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Adolescents in the United States can identify familiar foods at the time of consumption and when prompted with an image 14 h postprandial, but poorly estimate portions

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Abstract

Objective: To evaluate adolescents' abilities to identify foods and estimate the portion size of foods consumed in order to inform development of the mobile telephone food record (mpFR).
Design: Data were collected from two samples of adolescents (11–18 years). Adolescents in sample 1 participated in one lunch (*n* 63) and fifty-five of the sixty-three adolescents (87 %) returned for breakfast the next morning. Sample 2 volunteers received all meals and snacks for a 24 h period. At mealtime, sample 1 participants were asked to write down the names of the foods. Sample 2 participants identified foods in an image of their meal 10–14 h postprandial. Adolescents in sample 2 also estimated portion sizes of their breakfast foods and snacks.
Results: Sample 1 identified thirty of the thirty-eight food items correctly, and of the misidentified foods all were identified within the correct major food group. For sample 2, eleven of the thirteen food items were identified correctly 100 % of the time. Half of the breakfast and snack foods had at least one portion size estimate within 10 % of the true amount using a variety of measurement descriptors.
Conclusions: The results provide evidence that adolescents can correctly identify familiar foods and they can look at an image of their meal and identify the foods in the image up to 14·5 h postprandial. The results of the present study not only inform the development of the mpFR but also provide strong evidence of the use of digital images of eating occasions in research and clinical settings.

Keywords
Dietary assessment
Adolescents
Portion size estimation
Food identification

Measuring an individual's dietary intake presents more challenges than other environmental exposures. Diet assessment is a challenge with adolescents[1]. Portion size estimation and description of foods have been identified by adolescents as burdensome components of diet assessment[2]. The development of a mobile telephone application for dietary assessment that fits into the lifestyle of young people may address these barriers[3,4]. In previous studies, adolescents indicated that they would prefer dietary assessment methods using technology, e.g. a personal digital assistant with or without a camera or with a disposable camera[2]. The mobile telephone food record (mpFR) is an innovative dietary assessment tool in the developmental stages[4–6]. Ideally, a mobile telephone with a built-in camera that integrates image analysis, visualization methods and a nutrient database will be used to discretely 'record' foods eaten. Improvements in diet assessment methods will provide more accurate information about eating behaviours of adolescents.

The mpFR relies on a symphony of processes, both automatic and manual, that together will provide an accurate account of daily energy and nutrient intakes. The iterative cycle of capturing images, confirming or entering food descriptions and confirming or estimating portions is illustrated in Fig. 1. The primary method of acquiring a record of intake using the mpFR is akin to a traditional food record with fully automated processes (e.g. image analysis to identify foods and estimate volume). The user captures an image of his/her food and beverage before and after completing the eating occasion. The image is sent to the server where the image analysis software automatically identifies the foods and beverages on the basis of colour, texture and other visual characteristics[4]. Once a food is identified, geometric equations corresponding

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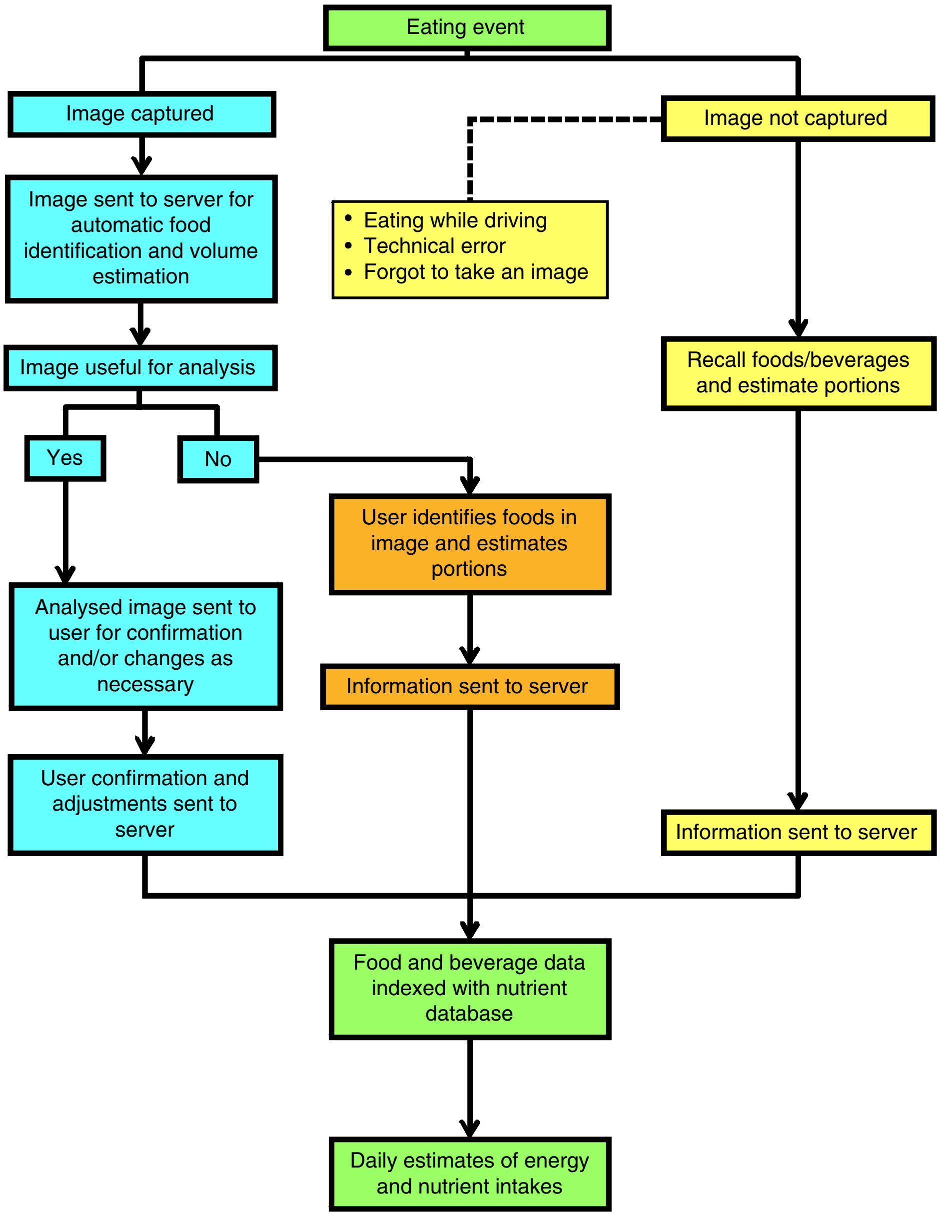

Fig. 1 Iterative process for automated and self-entered dietary data collection on the mobile telephone food record (□, common steps; □, image analysis method; □, alternative method; □, image-assisted record method)

to the shape of the food are used for automated computation of volume. After this process, the server returns an image of the labelled foods and beverages. The user can confirm the labels on each food/beverage or correct the labels when mistakes have been made in the automatic process. After confirmation, the information (i.e. food descriptions) is again sent to the server where the foods/beverages in the image are indexed with the US Department of Agriculture Food and Nutrient Database for Dietary Studies[6].

There may be times, however, when an individual takes a poor image in low lighting or when movement blurs the image. Such images cannot be used for automated image analysis. When an image is taken, but not useful for analysis, the user can type the names of the foods and beverages present in the image and estimate portions consumed. This process is referred to as an image-assisted record.

Technical error (e.g. dead battery, software malfunction) could prevent an image from being taken or an individual may be unable to take an image (e.g. driving a car). Adolescent-reported perceptions of mpFR use indicate that there will be times when a user may forget to take an image of an eating occasion[6]. Given a scenario when an image is not available, there must be an alternative method for self-reporting estimated portions of foods and beverages consumed. Pre-arranged reminders will aid in prompt entry when food images are not captured. Similar

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to the automated data, the self-entered data can be indexed with a nutrient database.

In this iterative cycle, participants will confirm and identify foods in an image, as well as recall and identify foods eaten when an image is not available. Portion size estimation is needed when an image is not useful for analysis and when no image is available; however, portion size estimation aids are limited by the small screen on mobile devices. Therefore, we have two hypotheses related to food identification and one regarding portion size estimation. First, adolescents can correctly identify foods at the time of consumption. Second, adolescents can correctly identify foods in an image of their meal up to 14 h postprandial. Our third hypothesis is that adolescents can estimate portions of foods eaten within ±10 % of the actual amount consumed when provided with a variety of portion size estimation aids suitable for a small screen.

Experimental methods

Recruitment and study design

Data were collected from two samples of adolescents. Sample 1 included adolescents recruited from summer camps on the campus of Purdue University. Sample 2 was a convenience sample drawn from the local community (*n* 15). Recruitment was limited to those individuals between 11 and 18 years of age as described previously[6]. Boys and girls from sample 1 participated in one lunch (*n* 63) and fifty-five of the sixty-three (87 %) returned for breakfast the next morning. Sample 2 volunteers received all meals (08.30, 12.30 and 18.00 hours) and snacks for a 24 h period. Between meals and snacks, activities such as scavenger hunts, bowling and miniature golf were scheduled to provide a camp-like experience.

At the time of the meal, sample 1 participants were asked to write down on a worksheet the names of the foods served to establish that adolescents can confirm food names, if needed (see Fig. 1, image analysis method). For sample 2, lunch and dinner food identifications were delayed up to 14 h to establish confirmation as in sample 1, but at a later and more convenient time. At 22.30 hours, the adolescents in sample 2 were asked to identify lunch foods and beverages (10 h postprandial) and estimate portion sizes of breakfast foods and daytime snacks. The estimation of portion sizes was to inform the development of the alternative method (see Fig. 1, alternative method). The food identification activity was repeated again at 08.30 hours the following morning at which time dinner foods consumed the previous evening were identified (14·5 h postprandial). The adolescents were not told to expect these activities. The study methods were approved by the Purdue University Institutional Review Board, and informed consent and assent were obtained from the volunteers and their parents, respectively.

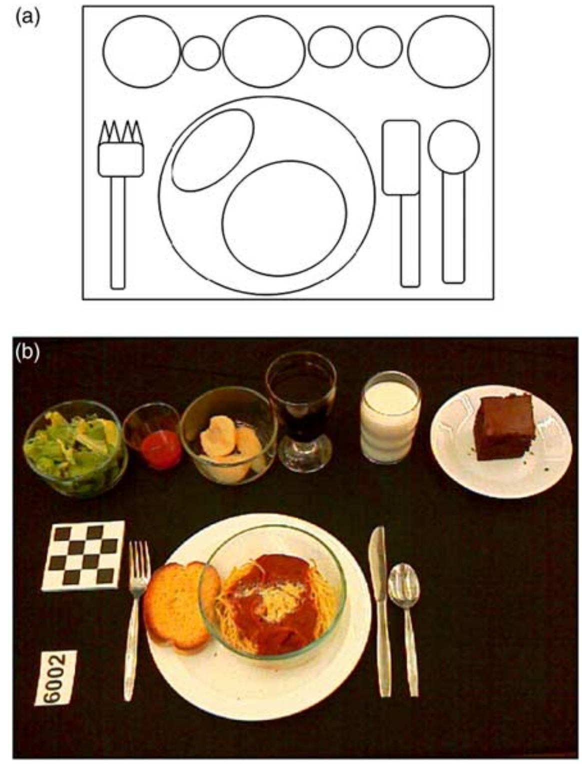

Fig. 2 Meal identification form (a) and image of dinner meal (b)

Food identification

Sample 1 participants were asked to identify the foods in the lunch and breakfast meals at the time of consumption. A worksheet representing the meal was provided and food names were written on the worksheet by each adolescent (see Fig. 2(a)). Thirty-seven different food items as listed in Table 1 were served to the participants in sample 1. The participants in sample 2 were asked to identify the foods from their lunch and dinner meals. A total of thirteen different food items as listed in Table 2 were served at lunch and dinner. In all, 10–14 h after their meals, participants in sample 2 were provided with an image of their meal along with the worksheet for food identification (Fig. 2(b)). This activity was designed to simulate typing labels for foods on the mpFR. For both samples 1 and 2, the adolescents were instructed to spell the words to the best of their ability and to use words they would usually use to describe the foods.

Portion size estimation

After 14 h of the breakfast meal, sample 2 participants were prompted with the names of the foods they were served at breakfast and as daytime snacks. They were asked to estimate the amount of each food consumed.

Two methods of portion size estimation were used. A worksheet modified from the 'What's In The Foods You Eat' Search Tool, 3·0 (http://www.ars.usda.gov/Services/docs.htm?docid=17032) included multiple measurement descriptors pertinent to each specific food and is referred

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Table 1 Adolescents' ability to identify and spell foods at the time of consumption

Meal	Number of participants	Correct identification		Misspelling		Phonetic misspelling	
		n	%	*n*	%	*n*	%†
Breakfast A	5						
Milk (2 %)		5	100	0	0	–	–
Peanut butter		5	100	0	0	–	–
Bagel		5	100	0	0	–	–
Apple juice		5	100	0	0	–	–
Cream cheese		2	40	0	0	–	–
Strawberry jam		5	100	0	0	–	–
Breakfast B	27						
Milk (2 %)		27	100	0	0	–	–
Yoghurt		26	96	9	33	6	67
Mini muffins		26	96	6	22	3	50
Granola bar		26	96	9	33	5	56
Orange juice		27	100	3	11	–	–
Breakfast C	12						
Milk (2 %)‡		24	100	0	0	–	–
Honey nut Cheerios®		12	100	3	25	3	100
Banana		12	100	2	17	2	100
Apple juice		12	100	1	8	1	100
Breakfast D	11						
Milk (2 %)		11	100	0	0	–	–
Sausage links		11	100	0	0	–	–
Scrambled eggs		11	100	0	0	–	–
White toast		11	100	0	0	–	–
Orange juice		11	100	1	9	1	100
Margarine		11	100	1	9	1	100
Jam		11	100	0	0	–	–
Lunch A	28						
Milk (2 %)		28	100	0	0	0	0
Grilled cheese sandwich		28	100	6	21	4	67
Chocolate chip cookie		26	93	4	14	3	75
Cheese puffs		27§	96	7	25	6	86
Apples		28	100	0	0	0	0
Celery		28	100	10	36	8	80
French dressing		22	79	7	25	6	86
Coke®		26	93	3	11	2	67
Lunch B	15						
Milk (2 %)		15	100	0	0	0	0
Peanut butter and jelly sandwich		15	100	1	7	0	0
Fruit cocktail		15	100	0	0	0	0
Potato chips		15	100	2	13	1	50
Carrot sticks		15	100	0	0	0	0
French dressing		13	87	0	0	0	0
Gummy bears		15	100	3	20	2	67
Coke®		15	100	1	7	1	100
Lunch C	11						
Milk (2 %)		11	100	0	0	0	0
Pudding		11	100	1	9	1	9
Hot dog on a bun		11	100	2	18	0	0
Orange, sliced		11	100	1	0	1	9
French fries		11	100	0	0	0	0
Catsup		11	100	0	0	0	0
Pickle relish		11	100	0	0	0	0
Mustard		11	100	0	0	0	0
Coke®		11	100	0	0	0	0
Lunch D	9						
Milk (2 %)		9	100	0	0	0	0
Sugar cookie		9	100	0	0	0	0
Peaches		9	100	0	0	0	0
Cheeseburger on a bun		9	100	1	11	0	0
French fries		9	100	0	0	0	0
Catsup		9	100	2	22	2	100
Coke®		9	100	0	0	0	0

†Phonetic/total misspelt × 100.
‡Milk served as beverage and as addition to cereal.
§One participant did not label food item.

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Table 2 Adolescents' ability to identify and spell foods up to 14 h postprandial (*n* 15)

Meal	Correct identification		Misspelling		Phonetic misspelling	
	n	%	*n*	%	*n*	%†
Lunch						
Milk (2 %)	15	100	1	7	1	100
Sugar cookie	15	100	2	13	2	100
Peaches	15	100	2	13	2	100
Cheeseburger on a bun	15	100	5	33	5	100
French fries	15	100	1	7	1	100
Catsup	15	100	5	33	5	100
Coke®	15	100	1	7	1	100
Dinner						
Milk (2 %)	15	100	0	0	–	–
Garlic toast	15	100	0	0	–	–
Spaghetti	15	100	9	60	9	100
Chocolate cake	10‡	67	4	27	3	75
Pears, canned	10	67	1	7	1	100
Salad greens	15	100	1	7	1	100
French dressing	14	93	2	13	1	50
Coke®	15	100	0	0	–	–

†Phonetic/total misspelt × 100.
‡One participant did not identify the food item.

to as the multiple descriptors (MDes) estimation aid. Examples for portion size descriptors of scrambled eggs were one egg (size not specified), one cup and one egg extra large. The second was a two-dimensional (2D) food portion visual (2D estimation aid) with 2D images of standard-sized plates and bowls with cubes depicting one-quarter, half, one and two cups (Block Dietary Data Systems, Berkeley, CA USA; http://www.nutritionquest.com). Participants were randomly divided into two groups. The first group (*n* 8) used the 2D estimation aid for breakfast foods and the MDes estimation aid for daytime snacks. The second group (*n* 7) used the MDes estimation aid for breakfast foods and the 2D estimation aid for snacks.

Data analysis

For an identified food to be considered an exact food match, the words used by the adolescent must have matched or meant the same thing as the food served (e.g. fruit cocktail was served and fruit salad was written on the worksheet). Second, the identified food was examined for being within the same major food group[7]. The words written by adolescents were evaluated as follows: Are their food identifications misspelt? Was the misspelling phonetic? Was a colloquial (or common) term used to identify the food?

For portion evaluation, the estimated intake of each food was converted into grams and compared with the actual weighed food intake in grams (estimated−actual). Paired *t* tests were used to examine the mean difference between the estimated intake and the weighed intakes.

Descriptive analysis included frequencies and percentages. All analyses were conducted using the Statistical Package for the Social Sciences statistical software package version 17·0 (SPSS Inc., Chicago, IL, USA).

Results

Food identification results

For sample 1, the results of the adolescents' abilities to identify and spell foods at the time of consumption are summarized in Table 1. Thirty of the thirty-eight food items were identified correctly by all the participants to whom they were served. Of the eight foods that were misidentified at least once, the names given by adolescents were within the same major food group. For example, one participant identified peaches as pears and Coke® was identified as root beer twice.

Twenty-two food items served to adolescents in sample 1 were misspelt at least once for a total of eighty-six misspelt food items. Fifty-nine of the eighty-six (69 %) misspellings were categorized as phonetic errors. Colloquial terms (e.g. soda, pop, PB&J, burger) were used at least once to describe thirteen of the foods served to sample 1 participants.

Sample 2 participants identified foods in an image of their meal 10–14·5 h postprandial. These results are summarized in Table 2. Eleven of the thirteen food items were identified correctly 100 % of the time. Foods that were misidentified at least once included: chocolate cake, which was identified as brownie by four adolescents; pears, which were identified as peaches three times and as applesauce one time; and French dressing, which was identified as Italian dressing once. Common terms were used to identify three of the foods served. Every food item was misspelt at least once and only one of the misspelt words was not a phonetic misspelling.

Portion size estimation results

Table 3 describes the results of the adolescents' abilities to estimate portion sizes of breakfast foods and daytime snacks.

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Table 3 Adolescents' ability to estimate portion size of breakfast foods and daytime snacks

Portion size estimation aid	Number of participants	Estimated (g)		Consumed (g)		Mean difference		Number of estimates within ±10 % of true intake
		Mean	SD	Mean	SD	Estimated (g)	Consumed (kJ)	
2D								
Scrambled eggs	8	93·6	55·4	64·7	26·1	+29·0	188	0
Sausage links	8	43·1	16·0	52·8	17·5	−9·5	−130	0
Margarine	7	33·9	20·3	5·6	4·5	+28·3*	636*	0
Jam	8	46·8	23·4	9·8	5·5	+37·0*	402*	0
Toast	7	43·5	21·4	46·0	25·4	−2·5	−29	1
Gummy bears	3	54·1	10·8	67·3	23·9	−13·2	−218	1
MDes								
Scrambled eggs	7	52·4	34·7	48·0	21·9	+4·3	29	4
Sausage links	7	66·3	92·5	46·2	0·6	+20·0	268	0
Margarine	7	12·0	12·4	8·8	7·7	+3·3	71	2
Jam	7	10·0	17·5	2·9	7·6	+7·1	79	6
Toast	7	69·5	35·8	41·3	17·0	+28·2*	347*	2
Brownie	3	34·0	0·0	42·9	8·3	−8·9	−142	1
Chocolate chip cookie	2	29·0	21·2	42·3	20·1	−13·3*	−272*	0
Gummy bears	3	108·6	64·2	40·2	0·5	+68·4	1134	1
Granola bar	1	18·0	–	30·3	–	−12·3†	−238†	0
Swiss roll	1	80·0	–	59·1	–	+20·9†	+83†	0
Ice cream sandwich	2	44·2	20·9	68·3	1·3	−24·0	−58	0
Sugar cookie	2	20·5	6·4	28·2	0·2	−7·6	−36	0

2D, two-dimensional; MDes, multiple descriptors.
*Significant difference between estimated and actual intake ($P < 0.05$).
†Paired *t* test cannot be computed as there is only one participant.

Using the 2D estimation aid, the mean estimates for toast, scrambled eggs, sausage links and gummy bears were not significantly different from the actual gram weight consumed. The other snacks consumed by those assigned to use the 2D estimation aid could not be converted to gram weights on the basis of the volume estimates and thus are not included in the analysis. Comparing the mean difference between estimates made using the MDes estimation aid and the actual weighed intakes of breakfast foods, no significant differences were found except for toast. The mean differences between the estimates and actual intake for gummy bears, ice cream sandwich and sugar cookie when the MDes estimation aid was used were not significantly different. Granola bar and Swiss roll were consumed by only one participant each; therefore, paired *t* tests could not be performed.

Considering all foods estimated by those using the 2D estimation aid, toast and gummy bears were each estimated within ±10 % of the true amount consumed once. For the MDes group, four participants estimated within ±10 % of the true amount consumed for scrambled eggs, two for margarine, six for jam, two for toast, one for brownie and one for gummy bears.

Discussion

The results of the present study indicate that adolescents can correctly identify foods at the time of consumption when foods are present and up to 14·5 h postprandial when prompted with an image of their meal. These results are in contrast to the results of studies that ask children and adolescents to recall foods consumed without a visual prompt[8–11]. Baxter *et al.*[10,12] validated children's self-report of dietary intake through the use of observed meals. One of the outcomes of these observational studies is the novel approach to compare the foods recalled with the actual foods consumed and identify omissions, intrusions and misidentified foods. In a study among fourth-grade students, longer intervals between consumption and recalled intake resulted in more intrusions[10], and in another study a shortened retention interval increased accuracy[11]. An image-assisted record could alleviate errors related to time sequencing, thus limiting omissions and intrusions. This suggests that individuals could be encouraged to take pictures of their foods and beverages throughout the day to assist with a 24 h dietary recall.

The results from the present study are congruent with other research indicating that portion size estimation is a challenge for adolescents. Using the MDes estimation aid, six foods (i.e. scrambled eggs, toast, jam, margarine, brownie and gummy bears) were estimated within ±10 % of the truth at least once. Only toast and gummy bears were estimated within ±10 % of the truth by the adolescents who used the 2D estimation aid. The range of estimates for the foods consumed further highlights the variability between participants that is sometimes overlooked. Even with the use of creative portion size estimation aids, such as modelling clay, photographs and tableware, children's estimates were considered a source of error in quantifying food and energy intake[13–15]. Many innovative estimation aids can be used on full-size computer screens. However, the use of an integrated estimation aid on the mpFR is limited by the small screen size.

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These results support that a single type of portion size estimation aid will not work well with all foods. Careful consideration should be given when choosing estimation aids to be displayed. An estimation aid used out of context of its original design could erroneously be perceived as a poor tool. For example, the smallest portion displayed on the 2D estimation is one-quarter of a cup; therefore this tool would not work well with foods usually eaten in amounts less than one-quarter of a cup, such as jam. The 2D estimation aid was likely most useful for gummy bears because the amorphous pile of gummy bears could be related to the amorphous piles of small cubes depicted in the 2D estimation aid. However, for other foods such as a brownie it may be easier for a participant to relate the shape to a portion descriptor (i.e. '1 brownie (2″ square)') as used in the MDes estimation aid. Our results indicate that a variety of portion size estimation aids that are tailored for the use of specific foods would result in better estimates of intake among adolescents. Technology, such as the mobile telephone, may allow for tailored estimation aids to be presented to the user.

The overall high proportion of foods correctly identified by the participants in the present study may be an artefact of serving foods familiar to adolescents[6]. Although the foods served were selected because they were familiar to 162 adolescents (aged 10–18 years) who participated in two 24 h recalls[16,17], information was not collected as to these foods being familiar to individual participants in the present study. There could be variation in identification of foods served at home, school or restaurants. Alternatively, identification may be influenced by how a food is served. For example, French dressing was served to sample 1 participants for use as a dipping sauce for celery or carrots and was identified correctly by 81 % of those to whom it was served (thirty-five out of forty-three). For sample 2, French dressing was served as salad dressing and only one participant out of fifteen misidentified French dressing. The possibility exists that participants in sample 2 were more likely to correctly identify French dressing because it was served in a familiar manner (i.e. salad dressing), whereas French dressing as a vegetable dip may not have been a familiar serving. Future studies should consider collecting information regarding how familiarity of foods served affects adolescents' abilities to identify food items.

Probing programmed into the mpFR is needed to obtain a more detailed account of foods eaten. A hamburger is a good example of a combination food that can contain a variety of condiments that contribute to changes in nutrient and energy intakes. The adolescents were served a hamburger on a bun with cheese, ketchup, lettuce and tomato; however, five of the twenty-four participants identified this food simply as 'hamburger' or 'burger'. For these participants, probing would potentially verify the other ingredients that may or may not accompany a hamburger, such as cheese, ketchup, tomato and lettuce, thus gathering important energy and nutrient intake data. Probing will also help to define foods when common terms such as soda, pop or cola are used. With more detail, a better match in the nutrient database can be made by the mpFR software leading to a more accurate estimate of energy and nutrient intakes. Probing would not correct misidentified food items. In the present study, chocolate cake was identified as brownie four times. Although probing would not necessarily lead an adolescent to correct the misidentified food to chocolate cake with frosting, the energy and nutrient content of the brownie with frosting is similar to the cake.

Researchers and programmers should be aware when designing food search tools for consumers, especially for adolescents, that the tool needs to accommodate misspellings, phonetics, abbreviations and common terms or synonyms. Words used by adolescents to describe foods inform the development of a search mechanism for the mpFR.

Many automated processes that will reduce error-related burdens make the mpFR unique when compared with other diet assessment methods integrating technology. The results of the present study not only inform the development of the mpFR but also provide strong evidence for the use of digital images of eating occasions in the clinical setting. A 24 h account of foods and beverages in the form of images has the potential to improve the accuracy of adolescents' 24 h dietary recalls. For the first time, there is documented evidence that adolescents can look at an image of their meal and identify the foods in the image up to 14·5 h postprandial. Most notable would likely be the decline in under-reporting due to food exclusion. The immediate benefits of image-assisted dietary assessment in research and clinical practice should not be overlooked.

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