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Digital photography: A new method for estimating food intake in cafeteria settings

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ABSTRACT. Objective: *The primary objective of this study was to test the comparability of digital photography and visual estimation procedures for estimating food intake.* **Research methods and procedures:** *The study sample included 71 breakfast meals and 59 lunch meals eaten in a university cafeteria during a single day. A total of 66 different foods were employed as test foods that could be selected by the students. Food selections and plate waste, as estimated by digital photography and visual estimation, were compared. For digital photography, three observers independently estimated portion sizes of each food item based upon digital photographs. One observer estimated portion sizes in the cafeteria setting, using visual estimation, a method that has been validated in other studies.* **Results:** *To test the accuracy of the two procedures for measuring food intake, the estimates of food weights derived from both procedures were compared using Bland-Altman regression. In comparison to visual estimation, the digital photography method yielded comparable estimates of food selections, plate waste, and total food intake for seven of nine comparisons. The two methods of estimating food portions yielded comparable results for most (78%) types of foods. The two methods also yielded similar variability.* **Discussion:** *These findings suggest that the digital photography method is an alternative to the traditional method of estimating food intake via direct observation.*

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Key words:
Food intake, digital photography method, visual estimation.

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INTRODUCTION

Collecting and analysing dietary intake data from large samples can be time consuming and expensive (1). Most methods rely on the individual's ability to keep accurate records or recall food consumed and have been criticised with respect to accuracy (2, 3). In particular, dietary intake reports from obese people and individuals from lower socioeconomic groups have been found to underestimate food intake (3-10). One method for estimating food intake is to directly observe food selections and foods remaining after eating (plate waste). This approach is known as visual estimation (11-13) and it has been frequently used in studies of eating behaviour in institutional settings such as cafeterias (13-17). The visual estimation method has been validated as one of the few accurate measures of food intake (18-23). Recently, an alternative method for estimating food intake in institutional settings was developed and validated by us (24, 25). This new approach, called "the digital photography method for estimating food intake", uses digital photography and computerised visual presentation of photographs of food. This approach has certain advantages over visual estimation in that it is less obtrusive and less disruptive of the eating environment. The primary aim of this study was to test the comparability of the digital photography method for estimating portion sizes of foods with the visual estimation method, in a naturalistic eating environment. An earlier study in a controlled laboratory environment (24) found that the two methods yielded similar estimates of food portion sizes and that both were highly accurate in comparison with weighed foods and with each other. A secondary aim was to test the agreement among three observers who estimated portion sizes using the digital photography method.

RESEARCH METHODS AND PROCEDURES

Test meals

A total of 130 test meals, 71 breakfast meals and 59 lunch meals, selected and con-

sumed by college students (on one day) were recorded for analysis by the two methods for measuring food intake. The identities of the students who selected and ate the meals were anonymous, so we had no information about their demographic characteristics.

Methods

A team of eight research associates provided visual estimates of test meals. One trained research associate visually estimated the portions of all food items for each person at each meal. The estimates were recorded as a percentage, in units of 10%, e.g., 90, 100 or 110%, of the prepared reference portion of each food. Visual estimation of plate waste was performed using the same methods used to estimate food selections and compared against the same reference portion. Reference portions were standard servings of foods served on the cafeteria line during the day of testing. The reference portions were carefully weighed before the photographs were taken. The recipe (and macronutrient composition) for each reference food item was documented on the day of testing. Students selected and consumed meals with no special instructions and appeared to eat normally.

The food selections and plate waste (for all participants) were also recorded using digital photography. Therefore, the same test meals were recorded using both methods. It should be noted that participants selected their own foods and cafeteria workers served the foods without carefully weighing or measuring them. The total amount of time for photographing a single meal was approximately two seconds. The selected foods and plate waste were photographed using a digital video camera mounted on a tripod with the lens 0.62 m (24.5 inches) above the meal tray with a camera angle of approximately 45 degrees. A place mat with marked regions for placement of the meal tray was fixed to the table supporting the camera tripod. This standardisation of camera angle, distance, etc, was used to ensure comparable sizes of the test meals in the digital photographs. The digital camera was connected to a computer equipped with a video capture board. Digital photographs of the reference portion, food selection, and plate waste for test meals were captured and incorporated into a computer application designed for estimation of food portions in digital photographs. The test meals and reference portions were photographed with the same camera angle and distance from foods so that the apparent size of all foods remained constant across all photographs. Three research associates used the software to simultaneously view photographs of the test meals along with photographs of the reference portion of each food. The observers independently estimated the percentage of the reference portion of each food in the photographs in units of 10% and these estimates were entered into a data grid in the computer software application.

Statistical methods

Estimates of food selections and plate waste were converted to grams, based on the comparison of visual and digital estimates to the reference portions for each food. Food intake was calculated by subtracting plate waste estimates from estimates of food selections. Estimates for all three measurements (selections, plate waste, and food intake) based on the visual estimation method were compared to each of three estimates based on the digital photography method using Bland Altman regression analysis. Agreement among the three observers using the digital photography method was tested using intraclass correlations.

RESULTS

Estimates of total food intake

Table 1 summarizes means and standard errors of estimates for total grams (averaged across all foods) using visual estimation and the digital photography method. Table 2 summarises the same information for individual observers. Bland Altman regression was used to compare the estimates of portion sizes by each of the observers using digital photography to the single estimate using visual estimation. The first row of Table 3 summarises the findings pertaining to the average bias (difference) between the two methods. For 7 of 9 (78%) comparisons, there were no differences between the estimates from the two methods. For Observer 1, the estimates differed for food selections and food intake, though the actual differences were small (less than 11 g).

TABLE 1
Estimates of mean grams of food using digital photography and visual estimation methods.

	Food selections (g)	Plate waste (g)	Food intake (g)
Visual estimation	156.3±5.8	23.4±2.1	133.1±5.5
Digital photography	160.3±5.6	22.7±1.7	137.8±5.2

Values are mean ± standard error. The two methods did not differ for food selections, plate waste, or food intake. The means represent the average grams of a specific food, i.e., not an entire meal.

TABLE 2
Estimates of mean grams of food across four observers, one using visual estimation, and three using the digital photography method.

Method	Observer	Food selections (g)	Plate waste (g)	Food intake (g)
Visual estimation	1	156.3±5.8	23.4±2.1	133.1±5.5
Digital photography	1	158.5±5.8	26.2±2.1	132.6±5.5
Digital photography	2	161.6±5.8	24.0±2.1	137.7± 5.5
Digital photography	3	160.9±5.8	18.0±2.1	143.1±5.5

Values are mean ± standard error. The two methods differ across observers for plate waste and food intake. The means represent the average grams of a specific food, i.e., not an entire meal.

Estimates of portion sizes for specific categories of foods

Comparability of the estimates of specific foods using the two methods was tested by classifying foods available at breakfast and lunch into six categories: beverages, condiments, desserts, entrees, fruits and vegetables, and starches. Differences between the two estimation methods were tested for food selections, plate waste, and food intake at breakfast and lunch using Bland Altman regression. The results of these analyses are shown in Table 3. In 42 of 54 comparisons (78%), the different methods yielded comparable estimates. Two food categories, beverages and starches, accounted for most (75%) of the significantly different estimates derived from the two methods. These tests indicated that, relative to visual estimates, the digital photography method tended to overestimate portion sizes for food selections of beverages and underestimate the portion sizes for starch food selections.

TABLE 3
Summary of mean differences (in grams) between the two procedures ± standard error.

	Observer 1	Observer 2	Observer 3
Average			
Food selection	*9.89±2.72	6.77±3.055	6.77±2.90
Plate waste	-0.65±1.14	0.97±1.40	7.15±1.25
Food intake	*10.50±2.70	5.80±3.05	0.38±2.86
Beverages			
Food selection	*41.06±9.34	5.74 ±12.41	-5.42±11.95
Plate waste	*9.01±3.43	*12.87±4.61	*14.11±4.38
Food intake	*32.05±9.35	-7.12±12.36	-19.53±11.62
Condiments			
Food selection	-10.39±5.33	*-25.50±7.00	-26.33±8.31
Plate waste	-3.33±4.56	-6.50±4.63	-10.92±5.70
Food intake	-7.06±5.45	*-19.00±6.16	-15.41±7.10
Dessert			
Food selection	17.05±7.80	20.85±10.05	15.6±8.37
Plate waste	8.96±6.27	7.85±4.65	6.17±5.26
Food intake	8.09±4.38	13.00±7.20	9.43±5.92
Entrée			
Food selection	-5.15±3.37	-3.23±3.01	-2.31±2.91
Plate waste	1.44±1.49	2.19±1.82	-3.03±1.54
Food intake	-6.58±3.32	-5.41±2.89	0.72±2.85
Fruit/Vegetable			
Food selection	15.72±16.67	-6.07±14.58	-21.11±10.10
Plate waste	*7.35±2.34	2.05±2.84	-4.88±3.13
Food intake	8.36±16.66	-8.11±14.69	-16.23±9.53
Starch			
Food selection	-3.26 ± 2.61	*-11.76 ± 2.68	*-16.95 ± 3.26
Plate waste	4.94 ± 2.28	3.31 ± 2.61	*-9.12 ± 1.88
Food intake	-8.21 ± 3.19	*-15.08 ± 3.25	-7.83 ± 3.68

Difference scores were defined as: digital – visual estimates. Therefore, positive signs indicate overestimates by the digital photography method. *p<0.01.

TABLE 4
Comparison of the variability of estimates derived from the two methods.

	Observer 1	Observer 2	Observer 3
Average			
Food selection	↓	0	0
Plate waste	↓	0	↓
Food intake	↓	0	↑
Beverages			
Food selection	↓	0	0
Plate waste	↓	0	0
Food intake	0	0	0
Condiments			
Food selection	0	↓	↓
Plate waste	↓	↓	↓
Food intake	0	↓	↑
Dessert			
Food selection	↑	↑	↑
Plate waste	↑	↑	↑
Food intake	0	↑	0
Entrée			
Food selection	0	↓	↓
Plate waste	0	0	0
Food intake	0	↓	0
Fruit/Vegetable			
Food selection	0	0	0
Plate waste	↑	0	↓
Food intake	0	0	0
Starch			
Food selection	0	0	0
Plate waste	0	↑	↓
Food intake	0	↓	0

↑ Signifies that the digital photography method yielded greater variability, ↓ signifies that the visual estimation method yielded greater variability, 0 signifies that the variability of the estimates of the two methods did not differ. For all analyses, alpha was p<0.01.

Tests of variability

The Bland Altman regression analyses also tested for differences in variability of data derived from the two methods. Table 4 summarises these data. The symbols indicate whether the digital photography method yield-

TABLE 5
Summary of intraclass correlations that tested agreement among three observers that used digital photography to estimate portion sizes.

	Food selection	Plate waste	Food intake
Average	0.89	0.56	0.84
Beverages	0.73	0.47	0.67
Condiments	0.69	0.60	0.72
Dessert	0.93	0.94	0.86
Entree	0.80	0.87	0.80
Fruit/Vegetable	0.69	0.69	0.71
Starch	0.88	0.65	0.71

All correlations are significantly different from zero, p<0.001

ed greater (↑), less (↓), or equivalent (0) variability in comparison to the visual estimation procedure. Averaging across foods (row 1, Table 4), the digital photography method yielded estimates of meal sizes with less variability in 4 of 9 comparisons with visual estimation. For specific foods, the two methods generally yielded similar variability. As shown in Table 4, 10 of 54 (18%) of the tests indicated greater variability for the digital photography method, 14 of 54 (26%) indicated less variability for the digital photography method, and 30 of 54 (56%) of the tests showed no differences in the variability of the two methods. The data from the digital photography method were most variable for estimates of desserts and least variable for condiments.

Agreement among observers

Intraclass correlations, summarised in Table 5, tested the degree to which the three observers for the digital photography method provided identical estimates of meal sizes (in total grams) and portion sizes for specific foods. These correlations are summarised in Table 5. In general, there was good agreement across observers. However, there was lower agreement for estimates of beverage plate waste.

DISCUSSION

The findings of this study generally provided positive evidence for the comparability of the digital photography method to visual estimation. The digital photography method yielded estimates of total meal size and portion sizes for specific foods that were similar to the estimates of the more established method of visual estimation (17-22). Using the digital photography method, there was no greater tendency to over- or underestimate food selections (5 of 18 tests, i.e., 6 food types X 3 observers) vs plate waste (5 of 18 tests). This tendency might be expected since the estimates for food selections are based on considerably larger amounts of food (on average, approximately 160 vs 23 grams). However, the results suggested that size or amounts of the foods did not strongly influence the estimates made using digital photographs.

The food categories associated with the greatest differences between the two methods, were beverages and starch dishes. The foods in the beverage category were: coffee, fruit juice, milk, and soft drinks, including punch. Beverages were estimated from clear cups, which is one of the most difficult foods to measure via photographs. The observers tended to overestimate the size of beverages. Foods in the starch category were: breads (bagels, biscuits, toast, rolls), cereals, cornbread, crackers, pasta, grits, hash brown potatoes, potato chips, rice, and waffles. The observers tended to underestimate the size of food selections in this category. These foods do not appear to be that much different from the other foods, so source of these underestimations is unclear.

In general, the digital photography method yielded similar variability in comparison to visual estimation. Considering the entire set of findings from the Bland-Altman regression analyses, one can conclude that the two methods yield fairly comparable estimates of meal and portion sizes for food selections and for plate waste, and that the two methods yield comparable variability of estimates.

A secondary aim of the study was to test the agreement of portion size estimates across three observers using the digital photography method. In general, there was good agreement across observers. The intraclass correlation related to plate waste for beverages was lower than the accepted standards for this type of analysis. The intraclass correlations from this study were slightly lower than those reported in our earlier studies of the digital photography method (24, 25).

On the whole, the findings of this study and the findings of an earlier study (24) support the contention that the digital photography method provides a valid alternative to the more conventional visual estimation procedure. It was our observation that the photography of foods using a digital video camera was accomplished with only minimal waiting time for the participant. Therefore, the procedure appeared to be relatively unobtrusive. This is the second study that has used the digital photography method in naturalistic eating environments such as military dining facilities (25) or school cafeterias.

The results of this study, combined with those of our two earlier investigations (24, 25) suggest that the digital photography method can provide rapid and valid acquisition of food intake data that is not highly disruptive of the eating environment. One of our earlier studies (24), compared the portions size estimates of the digital photography method to carefully weighed foods and found that the two methods yielded comparable estimates of portion sizes. Since the digital video camera photographs a continuous stream of images, the method can be used to gather data on relatively large samples. Therefore, when the research question requires measurement of total food intake with minimal disruption of participant's normal behaviour, the digital photography method is one approach that can be considered.

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