An evaluation of food photographs as a tool for quantifying food and nutrient intakes

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Abstract

Objective: To evaluate the errors incurred by young adults using single portion size colour food photographs to quantify foods and nutrients consumed at six meals on two non-consecutive days.

Design: Breakfast menus remained the same for the 2 days; but lunch and dinner menus varied. The amounts of food eaten by individuals were determined by weighing individual serving dishes pre- and post-consumption. The day after eating, all foods consumed were quantified in terms of fractions or multiples of the amounts shown in the food photographs.

Subjects: Thirty adult volunteers (15 male, 15 female), aged 18–36 years, completed the protocol for day one; 27 (90%) completed day two.

Results: Some foods were more difficult to quantify accurately than others. The largest error range was −38.9% to +284.6% (cheese), whereas the smallest errors were incurred for juice (−21.5% to +34.6%, day one). All subjects who consumed muesli (day one) overestimated (+3.7% to +113.7%). No other foods were consistently over- or underestimated. For foods consumed at breakfast by the same subjects on both days, individual estimation errors were inconsistent in magnitude and/or direction. At the group level, most nutrients were estimated to within ±10% of intake; exceptions were thiamin (+10.5%, day one) and vitamin E (−10.1%, day one; −15.3%, day two). Between 63% and 80% of subjects were correctly classified into tertiles on the basis of estimated intakes.

Conclusions: Despite some large food quantification errors, single portion size food photographs were effective when used to estimate nutrient intakes at the group level. It remains to be established whether, under the conditions used in this study, more photographs per food would improve estimates of nutrient intake at the individual level.

Keywords
Food photographs
Diet surveys
Food portion size

The methods used to quantify food and nutrient intakes of free-living humans may be divided into two broad categories; those in which foods are weighed directly, and those in which food quantities are estimated. Although weighing is more precise, there are several drawbacks such as substantial subject burden, financial and time costs, and the inability to assess past intakes. Diet history and recall methods, which can be administered by trained investigators in relatively short periods of time, circumvent many of these problems and are becoming more widely used. However the success of these methods is likely to depend heavily on the ability and willingness of subjects both to remember and accurately estimate the amounts of food which they have consumed.

Accurate estimation of portion size is problematic[1–7]. Visual aids, such as food photographs, may help to improve the accuracy of food quantification[3]. However, the results of studies which have attempted to evaluate their usefulness have been somewhat inconclusive[8–13]. Several of these studies have been conducted under highly controlled and non-representative conditions where subjects have used photographs to estimate quantities of foods which they either did not serve for themselves or did not eat[10,11,13]. Under these conditions it has been concluded that photographs may be an effective quantification tool, but it has also been postulated that factors such as the variability of perceptual cues, poor memory and lack of motivation routinely encountered in studies of free-living subjects, are likely to have a significant impact on the accuracy of the estimates[11]. Others have speculated that assessments of portion size estimates made when subjects neither choose nor consume food may be more accurate because their perception is not biased by factors such as an unwillingness to divulge what they have eaten[14].

Unfortunately the few studies which have attempted to assess the usefulness of photographic methods in situations where subjects actually consumed self-selected

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quantities of food have varied substantially in design, making direct comparisons difficult[8,9,12,15]. In addition, only one study to date has extensively detailed the errors made when subjects used food photographs to estimate amounts of food, and the subsequent errors incurred when nutrient intakes were calculated[12]. In that study, subjects were asked to select and eat food at one meal, and within 5 min of completing that meal they used photographs showing eight portions of each food to describe how much they had eaten. Percentage differences between the amounts of food eaten and the amounts estimated by subjects varied from a mean underestimate of −28.4% for baked beans to a mean overestimate of +242.9% for butter/margarine spread on crackers. However, despite some relatively large errors in the quantification of certain foods, the estimated nutrient intakes were, with the exception of vitamin C, within ±7% of the nutrient contents of actual amounts consumed. Clearly, photographs were of substantial benefit in helping subjects to report portion size[12]. Nevertheless, it must be borne in mind that the subjects described amounts eaten at one meal, within 5 min of consuming that meal. In most dietary surveys, however, subjects are usually asked to describe amounts of food consumed over several eating occasions, with a time lapse of at least 24 hours between consumption and estimation.

Therefore the aims of the present study were twofold. Firstly, to evaluate the magnitude and direction of the errors incurred by subjects using food photographs to quantify amounts of food known to have been eaten at six meals consumed over two separate days. Secondly, to determine the subsequent impact of the food quantification errors on the assessment of nutrient intakes.

Methods

Subjects

Thirty adults (15 male, 15 female) between 18 and 36 years of age, employed at the university, who responded to a poster advertising campaign, volunteered to participate in the study. All subjects had their height measured using a portable stadiometer and were weighed, wearing light indoor clothing and no shoes, using a digital electronic scale (Secca Delta, Model 707, Hamburg, Germany; 200 × 0.1 kg). They were fully informed of the purpose of the study before it commenced, and all confirmed that the foods to be provided during the study were acceptable to them.

Photographs

The food photographs were single colour prints (100 × 150 mm). The weight of food shown in each photograph was based on UK average portion sizes[16] with the exception of wheaten bread which, as a regional speciality, is not included. The portion weight for this food (50 g) was taken from a subsample of 7-day weighed record data previously obtained in Northern Ireland (C. McGrath, unpublished data). The foods were photographed on plates (240 mm diameter), bowls (150 mm diameter) or in glasses placed on a wooden table top. Milk was photographed in a tall glass as it was considered that a photograph of it poured over cereal would have been meaningless. A standard 55 mm static lens was fitted to a single lens reflex camera mounted on a tripod. The camera was set up to subtend an angle of approximately 45°, which was considered to provide the best compromise between showing both the depth and height of the foods. A knife and fork (310 mm apart) were included in every photograph to provide some idea of scale.

Procedure

The subjects were invited to eat three meals (breakfast, lunch and dinner) on two non-consecutive days. The breakfast menus were the same on each day whereas lunch and dinner menus differed over the 2 days. The daily menus are shown in Table 1. Each subject was provided with preweighed quantities of food, large enough so that choice was not limited by the amount provided. All subjects had the same amounts of food to choose from at each meal and they were allowed to help themselves from their allocated serving dishes as often as they wished. Water, tea and coffee were provided at every eating occasion but these were not weighed or estimated during the study as no photographs of beverages were available. The serving dishes and food leftovers were weighed (Miniscale, Cambridgeshire; 2000 × 0.1 g) when the subjects left the room and the amounts of every food eaten by each person were calculated.

On the day after eating in the metabolic suite, the subjects returned individually to estimate the quantities of all foods which they had consumed, in terms of fractions or multiples of the amounts shown in the appropriate single portion size colour photographs. Toast was not included as the bread was commercially sliced and therefore easily quantifiable. The tableware from which the subjects had eaten the food was the same as that shown in the photographs and all recalls were conducted by the same investigator. The entire procedure was repeated for the second eating day so that data concerning actual and estimated intakes for 2 days were obtained for every subject who completed the study.

Analysis and treatment of results

The amounts of food eaten, and subsequently estimated, over the 2 days were described at group level using means and standard deviations. The differences between mean amounts of food actually eaten and mean amounts estimated using the photographs were calculated and expressed at the group level as percentages of the weights of food known to have been consumed. Differences

Table 1 Menus and amounts of food* provided for individual subjects on day one and day two

Meal	Food	Amount provided
Breakfast (day one and day two)	Cornflakes	400 g
	Rice Krispies	400 g
	Muesli	500 g
	Milk (for cereal)	1 litre
	Orange juice	1 litre
	Butter/margarine	250 g
	Jam/marmalade	200 g
Lunch (day one)	Soup	700 g
	Wheaten bread	1 loaf (approx 450 g)†
	Butter/margarine	250 g
	Cheddar cheese (block)	500 g
	Apple pie	1 pie
Dinner (day one)	Bolognese sauce	500 g
	Pasta	600 g
	Broccoli	250 g
	Ice cream	350 g
Lunch (day two)	Vienna loaf	1 loaf (approx 400 g)‡
	Butter/margarine	250 g
	Coleslaw	250 g
	Quiche	1 quiche (400 g)
Dinner (day two)	Mashed potato	500 g
	Garden peas (boiled)	250 g
	Sliced carrots (boiled)	250 g
	Pork chop (grilled)	2 chops
	Fruit salad	500 g
	Baked rice pudding	500 g

*Tea, coffee and water were provided *ad lib.* but were not weighed or estimated.
†Wheaten bread: dense, wholemeal loaf, not commercially sliced.
‡Vienna loaf: white bread with brown crust, not commercially sliced.

between estimated and actual quantities were assessed using paired *t*-tests, with $P < 0.05$ considered to be significant. The distribution patterns of individual errors were described using ranges and 25th, 50th and 75th percentile errors for each food.

The nutrient contents of the subjects' actual and estimated food portions were calculated using a computerized version of UK food composition tables[17]. Foods were analysed for energy (MJ) and 10 different nutrients. Cumulative percentages of percentage differences between nutrient contents of amounts of food eaten and amounts estimated were determined. The numbers of subjects classified into the same, adjacent and opposite thirds for estimated and actual nutrient intakes were also calculated for both days. Pearson's correlation coefficients were calculated in order to evaluate the extent of the linear relationship between estimated and actual nutrient intakes at the individual level.

Results

Subjects

Twenty-seven subjects completed the protocol for both days of the study. Three male subjects could not attend on the second eating day resulting in completion rates of 100% for day one and 90% for day two. As results are presented separately for each day, all subjects who completed the procedure for each day are included. The subjects' characteristics are presented in Table 2.

Foods

The amounts of food (mean ± SD) eaten and subsequently estimated with the aid of single portion size photographs are presented in Tables 3 and 4. As there were no significant gender-related differences in the ability to estimate portion size using these photographs, data are presented for the whole group. The foods in each table are

Table 2 Subject characteristics (15 male, 15 female)

	Total group, mean (SD)	Males, mean (SD)	Females, mean (SD)
Age (years)	24.4 (3.6)	25.1 (3.6)	23.6 (2.9)
Height (m)	1.69 (0.10)	1.75 (0.31)	1.63 (0.10)
Weight (kg)	65.8 (10.8)	74.7 (10.2)	56.9 (10.5)
BMI (kg/m^2)	23.0 (2.4)	23.4 (2.8)	22.6 (3.2)

Table 3 Amounts of food eaten on day one compared with amounts estimated 24 hours later using single portion size colour photographs

Food	*n*	Amount eaten (g), mean (SD)	Amount estimated (g), mean (SD)	% difference*	*P*	Amount in photo (g)	Percentiles of % difference				
							Min.	25th	50th	75th	Max.
Muesli	8	93.0 (39.7)	128.0 (74.4)	+37.6	0.08	70	+3.7	+12.6	+25.2	+44.0	+113.7
Cheese	24	64.0 (34.8)	85.0 (52.2)	+32.8	0.007	40	−38.9	−12.0	+18.2	+83.6	+284.6
Cornflakes	16	42.6 (12.9)	52.6 (14.5)	+23.5	0.06	40	−35.4	−16.0	+17.6	+44.7	+110.5
Wheaten bread	28	147.8 (49.0)	178.7 (76.2)	+20.9	0.002	50	−19.0	+5.1	+15.4	+33.6	+100.0
Apple pie	20	95.0 (38.6)	105.3 (54.7)	+10.8	0.12	120	−38.8	−10.2	+12.0	+28.4	+104.3
Pasta	28	275.1 (106.2)	303.1 (120.5)	+10.2	0.09	230	−31.4	−15.4	+16.6	+32.4	+82.1
Soup	28	315.6 (80.2)	343.8 (113.3)	+8.9	0.12	220	−43.0	−17.1	−3.8	+31.2	+84.2
Orange juice	24	276.2 (81.7)	295.5 (103.0)	+7.0	0.08	200	−21.5	−6.6	+2.9	+14.0	+34.6
Jam/marmalade	22	20.3 (13.8)	21.4 (15.6)	+5.4	0.74	15	−85.7	−9.1	+18.5	+33.3	+164.7
Ice cream	27	102.0 (47.1)	102.4 (53.9)	+0.4	0.96	75	−54.3	−25.4	−5.0	+17.1	+74.2
Milk on cereal	26	236.3 (88.2)	221.1 (71.7)	−6.4	0.46	100	−63.2	−26.7	−4.2	+33.9	+97.4
Butter/marg. (L)	26	13.3 (5.7)	12.0 (7.3)	−9.8	0.03	10	−66.7	−41.2	−19.4	+16.7	+62.0
Bolognese	28	349.6 (91.4)	313.0 (121.9)	−10.5	0.04	220	−56.3	−30.3	−9.9	+11.9	+40.2
Butter/marg. (B)	25	11.2 (5.5)	9.0 (5.0)	−19.6	0.03	10	−70.8	−46.2	−8.4	+29.4	+49.0
Broccoli	24	85.3 (38.7)	65.5 (23.8)	−23.2	0.001	45	−61.5	−34.9	−22.8	+3.0	+87.5
Rice Krispies	5	41.2 (5.1)	31.6 (19.4)	−23.3	0.38	30	−92.0	−38.0	−11.8	+0.5	+36.8

B, food eaten at breakfast; L, food eaten at lunch; marg., margarine.
*% difference = [(mean amount estimated − mean amount eaten) × 100/mean amount eaten]. Difference between amounts eaten and amounts estimated assessed by paired *t*-test.

Table 4 Amounts of food eaten on day two compared with amounts estimated 24 hours later using single portion size colour photographs

Food	*n*	Amount eaten (g), mean (SD)	Amount estimated (g), mean (SD)	% difference*	*P*	Amount in photo (g)	Percentiles of % difference				
							Min.	25th	50th	75th	Max.
Muesli	11	88.5 (38.5)	111.3 (67.0)	+25.8	0.10	70	−30.7	−1.3	+34.7	+51.2	+86.7
Rice Krispies	7	30.9 (9.1)	38.0 (14.1)	+23.0	0.09	30	−11.8	+7.3	+17.9	+40.1	+71.4
Pork chop	22	90.1 (24.4)	99.7 (27.3)	+10.7	0.09	75	−32.4	−1.6	+2.9	+29.0	+81.8
Cornflakes	11	48.5 (11.1)	51.5 (14.9)	+6.2	0.32	40	−25.9	−12.6	+9.1	+27.6	+33.3
Mashed potato	27	278.1 (107.4)	292.7 (130.9)	+5.2	0.39	180	−56.0	−3.1	+11.1	+25.2	+64.2
Orange juice	21	292.0 (110.6)	300.7 (90.8)	+3.0	0.45	200	−20.9	−4.5	+1.5	+21.4	+62.6
Jam/marmalade	19	20.1 (7.7)	20.6 (9.6)	+2.5	0.93	15	−64.3	−31.8	−5.8	+36.0	+130.8
Quiche	27	163.7 (45.8)	159.2 (38.6)	−2.7	0.35	120	−34.8	−6.1	0	+4.7	+22.5
Garden peas	26	92.0 (34.1)	88.2 (29.0)	−4.1	0.46	65	−49.7	−16.7	0	+20.9	+60.7
Butter/marg. (L)	23	11.8 (6.1)	11.1 (7.6)	−5.9	0.66	10	−62.8	−39.1	−28.6	+31.2	+200.0
Rice pudding	18	145.3 (64.4)	133.8 (65.6)	−7.9	0.37	200	−61.5	−31.3	−15.3	+4.3	+230.9
Milk on cereal	25	223.2 (89.2)	189.6 (66.0)	−15.0	0.10	100	−79.3	−33.6	−16.3	+7.8	+100.0
Fruit salad	14	143.6 (64.5)	116.9 (85.0)	−18.6	0.07	105	−71.6	−39.2	−21.2	+11.1	+25.8
Vienna loaf	27	98.1 (42.5)	79.9 (38.1)	−18.6	0.01	50	−48.8	−43.0	−25.5	−9.4	+70.9
Butter/marg. (B)	25	12.1 (5.9)	9.8 (8.0)	−19.0	0.03	10	−66.7	−47.1	−28.6	+2.8	+100.0
Carrots	27	79.7 (28.7)	61.8 (27.3)	−22.5	<0.001	60	−62.0	−39.1	−26.5	−5.7	+22.0
Coleslaw	24	91.6 (50.1)	65.4 (38.8)	−28.6	<0.001	100	−67.2	−50.0	−30.5	−13.9	+34.0

B, food eaten at breakfast; L , food eaten at lunch; marg., margarine.
*% difference = [(mean amount estimated − mean amount eaten) × 100/mean amount eaten]. Difference between amounts eaten and amounts estimated assessed by paired *t*-test.

Table 5 Correlation of individual estimation errors with differences between amounts of food eaten and amount shown in photograph

	Day one				Day two		
Food	*n*	*r*	*P*	Food	*n*	*r*	*P*
Cornflakes	16	−0.46	0.07	Cornflakes	11	−0.09	0.79
Rice Krispies	5	−0.52	0.37	Rice Krispies	7	−0.08	0.87
Muesli	8	0.19	0.65	Muesli	11	−0.18	0.59
Milk added to cereal	26	−0.63	<0.001	Milk added to cereal	25	−0.52	0.007
Orange juice	24	0.06	0.79	Orange juice	21	−0.62	0.003
Butter/marg. (B)	25	−0.33	0.11	Butter/marg. (B)	25	−0.19	0.37
Jam/marmalade	22	−0.25	0.27	Jam/marmalade	19	−0.22	0.37
Wheaten bread	28	0.12	0.55	Vienna loaf	27	−0.20	0.31
Butter/marg. (L)	25	0.10	0.63	Butter/marg. (L)	23	−0.31	0.14
Cheese	24	−0.28	0.19	Coleslaw	24	−0.04	0.84
Soup	28	−0.28	0.15	Quiche	27	−0.34	0.08
Apple pie	20	−0.17	0.47	Mashed potato	27	−0.23	0.24
Bolognese	28	−0.01	0.95	Garden peas	26	−0.58	0.002
Pasta	28	−0.41	0.03	Carrots	27	−0.08	0.70
Broccoli	24	−0.57	0.004	Chop	22	−0.40	0.07
Ice cream	27	−0.08	0.70	Fruit salad	14	0.08	0.80
				Rice pudding	18	−0.24	0.33

B, food eaten at breakfast; L , food eaten at lunch; *r*, Pearson's correlation coefficient.

listed relative to the mean percentage errors incurred using the photographs. At group level on day one, 10 foods were overestimated (range +0.4% for ice cream to +37.6% for muesli), and six were underestimated (range –64% for milk added to cereal to −23.3% for Rice Krispies). For day two, seven were overestimated (range +2.5% for jam/marmalade to +25.8% for muesli) and 10 were underestimated (range −2.7% for quiche to −28.6% for coleslaw). The amounts of cheese, wheaten bread, butter/margarine, bolognese and broccoli estimated with the aid of photographs were statistically significantly different from the amounts eaten on day one. On the second day, estimated quantities of four of the 17 foods offered (Vienna loaf, butter/margarine (breakfast), carrots and coleslaw) were statistically significantly different from quantities consumed. The distributions of the errors made at the individual level for each food are also included in Tables 3 and 4. Errors in excess of +100% were incurred by individual subjects for several foods, and on day one, all subjects who ate muesli overestimated the quantities they had consumed. No other foods were exclusively over- or underestimated, although the estimated quantities of most foods did show a distinct bias in one or other direction. Overall, however, there was little evidence to indicate that any particular food shape or other visual characteristic influenced the extent of over- or under-estimation.

In order to determine the extent to which the size of the estimation errors were related to how close the amounts consumed were to the amount shown in each photograph, Pearson's correlation coefficients were calculated (Table 5). For the majority of foods, there was no significant relationship between the size of the error and the amount of food eaten relative to the photograph quantity. However, for milk added to breakfast cereal on both days, subjects who consumed amounts greater than that shown in the photograph were significantly more likely to underestimate quantities eaten. Similarly significant relationships were apparent for pasta and broccoli (day one) and orange juice and peas (day two).

For those breakfast foods which were consumed by the same subjects on day one and day two, the direction and magnitude of the errors incurred by individuals when quantifying intakes were not consistent over the 2 days. This is demonstrated in Fig. 1, which shows the percentage errors made by subjects who consumed (a) orange juice, (b) milk added to breakfast cereal, (c) muesli, (d) cornflakes, (e) butter/margarine and (f) jam/marmalade on both days.

Nutrients

Most nutrients were estimated, at the group level, to within ±10% of actual intake on both days. Exceptions were thiamin (+10.5%, day one) and vitamin E (–10.1%, day one; −15.3%, day two). On both days, none of the estimated intakes of nutrients were statistically significantly different from actual intakes, and no gender-related differences in reporting accuracy were apparent. The cumulative percentages of the distributions of the errors incurred when the nutrient contents of actual quantities of foods eaten were compared with estimated quantities are shown in Fig. 2. The estimates made by 87% and 96% of subjects were within ±20% of actual energy intakes on day one and day two, respectively. In contrast, for vitamin E, only 60% (day one) and 42% (day two) of subjects were within ±20% of actual intakes.

The subjects were then divided into thirds according to the nutrient contents of the quantities of foods which they had actually consumed. The numbers of subjects classified into the same, adjacent and opposite thirds when nutrient contents of estimated quantities were calculated are presented in Table 6. Between 63% and 80% of subjects

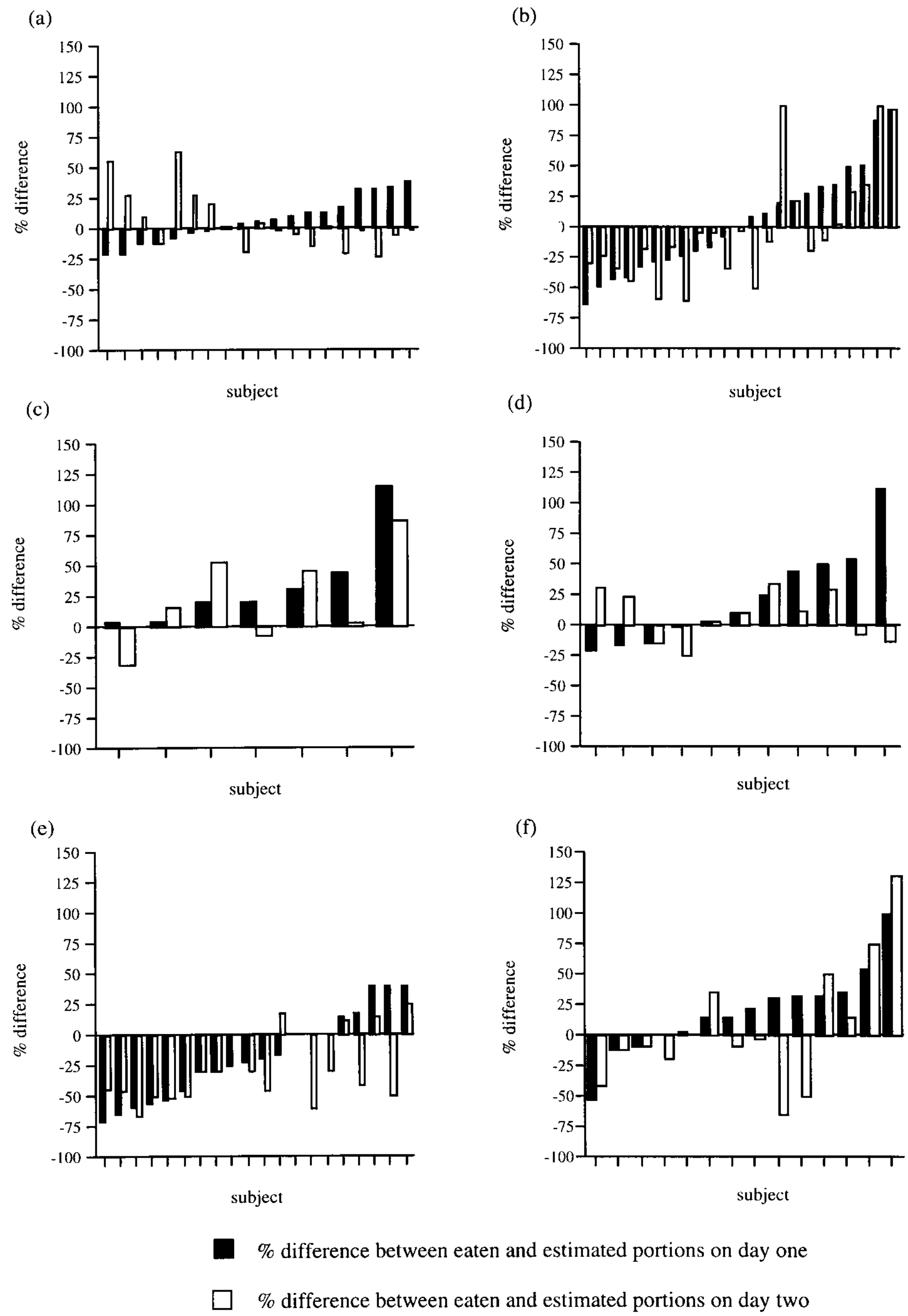

Fig. 1 Percentage estimation errors made by individual subjects who consumed the same foods on day one and day two: (a) orange juice, (b) milk added to breakfast cereal, (c) muesli, (d) cornflakes (e) butter/margarine, and (f) jam/marmalade

were correctly classified according to actual nutrient intake.

Table 7 presents the correlation coefficients between the nutrient contents of actual and estimated food quantities, compared with those obtained in previous studies. As the amounts of most nutrients consumed by males in the present study were significantly greater than those consumed by the females, the correlation coefficients are presented for the whole group (day one, $n=30$; day two, $n=27$), and separately for males and females. For the majority of nutrients, the coefficients were relatively high, suggesting that nutrient intakes estimated with the aid of food photographs were closely ranked with actual intakes. However, the coefficients obtained were not consistently higher for one sex or the other.

Discussion

Under the relatively controlled conditions of this study, it is highly likely that some subjects were more aware than

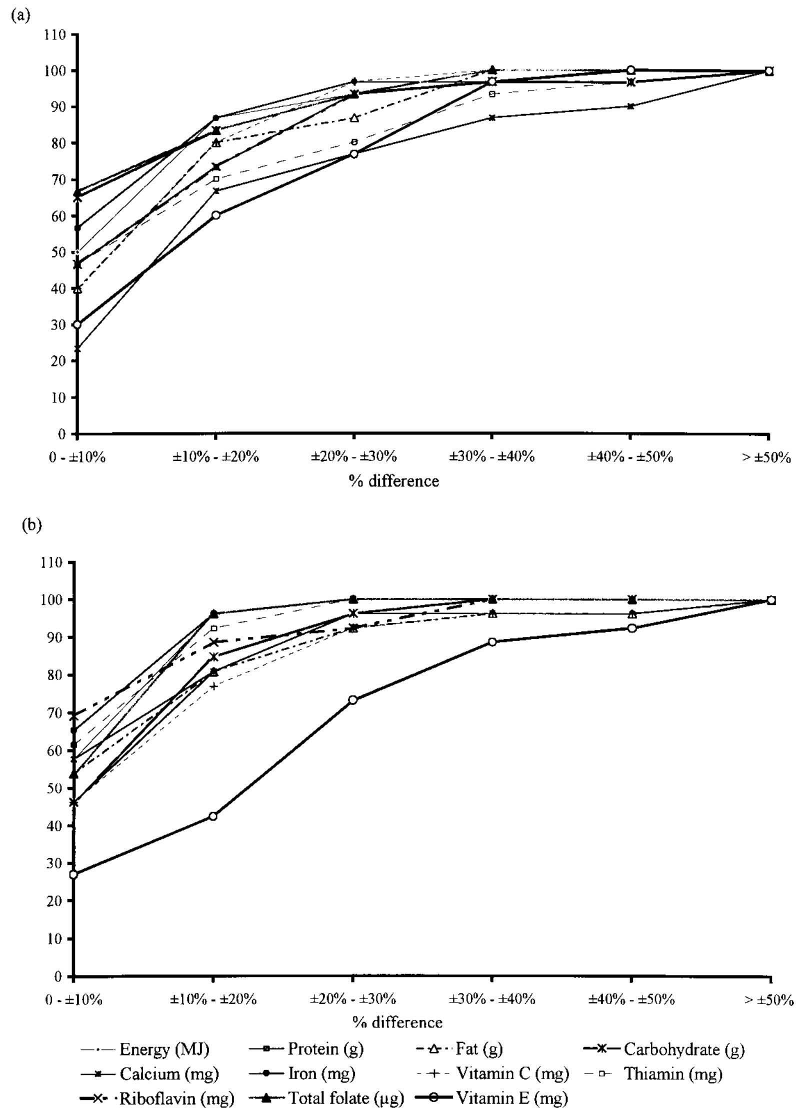

Fig. 2 Cumulative percentages of percentage differences between nutrient contents of amounts of food eaten and amounts estimated on (a) day one ($n=30$) and (b) day two ($n=27$)

Table 6 Numbers (%) of subjects classified into the same, adjacent and opposite thirds of the distribution for actual and estimated nutrient intake

	Day one ($n=30$)			Day two ($n=27$)		
Nutrient	same third *n* (%)	adjacent third *n* (%)	opposite third *n* (%)	same third *n* (%)	adjacent third *n* (%)	opposite third *n* (%)
Energy (MJ)	20 (66.7)	10 (33.3)	0	21 (77.8)	5 (18.5)	1 (3.7)
Protein (g)	18 (60.0)	12 (40.0)	0	21 (77.8)	6 (22.2)	0
Fat (g)	21 (70.0)	9 (30.0)	0	19 (70.4)	7 (25.9)	1 (3.7)
Carbohydrate (g)	24 (80.0)	6 (20.0)	0	21 (77.8)	6 (22.2)	0
Calcium (mg)	20 (66.7)	10 (33.3)	0	18 (66.7)	6 (22.2)	3 (11.1)
Iron (mg)	19 (63.3)	11 (36.7)	0	21 (77.8)	6 (22.2)	0
Vitamin C (mg)	24 (80.0)	6 (20.0)	0	19 (70.4)	8 (29.6)	0
Vitamin E (mg)	17 (56.7)	13 (43.3)	0	18 (66.7)	8 (29.6)	1 (3.7)
Thiamin (mg)	19 (63.3)	11 (36.7)	0	17 (63.0)	10 (37.0)	0
Riboflavin (mg)	21 (70.0)	9 (30.0)	0	17 (63.0)	8 (29.6)	2 (7.4)
Total folate (μg)	20 (66.7)	10 (33.3)	0	19 (70.4)	8 (29.6)	0

Table 7 Correlation coefficients between estimated and actual nutrient intakes compared with previous studies

				Present study					
				Day one			Day two		
Nutrient	Bird & Elwood[20]*	Brown *et al.*[21]*	Nelson *et al.*[12]†	M&F (*n*=30)‡	M (*n*=15)‡	F (*n*=15)‡	M&F (*n*=27)‡	M (*n*=12)‡	F (*n*=15)‡
Energy	0.86	0.95	0.92	0.89	0.89	0.86	0.93	0.95	0.89
Protein (g)	0.91	0.95	–	0.84	0.77	0.81	0.87	0.80	0.92
Fat (g)	0.90	0.96	0.93	0.89	0.91	0.79	0.86	0.68	0.90
Carbohydrate (g)	0.84	0.96	–	0.85	0.80	0.86	0.93	0.96	0.85
Vitamin C (mg)	0.97	1.00	0.91	0.89	0.71	0.95	0.94	0.96	0.92
Calcium (mg)	–	0.99	0.94	0.84	0.82	0.76	0.81	0.73	0.76
Iron (mg)	–	0.97	0.84	0.87	0.84	0.88	0.94	0.95	0.92
Thiamin (mg)	–	0.86	–	0.85	0.85	0.77	0.86	0.86	0.90
Riboflavin (mg)	–	0.96	–	0.90	0.91	0.86	0.89	0.89	0.82
Vitamin E (mg)	–	–	–	0.77	0.70	0.90	0.80	0.78	0.95
Total folate (μg)	–	–	–	0.90	0.73	0.89	0.93	0.91	0.89

F, female; M, male.
*Food quantities estimated by trained investigators.
†Correlation coefficients obtained when butter/margarine was excluded.
‡All correlations statistically significant at $P < 0.05$.

usual of the quantities of food and drink which they consumed. Thus, caution must be exercised when attempting to extrapolate the findings of this work to free-living situations. However these constraints must be accepted as it is difficult to obtain conclusive results concerning the effectiveness of food photographs in other situations. One study which did attempt to assess food photographs as a tool for quantifying food intakes in free-living populations asked subjects to keep weighed records and then calculated 'usual' portion sizes from these records[9]. Regression analyses demonstrated relatively weak relationships between estimated and weighed portions. It was concluded that this was unsurprising, given the relatively large intraindividual variation in food quantities consumed and the resulting difficulties with the concept of a 'usual' portion size[9].

The method used in the present study, therefore, was the only way to ensure that an actual measure of food intake was obtained, at least for those foods consumed during the evaluation procedure. The purpose of the study was to investigate the effectiveness of food photographs as a quantification tool in recall situations and not to validate the 24-hour recall method of assessing food and nutrient intake. Therefore the subjects were at liberty to consume foods other than the three meals provided on the two food intake days. They were also fully informed of the purpose of the study before participating. However, in an attempt to reduce the impact of the experimental situation, the atmosphere in the metabolic suite was made as normal as possible: subjects ate together in small groups and the food selection areas were screened from them while they were eating.

Overall the results for the quantification of foods are consistent with similar studies. The fact that some foods appear to be more difficult to estimate accurately than others is a common finding, regardless of the type of quantification tool used. In the present study, subjects had difficulty in quantifying cheese (group level error +32.8%; range −38.9% to 284.6%), whereas orange juice was quantified relatively accurately. The subjects in the study by Nelson *et al.*[12] found it difficult to use the available portion weights shown in eight portion size photographs to estimate amounts of butter/margarine spread on crackers (group level error +242.9%), whereas foods such as wedges of quiche and mounds of boiled rice incurred much smaller errors. Haraldsdottir *et al.*[15], who studied subjects' abilities to use photographs to describe amounts of food which they had eaten the previous week, found that foods such as margarine, paté and salami were the most difficult to estimate while fillets of fish were relatively easy.

The finding that many of the foods used in this study showed a distinct bias towards either over- or under-estimation of quantity supports earlier observations that perception problems exist with certain photographs[11], suggesting that the general pattern of errors associated with particular foods may be due more to their presentation in the photographs rather than to specific subject characteristics. The effect of subject characteristics on reporting ability has been a matter for some debate. In the present study, there were no significant gender-related differences in ability to use single portion size photographs to report amounts of food eaten. Other studies have also demonstrated that there are no differences between the accuracy of estimates made by males and females[1,7,15]. However, Nelson *et al.*[12] suggested that age, sex and body mass index (BMI) were potential confounders when subjects used eight portion size photographs of each food to estimate amounts consumed. In contrast, an Italian study suggested that age is not an important predictor of ability to estimate food quantity accurately[8] and others have concluded that level of education is also unimportant[18].

The design of the present study does provide some clues to suggest that reporting accuracy may not be influenced solely by characteristics which can be measured easily by investigators. If the ability to quantify foods accurately was confounded consistently by age, BMI, education and/or gender it would seem reasonable to expect that the errors incurred for a specific food by a specific subject would be similar whenever estimates were made. However this was not apparent in the present study. Subjects who overestimated the amount of a food eaten at breakfast on day one were just as likely to underestimate the amount of the same food eaten on day two and vice versa. Initially it was thought that this phenomenon may have been due to a learning effect. However estimates made on day two were not consistently more or less accurate than those incurred on day one. It was also considered that the difference in reporting accuracy on the 2 days may have been related to differences in amounts consumed on day one and day two, with one of the portions coming closer to the amount shown in the photograph. However, as there were few significant relationships between the sizes of the estimation errors and the amounts of food eaten, relative to the amount shown in the photograph, this seems unlikely. It is therefore conceivable that the errors made by subjects when quantifying foods may be due, in part, to factors which cannot be quantified or controlled such as motivation, cooperation, mood on the day of recall, restraint or inhibition as well as memory and perceptual ability. Undoubtedly, estimating food quantity with the aid of food photographs is a highly complex and multifaceted task. Therefore efforts to define objective characteristics which may be used to determine whether an individual or group of individuals will estimate portion size with reasonable accuracy may well be fruitless. It is possible that group trends may emerge with much larger sample sizes, but it is difficult to know whether these would be applicable to the general population or be specific to that particular sample of subjects. This is an issue which has not previously been described in the literature and, as such, requires further investigation.

It is interesting to note that, despite the difficulties which occurred with estimating certain foods in the present study, estimates of intakes of most nutrients were not associated with large errors at the group level. However, on examining the cumulative distributions of the errors incurred for individual nutrients, it is apparent that some nutrients were estimated with greater accuracy than others. The poor estimates for vitamin E, particularly on day two, are likely to be related to the fact that several individuals made large errors when attempting to estimate quantities of foods rich in vitamin E, such as butter and margarine. As Nelson *et al.*[12] have previously stated, this type of error becomes important for those subjects who substantially over- or underestimate amounts of specific foods which are particularly rich in one particular nutrient.

The correlation coefficients which resulted when estimated nutrient intakes were plotted against actual intakes were high, suggesting that estimates were closely ranked with actual intakes. While it is recognized that correlation coefficients are not the most informative or rigorous method of assessing agreement between methods[19], they provide the only means of comparing the results of the present study with others. Similarly high correlation coefficients have been observed in previous studies[12,20,21]. However, it should be noted that in the studies by Bird and Elwood[20] and Brown *et al.*[21], estimates of food (and hence nutrient) quantity were made by trained investigators who studied photographs or videos of food portions chosen and consumed by their subjects.

Despite the large estimation errors incurred by some subjects when estimating food quantity, between approximately 63% and 80% of subjects were classified into the correct tertile for nutrient intake on both days. No subjects were grossly misclassified on day one. In contrast, however, when eight portion size photographs were used by Nelson *et al.*[12] to help quantify amounts consumed at one meal, more subjects were likely to be correctly classified, suggesting that single photographs may be less effective quantification tools than multiple photographs. Unfortunately, owing to differences in methodology between the present study and that of Nelson *et al.*[12], it is unclear whether the greater likelihood of correct classification using multiple photographs was due to the number of photographs of each food presented to the subjects, or the fact that subjects were asked to estimate food quantities within 5 min of completing only one meal. Had the subjects in the present study been given the opportunity to estimate just after each meal rather than on the following day, it is possible that better ranking may have been obtained, even using single photographs. Again, this is an issue which requires further work as the number of photographs of each food which should be used in atlases has been a matter for debate. Nelson and Haraldsdottir do not recommend the use of single portion size photographs as 'subjects have difficulty estimating fractions or multiples'[22]. While few such difficulties were readily apparent in the present study, it is recognized that use of single photographs may cause problems for subjects who may be more representative of the general population. It must also be noted that single portion size photographs, showing amounts of food based on adult food portion sizes, are unlikely to be suitable for use in children. As children may not have fully developed the cognitive skills required to report in terms of fractions or multiples, it is possible that use of inappropriate single photographs could lead to a systematic bias in estimation of food quantity. Use of multiple photographs depicting a wide range of portion sizes would probably overcome this problem[22].

In conclusion, if the aim of a study is to assess and rank adult subjects according to nutrient intake, it appears that the single portion size colour photographs as used in this study may be a useful tool. However, it is also apparent that some of the food photographs were more effective than others at helping subjects to accurately describe amounts consumed. At this stage, given the apparently poor reproducibility of portion size estimates from one day to the next, it is difficult to ascertain whether certain foods are simply unsuitable for estimation using photographs, or whether the perceptual cues provided by some of the photographs used in the present study were inappropriate. It is possible that increasing the number of photographs to four or more per food may help to improve reporting accuracy but, as yet, the full potential of the use of food photographs in diverse populations over different recall periods has not been fully explored. It is therefore apparent that more work needs to be undertaken in this area before photographs can be confidently used as the sole quantification tool in dietary surveys.

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