairy products	387·5	267·0, 735·0	691·8	384·7, 923·5	196·1	0·0, 423·4	<0·001
Eggs	22·2	7·4, 22·2	11·1	7·4, 22·2	0·0	−7·4, 0·0	0·014
White meat	51·4	25·7, 68·6	51·4	25·1, 59·4	0·0	−25·7, 8·3	0·016
Red meat	68·0	55·9, 84·6	62·4	51·4, 74·1	−4·7	−31·0, 9·9	<0·001
Fish	60·2	38·1, 94·4	65·1	40·8, 98·0	0·0	−21·9, 27·9	0·544
Fats	12·7	8·2, 17·6	13·6	7·8, 21·5	0·0	0·0, 0·0	0·032
Bread	123·3	91·0, 157·6	131·4	92·3, 179·7	8·1	−42·9, 64·2	0·046
Rice, pasta, potatoes	172·1	132·9, 214·3	161·4	118·6, 199·1	−4·3	−62·3, 35·7	0·047
Sweets	65·2	37·8, 97·0	54·3	29·5, 93·1	−4·3	−39·6, 27·5	0·121
Vegetables	126·5	76·9, 188·2	124·8	69·5, 221·1	4·2	−52·0, 66·2	0·325
Fruits	313·3	226·5, 434·5	336·2	233·0, 498·9	21·5	−83·4, 159·8	0·029
Fast food	25·1	8·0, 48·1	17·1	8·0, 38·4	−3·3	−20·6, 9·1	0·001
Soup	231·8	65·8, 295·0	295·0	126·4, 295·0	0·0	0·0, 168·6	<0·001
Alcoholic beverages	0·0	0·0, 22·0	0·0	0·0, 0·0	0·0	−17·9, 0·0	<0·001
Coffee and tea	101·6	19·3, 128·3	45·0	0·0, 60·8	−15·8	−101·6, 0·0	<0·001
Soft drinks and fruit juices	258·0	106·6, 519·2	131·5	29·7, 285·5	−85·7	−206·7, 43·7	0·122

IQR, interquartile range.
†Food groups as defined by Erkkola *et al.*[39].
‡*P* values calculated using the Wilcoxon signed-rank test.

Table 3 Recommended dietary reference intakes (DRI), usual dietary daily nutrient intake and prevalence of intake inadequacy prior to and during pregnancy among the study subjects: sub-sample (*n* 249) of mothers in the Geração XXI birth cohort, Porto, Portugal, December 2004 to December 2005

	Year preceding pregnancy					During pregnancy					
		Usual daily dietary intake (FFQ1)					Usual daily dietary intake (FFQ2)				
				Prevalence of inadequacy					Prevalence of inadequacy		
Nutrient	DRI	Median	IQR	%	95 % CI	DRI	Median	IQR	%	95 % CI	*P*†
Energy (kJ)		10 019	8261, 11 706				10 145	8629, 11 882			0·175
Energy (kcal)		2393	1973, 2796				2423	2061, 2838			0·175
Carbohydrates (% of energy)	45–65‡	49·5	42·5, 60·0	13·7	9·4, 17·9	45–65‡	50·3	42·3, 62·1	10·8	7·0, 14·7	0·355
Total fat (% of energy)	20–35‡	31·0	25·6, 37·3	20·6	15·5, 25·5	20–35‡	30·6	26·1, 39·0	21·0	15·8, 25·9	0·933
SFA (% of energy)		10·0	8·1, 12·7				10·5	8·7, 13·1			0·015
MUFA (% of energy)		13·2	11·0, 15·9				13·0	10·6, 16·9			0·397
PUFA (% of energy)		4·8	4·0, 6·0				4·6	3·8, 6·1			0·484
Protein (% of energy)	10–35‡	17·6	14·6, 20·7	0·0	0·0, 1·5	10–35‡	18·4	15·4, 21·1	0·0	0·0, 1·5	0·011
Vitamin A (μg)	500·0§	1583·9	1135·9, 2289·4	5·6	2·8, 8·5	550·0§	1711·1	1162·2, 2512·6	3·6	1·3, 5·9	0·031
Vitamin C (mg)	60·0§	138·7	105·7, 176·7	3·2	1·0, 5·4	70·0§	142·6	110·7, 195·7	8·8	5·3, 12·4	0·294
Vitamin D (μg)	5·0‖	3·9	2·8, 5·4			5·0‖	3·6	2·7, 5·5			0·292
Vitamin E (mg)	12·0§	8·9	7·2, 11·0	83·1	78·0, 87·4	12·0§	9·3	7·5, 12·3	73·1	67·6, 78·6	0·016
Thiamin (mg)	0·9§	1·9	1·6, 2·2	0·0	0·0, 1·5	1·2§	1·9	1·6, 2·3	5·6	2·8, 8·5	0·093
Riboflavin (mg)	0·9§	2·4	1·9, 2·9	0·0	0·0, 1·5	1·2§	2·7	2·2, 3·3	3·2	1·0, 5·4	<0·001
Niacin (mg)	11·0§	24·6	20·3, 28·3	0·4	−0·38, 1·2	14·0§	23·4	19·0, 28·0	5·2	2·5, 8·0	0·156
Pyridoxine (mg)	1·1§	2·3	1·9, 2·7	0·8	−0·31, 1·9	1·6§	2·3	2·0, 2·8	9·6	6·0, 13·3	0·192
Folate (μg)	320·0§	293·5	239·4, 380·1	58·2	52·1, 64·4	520§	314·6	245·1, 400·8	90·8	87·2, 94·4	0·031
Vitamin B_{12} (μg)	2·0§	9·1	6·4, 12·1	0·0	0·0, 1·5	2·2§	9·0	6·6, 12·3	0·0	0·0, 1·5	0·859
Ca (mg)	1000·0‖	1067·8	799·6, 1439·2			1000·0‖	1380·1	1060·6, 1750·5			<0·001
Mg (mg)	255·0§	331·5	271·3, 400·9	18·5	13·7, 23·3	290·0§	362·4	301·2, 429·6	21·3	16·2, 26·4	<0·001
Fe (mg)	8·1§	15·9	13·3, 18·8	0·0	0·0, 1·5	22·0§	16·0	12·5, 19·2	88·0	83·9, 92·0	0·949
Alcohol (g)		0·0	0·0, 1·6				0·0	0·0, 0·0			<0·001
Caffeine (mg)		64·8	31·8, 99·7				34·4	17·3, 60·4			<0·001

FFQ1, FFQ on usual diet prior to pregnancy; FFQ2, FFQ on usual diet during the whole pregnancy; IQR, interquartile range.
†*P* value for the comparison of average nutrient intake between the two time periods.
‡Acceptable Macronutrient Distribution Range.
§Estimated Average Requirement.
‖Adequate Intake.

significantly higher estimates for vitamins C and E, pyridoxine and Mg than the FFQ2 (Table 4).

Overall, there were no clear relationships between the socio-economic and behavioural characteristics and the prevalence of nutritional inadequacy during pregnancy. After adjustment for maternal age and education, inadequacy in vitamin E intake was higher if the pregnancy had been planned (OR = 2·13; 95 % CI 1·18, 3·87; $P = 0·01$); inadequacy in Fe intake was higher among women who were overweight (BMI ≥ 25 kg/m^2) prior to becoming pregnant (OR = 3·45; 95 % CI 1·22, 9·71; $P = 0·01$), but lower among those with higher educational level (P for linear trend = 0·01) and those who reported suffering from nausea and/or vomiting in the first trimester (OR = 0·38; 95 % CI 0·16, 0·91; $P = 0·03$).

Vitamin and mineral supplements

Data on use of vitamins and minerals supplements were available for 99 % of the participating women (Table 5). Only 18·6 % reported preconception supplements of folic acid, but 96·8 % reported taking them during the first trimester and 73·5 % during the third. The median gestational age at initiation of folic acid supplementation was 6·5 (IQR 5, 9) weeks. The self-reported prevalence of Fe supplementation increased from 42·2 % in the first trimester to 75·9 % in the third, with a median gestational

Table 4 Prevalence of inadequacy in nutrient intake during pregnancy as estimated by the FFQ completed in the puerperium (FFQ2) and the average of three 3 d food diaries (FD) in the subset of women (n 101) who complied with both dietary methods: Geração XXI birth cohort, Porto, Portugal, December 2004 to December 2005

		Prevalence of inadequacy during the whole pregnancy as estimated by			
		FFQ2		Average of three 3 d FD†	
Nutrient	DRI	%	95 % CI	%	95 % CI
Protein (% of energy)	10–35‡	0·0	0·0, 2·9	0·0	0·0, 2·9
Carbohydrates (% of energy)	45–65‡	11·9	6·6, 19·3	16·8	10·4, 25·1
Total fat (% of energy)	20–35‡	25·7	17·9, 34·9	35·6	26·8, 45·3
Vitamin A (μg)	550·0§	4·0	1·3, 9·3	9·9	5·1, 16·9
Vitamin C (mg)	70·0§	8·9	4·4, 15·7	26·7*	18·8, 36·0
Vitamin E (mg)	12·0§	72·3	63·0, 80·3	89·1*	81·9, 94·1
Thiamin (mg)	1·2§	3·0	0·8, 7·9	2·0	0·3, 6·4
Riboflavin (mg)	1·2§	1·0	0·0, 4·8	2·0	0·3, 6·4
Niacin (mg)	14·0§	3·0	0·8, 7·9	1·0	0·0, 4·8
Pyridoxine (mg)	1·6§	7·9	3·7, 14·5	20·8*	13·7, 29·5
Folate (μg)	520·0§	92·1	85·5, 96·3	90·1	83·1, 94·9
Vitamin B_{12} (μg)	2·2§	0·0	0·0, 2·9	0·0	0·0, 2·9
Mg (mg)	290·0§	15·8	9·7, 23·9	46·5*	37·0, 56·3
Fe (mg)	22·0§	88·1	80·7, 93·4	93·1	86·8, 96·9

*Statistically significantly different ($P < 0·05$) from the corresponding FFQ2 estimate in this subset of women.
†One 3 d FD completed in each trimester of pregnancy.
‡Acceptable Macronutrient Distribution Range.
§Estimated Average Requirement.

Table 5 Prevalence of intake of selected vitamin and mineral supplements prior to and during pregnancy among the study subjects: sub-sample (n 249) of mothers in the Geração XXI birth cohort, Porto, Portugal, December 2004 to December 2005†

	Supplementation of		
Timing of supplementation	Folic acid	Fe	Mg
Preconception			
%	18·6	1·6	0·0
95 % CI	14·1, 23·8	0·5, 3·9	0·0, 2·0
Gestational age at initiation (weeks)			
Median	6·5	16·0	24·0
IQR	5·0, 9·0	11·0, 20·0	14·0, 30·0
First trimester			
%	96·8	42·2	12·0
95 % CI	94·0, 98·5	36·1, 48·4	8·4, 16·5
Second trimester			
%	90·0	76·7	28·5
95 % CI	85·0, 93·2	71·2, 81·6	23·2, 34·4
Third trimester			
%	73·5	75·9	36·1
95 % CI	67·7, 78·7	70·3, 80·9	30·4, 42·3

IQR, interquartile range.
†Data missing for two (0·8 %) women.

age at initiation of 16 (IQR 11, 20) weeks. Mg supplements were taken by 12·0 % of the women in the first trimester and by 36·1 % in the third, with a median gestational age at initiation of 24 (IQR 14, 30) weeks.

Discussion

Main findings

The present study showed that the intakes of energy and macronutrients were within recommended levels for most pregnant women. Energy requirements increase with pregnancy. In our sample there was no increase in energy intake with pregnancy but, despite this, energy intake remained above recommended levels. Thus, and in contrast to English pregnant women[37], we did not find any energetic deficit during gestation. As important as total energy intake is its distribution by the different macronutrients. The observed inadequacy in carbohydrates intake prior to and during pregnancy was mainly a result of low consumption, whereas the inadequacy in fat intake reflected mainly overconsumption. Protein intake was adequate in both time periods. These findings are in line with the dietary habits of the Portuguese adult population[38].

Preconceptional dietary intakes of vitamin E, folate and Mg were below the recommended levels for large proportions of women. The average daily intakes of these micronutrients increased with pregnancy, but as their requirements also increased, the prevalences of inadequacy in the intake of folate and Mg, although not of vitamin E, were higher during pregnancy than in the preceding year. The prevalence of inadequacy in vitamin E intake may have been, at least in part, overestimated as both the FFQ and FD may have underestimated the amount of fats added to dishes after cooking. The level of inadequacy in folate intake reported here is similar to that observed among Finnish pregnant women[39]. A recent US study[40] reported a much lower inadequacy prevalence (36 % *v.* 90·8 % in our sample) but, in contrast to Portugal, folate fortification of staple foods is common in the USA. A much lower prevalence was also observed in a large British study but the cut-off points used to define inadequacy of folate intake were very different[37] from those used in the present study. Intake of Fe prior to conception was within recommended levels for most women, but as requirements almost triple during pregnancy with no parallel increase in intake, the prevalence of inadequacy was very high during pregnancy. Average levels of intake of vitamin C, known to increase absorption of Fe, were well above recommended levels in both time periods.

The intakes of most macro- and micronutrients in our study were higher than those reported for pregnant women in England[37,41], but similar to those found among pregnant women in Finland[39], the USA[42] and Greece[43].

We attempted to identify groups of women who may be at particular risk of nutrient inadequacy and to whom dietary interventions should be targeted. We found no clear associations between the social and behavioural characteristics of the participants and intake inadequacy. These findings should be interpreted with caution as the power of the study to detect these associations was low. Conversely, the few observed associations may have arisen by chance given the large number of statistical tests performed.

Randomised trials[44–48] have shown that folic acid supplementation during the periconceptional period and early pregnancy can reduce the risk of neural tube defects by 80 % or more. Practically all women in the present study took folic acid supplements. However, few took them during the most critical period[49]. In our sample only 18·6 % of women used folic acid in the three months prior to becoming pregnant and only 20·2 % initiated supplementation before the fourth week of gestation. These values probably underestimate the true prevalence of folate inadequacy in the general population as our sample excluded pregnant women who had their first routine antenatal visit after 12 weeks of gestation and were thus less likely to have taken folic acid supplements in early pregnancy.

Mg supplementation in the first trimester was uncommon but it became more frequent subsequently. The main reasons for prescribing this supplement are abdominal pains and muscular cramps, not concerns of a possible nutritional deficiency. Thus, in the absence of symptoms, there is probably no justification to treat Mg deficiencies.

Strengths and weaknesses

Our study has some strengths. First, it used a paired design to compare food and nutrient intake prior to and during pregnancy in the same sample of women, thus minimising the potential for confounding by maternal characteristics. Second, a subset of 101 women was able to complete the various FFQ as well as a 3 d FD in each trimester of pregnancy. The study has also some weaknesses. Our sample was assembled in two public hospitals in Porto and therefore any extrapolations to the general population should be made with caution. Comparison with national statistics showed that the age composition of our sample was similar to that for all Portuguese pregnant women who delivered a live-born baby in the same time period (mean (95 % CI): 28·6 (28·1, 29·6) *v.* 29·6 years, respectively), but our participants were more likely to be primiparous (62·7 % (56·3 %, 68·7 %) *v.* 54·4 %, respectively), less likely to be married (86·3 % (81·4 %, 90·4 %) *v.* 94·0 %, respectively) and slightly less educated (percentage with $<$10 years of schooling: 60·9 % (54·5 %, 67·0 %) *v.* 49·7 %, respectively).

Because of the study design women with a gestational age above 13 weeks at entry and those whose pregnancies ended in miscarriages, stillbirths and very premature births (gestational age <32 weeks) were excluded. As diet has been shown to be associated with adverse pregnancy outcomes[50], these exclusions may have affected the estimates of food and nutrient intakes reported here.

The FFQ was chosen to assess dietary intake in our study as it allowed retrospective estimation of diet prior to and around conception. The FFQ is an appropriate tool for epidemiological studies where the main objective is to rank individuals according to their levels of intake and to identify extremes of intake[51–53]. Although an FFQ was used in the present study to quantify absolute intake, this approach seems reasonable because of the paired design. Comparison of the FFQ estimates with those derived from the average of the three 3 d FD in a subset of women show that, if anything, the FFQ underestimated somehow the prevalence of inadequacy in the intake of certain nutrients. This subset of women is unlikely to be unrepresentative as their FFQ estimates were similar to those for the whole study population. The differences between the two methods may partly reflect the fact that the FFQ tends to overestimate usual intake whereas the FD tends to underestimate it[53,54].

Preconceptional diet was assessed retrospectively in early pregnancy and the interviewers were instructed to remind women of the exact reference period several times throughout the FFQ administration. Recall bias due to pregnancy complications can be eliminated because the FFQ was administered in early pregnancy, but recall bias due to social desirability and nausea/vomiting cannot be excluded. Estimates of the usual dietary intake throughout the whole pregnancy were also obtained retrospectively, a few days after delivery. Knowledge of the pregnancy outcome could have affected recall of diet by the participants, but it is unlikely that this might have biased our findings considerably because the inadequacy prevalence estimates based on FFQ2 were similar to those derived from the FD in the subset of women who completed these prospectively throughout pregnancy.

Public health implications

Although nutritional requirements increase with pregnancy[34,35] as a result of maternal physiological changes and progressive fetal growth and development[55], few dietary changes are required within well-nourished populations with a balanced diet[56]. The present study showed that the diet of Portuguese women prior to conception and during pregnancy is likely to contain adequate amounts of most nutrients, except vitamin E, folate and Mg. Fe intake during pregnancy was also below recommended levels.

The prevalence of inadequacy in dietary Fe intake was high in our study. The physiological requirements of Fe tend to increase from mid-pregnancy[57], at a time when over 75 % of pregnant women in the present study were on Fe supplementation. Moreover, Fe inadequacy can be easily detected by monitoring Hb levels throughout pregnancy.

Folic acid supplementation was widespread, but the timing of its initiation was inappropriate for most women. Portuguese national guidelines on folic acid, issued in 1998, recommended supplementation for all women of childbearing age[58]. Our findings of a low dietary intake of folate combined with very late initiation of supplementation, nine years after the introduction of the current national guidelines, are disappointing. A recent analysis of data from ten European countries, including Portugal, showed that the issuing of recommendations on folate dietary intake and supplementation was not followed by a decline in the prevalence of neural tube defects in any of the populations studied[59]. In contrast, the introduction of population-based measures such as the widespread fortification of staple foods with folate was an efficient and low-cost approach in the USA, Canada, Chile and South Africa[60–63]. The introduction of widespread folate fortification in Portugal should be considered as a possible complementary approach to the current recommendations on dietary intake and supplements.

Acknowledgements

Sources of funding: The study was funded by Programa Operacional de Saúde – Saúde XXI, Quadro Comunitário de Apoio III and by Administração Regional de Saúde Norte. E.P. was funded by Fundação para a Ciência e a Tecnologia (SFRH/BD/19803/2004).

Conflict of interest declaration: There are no conflicts of interest.

Authors' contributions: H.B. and I.S.S. were responsible for designing the study and for obtaining funding. E.P. was responsible for subject recruitment, data collection, and all of the nutritional and statistical analyses. E.P. wrote the manuscript jointly with H.B. and I.S.S. All three authors contributed to the interpretation of the findings and the final version of the manuscript.

Acknowledgement: We are grateful to the families enrolled in the Geração XXI study for their generosity; the various members of the research team for their enthusiasm and perseverance; and the participating hospitals and their staff for their help and support. In particular, we would like to thank P. Sarmento, A.C. Cunha, A. Gouveia, E. Fernandes and L. Fernandes from Júlio Dinis Maternity Hospital, and N. Montenegro, M. Moucho, T. Rodrigues and L. Francisco from S. João Hospital.

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