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Evaluation of an FFQ to assess total energy and nutrient intakes in severely obese pregnant women

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Abstract

Objective: FFQ are popular instruments for assessing dietary intakes in epidemiological studies but have not been validated for use in severely obese pregnancy. The aim of the present study was to compare nutrient intakes assessed by an FFQ with those obtained from a food diary among severely obese pregnant women.
Design: Comparison of an FFQ containing 170 food items and a food diary for 4 d (three weekdays and one weekend day); absolute agreement was assessed using the paired *t* test and relative agreement by Pearson/Spearman correlation, cross-classification into tertiles and weighted kappa values.
Setting: Antenatal metabolic clinic for severely obese women.
Subjects: Thirty-one severely obese (BMI at booking $\geq$40·0 kg/m^2) and thirty-two lean control (BMI = 20·0–24·9 kg/m^2) pregnant women.
Results: The findings showed that nutrient intakes estimated by the FFQ were significantly higher than those from the food diary; average correlation was 0·32 in obese and 0·43 in lean women. A mean of 48·5 % of obese and 47·3 % of lean women were correctly classified, while 12·9 % (obese) and 10·0 % (lean) were grossly misclassified. Weighted κ values ranged from −0·04 to 0·79 in obese women and from 0·16 to 0·78 in lean women.
Conclusions: Overall, the relative agreement between the FFQ and food diary was lower in the obese group than in the lean group, but was comparable with earlier studies conducted in pregnant women. The validity assessments suggest that the FFQ is a useful tool for ranking severely obese pregnant women according to the levels of their dietary intake.

Keywords
FFQ
Validation
Obesity
Pregnancy

Extra dietary energy is required during pregnancy to compensate for the deposition of maternal and fetal tissues and the increase in BMR[(1)]. However, with recent data indicating that up to a quarter of adult women are now classified as obese in the UK[(2)], including in Scotland[(3)], the prominent nutritional problem faced by pregnant women in developed countries is overnutrition, including pre-pregnancy overweight/obesity and excessive weight gain during pregnancy. Maternal obesity is associated with detrimental effects in both mothers and offspring. Obese mothers are at higher risk of developing pregnancy complications such as gestational diabetes, pre-eclampsia and having large-for-gestational-age babies[(4)]. Therefore, evaluation of dietary intake in this population is important.

The FFQ is a popular instrument for assessing dietary intakes in epidemiological studies, mostly because it is relatively inexpensive and does not place a heavy burden on either the respondent or research staff. The FFQ also allows collection of information on usual or average food intake over an extended period, thus reflecting habitual intake, rather than a snapshot of a few days' diet[(5,6)]. Therefore FFQ have been used to investigate the nutritional status of pregnant women[(7–13)], but not severely obese pregnant women.

There are, however, some limitations in the use of the FFQ to estimate food intake. It relies heavily on an individual's ability to recall the foods he/she usually eats and to conceptualize portion sizes. The FFQ is therefore susceptible to measurement errors, as with the use of any dietary assessment instrument[(6,14)]. In addition, because dietary habits differ between populations and FFQ are therefore tailored for specific populations, care must be taken to use an appropriate FFQ to ensure the accuracy of information obtained[(5)]. It is therefore essential to assess the validity of an FFQ in the study population of interest[(6)].

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There is no consensus in the literature on the best method for validating FFQ. Ideally, FFQ validation should be done against an objective measure of energy expenditure, for example the doubly labelled water technique[15], or by use of other biomarkers such as nitrogen, sodium, vitamin C and fat-soluble vitamins[16]. However, the resources required for these techniques limit their use. Different methods of measuring dietary intake are affected by different sources of bias; however, the validity of one method can be assessed relative to another. A systematic review showed that 75 % of validation studies compared an FFQ against another dietary instrument[6]. A food record/diary, with or without food weighing, is commonly used as the reference method for FFQ validation because the food record/diary provides a more detailed and quantitative estimate of nutrient intake, is not influenced by recall bias and is likely to have the smallest correlated errors among dietary assessment instruments[6]. A food diary has been used previously to validate an FFQ in pregnant women in the general population[17–19]. Various statistical methods are recommended to test the consistency of results from different dietary assessments[6,20].

The Scottish Collaborative Group FFQ (SCG-FFQ) has been used extensively in Scottish pregnant women[9], but its validity and suitability for use in obese pregnant women have never been tested. The present study aimed to compare intakes of total energy and nutrients estimated by the SCG-FFQ with those from a 4 d food diary (FD; used as the reference method) and to assess the validity and reliability of the SCG-FFQ in the estimating food intake of severely obese pregnant women.

Experimental methods

Study design and participants

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the Lothian Research Ethics Committee. Written informed consent was obtained from all participants. Severely obese (BMI at antenatal booking $\geq$40·0 kg/m^2) and lean (antenatal booking BMI = 20·0–24·9 kg/m^2) pregnant women between 12 and 29 weeks' gestation were recruited from an ongoing cohort study of severe obesity in pregnancy at the Antenatal Metabolic Clinic, Royal Infirmary of Edinburgh, Edinburgh, UK. The women were asked to complete both the SCG-FFQ and FD at the same time point in gestation.

Scottish Collaborative Group FFQ

The semi-quantitative SCG-FFQ version 6·6 (Scottish Collaborative Group, University of Aberdeen, Aberdeen, UK) was used, which has been previously validated against 4 d weighted diet records in non-pregnant individuals[20]. The SCG-FFQ consists of a list of 170 foods and drinks which are divided into twenty-one food groups. Women were asked to describe the amount and frequency of consumption of each food on the list over the last 2 to 3 months. This included all meals, snacks and drinks eaten at home or away from home (e.g. at work, at restaurants or cafés and with friends or family). For each food, an example of one measure is provided to help estimate how much of each food is usually eaten (e.g. '1 medium slice' for bread). The amount is stated in Measures per Day (1 to 5+ measures) and the frequency in Number of Days per Week (1 to 7 d/week, or 'R' for foods which are rarely or never eaten and 'M' for foods which are consumed between once monthly to less than once weekly). If they chose 'R' for frequency, the women were asked to leave the amount section blank. In addition, the SCG-FFQ included a field called 'Other foods and drinks', in which the women could add any other foods or drinks that they usually consumed but were not included in the SCG-FFQ. The SCG-FFQ was checked after completion. If any data were missing, this was discussed with the woman during a clinic visit. Macro- and micronutrient intakes were extracted from questionnaires as previously described[20].

Food diary

The women were asked to keep a FD (Food and Drink Diary for Adults; University of Aberdeen) for 4 d (three weekdays and one weekend day), with detailed instructions for data collection. For each day, the women recorded the date, day of the week, time of meal, the type and amount of food and/or drink eaten during each meal and the amount left over, if any. They were asked to record everything they ate and drank at home or outside the home, in as much detail as possible (e.g. by including brand names, the type of bread/dairy products/cereals/drinks, type of fat or oil used in cooking, methods of cooking and the ingredients used for home-cooked meals). To help them describe the amounts, twenty-two pictures of portion sizes were provided within the food diary, as was an example of one day's record. If they consumed more or less than the amount in the picture, they could describe the amount by writing '1/2' or '2 times', etc. If appropriate, printed weights on packaged foods were used. Women were instructed to record any food left over at the end of the meal to avoid overestimation of food intake. They were advised to record intake at the time of eating, and not from memory at the end of the day. The returned FD was checked for completion. If any information was not complete or not understood, this was addressed with the woman. Data from FD were analysed using the WinDiets Standard dietary analysis software (Robert Gordon University, Aberdeen, UK).

Power calculation

We aimed for a sample size of between sixteen and thirty-six women in each group based on the numbers

(n 36 men and n 36 women) used in the previous validation of the SCG-FFQ in non-pregnant individuals[20] and on the assumptions and methods used in a previous study validating energy intake estimated from an FFQ against the doubly labelled water method[21]. The latter study demonstrated that a sample size of sixteen had 80 % power at the 5 % significance level to detect a 16 % difference (1400 kJ) between methods.

Statistical analysis

Normal distribution of data was assessed visually using histograms and Q–Q plots, and by the Shapiro–Wilk test. Total energy and nutrient intakes were not normally distributed and were normalized using natural logarithmic transformation. Significance was reported at $P < 0{\cdot}05$ and all statistical analyses were performed using the SPSS statistical software package version 14·0. Due to non-normal distributions of measured values data are presented as median (25th and 75th percentile), unless stated otherwise.

Within-subject differences between nutrient intakes estimated from the SCG-FFQ and FD were assessed using paired t tests. The relative agreement between the SCG-FFQ and FD was assessed using Spearman rank correlation and Pearson correlation on both reported and energy-adjusted values. The level of agreement between the SCG-FFQ and FD was assessed using Cohen's weighted kappa statistic (κ_w) for each nutrient[22], and the relationship between the methods using cross-classification. Women were classified into tertiles of intake by each dietary method. Percentages of women categorized into the same tertile by both methods or grossly misclassified into opposing tertiles were calculated.

To minimize the effect of measurement errors such as misreporting of energy intake, which would also affect the absolute intakes of nutrients, nutrient intakes were adjusted for total energy intake using the residual method. This was done by adding the residual (the difference between the observed nutrient value for each woman and the value predicted by a regression equation) to the nutrient intake that corresponds with the mean total energy intake of the study population[23]. Nutrient intakes from dietary supplements were not included in any of the analyses.

Results

Forty-eight obese and thirty-seven lean pregnant women agreed to take part, and thirty-one obese (52 %) and thirty-two lean (82 %) pregnant women completed the study. Four FD (from the obese group) were lost in the mail, two lean women withdrew from the study, nine obese and one lean women failed to complete the FD after reminder calls, and four obese and two lean women were not able to be contacted after initially agreeing to take part in the study. The demographic characteristics of women who completed the study are presented in Table 1. Obese and lean groups were of similar age, gestation and parity, and all women were Caucasian. However, obese women had significantly higher levels of socio-economic deprivation (derived from the Deprivation Category Score, which divides postcode sectors into categories in relation to income, employment, health, housing and education)[24] than lean women.

Absolute agreement

The crude nutrient intakes estimated by the SCG-FFQ and FD are shown in Table 2 (obese group) and Table 3 (lean group). All nutrient intake estimates from the FFQ were significantly higher than those from the FD in both obese and lean groups, with the exception of niacin and vitamin C. Intakes of niacin were estimated to be lower by the SCG-FFQ compared with the FD in both groups. Vitamin C intake was similar between SCG-FFQ and FD in the obese group.

Table 1 Sociodemographic characteristics of the participants: pregnant women between 12 and 29 weeks' gestation, Edinburgh, UK

	Obese (n 31)		Lean (n 32)		
	Mean or n	Range or %	Mean or n	Range or %	P value
Age (years)	33·6	21·0–44·5	33·1	21·1–42·3	0·672†
BMI at booking (kg/m^2)	43·3	38·6–50·2	22·8	19·9–25·4	0·001†
Parity (%)					
Primiparous	18	58·1	19	59·4	0·853‡
Multiparous	13	41·9	13	40·6	
Ethnicity (%)					
Caucasian	31	100·0	32	100·0	
DEPCAT status (%)					
Low	5	16·1	1	9·5	0·001‡
Middle	25	80·6	19	69·8	
High	1	3·3	12	20·7	
Gestation questionnaire completed (weeks)	26·7	12·8–28·7	27·3	12·0–29·6	0·789†

DEPCAT, deprivation category ('low' indicates living in the most deprived areas)[23].
†Tested using the independent t test.
‡Tested using the χ^2 test.

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Table 2 Median (25th percentile, 75th percentile; P_{25}, P_{75}) crude daily nutrient intakes estimated from the FFQ and the 4 d food diary (FD) in the obese group (*n* 31): pregnant women between 12 and 29 weeks' gestation, Edinburgh, UK

	FFQ		FD			
Nutrient	Median	P_{25}, P_{75}	Median	P_{25}, P_{75}	*P* value†	*P* value‡
Energy (kJ)	10 157	8453, 11262	6544	5062, 7465	<0·001	–
Protein (g)	103·3	78·8, 124·1	63·0	50·7, 72·2	<0·001	0·655
Fat (g)	97·9	73·2, 119·8	61·6	48·4, 77·0	<0·001	0·827
Carbohydrate (g)	287·8	241·6, 367·0	198·7	149·2, 235·4	<0·001	0·720
SFA (g)	37·2	27·1, 47·6	23·6	16·5, 27·6	<0·001	0·664
MUFA (g)	34·0	24·8, 40·4	20·6	16·1, 24·8	<0·001	0·588
PUFA (g)	16·5	13·8, 18·6	10·5	8·5, 14·3	0·004	0·168
Cholesterol (mg)	300	215, 420	185	133, 222	<0·001	0·466
Sugars (g)	134·0	113·8, 167·0	80·3	62·0, 101·4	<0·001	0·105
Starch (g)	138·0	121·0, 178·0	112·1	97·0, 132·9	0·001	0·362
Fibre (g)	22·0	16·1, 28·3	3·3	2·7, 4·3	<0·001	1·000
Na (mg)	3222	2448, 3972	2381	1884, 2782	0·002	0·293
K (mg)	3957	3300, 5166	2371	1860, 2834	<0·001	0·686
Ca (mg)	1197	922, 1596	776	584, 945	<0·001	0·735
Mg (mg)	416	338, 490	211	152, 268	<0·001	0·279
P (mg)	1783	1448, 2178	1075	890, 1230	<0·001	0·558
Fe (mg)	14·17	11·54, 17·34	8·40	6·05, 11·25	<0·001	0·504
Cu (mg)	2·83	2·36, 3·47	0·81	0·53, 1·11	<0·001	0·854
Zn (mg)	12·40	9·50, 15·40	6·60	5·65, 8·30	<0·001	0·671
Cl (mg)	4826	3788, 6061	3575	2772, 4036	0·002	0·165
Mn (mg)	4·30	3·30, 4·95	2·08	1·51, 2·71	<0·001	0·583
Se (μg)	67·0	47·0, 80·0	34·0	27·5, 47·5	<0·001	0·570
Iodine (μg)	254	182, 316	122	96, 152	<0·001	0·692
Retinol (μg)	325	236, 426	224	171, 326	0·012	0·690
β-Carotene equivalents (μg)	3381	2393, 7336	1093	826, 1656	<0·001	0·800
Vitamin D (μg)	4·05	2·61, 4·77	1·79	0·72, 2·54	<0·001	0·820
Vitamin E (mg)	11·98	9·03, 15·33	7·11	5·07, 9·03	<0·001	0·800
Thiamin (mg)	1·97	1·53, 2·40	1·36	1·11, 1·59	<0·001	0·145
Riboflavin (mg)	2·08	1·60, 2·89	1·30	1·01, 1·61	<0·001	0·970
Niacin (mg)	24·50	18·55, 29·85	27·80	23·65, 34·80	0·011	0·509
Vitamin B_6 (mg)	2·58	2·03, 3·30	1·59	1·40, 2·12	<0·001	0·155
Vitamin B_{12} (μg)	6·80	5·05, 8·80	3·89	2·78, 5·43	<0·001	0·541
Folic acid (μg)	323	240, 398	204	154, 231	<0·001	0·390
Pantothenic acid (mg)	6·53	5·20, 7·91	3·60	3·15, 5·00	<0·001	0·807
Biotin (μg)	46·5	36·7, 52·4	20·3	16·4, 26·5	<0·001	0·916
Vitamin C (mg)	150·0	116·5, 229·5	99·4	49·5, 173·2	0·197	0·907

†*P* value, log-transformed as necessary, crude intakes (paired *t* test).
‡*P* value, log-transformed as necessary, energy-adjusted intakes (paired *t* test).

Relative agreement

Tables 4 and 5 show the Pearson and Spearman correlation coefficients between nutrient intakes estimated by the SCG-FFQ and FD, for obese and lean groups respectively. For energy-adjusted data, Pearson correlation coefficients were similar in obese (range −0·19 to 0·71) and lean (range −0·25 to 0·74) groups. There was a significant correlation for total energy intake between the SCG-FFQ and FD in the lean group, but not in the obese group. In terms of macronutrients, in obese women there was a significant correlation between the two methods for fat, which did not persist when adjusted for total energy; whereas the correlation for protein became significant after energy adjustment. In lean women, there was a significant correlation for protein, but this was no longer significant after adjustment for total energy.

A correlation coefficient between dietary assessment methods of greater than 0·5 has been suggested as acceptable in validation studies of FFQ[25]. In the present study, Pearson correlation coefficients >0·5 were found for measurements of one nutrient (dietary cholesterol) in obese women and fifteen nutrients in lean women. After energy adjustment, Pearson correlation coefficients >0·5 were found for five nutrients in obese and eight nutrients in lean women. In obese women, significant correlation coefficients were observed for nine nutrients including SFA, dietary cholesterol, sugars, Ca, P, iodine and vitamins B_6, B_{12} and C, both before and after adjustment for total energy. In lean women, this was observed for a total of eighteen nutrients (SFA, PUFA, dietary cholesterol, fibre, K, Ca, P, Zn, Mn, iodine, β-carotene, riboflavin, niacin, biotin and vitamins B_6, B_9 and C). Correlation coefficients were lowest for fibre and Se in obese women, and carbohydrate and Cu in lean women.

The ability of the FFQ to rank the participants was determined by cross-classification. Percentages of women categorized into the same tertile or opposite tertiles of intake by each method, and associated κ_w statistics for each nutrient, are shown in Table 6. On average, about 48 % of women in both groups were correctly

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Table 3 Median (25th percentile, 75th percentile; P_{25}, P_{75}) crude daily nutrient intakes estimated from the FFQ and the 4 d food diary (FD) in the lean group (*n* 32): pregnant women between 12 and 29 weeks' gestation, Edinburgh, UK

	FFQ		FD			
Nutrient	Median	P_{25}, P_{75}	Median	P_{25}, P_{75}	*P* value†	*P* value‡
Energy (kJ)	10 421	8415, 12644	7335	6167, 8131	<0·001	–
Protein (g)	92·6	74·2, 122·0	65·8	56·2, 74·6	<0·001	0·782
Fat (g)	95·4	72·4, 129·0	66·1	54·9, 81·7	<0·001	0·873
Carbohydrate (g)	334·9	259·4, 358·4	222·8	188·6, 263·0	<0·001	0·819
SFA (g)	36·2	27·4, 50·4	22·5	19·8, 28·9	<0·001	0·651
MUFA (g)	33·1	25·0, 43·3	21·8	17·6, 25·0	<0·001	0·528
PUFA (g)	17·5	13·0, 21·0	12·0	9·3, 13·9	<0·001	0·072
Cholesterol (mg)	321	205, 388	210	144, 253	<0·001	0·364
Sugars (g)	144·1	114·1, 188·2	107·5	80·4, 123·4	<0·001	0·116
Starch (g)	170·5	130·2, 194·2	117·8	96·8, 140·9	<0·001	0·529
Fibre (g)	24·8	19·4, 30·0	5·1	3·0, 6·5	<0·001	0·952
Na (mg)	3299	2440, 4433	2336	2005, 2748	<0·001	0·302
K (mg)	4294	3420, 4928	2371	2104, 2994	<0·001	0·844
Ca (mg)	1372	1035, 1609	831	788, 1110	<0·001	0·715
Mg (mg)	468	389, 539	239	207, 301	<0·001	0·417
P (mg)	1931	1485, 2343	1169	1046, 1312	<0·001	0·481
Fe (mg)	17·68	13·70, 21·34	10·45	8·55, 12·13	<0·001	0·630
Cu (mg)	3·27	2·76, 4·36	1·06	0·86, 1·25	<0·001	0·856
Zn (mg)	12·55	8·78, 15·25	7·30	6·28, 8·90	<0·001	0·678
Cl (mg)	4986	3667, 6549	3362	2877, 3810	<0·001	0·161
Mn (mg)	4·40	3·98, 6·33	2·66	2·26, 3·32	<0·001	0·625
Se (μg)	67·0	50·0, 82·0	36·5	26·8, 48·2	<0·001	0·490
Iodine (μg)	276	193, 368	152	112, 174	<0·001	0·746
Retinol (μg)	339	252, 506	297	209, 345	0·028	0·592
β-Carotene equivalents (μg)	3925	2890, 8520	1608	951, 2088	<0·001	0·699
Vitamin D (μg)	4·68	2·88, 6·53	2·24	1·17, 3·53	<0·001	0·781
Vitamin E (mg)	13·69	9·38, 15·76	8·51	6·63, 10·71	<0·001	0·740
Thiamin (mg)	2·19	1·72, 2·48	1·43	1·19, 1·55	<0·001	0·242
Riboflavin (mg)	2·46	2·03, 2·87	1·66	1·41, 1·82	<0·001	0·970
Niacin (mg)	24·55	19·73, 28·15	29·90	26·05, 34·98	<0·001	0·405
Vitamin B_6 (mg)	2·84	2·11, 3·37	1·53	1·32, 1·81	<0·001	0·193
Vitamin B_{12} (μg)	7·35	4·80, 9·83	3·65	2·71, 5·04	<0·001	0·594
Folic acid (μg)	398	285, 450	230	182, 262	<0·001	0·587
Pantothenic acid (mg)	7·07	5·27, 8·46	4·20	3·58, 5·13	<0·001	0·840
Biotin (μg)	50·0	36·5, 61·4	26·1	22·2, 33·7	<0·001	0·962
Vitamin C (mg)	154·5	116·0, 221·2	108·5	77·6, 149·5	0·001	0·970

†*P* value, log-transformed as necessary, crude intakes (paired *t* test).
‡*P* value, log-transformed as necessary, energy-adjusted intakes (paired *t* test).

classified, whereas 13 % of obese and 10 % of lean women were grossly misclassified between the two methods. The κ_w value for total energy was lower in the obese group compared with the lean group. In general, $\kappa_w < 0$ indicates poor agreement, $\kappa_w = 0–0·2$ indicates slight agreement, $\kappa_w = 0·2–0·4$ fair agreement, $\kappa_w = 0·4–0·6$ moderate agreement and $\kappa_w = 0·6–0·8$ indicates substantial agreement[26]. Within macronutrients, substantial agreement was observed for fat in obese and protein in lean groups; moderate agreement was observed for protein in obese and fat in lean groups; and fair agreement for carbohydrates in both groups. There was poor agreement for fibre in the obese (in agreement with cross-classification and correlation) group and slight agreement for Cu, Se and vitamin B_{12} in the lean group. However, substantial agreement was shown for fat, SFA, PUFA, Cl, iodine and retinol in obese women, and for protein, SFA, PUFA, cholesterol, Ca, P, Fe, Zn, Mn, iodine, retinol, niacin and vitamin B_6 in lean women.

Discussion

In the present study of pregnant Scottish women aged 21 to 42 years, nutrient intakes estimated by the SCG-FFQ were compared with those recorded in a 4 d unweighed FD to evaluate the validity of the SCG-FFQ in severely obese pregnant women (BMI ≥ 40·0 kg/m^2). The principal use of the FFQ is to categorize individuals according to relative nutrient intakes, i.e. to distinguish people with low intakes from those with high intakes, to avoid the necessity of assessing absolute intakes of nutrients[27]. An FFQ's validity can be evaluated by comparing it with other dietary assessment tools such as food records, or with biochemical measurements of energy or nutrients[6]. A 4 d FD was chosen as the reference method in the present study due to its feasibility, detailed and quantitative estimates, and non-reliance on the participant's memory or ability to estimate portion sizes.

Assessments of absolute nutrient intakes between the two methods found that the SCG-FFQ generally reported

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Table 4 Pearson (r_P) and Spearman (r_S) correlation coefficients between the FFQ and 4 d food diary in the obese group (*n* 31): pregnant women between 12 and 29 weeks' gestation, Edinburgh, UK

	Pearson†		Spearman	
Nutrient	$r_P^{measured}$	$r_P^{energy-adjusted}$	$r_S^{measured}$	$r_S^{energy-adjusted}$
Energy (kJ)	0·28	–	0·33	–
Protein (g)	0·19	0·35*	0·25	0·30
Fat (g)	0·38*	0·12	0·49**	−0·01
Carbohydrate (g)	0·23	−0·03	0·26	0·20
SFA (g)	0·50**	0·45**	0·52**	0·30
MUFA (g)	0·43*	0·18	0·52**	0·09
PUFA (g)	0·19	0·16	0·20	0·15
Cholesterol (mg)	0·54**	0·46**	0·42*	0·22
Sugars (g)	0·35*	0·58**	0·44*	0·25
Starch (g)	0·29	0·42*	0·39*	0·21
Fibre (g)	−0·09	0·04	−0·07	−0·18
Na (mg)	0·33	0·18	0·51**	0·36*
K (mg)	0·29	0·70**	0·30	0·54**
Ca (mg)	0·41*	0·51**	0·45*	0·43*
Mg (mg)	0·25	0·41*	0·30	0·43*
P (mg)	0·38*	0·4*	0·44*	0·59**
Fe (mg)	0·10	0·42*	0·32	0·33
Cu (mg)	0·08	−0·19	0·15	−0·14
Zn (mg)	0·27	0·41*	0·37*	0·45*
Cl (mg)	0·37*	0·21	0·51**	0·43*
Mn (mg)	0·31	0·71**	0·37*	0·54**
Se (μg)	0·01	0·04	0·15	0·06
Iodine (μg)	0·48**	0·53**	0·48**	0·42*
Retinol (μg)	0·44*	0·31	0·50**	0·06
β-Carotene equivalents (μg)	0·18	0·24	0·21	0·13
Vitamin D (μg)	0·17	0·16	0·03	0·11
Vitamin E (mg)	0·03	0·39*	0·05	0·18
Thiamin (mg)	0·24	0·51**	0·20	0·34
Riboflavin (mg)	0·32	0·47**	0·27	0·47**
Niacin (mg)	0·08	0·20	0·07	0·15
Vitamin B_6 (mg)	0·38*	0·50**	0·30	0·48**
Vitamin B_{12} (μg)	0·46*	0·51**	0·30	0·29
Folic acid (μg)	0·26	0·42*	0·23	0·46**
Pantothenic acid (mg)	0·21	0·34	0·24	0·45*
Biotin (μg)	0·36*	0·34	0·37*	0·44*
Vitamin C (mg)	0·40*	0·69**	0·52**	0·52**

*Correlation is significant at the 0·05 level; **correlation is significant at the 0·01 level.
†For log-transformed nutrient intakes.

higher estimates than the FD. This corresponds well with findings from other validation studies conducted in pregnant women using similar dietary instruments (FFQ *v.* FD)[17–19]. Intakes of nutrients were also found to be higher when determined by FFQ compared with other dietary assessment methods such as 24 h recall[28]. Higher reporting using the FFQ may reflect over-reporting of the frequency of consumption of foods, larger portion size estimation by the FFQ or under-reporting of consumption by the FD or 24 h recall.

The correlations observed between the SCG-FFQ and FD were comparable with previous studies in pregnancy for our obese participants, and greater than in previous studies for our lean participants[17–19,28], particularly for intakes of total energy, macronutrients and essential nutrients during pregnancy. For example, correlations of measured total energy intake in our obese group were $r_P = 0{\cdot}284/r_S = 0{\cdot}334$ and in our lean group were $r_P = 0{\cdot}462/r_S = 0{\cdot}510$; compared with previous reports of $r_S = 0{\cdot}27$[17], $r_P = 0{\cdot}26$[28], $r_P = 0{\cdot}24$[18] and $r_S = 0{\cdot}28$[19] in pregnant women (where r_P is Pearson correlation, r_S is Spearman correlation). The reasons for closer correlation in our lean women are unknown, but may reflect that this was a group of lean women who had consented to participate in a study of obesity in pregnancy, and so were well motivated and interested in health behaviour and weight in pregnancy. A further reason is that we adjusted for total energy intake in order to minimize the effect of measurement errors such as misreporting of energy intake, which would also affect the absolute intakes of nutrients[23]. This method of analysis resulted in improved correlation between the two methods. Significant agreement was also seen for important nutrients such as Ca, Fe, vitamins E, B_6, B_{12} and C, and also for SFA, dietary cholesterol and sugars, in both our obese and lean groups, as observed by others[19]. However, correlations for energy-adjusted dietary fibre were poorer in the obese group ($r_P = 0{\cdot}044/r_S = -0{\cdot}183$) than the lean group ($r_P = 0{\cdot}377/r_S = -0{\cdot}294$), as well as other studies ($r_P = 0{\cdot}36\text{-}0{\cdot}47$[28] and $r_P = 0{\cdot}56$[18]). This suggests

Table 5 Pearson (r_P) and Spearman (r_S) correlation coefficients between the FFQ and 4 d food diary in the lean group (*n* 32): pregnant women between 12 and 29 weeks' gestation, Edinburgh, UK

	Pearson†		Spearman	
Nutrient	$r_P^{measured}$	$r_P^{energy-adjusted}$	$r_S^{measured}$	$r_S^{energy-adjusted}$
Energy (kJ)	0·46**	–	0·51**	–
Protein (g)	0·49**	0·11	0·62***	0·20
Fat (g)	0·30	0·04	0·44*	−0·02
Carbohydrate (g)	0·05	−0·08	0·31	0·07
SFA (g)	0·60***	0·53**	0·66***	0·36*
MUFA (g)	0·39*	0·31	0·38*	0·22
PUFA (g)	0·52**	0·40**	0·58**	0·41*
Cholesterol (mg)	0·66***	0·74**	0·50**	0·46**
Sugars (g)	0·08	0·21	0·15	0·27
Starch (g)	0·51**	0·15	0·42*	0·20
Fibre (g)	0·53**	0·38*	0·40*	0·29
Na (mg)	0·397*	0·24	0·38*	0·22
K (mg)	0·38*	0·52**	0·45**	0·49**
Ca (mg)	0·59***	0·37*	0·60***	0·32
Mg (mg)	0·39*	0·18	0·34	0·29
P (mg)	0·56**	0·45**	0·52**	0·34
Fe (mg)	0·59***	0·23	0·47**	0·26
Cu (mg)	0·04	−0·25	0·13	−0·08
Zn (mg)	0·66***	0·40*	0·64***	0·43*
Cl (mg)	0·45*	0·27	0·39*	0·20
Mn (mg)	0·63***	0·68**	0·61***	0·57**
Se (μg)	0·22	0·29	0·25	0·28
Iodine (μg)	0·52**	0·43*	0·52**	0·38*
Retinol (μg)	0·25	0·32	0·44*	0·43*
β-Carotene equivalents (μg)	0·43*	0·40*	0·33	0·27
Vitamin D (μg)	0·16	0·25	0·22	0·21
Vitamin E (mg)	0·52**	0·31	0·48**	0·28
Thiamin (mg)	0·46**	0·34	0·38*	0·22
Riboflavin (mg)	0·52**	0·37*	0·37*	0·33
Niacin (mg)	0·53**	0·56**	0·51**	0·25
Vitamin B_6 (mg)	0·49**	0·42*	0·50**	0·45**
Vitamin B_{12} (μg)	0·39*	0·34	0·24	0·14
Folic acid (μg)	0·39*	0·34	0·36*	0·23
Pantothenic acid (mg)	0·50**	0·42*	0·43*	0·17
Biotin (μg)	0·48**	0·43*	0·44*	0·32
Vitamin C (mg)	0·33	0·45*	0·37*	0·37*

*Correlation is significant at the 0·05 level; **correlation is significant at the 0·01 level; ***correlation is significant at the 0·001 level.
†For log-transformed nutrient intakes.

possible over-reporting of portion size/frequency of dietary fibre intake in the FFQ as opposed to under-reporting in the FD; it has been reported that fruits and vegetables are perceived as healthy and are more likely to be over-reported in FFQ[29].

The ability of the SCG-FFQ to rank individuals by intake was evaluated by the percentage of women who were classified into the same or opposite tertiles of (energy-adjusted) intake by both methods. Overall, in the present study, about half of the participants were correctly classified and about 10 % were grossly misclassified into the opposite tertile. Comparable results were reported by Robinson *et al.*[19] who cross-classified using quintiles and obtained an average of 35 % consistent classification and 6 % gross misclassification. Others have reported higher percentages (between 49 and 94 %) of consistent classification using the weighed food record[17] and 24 h diet recall[28] as reference method. These techniques may have advantages such as better food portion estimation (from weighing) and more complete information (from multiple-pass dietary interviews) compared with an unweighed FD.

The κ_w statistic tests ranking agreement between the FFQ and the reference method, taking partial agreement into consideration[22]. The κ_w value for total energy was lower in obese women as compared with lean. The κ_w values were found to show poor agreement for fibre in the obese group, and slight agreement for Cu, Se and vitamin B_{12} in the lean group. The highest κ_w values were found for SFA in obese women and Ca and Zn in lean women, whereas the lowest κ_w values were observed for dietary fibre in obese and Cu in lean women, in agreement with the results obtained from cross-classification and correlation methods. This is consistent with over-reporting of foods perceived to be 'more healthy' using the FFQ[29].

The use of a second group of lean pregnant women allowed comparison of our results with similar populations reported in the literature, demonstrating that the obese and lean groups did in fact behave differently in

Table 6 Percentages of women classified into the same and opposite tertiles of intake (according to the FFQ and the 4 d food diary) and weighted kappa values (κ_w): pregnant women between 12 and 29 weeks' gestation, Edinburgh, UK

	Obese (*n* 31)				Lean (*n* 32)			
	% classified in				% classified in			
Nutrient	Same tertile	Opposite tertiles	κ_w	*P* value	Same tertile	Opposite tertiles	κ_w	*P* value
Energy (kJ)	45	10	0·468	0·044	50	12	0·560	0·013
Protein (g)	42	10	0·471	0·043	53	3	0·743	<0·001
Fat (g)	61	6	0·687	0·001	50	12	0·559	0·013
Carbohydrate (g)	52	19	0·373	0·103	44	16	0·321	0·143
SFA (g)	64	3	0·789	<0·001	53	3	0·744	<0·001
MUFA (g)	55	3	0·721	<0·001	38	16	0·361	0·109
PUFA (g)	48	6	0·552	0·016	50	9	0·634	0·003
Cholesterol (mg)	45	13	0·483	0·038	50	6	0·674	0·001
Sugars (g)	48	10	0·520	0·024	31	16	0·282	0·180
Starch (g)	58	13	0·527	0·022	47	12	0·498	0·030
Fibre (g)	26	13	−0·039	0·541	50	12	0·548	0·015
Na (mg)	48	10	0·560	0·014	41	6	0·589	0·008
K (mg)	58	16	0·498	0·032	47	9	0·550	0·015
Ca (mg)	45	13	0·508	0·028	56	0	0·775	<0·001
Mg (mg)	42	13	0·409	0·078	53	9	0·578	0·009
P (mg)	55	13	0·586	0·009	47	3	0·675	0·001
Fe (mg)	32	13	0·269	0·198	50	6	0·626	0·004
Cu (mg)	45	19	0·201	0·272	34	16	0·003	0·496
Zn (mg)	45	13	0·465	0·046	62	3	0·765	<0·001
Cl (mg)	55	6	0·713	<0·001	41	9	0·471	0·041
Mn (mg)	61	13	0·539	0·019	56	22	0·645	0·003
Se (μg)	55	13	0·481	0·039	38	22	0·163	0·311
Iodine (μg)	52	6	0·636	0·004	53	9	0·649	0·002
Retinol (μg)	61	10	0·673	0·002	56	3	0·660	0·002
β-Carotene equivalents (μg)	35	13	0·306	0·161	44	12	0·467	0·043
Vitamin D (μg)	39	16	0·093	0·395	47	16	0·426	0·064
Vitamin E (mg)	35	16	0·247	0·221	41	12	0·435	0·059
Thiamin (mg)	48	22	0·226	0·244	44	9	0·500	0·029
Riboflavin (mg)	48	16	0·409	0·078	41	9	0·421	0·067
Niacin (mg)	48	39	0·250	0·217	53	6	0·656	0·002
Vitamin B_6 (mg)	58	13	0·566	0·013	56	6	0·708	<0·001
Vitamin B_{12} (μg)	35	10	0·408	0·078	38	22	0·163	0·311
Folic acid (μg)	45	16	0·215	0·255	47	9	0·586	0·008
Pantothenic acid (mg)	48	16	0·472	0·043	41	6	0·487	0·034
Biotin (μg)	52	10	0·543	0·018	50	9	0·568	0·011
Vitamin C (mg)	58	13	0·595	0·008	50	9	0·566	0·011

our study. The main limitation was that both the FFQ and FD were self-reported and therefore could be subject to similar measurement error and reporting bias. The use of an FD may also not represent habitual intake, as it may influence changes in eating behaviour through the act of recording[6]. In addition, responses to the FFQ and FD may differ in early pregnancy from later pregnancy due to nausea, sensitivity to food smells, vomiting, bloating and heartburn. It has been suggested that over-reporting could be due to either over-reporting of food portions and frequency in the FFQ, or under-reporting in the reference method[19]. Under-reporting of food intake has been found to be particularly prevalent in obese[15,30] and pregnant[31,32] women and occurs across dietary measurement instruments[33]. Since under-reporting most commonly involves recording of implausibly low food intake (evidenced by low total energy intake), this also affects estimates of absolute nutrient intakes. By adjusting for reported total energy intake, the proportion of the diet composed of each nutrient is represented. This reduces the possibility of measurement error caused by misreporting of total energy intake, making nutrient intakes independent of total energy[15]. As there is no 'gold standard' in dietary measurement, comparisons between measurement methods can only be relative, rather than assessing the accuracy of each instrument.

It has been demonstrated that the method of administration of an FFQ may affect the validity of results. Correlations between FFQ and a reference method have been reported to be higher for interviewer-administered than self-administered FFQ for certain nutrients[16]. Interviewer-administered methods may be advantageous as they allow immediate checking for any missing or incomprehensible response by the interviewer. However, the cost, time and resources involved must be considered. In addition, the presence of an interviewer may increase the likelihood of social desirability bias in the participants' responses. Discussing dietary patterns in such obese pregnant women is clearly a sensitive issue as demonstrated by our high attrition rate in the obese group.

Conclusions

The validity of the SCG-FFQ was found to be lower in obese than in lean pregnant Scottish women, as demonstrated by poorer agreement between the FFQ and FD. The SCG-FFQ was, however, able to rank individuals by levels of nutrient intakes, and was better for some nutrients such as SFA, dietary cholesterol, sugars and vitamin C, but poorer for other such as dietary fibre, in severely obese pregnant women. Overall, the SCG-FFQ appears to be a suitable tool for evaluating food intake during pregnancy in severely obese pregnant women.

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