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The USDA Automated Multiple-Pass Method Accurately Estimates Group Total Energy and Nutrient Intake[1,2]

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Abstract

The imperative to address the national obesity epidemic has stimulated efforts to develop accurate dietary assessment methods suitable for large-scale applications. This study evaluated the performance of the USDA Automated Multiple-Pass Method (AMPM), the computerized dietary recall designed for the National Health and Nutrition Examination Survey dietary survey, and 2 epidemiological methods [the Block food-frequency questionnaire (Block) and National Cancer Institute's Diet History Questionnaire (DHQ)] using doubly labeled water (DLW) total energy expenditure (TEE) and 14-d estimated food record (FR) absolute nutrient intake as criterion measures. Twenty highly motivated, normal-weight-stable, premenopausal women participated in a free-living study that included 2 unannounced AMPM recalls and completion of the Block and DHQ. AMPM and FR total energy intake (TEI) did not differ significantly from DLW TEE [AMPM: 8982 ± 2625 kJ; FR: 8416 ± 2217; DLW: 8905 ± 1881 (mean ± SD)]. Conversely, the questionnaires underestimated TEI by ~28% (Block: 6365 ± 2193; DHQ: 6215 ± 1976; $P < 0.0001$ vs. DLW). Pearson correlation coefficients for DLW TEE with each dietary method TEI showed a stronger linear relation for AMPM ($r = 0.53$; $P = 0.02$) and FR ($r = 0.41$; $P = 0.07$) than for the Block ($r = 0.25$; $P = 0.29$) and DHQ ($r = 0.15$; $P = 0.53$). Most mean absolute FR nutrient intakes were closely approximated by the AMPM but were significantly underestimated by the questionnaires. In highly motivated premenopausal women, the AMPM provides valid measures of group total energy and nutrient intake whereas the Block and DHQ yield underestimations. J. Nutr. 136: 2594–2599, 2006.

Introduction

Dietary assessment methodology has seen important advancement in the context of increasingly sophisticated computer technology. Initially employed to simplify nutrient calculations, computers have become a powerful means for collecting dietary data when using weighed food record systems (1,2), estimated food records (FR)[7] (3), 24-h recalls (4), and diet history questionnaires (5,6). Whether self-administered or conducted by trained personnel, computer-assisted dietary assessment hastens data processing, improves standardization of procedures, and allows flexibility in accommodating modifications (7). A recent advance in this area is the USDA Automated Multiple-Pass Method (AMPM) (8), a 5-step computerized dietary recall instrument used in the "What We Eat in America" survey, the dietary intake interview component of the U.S. National Health and Nutrition Examination Survey (NHANES) (9). The AMPM is built upon earlier paper and pencil multiple pass recall methods (10–13) but includes several substantial methodological changes that warrant validation of the new method. Advancements include a new portion estimation food model booklet designed for large-scale population studies (14), important new food probe questions with automatic response routing, and specialized training for interviewers and coders. The need also exists to understand the performance of the AMPM in contrast to other assessment methods designed for large-scale studies. Thus, our study compared the performance of the AMPM and 2 other commonly used methods designed for population studies, the Block food-frequency questionnaire (Block) (15), and the National Cancer Institute's Diet History Questionnaire (DHQ) (6), in 2 functions: *1*) validity of total energy intake (TEI) against the reference recovery biomarker of total energy expenditure (TEE), namely doubly labeled water (DLW);

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[2] Supplemental Tables 1–4 are available with the online posting of this paper at jn.nutrition.org.

[7] Abbreviations used: AMPM, Automated Multiple-Pass Method of dietary recall; BDI-II, Beck Depression Inventory II; Block, Block food-frequency questionnaire; DHQ, National Cancer Institute's Diet History Questionnaire; DLW, doubly labeled water; EI, energy intake; FR, estimated food records; NHANES, National Health and Nutrition Examination Survey; PA, physical activity; SDS, Marlowe-Crowne Social Desirability Scale; TBW, total body water; TEE, total energy expenditure; TEI, total energy intake.

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and 2) relative validity of total nutrient intake compared with the 14-d FR. Our hypothesis proposed that AMPM energy and nutrient estimations would not differ significantly from the criterion measures. An important design feature of this study is the selection of highly motivated subjects to decrease subject-induced methodological error. Thereby, this study sought to provide insight into the inherent error for each of the dietary assessment methods evaluated.

Materials and Methods

Participants, recruitment, and IRB approval

This study was part of a larger investigation of the validity of dietary and physical activity (PA) assessment methodology. Women were recruited from the University of California, Davis campus and the surrounding cities in Yolo County by means of advertisements. Women only, rather than both sexes, were selected to avoid the confounding effect of gender on diet self-report (16–18). Those contacting the recruitment center participated in telephone screening. Study eligibility criteria were: *1*) BMI 18.5–25.5 kg/m^2; *2*) age 25–40 y; *3*) current use of hormonal contraceptive [to minimize the effect of menstrual cycle phase on energy intake (EI) and energy expenditure (19,20)]; *4*) premenopausal; *5*) not pregnant or lactating; *6*) body weight-stable for ≥6 mo; *7*) not engaged in body weight-loss or weight-gain program; *8*) no acute or chronic health problems; *9*) no clinical depression or chronic anxiety; *10*) no cigarettes or drugs of abuse use; *11*) no use of medications with known effects on EI or metabolic rate; and *12*) lifestyle within the range of sedentary to moderately active.

From 838 telephone screenings, 106 women completed a health screening, which included measurements of height, wt, blood pressure, pulse, and temperature, a fasting blood draw, a spot urine collection, and completion of 6 written questionnaires related to health history, PA [Baecke Physical Activity Questionnaire (21)], psychological state [Beck Depression Inventory II (BDI-II) (22)], State-Trait Anxiety Inventory (23)], and eating behavior [Eating Attitudes Test (24), Eating Disorder Inventory-2 (25)]. Hematology measures were determined with fresh blood collected in EDTA tubes using a Cell Dyn 3200 Hematology System (Abbott Diagnostics). We conducted comprehensive metabolic, lipid, and iron panels, thyroid function, human immunodeficiency virus, and hepatitis B blood tests, and urine was screened for drugs of abuse by a clinical laboratory (University of California, Davis, Medical Center, Sacramento, CA).

Fifty-three women who met health-screening requirements were enrolled in a trial study designed to assess compliance and motivation in performing study activities. The trial study included an introductory laboratory appointment, 4 d of free-living activities, and a follow-up laboratory appointment. The free-living activities comprised measuring and self-recording fasting body wt each morning, collecting a second urine void sample each morning, keeping written food intake and computerized PA records for 4 consecutive d, and completing 3 questionnaires [the Block, DHQ, and Eating Inventory (26)]. Women who successfully performed all trial activities and indicated continuing interest were considered motivated and asked to enroll. The trial study preceded the research study by a mean of 7 wk. Twenty-two women participated in the research study; however, the DLW data from 2 women were incomplete and excluded from analyses; thus, the final number of research subjects was 20. Reasons for disqualification at the end of the trial study are listed in Supplemental Table 1. The Institutional Review Board of the Office of Human Research Protection at the University of California, Davis, approved the study protocol and subjects gave written informed consent. Subjects were paid $300 US for completing the study.

Experimental design

This study was conducted at the USDA Western Human Nutrition Research Center on the campus of the University of California, Davis. Women were enrolled singly or as pairs in the study, which encompassed 21 d, including 8 laboratory appointments and 14 consecutive d of free-living activities. Subjects were dosed with DLW on experimental d 0 and spot urine samples were collected on d 1–15 for determination of TEE. Fasting body wt was measured on d 1, 5, 8, and 15. AMPM dietary recalls were administered on d 0 and 19. Subjects kept FRs on d 1–14 and completed food-frequency questionnaires at the conclusion of the study. Women were instructed to follow their usual eating and activity patterns during the study.

Anthropometry and total body water

Fasting (12-h fast) body wt was measured to the nearest 0.01 kg using a calibrated electronic scale (Circuits and Systems, Model SX-501). Women wore surgical scrubs without shoes and voided before the wt measurement. Height was measured to the nearest 0.0001 m (0.01 cm) using a wall-mounted stadiometer (Ayrton Corporation, Model S100).

On the day prior to DLW dosing, total body water (TBW) was measured 2 h postprandial using bioelectric impedance spectroscopy (Hydra ECF/ICF Model 4200, Xitron Technologies) with the subject supine and her arms and legs abducted from the midline of the body. Electrodes were attached to the dorsal surface of the left hand and wrist, and left foot and ankle, and frequencies ranging from 5 kHz to 1 MHz were applied. The accuracy of the instrument was verified daily using the manufacturer-supplied Verification Module TS4201. Internal laboratory calibration of the instrument demonstrated a reliability of 0.08% CV for TBW. TBW was used to calculate the DLW dosage.

DLW TEE (reference method for EI)

The DLW technique (27) was used as the reference in estimating TEE over the 14-d free-living period. Subjects were not informed that DLW TEE was to be used in validating self-reported dietary intake. On the morning of d 0, subjects arrived to the laboratory after a 12-h fast and provided baseline urine and saliva samples. Saliva was collected using the Salivette with cotton swab (Sarstedt). Subjects were orally dosed with 0.12 g 99.9% ^2H_2O/kg TBW [PerkinElmer Life and Analytical Sciences (formerly New England Nuclear)] and 2.5 g 10% $H_2^{18}O$/kg TBW (Icon). The dose container was rinsed twice with ~20 mL of bottled drinking water (Arrowhead, Nestle Waters of North America) and the subject ingested both rinses. Postdose saliva samples were collected in the laboratory at h 2, 2.5, and 3 of d 0; a postdose urine sample was collected at h 3. On each of experimental d 1–15, subjects collected spot samples of their second void of the morning; collections on d 1, 5, 8, 12, and 15 occurred in the laboratory, whereas those on the remaining days occurred in the subjects' homes and were transported frozen in thermal cases to the laboratory. Subjects or staff recorded the times of collection at home or the laboratory, respectively. Saliva and urine samples were transferred to aliquot tubes and frozen at –20°C until analyses. Enrichment of ^2H and ^{18}O in saliva and urine samples was measured by isotope ratio mass spectrometry (Europa). The spectrometer was calibrated prior to analysis of each subject's samples. For analysis of deuterium, a platinum catalyst was added to a 1-mL sample in a glass tube and the air was evacuated. Samples equilibrated for 72 h prior to analysis. For analysis of oxygen, a 1-mL sample was placed in a tube and air was evacuated and replaced with 5% CO_2 and 95% N_2 gas. These samples equilibrated for 24 h prior to analysis. Standards for both isotopes were prepared and calibrated to standard mean ocean water. All samples were analyzed in triplicate. To minimize the effect of analytic variability, samples for 1 subject were analyzed at the same time using the same standard curve. Reference standards and controls were included in each batch for each subject. The CV for the ^2H and ^{18}O analyses were 0.20% and 0.05%, respectively. TEE was calculated for experimental d 1–14 from the ^2H and ^{18}O decay kinetics derived from regression analysis using multiple points (28). This method assumes a respiratory quotient of 0.85 (29) and a dilution space ratio of 1.034 (28).

Dietary assessment

Two AMPM dietary recalls, 14 consecutive d of estimated FR, and 1 administration each of the Block and DHQ were used to assess dietary intake. The study was conducted over 20 mo and encompassed all seasons. Micronutrient intake from nutritional supplements was not included in analyses.

Dietary recall. USDA's AMPM was used to collect 2 nonconsecutive 24-h dietary recalls (study d 0 and 19). These days were selected to

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capture data from 1 weekday and 1 weekend day, as well as to not overlap with FR recording days. Two registered dietitians, trained by USDA Food Surveys Research Group staff (Beltsville, MD) in the use of this automated program, conducted the unannounced dietary recalls. The subjects were shown the USDA Food Model Booklet (14) and measuring cups and spoons before proceeding with the computerized, step-by-step interview. The dietary recall steps include: *1*) the quick list, when the subject first quickly recalls foods and beverages consumed during the previous 24 h; *2*) the forgotten-foods list, when the interviewer prompts the subject for foods possibly forgotten during the quick list using a standardized list of 9 food categories; *3*) the time-and-occasion step, in which the time-of-day foods were eaten and the name of each eating occasion are collected; *4*) the detail cycle, during which detailed descriptions of foods, portion sizes consumed, and additions to the foods are collected, eating occasions reviews are conducted, and omitted food probes are administered for foods eaten between occasions; and *5*) the final probe that asks for anything else consumed, even small amounts, during the day. The Food Model Booklet, a companion to the AMPM and designed to help subjects estimate portion sizes, contains life-size drawings of drinking glasses, mugs, and bowls; drawings of pats and mounds for estimating foods that mound when served; circles; a grid; thickness blocks for height/thickness; and a small and large wedge for triangular foods such as pie and pizza. Nutrient values for the 2 recalls were averaged for each subject prior to data analyses.

14-d FRs (reference method for nutrient intake). Subjects kept written FR on consecutive d 1–14. The same 2 dietitians who conducted the dietary recalls also trained the subjects to estimate and record all food and beverages consumed. Subjects were instructed to make entries in the FR throughout the day and to review their entries at the end of each day. Subjects estimated portions using household measuring tools, restaurant menus, and package labels; food scales were not provided to the subjects. On laboratory visit d 5, 8, 12, and 15, a dietitian reviewed the FRs and resolved questions with the subject. Nutrient values for the 14-d FR were averaged for each subject prior to data analyses.

Coding and analysis of dietary recalls and FRs. The USDA software Survey Net (30) was used to process the AMPM dietary recalls and FR. Data from the USDA Food and Nutrient Database for Dietary Studies [FNDDS, 1.0 (2004)] (31) were used to convert portion sizes to grams and to determine the nutrient content of each food consumed. The FNDDS is complete for all nutrients reported. Three USDA Food Surveys Research Group personnel processed both the AMPM and FR data.

Food-frequency and diet history questionnaires. Habitual food intake was assessed with 2 self-administered, booklet-form questionnaires, the Block (version 98.2; NutritionQuest) (15,32) and the National Cancer Institute's DHQ-1 (1998) (6). (At the time this study was initiated, the computer-assisted DHQ was not yet available; thus our use of the booklet form. Also, calcium fortification updates to the Block had not been made). Subjects were randomized to complete the Block on either laboratory visit d 15 or 19; the DHQ was assigned on the alternate day. Questionnaires were self-administered but reviewed by a dietitian for completeness upon submission. Both questionnaires were scanned by NutritionQuest to generate ASCII-format files. NutritionQuest performed data analyses on the Block, using a nutrient database developed from NHANES III and Continuing Food Survey of Food Intake by Individuals data and the USDA Database for Standard Reference, Release 12. The DHQ data were analyzed using Diet*Calc software (Diet*Calc Analysis Program, version 1.4.2, National Cancer Institute, Applied Research Program) (6). The DHQ database of food lists and portion sizes is based on Continuing Food Survey of Food Intake by Individuals data, and estimates of nutrient intake are calculated using the method described in Subar et al. (33). The DHQ and Block nutrient databases are complete for all nutrients reported.

Behavioral questionnaires

Tendency to report socially desirable information was assessed using the Marlowe-Crowne Social Desirability Scale (SDS) (34). This self-administered questionnaire is composed of 33 statements concerning personal attitudes and traits that require true or false responses. The maximum score indicates actions and attitudes supported by society; higher scores are associated with a propensity to respond in culturally approved ways under testing conditions. Symptoms of depression, particularly those related to appetite and body wt, were assessed using the 21-item BDI-II (22). Cut-score guidelines (35) interpret score ranges of 0–13, 14–19, 20–28, and 29–63 as indicative of minimal, mild, moderate, and severe depression, respectively. The Eating Inventory (26) was used to measure 3 dimensions of eating: cognitive restraint of eating, disinhibition, and hunger. Normative guidelines for interpreting scores (36) assign the following classifications: a cognitive restraint-of-eating score of 0–10 = low to average restraint, 11–13 = high restraint, and ≥14 = restraint in the clinical treatment range; a disinhibition score of 0–8 = average disinhibition, 9–11 = high disinhibition, and ≥12 = disinhibition in the clinical treatment range; and a hunger score of 0–7 = average range, 8–10 = high range, and ≥11 = clinical treatment range. Behavioral questionnaire scores were included as variables in analyses of self-reported food intake. All behavioral questionnaires were self-administered but were reviewed by a research staff member for completeness upon submission.

Statistical analyses

Statistical analyses were performed using PC-SAS (version 9.1; SAS Institute). DLW was the reference method for TEI, whereas 14-d FR served as the reference method for macro- and micronutrient comparisons. Energy and nutrient data distributions were evaluated and variables displaying heterogeneous variance were transformed using the Box-Cox approach (37) prior to tests for statistical significance. A randomized complete block model without subsampling was used with dietary method as the fixed effect and subject as the random effect. Assumptions held that the errors were independently and identically distributed with mean = 0 and variance = σ^2. Comparisons among methods in estimating energy and nutrient intake were evaluated using Mixed Models Analyses followed by Tukey's adjustment to multiple comparisons tests. Mean bias, limits of agreement, and distribution of bias over the range of energy values for each dietary method were assessed using the method of Bland and Altman (38). Pearson correlation coefficients were calculated to evaluate the relation between criterion and comparative measures of energy and nutrient intake. Back-transformed nutrient intakes are reported as medians with interquartile ranges. EI are reported as means with SD. *P*-values were 2-sided at $\alpha < 0.05$.

Results

Subject characteristics. Most of the women were Caucasian graduate students displaying minimal tendencies toward restrained eating, disinhibition, hunger, and depressive symptoms (**Table 1**). Mean body wt did not differ significantly between d 1 and 15 (d 1 = 60.9 ± 7.5; d 15 = 60.5 ± 7.4 kg). Wt change between d 1 and d 15 ranged from −1.0 to 2.2 kg with a median of 0.94 kg. Propensity to self-report in accordance with social expectations, as assessed by the Marlowe-Crowne SDS, was similar to that seen elsewhere in normal-weight women (39).

Validity of TEI assessment. Mean TEI measured by the AMPM and FR approximated DLW TEE within 4% and was not significantly different from DLW (AMPM = 103.2 ± 31.6%; FR = 101.5 ± 31.0%; P > 0.10) (**Table 2**). In contrast, the Block and DHQ significantly underestimated DLW by ~27% (Block = 73.7 ± 27.2%; DHQ = 72.4 ± 26.6%, $P < 0.001$ vs. 100% DLW). The AMPM demonstrated a mean bias close to 0, with an equal distribution of individual values above and below 0 (**Fig 1***A*, **Table 2**). FR was biased toward underestimating TEI; this difference appeared more pronounced at the higher kilojoule values (Fig 1*B*), yet the significance of the correlation was only marginally significant ($P = 0.07$). Both the Block and DHQ performed similarly, showing large negative mean biases that were not associated with TEI level (Fig 1*C*,*D*). Pearson correlation coefficients for DLW TEE with each dietary method

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TABLE 1 Subject characteristics[1]

Age, *y*	30.0 ± 3.9
Anthropometrics	
Height, *m*	1.66 ± 0.1
Weight, *kg*	60.8 ± 7.5
BMI, *kg/m²*	22.1 ± 1.9
Ethnicity, *%*	
Caucasian	65
Hispanic	15
Asian	10
Other	10
Education, *%*	
College student	25
College graduate	30
Graduate student	45
Behavioral questionnaire scores	
Marlowe-Crowne SDS	17.4 ± 4.4
BDI-II	1.8 ± 3.2
Eating Inventory	
Cognitive restraint of eating	4.8 ± 4.0
Disinhibition	4.0 ± 2.2
Hunger	3.5 ± 1.9

[1] Values are means ± SD or %; $n = 20$.

TEI showed a stronger linear relation for AMPM (r = 0.53; $P = 0.02$) and FR (r = 0.41; $P = 0.07$) compared with that for the Block (r = 0.25; $P = 0.29$) and DHQ (r = 0.15; $P = 0.53$). Social desirability trait and symptoms of cognitive restraint of eating, disinhibition, hunger, and depression were not significantly ($P > 0.10$) associated with accuracy of self-reported TEI (percent DLW) for any of the methods.

Comparative validity of macronutrient and micronutrient intake assessment. Mean absolute nutrient measures between the AMPM and FR did not differ significantly (Supplemental Table 2). Consistent with the findings for TEI, intakes of many macro- and micronutrients were significantly higher for the AMPM and FR than the Block and DHQ. Exceptions were measures of polyunsaturated fat, linoleic acid, α-tocopherol, vitamin B-6, vitamin C, cholesterol, lycopene, and lutein, which did not differ significantly among methods. Controlling for energy density (expressing nutrients/4186 kJ) abolished many of the differences seen in the unadjusted intakes and revealed others (Supplemental Table 3). There were no significant differences in mean adjusted nutrient measures between the AMPM and FR. Only for α- and β-carotene did adjusted intakes differ significantly between both questionnaires and the AMPM and FR, with the questionnaires estimating higher levels of these dietary constituents/4186 kJ than either the AMPM or FR. Pearson correlation coefficients between the 14-d FR (reference measure) and the AMPM, Block, and DHQ were significant for absolute measures of 4, 7, and 15 of the 29 calculated nutrients/food components, respectively (Supplemental Table 4). In particular, the DHQ exhibited strong agreement with the reference method for β-carotene, vitamin C, calcium, phosphorus, zinc, and potassium, and the Block for β-carotene and iron. For energy-adjusted intakes, correlations with FR measures were significant for 15, 15, and 12 nutrients/food components for the AMPM, Block, and DHQ, respectively.

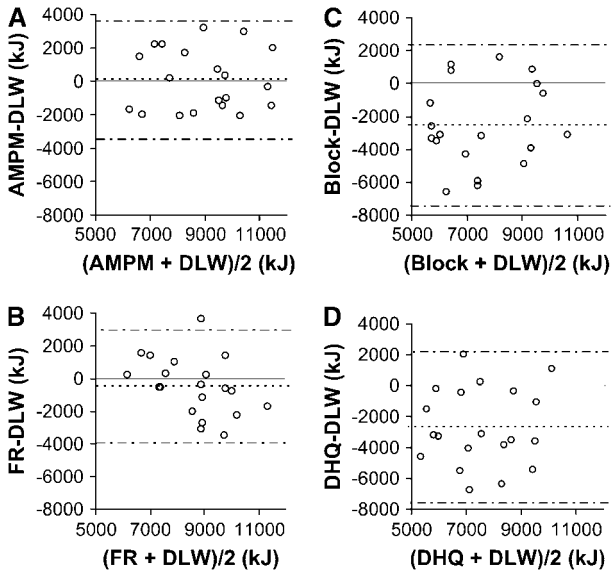

Figure 1 Agreement of energy measurements of women by dietary method and criterion method (DLW). AMPM (*A*); FR (*B*); Block (*C*); DHQ (*D*). Dotted line represents mean bias of the specified dietary method; solid line represents zero bias; dot and broken line represents ± 2 SD from the mean (limits of agreement).

TABLE 2 Total energy intakes of premenopausal women assessed by different methods[1]

Method	EI	Bias[2]
	kJ	
DLW TEE[3] (reference)	8905 ± 1881	
AMPM[4]	8982 ± 2625	77 (−775 to 930)
14-d FR	8416 ± 2217	−489 (−1325 to 346)
Block[5]	6365 ± 2193**	−2540 (−3713 to −1367)
DHQ[6]	6215 ± 1976**	−2690 (−3868 to −1513)

[1] Values are means ± SD, $n = 20$. **Different from DLW, $P < 0.0001$.
[2] Bias = Dietary method − DLW (95% CI).
[3] DLW total energy expenditure.
[4] Block.
[5] National Cancer Institute's DHQ.

Discussion

An important finding of this study with highly motivated, free-living women was that the AMPM dietary recall accurately measured mean total energy and absolute nutrient intakes at the group level, whereas these dietary measures were significantly underestimated by the food-frequency questionnaires. The level of accuracy observed in this study represents a best-case scenario for all the dietary methods studied. Only subjects willing and able to comply optimally with our study's protocol were selected to minimize error caused by subjects. This provided an opportunity to assess inherent methodology error by removing much of the subject-induced error. Therefore, this study demonstrates the highest level of performance attainable for the dietary methods studied. This kind of information is essential to understanding the utility of dietary methods in assessing total energy and absolute nutrient intakes for groups and individuals.

AMPM's mean TEI approximated group DLW TEE within 4% and without bias, thereby supporting the method's inherent validity for assessing group EI in light of results from numerous DLW studies demonstrating the vulnerability of dietary assessment to subject misreporting (40). Also, the accuracy of the

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AMPM in approximating group DLW TEE in this study exceeded that reported for women completing a forerunner of the AMPM in the OPEN Study (11): 103.1% DLW TEE (AMPM in this study); 82% (OPEN 5-pass dietary recall). Methodological advancements in combination with population differences probably account for this accuracy improvement. In contrast, mean TEI by the Block and DHQ underestimated group DLW TEE by ~28%. This underestimation of TEI by the Block and DHQ compared with DLW TEE supports previous literature reports. Mean energy underreporting by the DHQ reached 38% in the OPEN Study and 42% in a recent study of postmenopausal women (41). In another study with men using the Block, EI was underreported by 22% (42). The difference in the degree of EI underestimation between this study and the other literature reports for these food-frequency questionnaires is likely a consequence of the populations studied.

Another important finding of this study was that mean absolute nutrient intake quantified by 2 nonconsecutive administrations of the AMPM dietary recall was statistically equivalent to that measured by 14-d FR (the reference method). Fourteen d of FRs were included in this study to represent an established, rigorous method of dietary self-report, and regular review of the FRs throughout the study was used to optimize accuracy. The appropriateness of using 14-d FR as the criterion nutrient intake assessment method in this study is supported by the ability of FR TEI to approximate DLW TEE without significant difference. Considering that the food codes, coding personnel, and nutrient database used in analyzing the AMPM and FR were identical, the main differences between these 2 methods were the duration and methodology of data collection. Attaining accuracy in less time and with less subject burden is a clear advantage of the AMPM over FR. Moreover, the strengths of computer technology (e.g., improved standardization of procedures) afford important benefits to users of the AMPM.

In contrast to the similarity between the AMPM and FR methods in measuring nutrient intake, the Block and DHQ methods significantly underestimated mean absolute nutrient intake relative to the 14-d FR reference method. This finding supports previous reports expressing concern about the use of food-frequency questionnaires as quantitative surveillance tools for measuring absolute nutrient intake in large-scale studies/national surveys (43,44). The observed underestimation in this study is probably a consequence of a combination of factors, including EI underreporting, the time period targeted for assessment (the Block and DHQ are designed to assess habitual intake, whereas FR and the AMPM evaluate recent food intake) and the databases used to translate foods to nutrients (the Block and DHQ nutrient databases differ from the FNDDS, used in analyzing the AMPM and FR). However, for energy-adjusted nutrient intakes, the Block and DHQ produced results equivalent to the AMPM and FR methods, suggesting that questionnaire underreporting in this study was proportional to total dietary intake, i.e., underreporting was associated with generalized underestimation of portion sizes or random omission of foods. Questionnaires can provide accurate energy-adjusted nutrient measures without the practical and cost limitations associated with 24-h recalls and FR. On the other hand, the literature generally shows that energy underreporting occurs with selective underreporting of specific types of food, such as those rich in fat and sugar, in certain populations (16,45,46). Therefore, energy density adjustment cannot be reliably applied to all subject groups.

When assessing dietary intakes, the goal for groups is to estimate accurately mean absolute intake levels as well as the proportion of the group with intakes below their requirements or above upper tolerance levels using established methods (47). For this purpose, it is important to select methods without substantial bias because the statistical methods for removing day-to-day variation do not remove the effects of bias. For most nutrients, negative bias will overestimate the prevalence of inadequacy in a population. Thus, the utility of the AMPM in assessing intake at the population or group level is supported by this study. On the other hand, the goal when assessing an individual is to estimate the probability that the specific person's intake is below his or her own requirement. None of the methods evaluated in this study appeared to perform satisfactorily in estimating energy or absolute nutrient intake at the individual level, as evidenced by the Bland-Altman plots and correlations. The low correlations between AMPM and the criterion method's absolute nutrient intakes are probably the result of the AMPM's inability to capture day-to-day variability in dietary intake and infrequently consumed foods. This latter limitation of the AMPM is evidenced in the significantly lower energy-adjusted measurements of α- and β-carotene by the AMPM vs. questionnaires. However, all methods performed well on an energy-adjusted basis.

The absence of an effect of behavioral characteristics on the accuracy of dietary self-report in this study probably reflects the small size and homogeneity of the subject population. Our study criteria excluded women with symptoms of depression and disordered eating, thus selecting subjects whose behavioral measures were within defined normal ranges. When subjects of diverse behavioral characteristics are studied, correlations between factors such as social desirability or body dissatisfaction and dietary self-reporting accuracy are seen (39,48,49).

In summary, the AMPM, a recently developed computer-assisted 24-h recall, performed as well as 14-d FR and superior to the Block and DHQ in quantifying group energy and absolute nutrient intake. This is the first study, to our knowledge, validating the AMPM against the DLW gold standard in free-living subjects. These results were demonstrated in a relatively small sample of highly motivated, normal-weight women and therefore represent an optimistic outcome; further research on larger, more diverse groups is needed. In evaluating new methodology, an important first step is to demonstrate good performance under best-case conditions. This study provides initial evidence supporting the inherent methodological accuracy of the AMPM, the method used for the dietary component of the U.S. NHANES survey.

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