

Validation of improved 24-hour dietary recall using a portable camera among Japanese population, having large variety of food and food preparation

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Abstract

Background The collection of weighed food records (WFR) is a gold standard for dietary assessment. However, what a person eats changes every day, and it is practically difficult to weigh foods and drinks daily and calculate their nutrient contents. The validity of 24-hour dietary recall with the use of a portable camera (24hR-camera) was examined by comparison with the WFR.

Methods The study subjects were recruited from 30 male adults who were fathers of university students and cooked rarely. For the validation of the 24hR-camera, we compared it and the WFR. The digital photographs were taken by the subjects of all food consumed during a day and a 24-h recall questionnaire was conducted by a registered dietitian who was trained on the survey methodology. An estimate of the amount of food consumed was made using a food atlas and the photographs taken by the subjects. For validation, comparison was made between the calculations, by both methods, of the levels of food group and nutrient.

Results Correlation coefficients between the two methods were 0.7 or higher in most food groups but were low in food groups that are difficult to see, such as oils, fats, condiments, and spices. The intake of vegetables was significantly lower for the 24hR-camera method compared to the WFR method. For other food groups, except for algae, of which intake amount (in weight base) is very low, the percentages of mean difference between 24hR-camera and WFR s were -22.1% to 5.5%, with no significant differences between the methods. The correlation coefficients between the two methods were 0.774 for energy, and 0.855, 0.769, and 0.763 for the three major nutrients, proteins, lipids, and carbohydrates, respectively, demonstrating high correlation with coefficients greater than 0.75. The correlation coefficients between the two methods were 0.583 and 0.560 for salt and potassium intake, respectively, but no significant differences in intake were observed.

Conclusions The method of 24-hR-camera satisfactorily estimated the intake of energy and major nutrients (except salt and potassium) in Japanese males, and was confirmed as a useful method for dietary assessment.

Background

The collection of weighed food records (WFR) is a gold standard for dietary assessment. However, it is practically difficult to weigh foods and drinks daily and calculate their nutrient contents. Therefore, a 24-hour dietary recall is widely used for dietary assessment [1]. The 24-hour dietary recall involves a specialist to calculate the nutritional value based on a participant's memory, and can be used for nutrition guidance. However, a disadvantage is that it cannot be used to assess the correct nutrient value because it is difficult for a participant to record the correct amounts of food and condiments and recall every food and drink consumed between meals, such as candy and chocolate, which results in the omission of records. On the other hand, the participants sometimes record the food that they didn't eat really. To compensate for this disadvantage of 24-hour dietary recall, we conducted a survey to investigate the use of a portable camera (24hR-camera) and the manual [2], which is a food atlas of portion sizes for various foods commonly consumed in Japan, to improve the precision of estimated amounts of consumed food and drink. The validity of 24-hour dietary recall with the use of a portable camera was examined by comparison with the WFR as the gold standard.

Methods

Participants

The study subjects were recruited from male adults who were fathers of university students and cooked rarely. A total of 30 subjects agreed to participate to the study.

Survey methodology

On the day before the survey, use of the 24hR-camera was explained to participants. On the day the survey was administered (test day), participants photographed every food and drink item consumed during a 24-hour period (AM0 to PM12). For scale, the authors provided either a sheet of colored paper the size of a credit card or a lunch mat with grids, which was placed in front of or under the food and drinks, respectively. Photographs of the food and drinks consumed by participants were taken before and after breakfast, lunch, and supper, and between meals on the test day (examples are shown in Fig. 1).

On the day following the test day, a registered dietitian who was trained on the survey methodology interviewed each participant and recorded the food and drinks consumed, based on the memory of each participant. The dietitian recorded the digital photographs taken with the portable camera and the manual [2] on 24-hour dietary recall record sheets. The record sheets consisted of meal time, place where the participant consumed the meal, dishes, foodstuffs, portion size, food preparation, amount of food left, and intake of any supplement. The dietitian also calculated food weight and estimated dietary intake. Additionally, food and drink consumed by the participant between meals was recorded. The detail of the method is shown in the manual [2].

Weighed food record (WFR)

The WFRs were compiled by a registered dietitian who was specifically trained for this study. Before the food was served to participants, all ingredients and amounts were recorded by the person responsible for cooking. In cases where a participant left some food on the plate, the portion that remained was measured to calculate the actual intake amount.

Calculation of nutritional value

Nutritional values were calculated by a registered dietitian separately for the 24hR-camera and WFR data by using the *Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition 2010* [3].

Body mass index

Body mass index (BMI) was calculated from the self-reported height and weight ($BMI = \text{weight [kg]} / \text{height [m}^2\text{]}$) of each participant.

Statistical analysis

Values were summarized as mean and standard deviation (SD) or standard error (SE). The validity of 24hR-camera was examined by comparing with WFR in terms of mean difference and Pearson or Spearman correlation coefficient. The Bland-Altman plot, which was a graphical tool to compare the measurements of different methods, was used to examine the agreement of 24hR-camera and WFR [4]. In this method, the mean difference of intakes of each food group or nutrient by 24hR-camera and WFR were plotted against its mean value for each subject. All analyses were performed using SPSS for Windows version 15.0 (SPSS, Chicago, IL).

This research was conducted after approval was obtained from the ethics committee of Kanagawa Institute of Technology (Kanagawa, Japan). Written informed consent was obtained voluntarily from all participants.

Results

The characteristics of the subjects were shown in Table 1.

Table 1 Characteristics of the subject

		Mean	SD
Age	years	49.3	6.8
Height	cm	170.4	4.5
Weight	kg	70.4	11.6
BMI	kg/m ²	24.2	3.5

n=30

A comparison of the intake of each food group calculated by the 24hR-camera and WFR methods is shown in Table 2 and Fig. 2. Correlation coefficients between the two methods were 0.7 or higher in most food groups but were low in food groups that are difficult to see, such as oils, fats, condiments, and spices. The intake of vegetables was significantly lower for the 24hR-camera method compared to the WFR method.

Percentages of mean difference between 24hR-camera and WFR in each food category were calculated as: % of the difference = (mean amount from 24hR-camera minus mean amount from WFR) / mean amount from WFR * 100. For other food groups, except for algae, of which intake amount (in weight base) is very low, the differences between two groups were -22.1–5.5%, with no significant differences between the methods.

Table2 Comparison of intakes of food between 24hR-camera and WFR

Food category	24hR-camera			WFR			Difference 24hR-camera - WFR				correlation coefficient			
	Mean	±	SD	Mean	±	SD	Mean	±	SD	Mean difference	SE	P [¶]	Spearman	Pearson
01: Cereals	553.5	±	139.5	589.5	±	143.1	-35.9	±	97.7	-6.1	17.8	0.053	0.783	0.761
02: Potatoes and Starches	54.3	±	63.5	69.7	±	92.5	-15.4	±	58.6	-22.1	10.7	0.160	0.897	0.780
03: Sugars and Sweeteners	5.5	±	7.1	4.6	±	4.8	1.0	±	5.3	21.1	1.0	0.329	0.514	0.670
04: Pulses	63.1	±	62.8	66.7	±	63.4	-3.6	±	41.4	-5.4	7.6	0.637	0.764	0.785
05: Nuts and Seeds	3.8	±	12.1	3.9	±	12.4	-0.1	±	3.3	-2.2	0.6	0.891	0.719	0.964
06: Vegetables	336.2	±	132.1	372.0	±	111.7	-35.8	±	93.4	-9.6	17.0	0.045	0.738	0.719
07: Fruits	77.6	±	80.9	86.6	±	83.4	-9.0	±	33.9	-10.4	6.2	0.157	0.906	0.915
08: Mushrooms	29.8	±	44.6	31.2	±	35.3	-1.3	±	28.9	-4.2	5.3	0.805	0.889	0.762
09: Algae	10.0	±	12.8	6.4	±	9.7	3.6	±	9.7	56.3	1.8	0.052	0.855	0.655
10: Fishes and Shellfishes	75.0	±	57.3	81.3	±	60.4	-6.3	±	33.8	-7.7	6.2	0.317	0.852	0.836
11: Meats	96.6	±	63.7	101.4	±	64.5	-4.8	±	23.7	-4.8	4.3	0.272	0.946	0.932
12 :Eggs	53.5	±	44.7	50.7	±	37.4	2.8	±	19.1	5.5	3.5	0.429	0.865	0.907
13: Milks	88.2	±	101.7	101.6	±	112.4	-13.4	±	36.2	-13.2	6.6	0.053	0.970	0.948
14: Fats and oils	14.5	±	10.4	12.8	±	9.0	1.7	±	9.8	13.1	1.8	0.356	0.533	0.497
15: Confectioneries	18.3	±	37.8	18.2	±	38.4	0.1	±	3.3	0.6	0.6	0.871	0.969	0.996
16: Beverages	673.6	±	382.8	661.3	±	357.4	12.3	±	78.8	1.9	14.4	0.399	0.955	0.980
17: Seasonings and Spices	176.2	±	135.3	153.3	±	148.5	22.9	±	163.3	15.0	29.8	0.448	0.465	0.341

[¶]Percentage of mean difference between 24hR-camera and WFR in each food category (calculated as: % of the difference = ((mean amount from 24hR-camera - mean amount from WFR)/ mean amount from WFR)*100).

[¶]paired t-test

***95% limits of agreement for the difference between 24hR-camera and WFR, in the corresponding units for each food group and percentage under and over-estimation for the agreement between both methods.

See also Figure 2.

A comparison of the nutrient intake calculated by the 24hR-camera and WFR methods is shown in Table 3 and Fig. 3. The correlation coefficients between the two methods were 0.774 for energy, and 0.855, 0.769, and 0.763 for the three major nutrients, proteins, lipids, and carbohydrates, respectively, demonstrating high correlation with coefficients greater than 0.75. The differences in intake between the 24hR-camera and WFR methods were not significant for energy and lipids, whereas the intake of proteins and carbohydrates was significantly less for the 24hR-camera method. The correlation coefficients between the two methods were 0.583 and 0.560 for salt and potassium intake, respectively, but no significant differences in intake were observed. The correlation coefficients for almost all other nutrients were 0.70 or higher, demonstrating high correlation.

Table3 Comparison of intakes of energy and nutrients between 24hR-camera and WFR

Nutrition		24hR-camera			WFR			Difference 24hR-camera - WFR			P _{II}	Spearman	correl coeffi	
		Mean	±	SD	Mean	±	SD	Mean	±	SD				Mean difference
									24hR- camera - WFR(%)*					
Energy	kcal	2284.5	±	401.9	2375.7	±	457.5	-91.3	±	264.1	-3.8	48.2	0.068	0.774
Protein	g	86.6	±	16.9	90.1	±	17.8	-3.5	±	8.5	-3.8	1.5	0.033	0.855
Lipid	g	68.2	±	23.9	68.2	±	23.4	0.0	±	13.9	0.1	2.5	0.985	0.769
Carbohydrate	g	295.6	±	62.2	315.5	±	65.2	-19.8	±	39.5	-6.3	7.2	0.010	0.763
Ash	g	20.1	±	3.3	20.8	±	4.9	-0.6	±	3.8	-3.0	0.7	0.373	0.668
Potassium	mg	2844.3	±	559.8	2944.7	±	584.2	-100.4	±	523.1	-3.4	95.5	0.302	0.560
Calcium	mg	548.4	±	227.8	570.7	±	177.9	-22.2	±	123.1	-3.9	22.5	0.331	0.909
Magnesium	mg	312.2	±	62.1	326.3	±	73.9	-14.1	±	53.3	-4.3	9.7	0.158	0.803
Phosphorus	mg	1274.5	±	255.7	1319.5	±	256.1	-45.0	±	145.5	-3.4	26.6	0.101	0.838
Iron	mg	8.9	±	2.0	9.2	±	2.2	-0.3	±	1.2	-3.5	0.2	0.150	0.908
Zinc	mg	9.6	±	2.2	10.3	±	2.4	-0.6	±	1.0	-6.2	0.2	0.001	0.894
Copper	mg	1.4	±	0.3	1.5	±	0.3	-0.1	±	0.2	-7.1	0.0	0.006	0.736
Manganese	mg	4.2	±	2.0	4.2	±	1.2	0.0	±	1.7	0.6	0.3	0.931	0.781
Retinol	µg	152.6	±	83.0	164.4	±	87.7	-11.7	±	42.9	-7.1	7.8	0.145	0.867
beta-Carotene	µg	5624.0	±	3782.2	5154.5	±	3214.8	469.6	±	2584.9	9.1	471.9	0.328	0.735
Retinol activity equivalents	µg	625.6	±	317.8	598.2	±	264.0	27.5	±	209.0	4.6	38.2	0.477	0.822
Vitamin D	µg	11.4	±	11.6	10.6	±	9.9	0.8	±	5.4	7.6	1.0	0.418	0.890
α-Tocopherol	mg	8.4	±	2.8	8.1	±	2.3	0.3	±	2.5	4.2	0.5	0.463	0.599
β-Tocopherol	mg	0.5	±	0.2	0.5	±	0.2	0.1	±	0.2	12.7	0.0	0.048	0.727
γ-Tocopherol	mg	13.5	±	6.3	11.3	±	4.6	2.2	±	4.9	19.8	0.9	0.018	0.449
δ-Tocopherol	mg	3.4	±	1.6	2.7	±	1.4	0.6	±	1.1	23.1	0.2	0.003	0.706
Vitamin K	µg	372.7	±	193.3	390.9	±	199.5	-18.2	±	107.3	-4.7	19.6	0.359	0.920
Vitamin B ₁	mg	1.2	±	0.5	1.3	±	0.5	-0.1	±	0.3	-5.3	0.0	0.177	0.912
Vitamin B ₂	mg	1.4	±	0.4	1.4	±	0.4	-0.1	±	0.2	-4.0	0.0	0.078	0.940
Niacin	mg	22.0	±	7.3	22.4	±	6.9	-0.4	±	4.7	-1.8	0.9	0.653	0.669
Niacin equivalent	mg	38.1	±	9.7	39.2	±	9.4	-1.1	±	5.9	-2.7	1.1	0.327	0.775
Vitamin B ₆	mg	1.6	±	0.4	1.6	±	0.5	-0.3	±	0.3	-2.1	0.1	0.508	0.734
Vitamin B ₁₂	µg	6.6	±	5.2	6.1	±	4.2	0.5	±	2.4	8.4	0.4	0.245	0.903
Folate	µg	377.0	±	115.1	377.4	±	84.6	-0.3	±	77.2	-0.1	14.1	0.981	0.797
Pantothenic acid	mg	7.2	±	1.7	7.6	±	1.6	-0.4	±	1.0	-4.7	0.2	0.057	0.820
Vitamin C	mg	103.5	±	51.5	111.7	±	52.8	-8.2	±	32.0	-7.3	5.8	0.173	0.883
Fatty acid, saturated	g	18.6	±	7.5	19.2	±	8.2	-0.6	±	4.6	-3.1	0.8	0.495	0.851
Fatty acid, monounsaturated	g	25.4	±	10.7	26.1	±	11.3	-0.6	±	5.9	-2.4	1.1	0.562	0.805
Fatty acid, polyunsaturated	g	15.7	±	5.8	14.5	±	4.3	1.2	±	4.1	8.2	0.7	0.119	0.640
Cholesterol	mg	397.7	±	219.2	397.9	±	198.2	-0.2	±	76.2	-0.1	13.9	0.987	0.909
Dietary fiber, soluble	g	4.1	±	1.3	4.3	±	1.3	-0.2	±	1.0	-5.2	0.2	0.249	0.748
Dietary fiber, insoluble	g	13.6	±	5.6	14.2	±	4.3	-0.6	±	3.4	-4.3	0.6	0.332	0.797

Dietary fiber, total	g	18.5	±	6.9	19.0	±	5.4	-0.6	±	4.5	-3.1	0.8	0.484	0.715
Salt equivalents	g	11.6	±	2.8	11.7	±	3.7	-0.2	±	3.3	-1.5	0.6	0.772	0.583

[□]Percentage of mean difference between 24hR-camera and WFR (calculated as: % of the difference = ((mean nutrient from 24hR-camera - mean nutrient from WFR) / mean nutrient from WFR)*100).

[□]paired t-test

***95% limits of agreement for the difference between 24hR-camera and WFR, in the corresponding units for each nutrient and percenta over-estimation for the agreement between both methods.

See also Figure 3.

Comparison of intakes of food between 24hR-camera and WFR by Bland-Altman plots. The differences between the amounts of foods or intakes of energy and nutrients estimated by 24hR-camera and WFR (Y-axis) were plotted against their mean values (X-axis) in Fig. 2 and Fig. 3. The dotted line shows the average difference between the two methods; the smaller the difference, the smaller the systematic bias. The solid lines show the 95% limits of agreement that represent the range in which most differences are expected to fall; the smaller the range, the smaller the difference between two methods for most individuals. Extreme outliers that exceeded 95% limits of agreement were rarely seen. The difference between intakes of the two methods was not correlated to the average intake of them.

Discussion

The 24hR-MP camera method, which also used the manual [2] during interviews with participants, was found to be feasible for estimating the intake of foodstuffs and nutrients at a degree similar to that of the WFR method. The correlation coefficient for salt intake was low between the 24hR-camera and WFR methods because intake is difficult to estimate for invisible ingredients such as oils, fats, condiments, and spices. The intake of vegetables was underestimated with the 24hR-camera method compared to the WFR method because in Japan vegetables are frequently consumed after being cooked, which reduces their volume. This was likely a reason why the correlation coefficient for salt was low between the 24hR-camera and WFR methods.

Studies have been conducted that compared 24-hour dietary recall and WFRs. In a 2-day survey of 41 people in China aged 18 to 65 years, no significant differences were observed except for total fat, saturated fatty acid, thiamine, potassium, and magnesium [5]. A 1-day survey of 65 university students in Malaysia aged 18 to 29 years found no significant differences between the methods for measuring energy and nutrients [6]. In a 1-day survey of 58 rural Ethiopian women aged 15 to 49 years, the medians for energy and almost all nutrients were significantly lower in 24-hour dietary recall than in WFR [7]. The correlation coefficients for energy and the three major nutrients (protein, lipid, carbohydrate) between the 24-hour dietary recall and WFR measurements were almost the same as those reported by Marjan *et al.* [6] but higher than those reported by Xue *et al.* [5], who adjusted energy.

The 24-hour dietary recall method relies on the memory of a participant, and studies have been conducted using a camera to supplement that memory. In a survey of 45 women aged 20 to 52 years in a rural area of Bolivia, the medians of almost all food groups, except drinks and vegetables, were smaller for the 24-hour dietary recall using camera method compared to the WFR method. The intake values were lower for 24-hour dietary recall using camera than for WFR for almost all nutrients, but Pearson correlation coefficients of nutrition intakes between the methods were high (0.96 or higher) [8]. A 2-day study conducted in England on 10 subjects compared 24-hour dietary recall that used a camera that automatically took photographs in response to movement, heat, and light, with 24-hour dietary recall that did not use a camera [9]. Results demonstrated that “healthy” foods were not over-reported and “unhealthy” foods were not consistently under-reported. Another study showed the effectiveness of dietary assessment using a camera-equipped personal digital assistant and a cell phone card by comparing it with a weighing method. The study subjects were 75 Japanese volunteers consisting of 27 men and 48 women. The study clearly showed that the method was a useful new dietary assessment method [10].

In terms of energy and the three major nutrients (proteins, lipids, carbohydrates), correlation coefficients between our 24hR-camera method and the WFR method were at least 0.80; the correlation was low for salt and potassium, but the coefficients for almost all other nutrients were 0.7 or higher. In a study reported by Lazarte *et al.* [8], the correlation coefficients of energy and the three major nutrients were 0.96 or higher (at least 0.97 for other nutrients), which showed high correlation, but salt and potassium were not calculated. The difference in correlation coefficients between our study and that by Lazarte *et al.* was likely attributed to differences in dietary diversity. Furthermore, Lazarte *et al.* recognized that a limitation of their study was that differences in dietary pattern by individuals were small because the survey was conducted in a low-income nation, which led to easy estimation from the perspective of a nutrition survey. This likely led to the exceedingly high correlation coefficients. In a study with Japanese people, the effectiveness of dietary assessment using a camera-equipped personal digital assistant and a cell phone card was examined by comparing that with WFR, and the correlation coefficients between values obtained by both methods were 0.615 for energy intake, 0.658 for protein intake, 0.773 for fat intake, 0.708 for carbohydrate intake, and 0.408 for salt intake in men, which were lower than those obtained in our study [10]. The authors mentioned that lack of a unified way to take photographs and low quality of digital photographs might cause the decrease in the correlation coefficient. It is considered that we could obtain a high correlation rate because we improved this point. A study comparing 24-hour meal recall and WFR for two days in 41 Chinese people reported a correlation coefficient of 0.76 for energy intake, which was lower than that obtained by us [11].

We compared the 24hR-camera method with the WFR protocol. Using absolute values, the 24hR-camera method produced significantly lower results in the vegetable food group, but there were no significant differences in the other food groups when compared with the WFRs. We also compared intake of the three

major nutrients using absolute values. Protein and carbohydrate contents were lower in the 24hR-camera method compared with WFRs. The low protein intake estimation by the 24hR-camera method may have been due to shrinkage in the fish, shellfish and meat groups when cooked. The reduced carbohydrate estimate may be due to a low estimation in the amount of rice consumed. The intake of micronutrients, such as zinc and copper, was also lower with the 24 h R-camera method compared to the WFR method; this may be due to the fact that the absolute intake amounts of these nutrients were small. In addition, there were large differences in the intake of these nutrients in the study population which led to high correlation coefficients but difficulty in obtaining absolute values.

Most dishes in Japan are not made of a single foodstuff but instead contain various ingredients in addition to salt, pepper, oil, and other condiments, as exemplified by stew, stir-fried meat, and vegetables. Therefore, it is difficult for a participant to estimate what he or she has eaten, and this likely explains our study's lower correlation coefficients compared to the study by Lazarte et al. Despite the difficulty doing the survey of complexed diet, the correlation coefficients of 0.8 or higher for energy and the three major nutrients imply sufficiently high correlation, and suggest that the 24hR-MP camera method is useful for dietary assessment. Additionally, our study was novel because the participants were males, who do not cook on a daily basis, while participants in the Lazarte et al. study were females. Compared to women, men have difficulty evaluating the kind and amount of foodstuff. Therefore, the high correlation, even with male participants, indicated a significant result and implies that this dietary assessment method is also applicable to women.

Regarding the intake of each food group, it is difficult to directly compare our study with that of Lazarte et al., which used a different approach. Our results demonstrated correlation coefficients of 0.7 or higher in almost all food groups except oils, fats, condiments, and spices, which had low correlations of 0.3 to 0.5. The correlation coefficient between the two methods for salt was also low. It is likely the correlation coefficients were low for these ingredients because they are not visible and have to be evaluated by the taste.

Lazarte et al. investigated fewer food groups than our study and did not evaluate oils, fats, condiments, or spices. Their participants consumed much fewer vegetables (a median of 52 g) than did the Japanese (372.0 g on average) who participated in our study. Japanese also eat vegetables but are generally accustomed to eating them cooked. Considering that cooking reduces the volume of vegetables, our participants probably underestimated the total intake, which was likely to have resulted in underestimation of potassium intake. The study by Lazarte et al. did not assess potassium.

Taking photographs of actual meals before and after eating is likely to help individuals estimate the correct intake (including leftovers) and prevent them from forgetting to record what they ate or drank [12–20]. One advantage of the camera for a surveyor is that it enables correct assessment of nutrient intake. The amount (in weight base) of foods taken is estimated by the following procedures in 24-hour dietary recall method and 24hR-camera method: 1) Make a distinction between breakfast, lunch, supper, snack, and late-night snack; 2) name each dish; 3) presume food components that make up the dish; 4) classify the food components into the component listed in the Standard Tables of Food Composition in Japan, in principle; 5) presume seasonings and condiments used; and 6) estimate wet weight of foods taken. Because the 24hR-camera, it has the following advantages in the above-mentioned steps: 1) Distinction between breakfast, lunch, dinner, snack, and late-night snack becomes clear; 2) the name of dishes can be objectively determined by an investigator; 3) the food components that make up a dish can be objectively determined by an investigator; 4) the food can be more accurately classified into the food listed in the standard tables of food composition; 5) the type and usage of seasonings and condiments can be confirmed; and 6) weight or wet weight of foods can be more accurately estimated as compared with the 24-hour dietary recall method. Therefore, the 24hR-camera method is expected to estimate the intakes of food, energy and nutrients more accurately than 24-hour dietary recall method. Since it is customary for many people to take photographs easily with a mobile camera nowadays, taking photographs before and after eating is not that big of a deal.

There have been studies to validate a method that combined 24-hour dietary recall and use of photo atlas during participant interviews by comparison to the WFR method [21–23]. These studies confirmed that the combination method was useful for participants. Similarly, we were able to obtain high correlations in food groups as well as nutrients because we used the manual [2] during interviews and implemented a method of taking photographs before and after each meal.

One limitation of our study was that it had a relatively small sample size. However, the number of patients ($n = 30$) had a statistical power of 80% with a significance level of 5% to detect a true correlation coefficient of 0.5 and most of the correlation coefficients in this study were larger than it. It is significant that we were able to assess salt and potassium, which are crucial to the prevention and treatment of lifestyle-related diseases, such as stroke and coronary heart diseases, but it is also a limitation of this survey method that correlations of these nutrients were lower compared to other nutrients. We did not confirm the reproducibility of the test methods in this study, and it is future subjects.

The strength of this study was that we developed a dietary assessment method to evaluate male participants who eat Japanese-style meals that commonly have diverse foodstuffs cooked in diverse ways (boiled, stir-fried, deep-fried, etc.), but who also regularly eat Western-style foods such as hamburger steak and stew, as well as Chinese, Spanish, and French cuisines. There is a large variety of food and food preparation in Japan, and thus it is difficult to accurately assess meal intake. The methodology imposed a relatively small burden on participants, as evidenced by 100% participation in the survey. Finally, because the results from this study pertain to meals consumed under regular life conditions, the method is likely to be feasible for the assessment of daily diet and the results would be internationally comparable.

Conclusion

The combination method of 24-hour dietary recall with the use of a portable camera satisfactorily estimated the intake of energy and major nutrients (except salt and potassium) in Japanese males, and was confirmed as a useful method for dietary assessment.

Abbreviations

WFR: weighed food records

24hR-camera: 24-hour dietary recall with the use of a portable camera

Declarations

Ethics approval and consent to participate

This research was conducted after approval was obtained from the ethics committee of Kanagawa Institute of Technology (kanagawa, Japan). Written informed consent was obtained voluntarily from all participants.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no conflict of interest.

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Authors' contributions

YM takes full responsibility for the work as a whole, including the study design, access to data, and the decision to submit and publish the manuscript. YM, TT, KA, EH, HT[⊗], HT[⊗], YT, NS, and MF researched data. YM, TT, KA, EH, HT[⊗], HT[⊗], YT, NS, MF, HT¹⁰, and TY contributed to discussions. YM wrote the manuscript. TT, KA, EH, HT[⊗], HT[⊗], HT¹⁰, and TY reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Figures

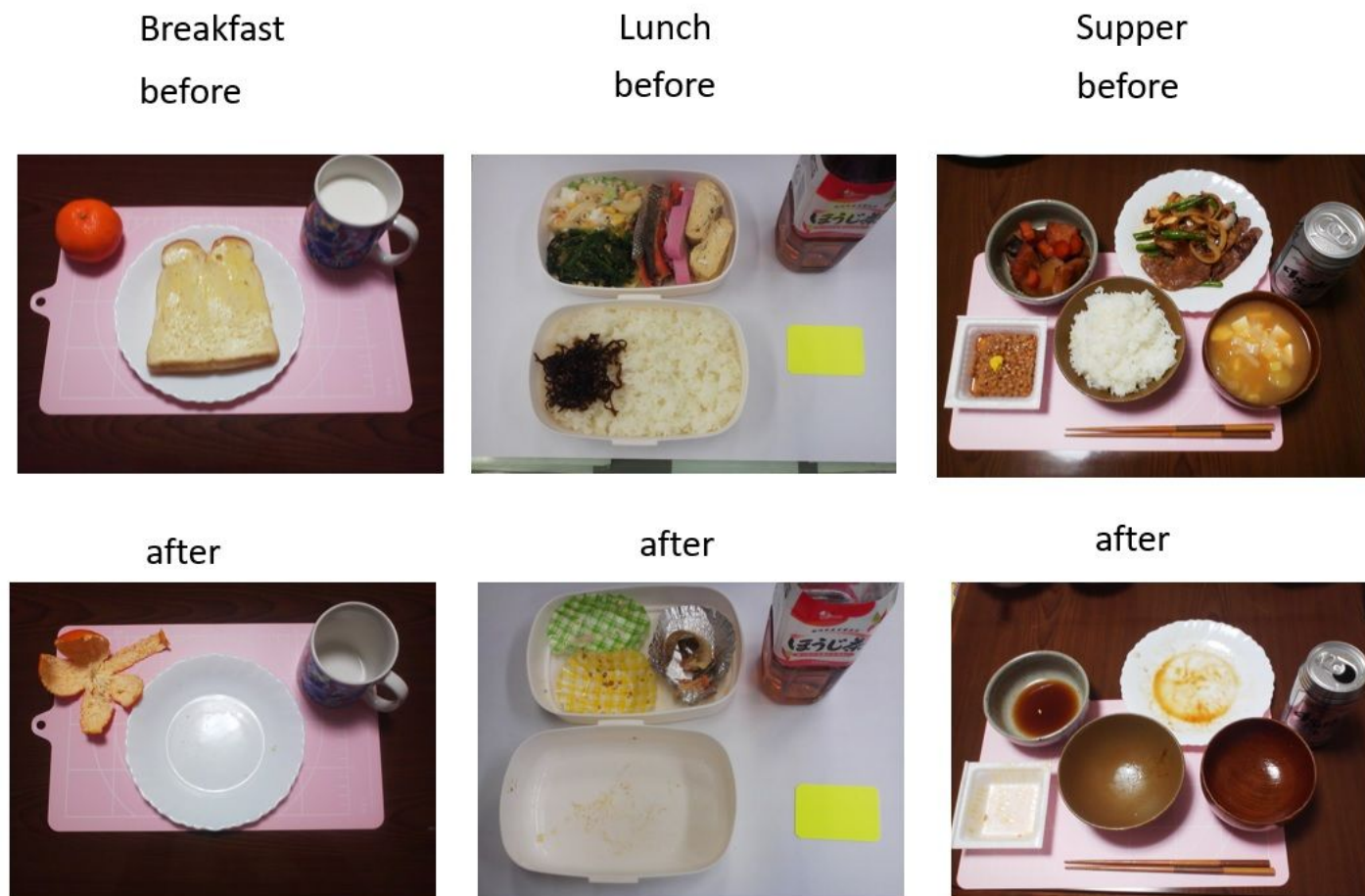


Figure 1

Examples of photographs of breakfast, lunch, and supper. The actual amount of foods consumed was estimated by comparing before and after having meal.

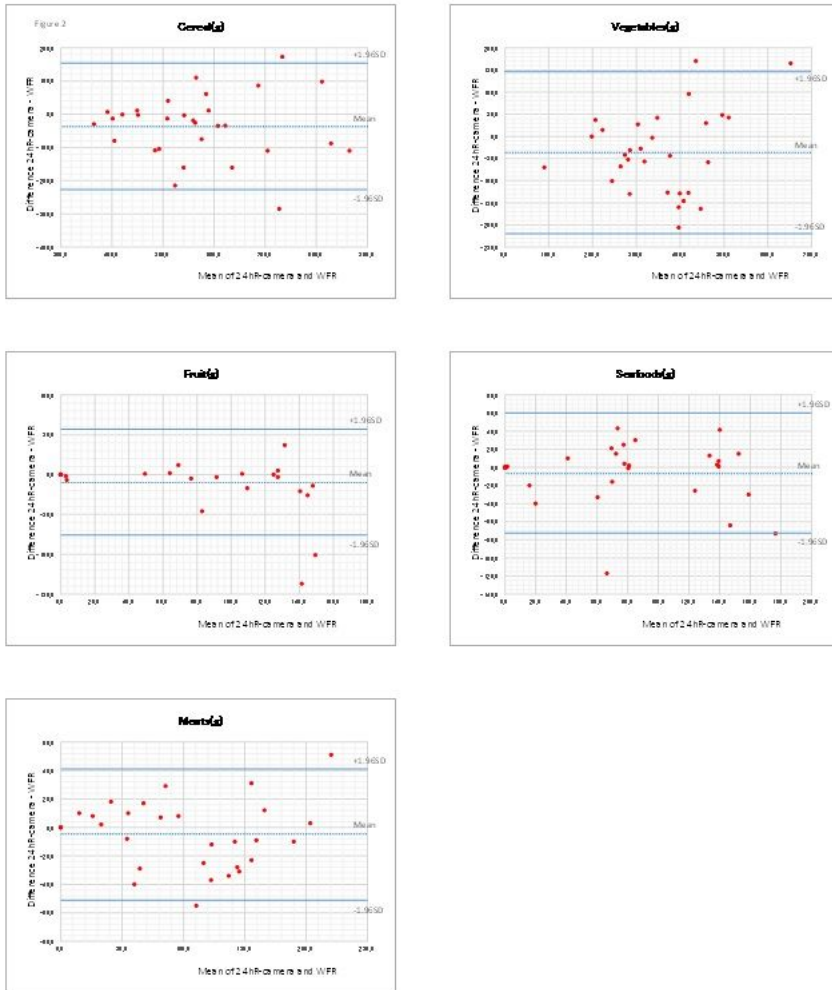


Figure 2
 Comparison of intakes of food between 24h-camera and WFR by Bland-Altman plots. The differences between the amounts of foods estimated by 24h-camera and WFR (Y-axis) were plotted against their mean values (X-axis). The dotted line shows the average difference between the two methods; the smaller the difference, the smaller the systematic bias. The solid lines show the 95% limits of agreement that represent the range in which most differences are expected to fall; the smaller the range, the smaller the difference between two methods for most individuals.

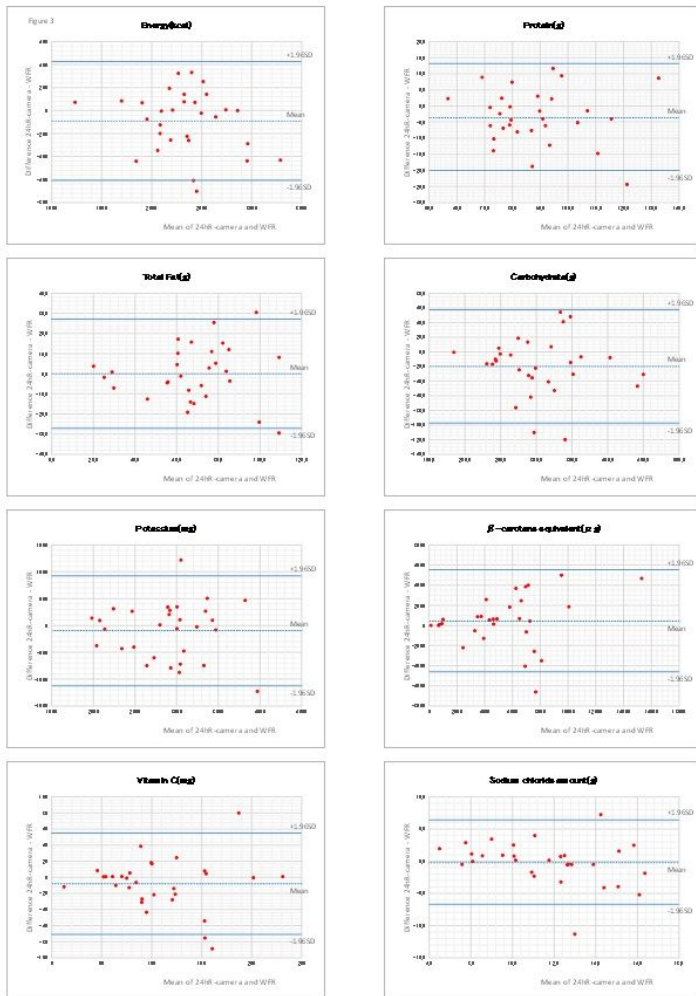


Figure 3

Comparison of intakes of energy and nutrients between 24hR-camera and WFR by Bland-Altman plots. The differences between the amounts of energy and nutrients estimated by 24hR-camera and WFR (Y-axis) were plotted against their mean values (X-axis). The dotted line shows the average difference between the two methods; the smaller the difference, the smaller the systematic bias. The solid lines show the 95% limits of agreement that represent the range in which most differences are expected to fall; the smaller the range, the smaller the difference between two methods for most individuals.