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Validation of a Mexican food photograph album as a tool to visually estimate food amounts in adolescents

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Abstract

The aim of the present study was to validate a food photograph album (FPA) as a tool to visually estimate food amounts, and to compare this estimation with that attained through the use of measuring cups (MC) and food models (FM). We tested 163 foods over fifteen sessions (thirty subjects/session; 10–12 foods presented in two portion sizes, 20–24 plates/session). In each session, subjects estimated food amounts with the assistance of FPA, MC and FM. We compared (by portion and method) the mean estimated weight and the mean real weight. We also compared the percentage error estimation for each portion, and the mean food percentage error estimation between methods. In addition, we determined the percentage error estimation of each method. We included 463 adolescents from three public high schools (mean age 17·1 (SD 1·2) years, 61·8 % females). All foods were assessed using FPA, 53·4 % of foods were assessed using MC, and FM was used for 18·4 % of foods. The mean estimated weight with all methods was statistically different compared with the mean real weight for almost all foods. However, a lower percentage error estimation was observed using FPA (2·3 *v.* 56·9 % for MC and 325 % for FM, $P<0·001$). Also, when analysing error rate ranges between methods, there were more observations ($P<0·001$) with estimation errors higher than 40 % with the MC (56·1 %), than with the FPA (27·5 %) and FM (44·9 %). In conclusion, although differences between estimated and real weight were statistically significant for almost all foods, comparisons between methods showed FPA to be the most accurate tool for estimating food amounts.

Key words: Food photographs: Dietetic assessment: Visual perception

Data obtained from food consumption surveys is a basis for determining public policy[1,2], such as the establishment of healthcare programmes for the prevention and treatment of nutritional deficiencies or excesses[2,3]. Therefore, adequately determining the amounts of foods consumed by subjects is critical to the analysis of results and decision-taking[1,4–6]. Food amount estimation in food consumption surveys allows the identification of diet characteristics in groups or individuals[7]. For this reason, differences between true and estimated amounts are so relevant. On the other hand, when food amount estimation is required in epidemiological studies, the aim is to generate or test hypotheses to explore the

Abbreviations: SMAE, Sistema Mexicano de Alimentos Equivalentes; UDG, Universidad de Guadalajara.

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relationship between diet and disease risk (or disease prevention)[8], so that correlations between true and estimated amounts are more relevant.

Determining food amounts consumed by subjects is difficult, especially in studies where this amount is estimated, since there are many factors that affect estimates made by individuals (food characteristics such as shape and size, and personal characteristics such as age, sex, socio-economic status, habits, body weight, etc.) which may lead to large estimation errors[1,5,9–15]. In the case of age, according to Piaget, adolescents have already built their mental schemes, structures, organisations, adaptations, assimilations, accommodations and balances that allow them to estimate and give a specific dimension to spatial quantities with the same capacity as adults. The mathematical-cognitive development is already formed since the stage of formal calculations (around 11 years old): the abstraction of specific knowledge is established and this situation allows the correct application of inductive and deductive logical reasoning[16].

To minimise food amount estimation errors, the use of visual aids, such as measuring cups (volumetric containers), food models or food replicas (three-dimensional models) and photographs as an almost mandatory strategy, has been proposed[1].

The use of food photographs has been very useful in dietary assessment studies and offers many advantages; the characteristics of tools that include food photographs have already been described in other studies[9,14,17–19]. Albums, manuals, atlases and catalogues of food photographs have been designed and validated in a number of countries: Malaysia[17], China (catalogue developed by Leung and cited by Woo *et al.*)[20]; England (developed by Nelson *et al.*[3], validated in their 1994 and 1996 studies[9,14]; and cited by Foster *et al.*[3] USA[21]; Spain[19]; South Africa[22]; France[23]; Brazil (three papers: Trigo *et al.* in 1993 and cited by Lopes *et al* [2], Zabotto *et al.* in 1996, the most used in the country and cited by other authors[24,25] and the study by Lopes[2]); Norway[5]; and Italy[18].

In the case of Mexico, no such tools for assessing dietary intake have been published yet. There is a book about common foods, portions and sizes developed by nutritionists[26] that is based on the Mexican Food Equivalents System (Sistema Mexicano de Alimentos Equivalentes, or SMAE) in its second edition[27]. This work provides a useful overview of basic food concepts, but does little in regards to the quantification of food amounts in dietary surveys because it presents a single 'portion' defined by SMAE which does not correspond to the amount typically consumed by subjects. For this reason, we developed a food photograph album which is in the edition process and this is the one that we will be referring to in this paper.

Hence, the objective of our present study was to validate a food photograph album used to estimate food amounts perceived visually by adolescents and to compare such estimates with real weight and with those obtained using measuring cups and food models.

Methods

Study design

The present investigation is a validation study of a food photograph album based on the visual perception of adolescents.

Sample

To determine the number of subjects required to validate the album, a convenience sampling was performed[28]. We included 463 subjects aged 14–19 years who were enrolled in three high schools of Universidad de Guadalajara (UDG) and who agreed to participate in the study on a voluntary basis. These subjects did not suffer from any known severe vision problems, had scheduling availability and signed a consent waiver. We calculated that 136 individuals would be enough to have a power of 80 % to declare as statistically significant differences of 14 % on overall mean percentage of errors between album of food photographs (7 (SD 24·5) %) and food models (21 (SD 32·5) %) as observed in Foster *et al.*[29] when the criterion for significance (α) was set at 0·05 for a two-tailed test. We enrolled 463 individuals in order to have also enough power even for comparisons at food-group level and when including a third method (cups).

Foods selection

We developed a food photograph album (in edition process) which includes 359 foods classified into nine groups, according to the classification used by the SMAE in its third edition, with some adaptations[30]: cereals and tubers (*n* 129); vegetables (*n* 52); fruits (*n* 51); animal foods such as beef, chicken, pork, etc. (*n* 56); dairy products (*n* 14); high-fat foods (*n* 14); sugars (*n* 31); legumes (*n* 8) and nuts/oilseeds (*n* 4). Since 2001, the Mexican Organisation 'Fomento de Nutrición y Salud, A.C.' has proposed this resource as a tool to promote a healthy diet and to provide nutrition education in the Mexican population[30]; so we determined that the food photograph album should have a similar foods categorisation.

For the study, we selected 163 foods according to these specifications: sweet breads were not selected, due to significant variations in size, weight etc., nor foods with a standardised weight of any particular brand, such as biscuits, chocolates, cereal bars and boxed breads. Also, when the presentation of some foods was similar, a representative food was selected, except for tortillas. For example, chopped papaya was selected to represent chopped watermelon.

Photograph preparation and presentation

Almost all foods (except for cereals) were photographed on a light-brown plate (25 cm diameter) with a knife to the right of the plate and a fork to the left against a yellow background. Cereals were photographed on a light-brown bowl of 15 cm diameter. All photographs were taken from an angle of 45°.

Only three foods were presented in each page of the album in four different portion sizes in descending order and identified with labels A, B, C and D. The size of each photograph 4·1 × 6·1 cm and the size of pages is 21·6 × 35·6 cm. For food amount estimation, the subject is asked to select the photograph that best represents the real food amount. The grams corresponding to each photograph of the different foods were recorded in a database to which only the principal researchers had access.

The elaboration of this album is described in detail elsewhere[31].

Measuring cups and food models

There were six sets of white measuring cups (one per interviewer). For each set, there were four different sizes: $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$ and one cup. For food models, we used those manufactured by NASCO. Each food model represents a specific food amount.

Procedures for validation

The data collection procedures and strategies are detailed as follows:

(1) Organisation of sessions: A total of fifteen sessions were conducted (with different participants in each) from September to December 2009 in the schools selected. The duration of each session was 2 h. In coordination with the officials of each school, schedules were drawn up for the groups participating in the validation. One day before conducting assessments, the adolescents were informed of the study's purpose, where it would be carried out and its schedule.

During each session, food amounts of ten to twelve foods were estimated from all groups and with different presentations (bits, pieces, chopped up, etc.) to make presentation of foods as varied as possible, within the same food group and among different groups. For each food to be validated, two different portions were presented (a total of twenty to twenty-four plates per session and per subject): 'portion 1' corresponded to the exact amount of one of the photographs in the album (A, B, C or D), while 'portion 2' corresponded to an arbitrary amount, different for each food, that could be a quantity between two photographs, or bigger than that shown in photograph A, or lesser than that shown in photograph D. To select the food amounts to be presented and estimated in portion 1, we assigned an option number to each photograph option (A = 1, B = 2, C = 3, D = 4) and with the support of a random numbers table with this number options, we determined for each food the quantity to be estimated. A similar procedure was carried out with portion 2, although option numbers were differently assigned (greater than A = 1 between A and B = 2, between B and C = 3, between C and D = 4, less than D = 5).

(2) Before the assessments: Before each validation session, foods were prepared and weighed (Seca food scale, model 851, with a 2200 g capacity and 2 g accuracy) by a previously trained and supervised person, who also put each item in a container with a label specifying (with text) which food was inside and its portion number (1 or 2). The food preparer was also in charge of weighing out in grams the equivalent to one cup of each food that could be assessed using this method and recording this data in a special form. After the foods had been weighed and packaged, the researchers took them to the assessment site and handed them over to fieldwork supervisors or moderators.

(3) During the assessments: The moderators were in charge of arranging the foods on the plates, covering it with a dish cover (so that the interviewers could not see the food amounts before or during the assessments) and labelling them so that the name of the foods and the portion number (1 or 2) could be identified by the moderators and interviewers (for control purposes). Before starting their sessions, the moderators recorded the order or sequence in which visual tools would be used (assessment sequence) on the assessment form for each student. The three methods were arbitrarily assigned as 1, 2 and 3 (album, cups and models, respectively). Assessment sequences were assigned beforehand. For example: student 1 was given option 1-2-3, student 2 was assigned option 1-3-2, student 3 was given option 2-1-3, and so on. This was done to prevent the estimate made by subjects from being affected by always being presented with the same sequence.

The moderator distributed to the interviewers (all with a Bachelor's degree in Nutrition), the plates that each of them were going to use in the assessment (six interviewers in total, about four plates per interviewer). The interviewers were previously trained and standardised (six sessions of 2 h length = 12 h of training) to perform the assessments.

Each interviewer was given a table for conducting assessments. Each table held the plates of foods to be assessed, a set of measuring cups, the corresponding food models and the pages of the food photograph album showing the foods to be assessed. To avoid induced responses, interviewers did not know which portion was portion 1 or portion 2, and they did not know the weight of the foods on each plate. Also, they did not see the foods during assessments so as not to influence the subjects' responses.

The session began with the moderator handing out the assessment forms to students in order for them to fill in identification data. The moderator then told the students to take their assessment forms to one of the interviewers. Each interviewer asked the students to look at the food shown on the plate and estimate its amount with the help of different visual tools, in accordance with the established sequence, and the interviewer wrote down the answer in the form. With the album, subjects could select one of the four photographs options, the sum of the amount represented in two or more photographs, less than photograph D, more than photograph A, or an amount between two photographs (between photograph A and B). When subjects selected

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less than photograph D, more than photograph A or an amount between photographs, they specified which fraction or multiple of a specific photograph was presented (for example, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ of photograph B; two times the amount of photograph A, 1·5 times the amount of photograph C). In the case of measuring cups, subjects could choose one of the four sizes of cups shown ($\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, 1 cup), or combine two or more options; for example $1+\frac{1}{2}$, or $\frac{1}{2}+\frac{1}{4}$. Finally, in the case of food models, subjects could select the amount represented in the whole model or multiples or fractions of it ($\frac{1}{4}$, $\frac{1}{3}$, $\frac{3}{4}$, $\frac{1}{2}$, two times the quantity represented in the food model, etc.).

After the assessment of all foods on their table was completed, the interviewer returned the assessment form to the student and, with the assistance of the moderator, the student went to the next interviewer. Students passed through the six tables in this manner. At the end of the process, students gave their forms to the moderator for filing.

Statistical analysis

Data entry into an Excel database (Microsoft Office 2007) was performed by two previously trained collaborators. Statistical analyses were carried out using the program Statistical Package for the Social Sciences version 17.0 (SPSS, Inc.). A result of $P<0.05$ (two-sided) was considered as statistically significant. Quantitative variables were presented as means and standard deviations. Qualitative variables were presented as frequencies and percentages.

To determine the estimation accuracy of each method, first we calculated the estimated weight of each food and portion: (1) for the food photograph album, the fraction or multiple of the amount presented in the photograph selected by the student as most representative of the amount on the plate was multiplied by the actual weight of the item in the selected photograph. For example, if the subject believed that the weight of the food was half of what was shown in photograph A, the actual weight of what was shown in photograph A was multiplied by 0·5. (2) In the case of the measuring cups, we multiplied the fraction or multiple of the cup pointed out by the subject by the weight in grams of one cup of the assessed food. (3) For the food models, the weight represented by the model was multiplied by the fraction or multiple thereof that was identified by the subject.

Then, we calculated the mean real weight of each food (actual weight of portion 1 plus the actual weight of portion 2, divided by 2) and the mean estimated weight between portions for each food and each method (estimated weight of portion 1 plus the estimated weight of portion 2, divided by 2). Next a paired t test was performed between the mean estimated weight and the mean real weight.

To compare the accuracy of estimates between methods, a calculation was made of the difference in weight (estimated – actual) and the percentage error estimation (weight difference × 100/actual weight) for each method, food and portion. Then, we calculated the mean error percentage between portions 1 and 2 of each food for which was compared between methods (for the foods for which two or more estimation methods were applied) using ANOVA.

We also determined the mean percentage error of each method, that is to say, the average error for all foods, and the mean absolute percentage error, which is the average error for all foods not considering the sign (over- or subestimation), but the absolute value. Both values were compared between methods using ANOVA.

Finally, we compared error percentage ranges between methods through a χ^2 test.

Ethics

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the ethics committee 'Comisiones de Ética, Investigación y Bioseguridad' from the 'Centro Universitario de Ciencias de la Salud' from 'UDG'. Written informed consent was obtained from all subjects.

Results

For validation of the album, 463 students participated in the study. The mean age of the study population was 17·1 (SD 1·2) years old. More than half were female (61·8 %).

Not all foods could be assessed with the three visual aids because some foods could not be assessed in cups due to their morphological characteristics, and also because models were not available for all foods to be validated. In summary, all foods were assessed using the album, 53·4 % could be assessed using cups and only 18·4 % (thirty foods) could be assessed using models (Table 1). A total of 9988 assessments were conducted with the food photograph album, 5308 with cups and 1378 with the food models.

A paired t test comparing the mean estimated weight obtained using all of the methods with the mean real weight of the foods produced statistically significant differences (82·2 % of the foods assessed using the album, 88·1 % of those assessed using cups and 76·7 % of those assessed using the models; data not shown).

However, upon analysing the mean estimation error, we found that of 104 foods for which the comparison between methods could be made (for fifty-nine, the assessment was

Table 1. Foods assessed by method of estimation and food groups (Number of foods and percentages within food group)

	Album		Cups		Models	
Food groups	*n*	%	*n*	%	*n*	%
High-fat foods	9	100·0	3	33·3	1	11·1
Animal foods	34	100·0	11	32·6	10	29·7
Sugars	4	100·0	2	50·0	0	0·0
Cereals and tubers	41	100·0	20	46·8	5	12·2
Fruits	26	100·0	12	46·2	3	11·5
Nuts/oilseeds	3	100·0	3	100·0	0	0·0
Dairy products	8	100·0	7	87·5	3	37·5
Legumes	6	100·0	6	100·0	2	33·3
Vegetables	32	100·0	23	71·9	6	18·8
Total (from foods)	163	100·0	87	53·4	30	18·4

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only carried out using the album), the best estimate was made using the album, as occurred in sixty-eight instances (65·4 % of all foods); in thirteen instances (12·5 % of all foods) best estimates was made using the cups (15·5 % of the eighty-four foods assessed using cups); in twelve (11·5 % of all foods), the best estimates were made using the models (40 % of the thirty food models assessed); and in eleven foods (10·6 % of all foods), no differences between the methods were found (see Appendix 1 of the supplementary material, available online).

When analysing the mean estimation error by food group and depending on the method, we found that in most groups (six of nine), the lowest mean error occurred when using the food photograph album. However, in the case of high-fat foods, there was only one food (cooked bacon) that could be assessed with models, and in the case of fruits and dairy products, there were only three in each group: banana, pear and peach in the case of fruits, and manchego cheese, panela cheese and yoghurt in the case of dairy products (Table 2).

In making the analysis by assessment method, the method with the lowest estimation error was the food photograph album, with an average estimation error of 2·3 %, compared with 56·9 % for cups and 32·0 % for models (Table 3). When analysing the mean absolute percentage error (without considering if there was a sub- or overestimation), the trend was the same: the album showed an error percentage of 30·9 %, *v.* 68·6 % for cups and 53·9 % for models (Table 3).

Moreover, an analysis of error percentage ranges was performed to determine which method had the highest frequency of food estimates with fewer errors. For example, we noted that the number of observations with a percentage error of 20 % or less varied depending on the method: 41·5 % of observations using the album, 29·4 % using models and only 19·6 % using cups. In addition, there were more observations showing estimation errors higher than 40 % when assessments were carried out using the cups (56·1 %), compared with that reported when the albums (27·5 %) and models (44·9 %) were used (Table 4).

Discussion

There were statistically significant differences between the actual and estimated weights using all methods for almost all foods. However, in comparison with the other tools, the food photograph album proved to be the most accurate or realistic visual medium. This assertion is based on four essential points observed in the results: (1) upon analysing each food individually, estimation errors ranged from − 0·2 to 172·5 %, while using the cups the variation was between − 3·6 and 431·1 % and when using the models it fell between 2·8 and 355·7 % (details not shown); (2) when performing the analysis by food groups, in six of nine groups the album was more accurate; (3) upon carrying out the global analysis, the mean percentage error of the album was 2·3 % (30·9 % in absolute figures), followed by the models with 32 % (54·0 % in absolute values, although there were fewer foods assessed using this method) and cups with 56·9 % (68·6 % in absolute value) and (4) upon making the analysis based on ranges of error estimation percentages (absolute value), we found a higher proportion of foods with estimation errors of 20 % or less when the album was used (41·5 % for the album, 19·6 % for the cups and 29·4 % for the models).

Also, when a food was estimated with all methods (thirteen foods), the food photograph album had the lowest percentage error, both in portion 1 (eight foods of thirteen) and portion 2 (nine foods of thirteen) (data not shown).

Although one could think that the album has an advantage over the other methods because one amount always corresponded exactly to an amount shown on the food photograph, this idea was not always true, since some foods had the lowest percentage error estimation with portion 2 rather than with portion 1 (from 106 foods with significant differences between portion 1 and 2, thirty-four (32 %) had a significant lower percentage error estimation with portion 2; for more details, see Appendix 2 of the supplementary material, available online). Also, if we compare the percentage error estimation using only portion 2 (excluding portion 1 estimations), the album has the lowest error with 7·4 (SD 52·9) % (n observations = 4926, $P<0·001$), *v.* 56·9 (SD 41·5) % with measuring cups (n observations = 2645) and 34·5 (SD 57·8) %

Table 2. Mean percentage error by estimation method and food groups
(Mean values and standard deviations)

	Album			Cups			Models		
Food groups	Mean	SD	*n*‡	Mean	SD	*n*	Mean	SD	*n*
High-fat foods	− 17·6	33·7	548	56·5	74·9	182	− 5·6***	30·4	60
Animal foods	3·5***	41·3	2100	102·4	89·8	682	40·3	98·2	471
Sugars	− 15·9†††	27·0	234	76·8	51·9	114	–		–
Cereals and tubers	10·8***	38·2	2520	46·2	105·8	1214	39·2	67·1	266
Fruits	5·0	28·6	1606	44·7	54·9	740	− 0·9***	54·1	123
Nuts/oilseeds	− 18·6†††	18·1	176	22·8	46·3	176	–		–
Dairy products	20·6	81·3	474	53·4	56·2	416	7·0***	36·9	119
Legumes	− 4·6***	33·9	366	84·7	266·9	366	32·5	37·3	89
Vegetables	− 5·4***	31·4	1964	47·1	63·9	1418	45·6	97·2	250

ANOVA between methods: we highlight the method with lower mean percentage error: *** $P<0·001$.
Non-paired t test between methods: we highlight the method with lower mean percentage error: ††† $P<0·001$.
‡ Number of assessments or observations.

Table 3. Mean percentage error and mean absolute percentage error, according to estimation method

(Mean values and standard deviations)

		Mean percentage error		Mean absolute percentage error	
Visual aid	No. of observations	Mean	SD	Mean	SD
Album	9988	2·3***	39·7	30·9***	28·8
Cups	5308	56·9	104·9	68·6	98·8
Models	1378	32·0	81·5	54·0	72·9

ANOVA between methods: we highlight the method with lower mean percentage error: *** $P < 0.001$.

Table 4. Error rate ranges according to estimation method

(Number of observations and percentages)

	Album†***		Cups‡		Models§	
Error rate ranges	*n*	%	*n*	%	*n*	%
≤10 %	1952	19·5	372	7·0	171	12·4
>10 to ≤20	2198	22·0	670	12·6	234	17·0
>20 to ≤30	1692	16·9	748	14·1	194	14·1
>30 to ≤40	1396	14·0	542	10·2	160	11·6
>40 to ≤50	1230	12·3	488	9·2	124	9·0
>50	1520	15·2	2488	46·9	495	35·9

χ^2: we highlight the method with higher frequency of observations with low estimation errors: *** $P < 0.001$.

† *n* foods = 163, *n* observations or assessments = 9988.

‡ *n* foods = 87, *n* observations = 5308.

§ *n* foods = 30, *n* observations = 1378.

with food models (*n* observations = 519). This same tendency is observed with the estimation with absolute values: 38·5 (SD 37·1) % with album, *v.* 67·6 (SD 72·8) % with cups and 46·8 (SD 48·4) % with food models ($P < 0.001$).

All these observations tell us that although some foods were best estimated by models or cups, the best assistance method was the album, followed by the models and lastly the cups.

The use of the food photograph album has other advantages in addition to providing the best estimates of food amounts, which were: (1) the photographs could be reproduced more easily and their use could be more accessible, while the cups or the models were more difficult to transport and use, especially because more than one interviewer participated in the study; (2) the album could be used with greater number of foods than could the cups (not all foods could be assessed using volumetric measurements) or the models (not all foods had a three-dimensional model that could represent them; in addition, these models are expensive). Indeed, it is important to note that error percentages could be higher using other methods such as food models because they were not always used for assessments of both portions, and because this situation could increase or decrease the mean error percentage. In this case, having a larger number of foods for which there is a visual aid for estimating their quantity, affords an advantage to the use of the album; (3) the fact that the food photograph album depends on visual perception means it can be used with illiterate people or those who are unable to report their food intake numerically, although this is an area which requires future study.

The best estimate of food amounts obtained through use of the models compared with cups (Werhan in 1982 cited by Cypel et al.[13] and Pao in 1987, cited by thompson & Byers[10]), is a situation also observed in our study. On the other hand, in some previous studies comparing the accuracy of estimates obtained using food photographs and food models, conflicting results have been reported: some propose models as the most accurate visual tool[1], while others found no statistically significant differences between methods, though food photographs produced the lowest estimation error (Kirkcaldy *et al.* (1980) and Kuehneman *et al.* (1994)[13]). In yet another study, the best estimates were obtained when photographs were used[29].

There are many methodological differences between studies that validate food albums, making it difficult to compare results between studies and to compare the accuracy of reported estimates. This is due to several variables, which are discussed below.

The cognitive process used

The traditional positivist concept of validity refers to the relationship between a real image and the image that results from a cognitive process. According to this concept, the assessment of food amounts from photographs can be carried out through the use of three cognitive functions: perception (the ability to link an amount of real food to one shown in a photograph); conceptualisation (the ability to make a mental construction of the amount of food not present and relate it to that shown in a photograph); and memory (the ability to remember the amount ingested)[9,14]. Typically, validation studies compare the estimated food amount with the real amount, through conceptualisation-memory[6,10,13–15,17,18,29,32–39]. The validation method in our study was perception. As in other studies that used this cognitive process[4,5,9,40,41], estimation accuracy varied significantly between foods. There is one study that assessed all three cognitive processes; authors also found that individual estimation errors were large for all foods (beverages, margarine and bread), but at the group level, food amounts estimation was acceptable for some of the foods, as we found[42].

The characteristics of the subjects assessed

The age of the subjects, sample size, the ratio between men and women, socio-economic status, and nutritional status, among others, are factors that affect the accuracy of estimating amounts of foods and different studies. For example, our study was conducted on more than 400 adolescents, with a ratio of three women for every man, different from other studies. This proportion was almost the same in all sessions (except for four sessions where the proportion between sexes was near 50/50).

The number of foods validated

In our study, the number of validated foods was 163, while in other studies fewer than 100 were assessed on average[4–6,9,13,17,32,37,39].

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Statistical analysis

In conceptualisation or memory studies, because they are studies in which the actual amount of foods depends on the amount consumed by the subjects, it is possible to obtain correlations between actual and estimated weights, something which could not be done in this present study because the actual weight of each serving of food was constant. In the studies of perception[5,9,40,41], paired and unpaired *t* tests and ANOVA have been used, as they were in our study.

Method used to present results

In this section, we will review various points presented in the results section of the studies we examined: (1) the degree of error between the actual and estimated weight (in grams or as a percentage). In several studies, a statistically significant error was reported between the actual and estimated weights[9,14,16], although others mention non-significant errors[6,13]. The existence of differences between the actual and estimated weight, which we also found, led us to suspect that without visual tool assistance, the degree of error could have been even greater. Moreover, a comparison was not always made to determine whether the degree of error was statistically significant. The error percentage ranges for each food were generally analysed. In this regard, great variation in estimation errors between foods was mentioned, for example: from −8 to 6 %[9], from −37 to 13 %[14], from 20 to 50 %[13], from −20 to 12·05 %, from −47·2 to 5 %[15]; from −28 to 242 %[14], just to name a few examples. It is noteworthy that, as discussed by Turconi *et al.*[18], the large quantity of observations leads one to expect that the error between the estimated and actual weight would be greater, a situation that was reported in our study. (2) Estimation accuracy of the tool used. In different studies, comparisons between estimated and actual weights are generally performed on foods on an individual basis and in most cases the average estimate error for the visual support tool being studied is omitted. In the cases in which the average general error percentage is mentioned, we can observe differences between authors. For example, in the study by Nelson *et al.*[9] based on the perception of subjects, the average error was 13 %; in their 1996 study[12], it was 32 %; in the Krikcaldy study, cited by Cypel *et al.*[13], the average error of the album was 37 %; in the study by Foster *et al.*[29], the average error was 8 %; in the study by Bonifacj *et al.*[4] it was about 11·5 %, while the album proposed in our study produced the lowest average estimated error of 2·3 %. Also mentioned was the estimation precision of other tools such as models and cups, which have lower estimation precision and estimation errors exceeding 40 %[13,29]. (3) Percentage of overestimated, underestimated or correctly estimated food, or the percentage of subjects who overestimate, underestimate or correctly estimate food. This is one of the most common ways of presenting the results, especially in terms of percentage of foods correctly or incorrectly estimated. In general, it is difficult to determine at what point an over- or underestimation occurs. Arbitrarily, an estimate is considered accurate if done with an error of ± 10 %[4]. In this respect, the trends differ greatly from study to study, although the percentage of correctly estimated food ranges from 25 to 61·4 %. For our study, foods correctly estimated (which fell in the ± 10 % range) was 28·7 % in the case of the album, a higher percentage than that reported for the cups (11·5 %) and the models (23·3 %). According to this criterion, for the album there is no clear trend in terms of over- or underestimation (36·5 % of the foods were underestimated and 34·8 % were overestimated). However, in the case of the cups and models, foods tended to be overestimated (86·2 and 63·3 %, respectively).

Having reviewed the results of other studies, we are in a position to outline the strengths of ours: not only did we assess the estimation accuracy of the album, but also we compared it with that obtained using other visual support tools. We included a larger quantity of foods and subjects for the validation of the foods. We also reported the mean estimation error for each meal for each food and also for the method itself. Added to this, one reason the estimates using photographs might have been better than those obtained from the food model is that we supplied four different serving sizes with the photographs, while the models were produced in only one portion size. This fact alone represents one of the advantages gained by using the album. In addition, even though the visual support tools are used ‘during’ the administration of dietary surveys, in these processes the interviewee used other cognitive functions, namely conceptualisation and memory. With these methods, there are a greater number of factors which may lead to confusion on the part of the subject and contribute to potential sources of error in estimating quantities and which do not allow the accuracy of the tool used to be assessed. Thus, perception-based validation eliminates those factors inherent to the cognitive functions used by subjects.

It is worth noting that our study has certain limitations that were in some ways linked to the study’s design itself. The population on which the validation was performed only included adolescents, but it is in this population where the use of visual support tools is essential (to better characterise the quantity of foods consumed by young people who, in most cases, do not have the experience in preparing foods or using fractions or multiples of a quantity). Besides, as we stated in the Introduction section, mathematical-cognitive development is already formed at the age of 11 years: the abstraction of specific knowledge is established and this situation allows the correct application of inductive and deductive logical reasoning[16]. Based on this idea, our theory is that if the tool works for adolescents, there is a high likelihood that it would also work with adults; nevertheless, it may be important to prove this theory. Another limitation in the case of the models is that because they validate two different portion sizes, we did not always have a model for each serving size. This meant that in fifteen of the thirty foods for which assessments were carried out using models, the replica was only used in one of the two portions, which limited comparisons between methods. Although we had pointed out the strengths of validating a food photograph album using perception as the only cognitive function implied (since it is important to analyse the estimation error without considering memory and conceptualisation, which can modify the estimation), in practice these functions are present when performing food consumption surveys and this situation could limit the generalisation of our findings in this context.

There are several aspects that should be addressed in future studies that will help us better understand the role of food photograph albums in estimating food amounts: the use of the food photograph album in studies of highly marginalised populations; the use of the food photograph album in studies of conceptualisation or memory; a multivariate analysis to know how different factors that influence perception (sex, age, nutritional status, shape of the foods, socio-economic factors, etc.) affect the accuracy of food amount estimates or to find a pattern in the type of foods that can be estimated best by each method; analysing the errors of estimate of energy and nutrients, among others.

Finally, it is important to note that despite the advantages of using food photograph albums, differences between estimated weight and actual weight of most foods and portions were statistically significant, which in turn may affect estimates of macro- and micronutrient intake, and therefore energy intake. Estimating food amounts is a challenging task. In most cases, people do not pay attention to food amounts, and even if they do, the act of visualising and remembering what they see and translating that perception into an image is a complicated task. Estimation errors are present even when using different visual support aids. In addition, estimation is even more complex when, in addition to perception, conceptualisation and memory are involved, as in the case of 24 h memory recalls, and these factors can affect the accuracy of the estimate. This is why the use of visual support tools, especially a food photograph album, offers many advantages and can be an excellent aid to help nutritionists and health professionals estimate food amounts.

In conclusion, the food photograph album was the best estimation method. It had the lowest mean error percentage estimate at 2·3 % (30·9 % in absolute terms), and using this method almost 50 % foods fell within the estimation error range of up to 20 %. In addition, the food photograph album has the advantage that it can be used to estimate amounts for more kinds of foods than the cups or the models. It is also a more practical model, as it requires less space for storage, and is more portable and less expensive than the food replicas.

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Supplementary appendices are available online at http://www.journals.cambridge.org/bjn

References

1. Matheson DM, Hanson KA, McDonald TE, *et al.* (2002) Validity of children's food portion estimates. A Comparison of 2 measurement aids. *Arch Pediatr Adolesc Med* **156**, 867–871.
2. Lopes de Sales R, Santana-Silva MM, Brunoro-Costa NM, *et al.* (2006) Desenvolvimento de um inquérito para avaliação da ingestão alimentar de grupos populacionais (Development of a questionnaire to assess food intake of population groups). *Rev Nutr* **19**, 532–552.
3. Foster E, Matthews JNS, Nelson M, *et al.* (2006) Accuracy of estimates of food portion size using food photographs – the importance of using age-appropriate tools. *Public Health Nutr* **9**, 509–514.
4. Bonifacj C, Gerber M, Scali J, *et al.* (1997) Comparison of dietary assessment methods in a Southern French population: use of weighed records, estimated-diet records and a food-frequency questionnaire. *Eur J Clin Nutr* **51**, 217–231.
5. Lillegaard ITL, Øverby NC & Andersen LF (2005) Can children and adolescents use photographs of food to estimate portion sizes? *Eur J Clin Nutr* **59**, 611–617.
6. Subar AF, Crafts J, Palmer-Zimmerman T, *et al.* (2010) Assessment of the accuracy of portion size reports using computer-based food photographs aids in the development of an automated self-administered 24-hour recall. *J Am Diet Assoc* **110**, 55–64.
7. Patterson RE & Pietinen P (2006) Evaluación del estado nutricional en individuos y poblaciones (Assessment of nutritional status in individuals and populations). In *Nutrición y Salud Pública (Nutrition and Public Health)*, 1st ed., pp. 73–92 [MJ Gibney, BM Margetts, JM Kearney and L Arab, editors]. Zaragoza: Acribia.

8. Willet W & Lenart E (1998) Foods and nutrients. In *Nutrition Epidemiology*, 2nd ed., pp. 18–32 [W Willet, editor]. New York, NY: Oxford University Press.
9. Nelson M, Atkinson M & Darbyshire S (1994) Food photography I: the perception of food portion size from photographs. *Br J Nutr* **72**, 649–663.
10. Thompson FE & Byers T (1994) Dietary assessment resource manual. *J Nutr* **124**, 2245S–2317S.
11. Lucas F, Niravong M, Villeminot S, *et al.* (1995) Estimation of food portion size using photographs: validity, strengths, weaknesses and recommendations. *J Hum Nutr Diet* **8**, 65–74.
12. Young L & Nestle M (1995) Portion sizes in dietary assessment: issues and policy implications. *Nutr Rev* **53**, 149–158.
13. Cypel YS, Guenther PM & Petot GJ (1997) Validity of portion-size measurement aids: a review. *J Am Diet Assoc* **97**, 289–292.
14. Nelson M, Atkinson M & Darbyshire S (1996) Food photography II: Use of food photographs for estimating portion size and the nutrient content of meals. *Br J Nutr* **76**, 31–49.
15. Robson PJ & Livingstone MB (2000) An evaluation of food photographs as a tool for quantifying food and nutrient intakes. *Public Health Nutr* **3**, 183–192.
16. Piaget J (editor) (1978) *Equilibración de las estructuras cognitivas (Equilibration of Cognitive Structures)*. Mexico: Siglo XXI.
17. Zamaliah MM (1995) Evaluation of food photographs for 24-hour recall method. *Mal J Nutr* **1**, 95–104.
18. Turconi G, Guarcello M & Gigli-Berzolari F (2005) An evaluation of a color food photography atlas as a tool for quantifying food portion size in epidemiological dietary surveys. *Eur J Clin Nutr* **59**, 923–931.
19. Gómez-Candela C, Loria-Kohen V & Lourenço-Nogueira T (editors) (2007) *Guía visual de alimentos y raciones (Foods and Food Protions Visual Guide)*, 1st ed. Madrid: Editores Médicos, S.A.
20. Woo J, Leung SSF, Ho SC, *et al.* (1997) A food frequency questionnaire for use in the Chinese population in Hong Kong: description and examination of validity. *Nutr Res* **17**, 1633–1641.
21. Abbott-Hess M, (editor). (1997) *Portion Photos of Popular Foods*. Chicago: The American Dietetic Association and Center of Nutrition Education University of Wisconsin.
22. MacIntyre UE, Venter CS & Vorster HH (2001) A culture-sensitive quantitative food frequency questionnaire used in an African population: 1. Development and reproducibility. *Public Health Nutr* **4**, 53–62.
23. Hercberg S, Deheeger M & Preziosi P (editors) (2002) *Portions alimentaires. Manuel photos pour l'estimation des quantités (Food Portions. Photograph Manual for Estimating Quantities)*. Paris: Candia/Polytechnica.
24. Leite de Lima FE, Fisberg RM & Slater B (2003) Desenvolvimento de um questionário quantitativo de freqüência alimentar (QQFA) para um estudo caso-controle de dieta e câncer de mama em João Pessoa-PB (Development of a quantitative food frequency questionnaire (QFFQ) for a breast cancer and diet case-control study in João Pessoa). *Rev Bras Epidemiol* **6**, 373–379.
25. Bismarck-Nasr EM, Petroli-Frutuoso MF & Dianezi-Gambardella AM (2006) Importância nutricional dos lanches na dieta de adolescentes urbanos de classe média (Nutritional importance of snacks in urban middle-class adolescent diet). *Pediatria (Sao Paulo)* **28**, 26–32.
26. DV Vargas-Gutiérrez, JA Ledesma-Solano & A Gulias-Herrero (editors) (2008) *Alimentos comunes, medidas caseras y porciones (Common Foods, Household Measures and Portions)*, 1st ed. Mexico: Mc Grawn Hill.
27. Marván-Laborde L, Pérez-Lizaur AB & Palacios-González B (2006) *Sistema Mexicano de Alimentos Equivalentes (Mexican Food Equivalents System)*, 2nd ed. Mexico: Fomento Nutrición y Salud, A.C.
28. Celis AJ Rosa de la, (editor). (2008) *Bioestadística (Biostatistics)*, 2nd ed. Mexico: El manual moderno.
29. Foster E, Matthews JNS & Lloyd J*et al.* (2008) Children's estimates of food portion size: the development and evaluation of three portion size assessment tools for use with children. *Br J Nutr* **99**, 175–184.
30. Pérez-Lizaúr, A, Palacios-González, B & Castro-Becerra A (editors) (2008) *Sistema Mexicano de Alimentos Equivalentes (Mexican Food Equivalents System)*, 3rd ed. Mexico: Fomento de Nutrición y Salud, A.C., Ogali.
31. Rodríguez-Rocha N (2009) *Proceso de elaboración de un álbum fotográfico de alimentos y evaluación de su precisión para la estimación de cantidades de alimentos en estudiantes de nutrición (Creation Process of a Food Photograph Album and Evaluation of its Accuracy in the Estimation of Food Quantities Among Nutrition Students) (Thesis)*. Guadalajara: Universidad de Guadalajara.
32. Faggiano F, Vineis P, Cravanzola D, *et al.* (1992) Validation of a method for the estimation of food portion size. *Epidemiology* **3**, 379–382.
33. López L, Longo E, Carballido M, *et al.* (2006) Validación del uso de modelos fotográficos para cuantificar el tamaño de las porciones de alimentos (Validating the use of photographic models to determine the size of food portions). *Rev Chil Nutr* **33**, 480–487.
34. Ocké MC, Bueno-de-Mesquita HB, Goddijn HE, *et al.* (1997) The Dutch EPIC food frequency questionnaire. I. Description of the questionnaire, and relative validity and reproducibility for food groups. *Int J Epidemiol* **26**, Suppl. 1, S37–S48.
35. Robinson F, Morritz W, McGuinness P, *et al.* (1997) A study of the use of a photographic food atlas to estimate served and self-served portion sizes. *Hum Nutr Diet* **10**, 117–124.
36. Frobisher C & Maxwell SM (2003) The estimation of food portion sizes: a comparison between using descriptions of portion sizes and a photographic food atlas by children and adults. *J Hum Nutr Diet* **16**, 181–188.
37. Williamson DA, Allen R, Davis-Martin P, *et al.* (2003) Comparison of digital photography to weighed and visual estimation of portion sizes. *J Am Diet Assoc* **103**, 1139–1145.
38. Huybregts L, Roberfroid D, Lachat C, *et al.* (2007) Validity of photographs for food portion estimation in a rural West African setting. *Public Health Nutr* **11**, 581–587.
39. Martin CK, Han H, Coulon SM, *et al.* (2009) A novel method to remotely measure food intake of free-living individuals in real time: the remote food photography method. *Br J Nutr* **101**, 446–456.
40. Weber HK, Cunningham-Sabo L, Skipper B, *et al.* (1999) Portion-size estimation training in second- and third-grade American Indian children. *Am J Clin Nutr* **69**, Suppl. 4, 782S–787S.
41. Ovaskainen ML, Paturi M, Reinivuo H, *et al.* (2008) Accuracy in the estimation of food servings against the portions in food photographs. *Eur J Clin Nutr* **62**, 674–681.
42. De Keyzer W, Huybrechts I, De Maeyer M, *et al.* (2011) Food photographs in nutritional surveillance: errors in portion size estimation using drawings of bread and photographs of margarine and beverages consumption. *Br J Nutr* **105**, 1073–1083.