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Computerized portion size estimation compared to multiple 24-hour dietary recalls for measurement of fat, fruit, and vegetable intake in overweight adults

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Abstract

Validated self-report methods of dietary assessment exist, and might be improved both in terms of accuracy and cost-efficiency with computer technology. The objectives of this preliminary study

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were to develop an initial version of an interactive CD-ROM program to estimate fruit, vegetable, and fat intake, and to compare it to multiple 24-hour dietary recalls (24HR; averaged over 3 days). In 2009, overweight male and female adults ($N = 205$) from Lane County, OR completed computerized and paper versions of fruit, vegetable, and fat screening instruments, and multiple 24HR. Summary scores from the ten-item NCI Fruit and Vegetable Scan (FVS) and the 18-item Block Fat Screener (BFS) were compared to multiple 24HR-derived fruit/vegetable and fat intake estimates (criterion measures). Measurement models were used to derive deattenuated correlations with multiple 24HR of paper and CD-ROM administrations of FVS fruit intake, FVS vegetable intake, FVS fruit and vegetable intake, and BFS fat intake. The computerized assessment and paper surveys were related to multiple 24HR-derived fruit/vegetable and fat intake. Deattenuated correlation coefficients ranged from 0.50 to 0.73 (all $P \leq 0.0001$). The CD-ROM-derived estimate of fruit intake was more closely associated with the 24HR ($r=0.73$) than the paper-derived estimate ($r=0.54$; $P<.05$), but the other comparisons did not differ significantly. Findings from this preliminary study with overweight adults indicate the need for further enhancements to the CD-ROM assessment and more extensive validation studies.

Keywords

food portion estimation; fruit and vegetable intake; fat intake; overweight adults

Validated self-report methods of dietary assessment might be improved in terms of accuracy and cost-efficiency with computer technology (1,2). Accurate dietary measurement is necessary for developing and testing dietary interventions to reduce obesity and to address other diet-related medical concerns. Traditional dietary assessment techniques are subject to portion-size and other inaccuracies (3–6), and studies using biomarkers indicate that self-report instruments generally result in under-reporting of energy intake (7–14).

Given the known inaccuracies in serving-size estimation (15), various methods have been used to verify serving sizes, including weighed food records (16), special plates and bowls (17–19), direct or covert observation (20,21), matching foods to models (22), two- or three-dimensional realistic or abstract aids (23–27), portion-size photographs (28,29), food models plus photos (4), and portion-size photographs compared to self-served foods (30). Nelson, Atkinson, and Darbshire (2) showed that using multiple photographs was more accurate than a single, average-portion photograph. However, Beasley, Davis, and Riley (31) found that a Web-based dietary history questionnaire using food photographs had comparable reliability and validity as the paper version, but did not improve the relationship of the diet history questionnaire to other food intake measures (eg, 24HR, food records).

A few serving-size estimation trials have employed computer technology (30,32–34). A Web-based serving-size estimation program by Riley et al (35) shifted under- to overestimation. An interactive serving-size assessment by Foster et al (36) produced estimates closer to the actual weight of the food compared to food models and photographs. A key advantage of computerized dietary assessment is that users may adjust the size of on-screen servings to match intake (2,37–39). Other potential benefits are multilingual and low-literacy capacity (40), increased engagement (41), and accessibility for ethnically diverse subgroups (42–46). Existing validations of standard dietary assessment methods indicate that <50% of the variability in the true criterion method is accounted for by standard test methods, including doubly labeled water (47,48). Reporting accuracy depends on estimating portion sizes of food consumed, as well as bias, forgetting, and other sources of inaccuracies. Therefore, opportunities exist for potentially improving the accuracy of brief screeners and other frequency methods with the use of interactive visual information. Since

rates of overweight and obesity among adults are especially troublesome, there is a need for accurate dietary estimation and effective dietary interventions in this population.

The purpose of the present study was to develop a preliminary version of an interactive computer program (CD-ROM) to estimate fruit, vegetable, and fat intake, and then correlate these estimates with multiple 24-hour dietary recalls (24HR; averaged over 3 days) in a sample of overweight adults. The CD-ROM-based program was built on previous methods developed and/or tested by Block and colleagues (49), Thompson and colleagues (50,51), and Peterson and colleagues (52). The primary research question was: Can a computer program be designed to provide estimates of fruit/vegetable and fat intake that are more highly correlated with the multiple 24HR estimates than paper versions?

METHODS

Sample

A total of 207 overweight or obese adults was recruited and enrolled in the study from June, 2007 through November, 2009. Participants were paid \$50. The Oregon Research Institute Institutional Review Board approved the study protocol and all participants provided written informed consent. Power analyses indicated that with 200 individuals the study had sufficient power to detect medium to small effects ($R^2=0.05$).

Interactive CD-ROM Program

Two widely used dietary screeners were adapted for the CD-ROM program: the National Cancer Institute's (NCI) revised Fruit and Vegetable Scan (FVS) (51–55) and the Block fat screener (BFS) (49). The FVS assesses frequency of eating nine food categories, includes four portion size options, and estimates daily servings of fruits and vegetables using the 1998 United States Dietary Assessment Food Guide Pyramid defined servings (56). The original BFS (49,55,57) consisted of foods from the Second National Health and Nutrition Examination Survey that primarily contribute to fat intake. Fried chicken, pizza, and ice cream were added because of their high fat content and popularity (58). A fourth portion size option was added to the BFS to parallel the FVS. Respondents reported food intake over the past 2 months.

The computer program featured life-size color photographs for each portion size of each food on the BFS and FVS. Photographs were taken at an angled perspective similar to that experienced by a person seated at the table. Foods were cooked and styled as they are most commonly prepared and served. Each food serving was shown on the same dining plate, with silverware, napkin, and placemat as size referents (18). Most foods were photographed in multiple forms (eg, mashed or baked potatoes). For each food, users first chose the form in which they wanted to view the food. Then, presented with a full-size on-screen image of the food, users could use a slider bar to view four different portion sizes before selecting their own serving. To reduce response bias, options were not labeled “small,” “medium,” “large,” and “super-size”; they were shown as four points, with measurement information below (eg, ½ cup, 1 cup, 2 cups, more than 2 cups).

Study Procedures

Participants completed an informed consent form and demographic and other psychosocial measures, and received materials for their first three telephone-administered 24HR. Two weeks later, they returned for a second visit, at which they completed the CD-ROM program and paper versions of the FVS and BFS (with order randomly assigned). Three more 24HR were conducted in the 14 days after this visit, and then participants returned for a third visit to repeat the CD-ROM and paper surveys (data not presented).

Measures

Demographic data and participant characteristics—Variables included height and weight (using a stadiometer and calibrated digital scale), education, employment status, income, marital status, race/ethnicity (categories defined by the investigator), health status, smoking status, living arrangement, whether the participant was currently on a diet to lose weight, where most meals were eaten, who did most of the cooking, who served the food, and how often the participant ate second helpings. The baseline survey included an 18-item version of the impression management scale of the Balanced Inventory of Desirability Responding (59) and two scales from the short Test of Functional Health Literacy in Adults (S-TOFLA) (60).

Dietary intake—Up to three 24HR recalls, including one weekend day, were obtained by telephone per participant. The interviews were conducted by registered dietitians at the Diet Assessment Research Unit of the University of South Carolina who were trained in the use of Nutrition Data System for Research (NDSR) software versions V2007 and V2008, developed by the Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN. Final calculations were completed using NDSR version V2008. Participants were given a validated two-dimensional visual aid to help them estimate the amounts of foods they had eaten (24). NDSR software generates summary information about food intake that may be compared with BFS and FVS summary variables.

Statistical Analyses

Scores were calculated for multiple-item instruments using procedures previously established for each instrument. From the FVS, constructs were created to estimate total daily servings of fruits, vegetables, and fruits and vegetables combined (51). From the BFS, an estimate of daily grams of fat intake was computed (49). From the multiple 24HR averaged over 3 days, variables were created to reflect daily servings of fruits, vegetables, fruits and vegetables combined, and total fat grams, using the food group serving count system integrated into NDSR. The FVS variables were positively skewed and were square-root transformed for a more normal distribution.

Differences between the screener values and multiple 24HR (averaged over 3 days) values were calculated for each variable. The mean of multiple 24HR was calculated to estimate average intake for all outcome variables, as well as used to calculate the difference with screener estimates of intake. To estimate deattenuated correlations, a measurement error model (61) was specified, in which the multiple 24HR was the reference instrument for the CD-ROM program and paper surveys. The model assumes that the multiple 24HR is unbiased and contains only within-person error. Measurement error models were run separately for CD-ROM vs multiple 24HR and for paper vs multiple 24HR for fruit intake, vegetable intake, fruit and vegetable intake, and fat intake. Additional separate models were fit containing either age, sex, or order of administration as a covariate (these factors had minimal impact and are not discussed further). $P \leq 0.05$ was used for the measurement models to reject the null hypothesis.

All statistical analyses were conducted using SPSS for Unix (release 6.1, SPSS Inc., 217 Chicago, IL) and Statistical Analysis Software (version 9.2, 2009, SAS Institute Inc., Cary, NC).

RESULTS

Participant characteristics

Of people reached by telephone, 70% were deemed eligible, 97% agreed to participate, and 85% completed all three assessments. Of those not completing the study, most missed appointments and were thereafter unreachable ($n=28$). Baseline participant characteristics are presented in Table 1. The recruited sample averaged 59 years of age. Most were female, were self-identified as white, had less than a \$50,000 income, and were not employed. Average body mass index was 32.2 kg/m², and most participants had few comorbidities. Average health literacy and numeracy were moderate to high, and socially desirable responding scores were low.

Comparison of screener scores relative to multiple 24HR

The paper and computerized FVS versions produced similar estimates of fruit intake (mean=1.84 servings for paper vs 1.87 for CD-ROM; difference nonsignificant); see Table 2. The two FVS versions yielded significant, but small (0.3 servings per day) differences in estimates of vegetable intake (mean=3.68 for paper vs 3.97 for CD-ROM, paired $t(194)=2.35$, $P=.02$) and of fruit and vegetable intake combined (5.52 for paper vs 5.83 for CD-ROM, paired $t(194)=2.27$, $P=.02$). Fat intake estimates from the two BFS versions did not differ significantly. Computerized and paper screeners yielded higher estimates of fruit, vegetable, and fruit and vegetable servings, and lower estimates of fat intake, compared to the multiple 24HR variables.

As shown in Table 3, deattenuated correlations between the multiple 24HR and paper and CD-ROM versions of the screeners were similar. To test for significance between CD-ROM and paper deattenuated correlations, r values were converted to Z scores, and the difference in Z scores was then divided by the pooled standard error. Using this method, the CD-ROM fruit intake estimate had a significantly stronger association with the multiple 24HR estimate than the paper fruit intake estimate ($r=0.73$ for CD-ROM vs 0.54 for paper; $P<.05$); other comparisons between CD-ROM and paper versions, however, were not significantly different.

DISCUSSION AND APPLICATIONS TO GENERAL PRACTICE

Discussion

Accurate portrayal of dietary intake requires both frequency and portion size; frequency is the more important of the two (54,62–65), but portion size estimation makes an important contribution (3–6). The computerized screeners developed in this preliminary investigation and tested in a sample of older, overweight adults focused on enhanced portion-size estimation, and produced correlations with multiple 24HR in line with previously published studies (49–52,54).

Fruit and vegetable intake

The original performance evaluation of the paper version of the FVS (51), with 462 adults aged 20–70, reported correlations with the multiple 24HR of 0.66 for men and 0.51 for women, compared to 0.54 (CD-ROM) and 0.53 (paper) in the present study. Peterson and colleagues (52) ($N=315$) reported an overall correlation of 0.40 between the FVS and 24HR. Thompson et al (61) found that estimates of daily fruit and vegetable intake were within 1.2 servings per day of the 24HR estimates, while in the present study estimates were within on average 2.7–3.0 servings per day of the 24HR estimates. It is possible that lower estimates of fat intake might be because fewer questions are asked on the brief screener than the 24HR.

For estimated usual fruit and vegetable or fat intake, a complete FFQ or 24HR is recommended. According to Thompson and colleagues (51), the FVS and the much-longer FFQ performed similarly in terms of relative risk estimates, suggesting that the FVS might suffice in situations requiring brevity.

Fat intake—The computerized and paper assessments were about equally correlated with the multiple 24HR in measuring fat intake. Correlations were 0.55 (CD-ROM) and 0.50 (paper) with multiple 24HR fat intake, similar to the 0.58 correlation reported in Block et al (49) and higher than the 0.45 correlation reported in a previous worksite study (66). Both screener versions estimated less total fat, although the CD-ROM estimate was closer to the 24HR. Social desirability was not significantly related to the BFS. The discrepancy between both BFS versions compared to the multiple 24HR may be related to the concept of “good” vs “bad” foods (67). It is possible that users felt freer to report their intake of “bad” (ie, higher-fat) foods to a machine. Less complex BFS foods like eggs and hot dogs had higher agreement between the two screeners than more amorphous foods such as potato chips. The lower estimates of fat intake might be because fewer fat intake questions are asked on the brief screener than the multiple 24HR, and high correlations between the two modalities may not to be expected.

Limitations—The multiple 24HR is not devoid of error. The screeners measure a typical diet over 2 months and the multiple 24HR measures particular days. If large dietary changes occurred during the assessment period, agreement would be lowered. A limitation of the multiple 24HR (analyzed with the NDSR software) as a criterion for portion estimation is that it does not readily provide individual food serving size information for the *identical* foods on the screeners. Thus, comparisons with the multiple 24HR may not ensure “validity” of the computerized or paper screeners. Future studies might use methods that focus on the assessment of actual portion size consumed, such as observational feeding (30). The present sample was composed of mostly female overweight adults, many of whom were dieting to lose weight. The preponderance of females was expected, given the focus on diet and given the larger proportion of females in the general older adult population in the area (60.8% female over 65 years of age; 2000 U.S. Census).

Applications to General Practice

The study indicated that interactive computerized dietary screeners offer similar estimates to paper assessment and significantly correlate with multiple 24HR estimates for measuring fruit/vegetable and fat intake in overweight adults. Our findings suggest that the computerized version of the FVS and BFS is feasible for use in qualitative clinical or quantitative research situations where it is not possible to administer longer dietary assessments.

FUTURE RESEARCH

This study is one of very few focused specifically on increasing portion size estimation accuracy. Results are encouraging. The next step in this line of research is to identify and test more innovative ways to increase accuracy of portion estimation. Also, more formal validation is needed. Future research should vigorously test a revised version with other populations and with the use of “in vivo” observational portion-serving methods in addition to multiple 24HR, and incorporate a wider range of food serving sizes.

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Table 1

Baseline characteristics of the recruited sample

Variable	Mean or %	S.D.
Age (years)	59.2	8.2
Female (%)	70.8	
Body mass index (kg/m ²)	32.18	6.59
<u>Household income (annual)</u>		
<\$20,000 (%)	17.2	
\$20,000–\$49,999 (%)	44.9	
\$50,000+ (%)	37.9	
<u>Race</u>		
White (%)	88.1	
All other (%)	11.9	
Current smoker (%)	7.9	
Comorbidities (range=0–10)	0.79	1.34
Health literacy (range=1–5; lower=greater literacy)	1.46	0.56
Numeracy (range=1–6; higher=greater numeracy)	4.25	0.98
Self-rated knowledge of portion recommendations (range=1–5; higher=more knowledge)	3.56	1.07
Currently dieting (%)	20.4	
Eat most meals at restaurants (%)	6.9	
<u>Cooking behaviors</u>		
Self cooks most meals (%)	63.0	
Other cooks most meals (%)	9.0	
Self and other cooks most meals (%)	28.0	
<u>Serving behaviors</u>		
Self serves most meals (%)	80.0	
Other serves most meals (%)	4.0	
Self and other serves most meals (%)	16.0	
<u>Frequency of second helpings</u>		
Rarely (%)	40.5	
Sometimes (%)	47.0	
Often (%)	12.5	
Socially desirable responding (BIDR Impression Management) (range=0–17; higher=more socially desirable responding)	7.75	3.37

Table 2

Mean (S.D.) values for daily fruit, vegetable, and fat intake derived from multiple 24-hour food recalls, paper screener surveys, and computerized screeners

	24HR		Paper Survey		Computer Assessment	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Servings per day of						
Fruit	1.40	1.19	1.84	1.45	1.87	1.76
Vegetables	1.43	1.16	3.68	2.72	3.97	3.08
Fruits/Vegetables	2.83	1.73	5.52	3.61	5.83	4.01
Total fat (grams)	73.71	30.87	40.52	50.48	42.73	45.46

Table 3

Deattenuated correlations with multiple 24HR of paper and CD-ROM administrations of FVS fruit intake, FVS vegetable intake, FVS fruit and vegetable intake, and BFS fat intake^a

	<i>n</i>	<i>r</i>	<i>S.E.</i>
<u>FVS: fruit intake</u>			
CD-ROM	190	0.73 *	0.06
Paper	190	0.54 *	0.08
<u>FVS: vegetable intake</u>			
CD-ROM	190	0.51 *	0.10
Paper	190	0.57 *	0.10
<u>FVS: fruit and vegetable intake</u>			
CD-ROM	190	0.54 *	0.08
Paper	190	0.53 *	0.08
<u>BFS: fat intake</u>			
CD-ROM	189	0.55 *	0.09
Paper	188	0.50 *	0.06

^aDeattenuated correlations were estimated with a ME model (see text). The FVS variables were square-root transformed for analysis. There were no outliers in the FVS data, and three outliers were identified and removed in the BRS data prior to analysis (two from the paper survey data and from the CD-ROM program data). Models were run separately for paper vs. multiple 24HR and CD-ROM vs. multiple 24HR. Additional separate models were then fit containing either age, sex, or order of administration as a covariate; these factors had very little impact on the correlations and therefore the results are not reported here.

* $P < .05$.