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Validity and Feasibility of a Digital Diet Estimation Method for Use with Preschool Children: A Pilot Study

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Abstract

Objective—The goal of the study was to assess the validity and feasibility of a *digital* diet estimation method for use with preschool children in *Head Start*.

Methods—Preschool children and their caregivers participated in validation (n = 22) and feasibility (n = 24) pilot studies. Validity was determined in the metabolic research unit using actual gram weight measurements as the reference method. Feasibility of using the digital diet estimation method was determined in *Head Start* and in the home by assessing 3 separate lunch and dinner meals.

Results—The average correlation between estimated weights and actual weights was 0.96 ($P < .001$), and the average mean difference was 10.6 g. The digital diet estimates were 5% lower than the actual weights.

Conclusions and Implications—The digital diet estimation method may be a valid and feasible method for assessing food intake of preschool children.

Keywords

nutrition assessment; child; preschool; eating behavior; Head Start

INTRODUCTION

Accurate methods of dietary assessment in young children are needed to determine whether their diets are adequate for normal growth and development. Although the potential influence of diet on overweight and obesity is important for all children, it is especially so during the preschool period, when health habits are being established.¹ Low-income children are more likely to be obese than their higher income counterparts,² and preschool children in *Head Start* (HS), who come from low-income families, are vulnerable to obesity.^{3,4}

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Despite the importance of understanding the dietary assessment of preschool children, collecting accurate and reliable dietary intake information from this population has been challenging.⁵ Methods that have been used to estimate dietary intake of preschool children include direct observation with recorded intake,⁶ dietary recalls,⁷ food frequency questionnaires,⁶ and food weighing.⁶ There are significant limitations to each method. Over- or underestimation of energy associated with memory or portion size estimation inaccuracies are major limitations of dietary recalls and food questionnaires.⁵ Portion size estimation is a limitation of food diaries. In children 6 months to 4 years of age, food weighing has been shown to be the most accurate method of dietary assessment⁸; however, this method has a high participant (caretaker) response burden and may be impractical for preschool children with multiple caregivers in multiple care venues, as discussed below.⁹

Estimates of preschool children in childcare vary, but some reports show as many as 61% of children (12 million) under 6 years of age were enrolled in child care facilities.¹⁰ Approximately 47% of children whose mothers were employed full time were in full-time childcare;¹¹ thus, many children consume 1 or 2 daily meals plus snacks away from the direct influence of their families. One study showed that one third of the total energy intake of HS children came from meals served at the HS center.¹² Thus, some of the responsibility for feeding young children has shifted from family members to child care providers. This change has directly affected the accuracy of dietary studies in preschool children, since although mothers of preschool children could report accurately intake of food their children consumed at home,^{5,13,14} they could not do so if the child was away from home more than 4.5 hours/day.⁷

Technology, including the digital diet estimation method and the use of hand-held devices such as personal digital assistants, has recently been shown to be a cost-effective method to accurately assess dietary intake of children, adolescents, and adults.^{15–22} Photographic methods use procedures similar to the direct visual estimation method, but instead of the observers hand recording food consumed, food selections and plate waste are recorded using a digital camera or personal digital assistants. Since these methods can be standardized, they offer a way to enhance the reliability and validity of recording dietary intake of preschool children with multiple caretakers in multiple feeding venues.¹⁵ However, this methodology has not been adequately assessed in these children.

To overcome the gaps of dietary assessment of preschool children and the unique barriers of this age group, valid, reliable, and age-appropriate measures are needed that are both practical and nonintrusive. The primary aim of this pilot study was to validate the use of a digital diet estimation method for assessing food intake of meals consumed by preschool children. A secondary aim was to test the feasibility of using this method in the HS center and home environments.

METHODS

Procedure

There were 2 phases to this pilot study. Phase I was to validate the digital diet estimation method (estimated weights) of food with actual gram weight measurements of the same food in a controlled laboratory setting, a metabolic research unit (MRU). Phase II was to test the feasibility of using the digital diet estimation method to assess food intake of meals consumed by preschool children in the HS center and home environments. The study protocols for phase I and phase II were reviewed and approved by the Institutional Review Board at the Baylor College of Medicine. Direct consent was obtained from adult participants, and parental permission was obtained for child participants.

A detailed description of the digital diet estimation method is provided in previous studies.^{16–18} The digital diet estimation method was standardized for taking pictures of food selections, plate waste, and reference portions in both phases of this study. Trained research staff took all of the photographs. The food was photographed using a digital camera (Sony Digital Handy Cam DCR-VX1000; Sony Corporation of America, New York, NY) mounted on a tripod with the lens 2 feet above and 2 feet away from the center of the meal plate with a camera angle of approximately 45°. A placemat with marked regions for placement of the meal plate was fixed to the table supporting the camera tripod to ensure optimal visibility of the meal in the digital photographs. Within each digital camera there were 4 corner brackets. If the meal plate was outside the brackets, the research staff immediately knew that they did not have the correct position for taking the photograph of the meal plate. All meal plates and cups were standardized across HS centers and in the homes.

On each day of data collection, additional servings of food were prepared so that reference photographs could be taken of the actual food that was served to the children. In the MRU and HS centers, the research staff collected additional food needed, and the digital photographs were taken on each day of data collection after the children finished the meal or snack. In the home, parents were provided with plastic containers into which to place the additional servings of food. Research staff collected the containers of food and brought them back to the MRU so that digital photographs could be taken. Each food item was placed on the plate in 10 g increments, and photographs were taken until approximately 200 g of food was reached. For beverages, the weight of the beverage served was the weight in the original serving vessel, and plate waste was the amount poured into a clear glass for measurement.

Trained estimators accessed the reference picture library that contained the field photographs of the meal plates. The estimators scrolled through the reference photographs and identified the portion in the reference photographs that was closest to the portion size of the food item in the meal plate.

The research staff probed for specific ingredients and preparation or cooking procedures from the food preparer on each day of data collection in the MRU, HS center, and home. Detailed information on all menu items, recipes, and preparation method were recorded. All menus and recipes on each day of data collection were entered into the Nutrition Data System-Research (version 4.06, Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN, 2006) and analyzed for nutrient content.

Digital scales (Ohaus Model Pro Scout SP601, Parsippany, NJ) were calibrated, and a standard plate was used. Each food item was placed on the plate and the weight was recorded. Once all food items were on the plate and a final weight was recorded, a digital photograph was taken of all food items on the plate. For plate waste, a photograph of the plate was taken. The food was then transferred to another plate, the scale was adjusted to zero, and the weight was recorded after each food item was placed on the plate. Research staff weighed the food and were blinded to the estimations. Actual weights of food items were determined in both the validation and feasibility studies.

Phase I: Validation Study

The validation study was conducted in the MRU to validate the digital diet estimation method (estimated weight) with actual weighing of food. Preschool children (n = 22) were served several food items as a lunch meal in a controlled laboratory setting in the MRU. Each meal was weighed before the child ate to obtain actual weights of each food item served at that meal. During each eating occasion, a photograph was taken of the food items that were served and then matched to weighed reference photographs to estimate the amount of food in the photographs.

Phase II: Feasibility Study

The feasibility study was conducted with HS children ($n = 12$) in the HS center during their lunch meal on 3 separate occasions and with another group of HS children ($n = 12$) in the home environment during their dinner meal on 3 separate occasions. All of the procedures used in the digital diet estimation protocol, described earlier, were followed to obtain data on children's average nutrient intake from a lunch or dinner meal.

Statistical Analyses

All statistical analyses were run using the Statistical Analysis Software package (version 9.1.3, SAS Institute, Inc, Cary, NC, 2006). Data were tested for normality using graphical and numerical methods. Means and standard deviations for gram amounts and nutrients served and consumed were determined. Pearson product moment correlations were performed between actual weights and estimated weights to assess the validity of the digital diet estimation method. A paired t test was used to test whether the results from the 2 estimation methods were significantly different. The Bland-Altman method was used to measure the agreement between digital-photography estimated weight and actual weight.²³ This method uses a 2-step process that evaluates the accuracy (validity) of a “new” measurement technique compared to an existing “gold standard,” which was the actual weights of food items. In the first step, a t test was used to determine whether the mean error associated with the new method differed significantly from 0 (error was calculated by subtracting the new method's value from the values of the weights). This step determined whether the new method was associated with significant error or “bias” (ie, under- or overestimation). Second, regression analysis was used to determine whether bias differed over levels of the variable being measured. This was an important step, since self-reported food intake (eg, food records) results in larger underestimates of food intake among people who are heavier and who have higher energy intakes.²⁴ This differential bias negatively affects the utility of the method. The statistical analysis α level was set at $< .05$.

RESULTS

Validation Study

Twenty-two preschool children (16 boys, 6 girls, 14 African Americans [AA], and 8 Hispanics [H]) participated in the validation study. The average correlation between estimated weights and actual weights was 0.96 ($P < .001$; data not shown). The comparison between the actual weight of typical HS lunch meals served and the estimated weight using the digital diet estimation method is presented in Table 1. There was no significant difference in the total gram amount of food served vs the estimated gram weight (Table 1). There was only a 10.6 g difference between the estimated and the actual gram amount of total food served, resulting in a 25 kcal difference (not significant) between the estimated and actual amounts.

The mean difference in energy intake for the lunch meals was 13.5 kcal lower for the digital diet estimates vs the weighed method under controlled laboratory conditions (data not shown). There was a significant difference in the estimated and actual amounts of carbohydrate served, but that was not the case for fat or protein. The 95% confidence limits showed that most children fell in the range of ± 30 kcal/lunch meal. On the basis of % kcal/meal, the estimation was about 5% lower in the digital diet estimates. In addition, there was no significant systematic or magnitude bias (Figure).

Feasibility Study

The total gram amount of food consumed and average nutrient intake of the lunch meal (on 3 separate occasions) served to 12 preschool children at HS is shown in Table 2. The

convenience sample of children consisted of 50% boys and 50% AA. The total amount of food consumed (and estimated by the digital diet estimation method) was 147.8 ± 56.8 g (43% from the entrée, 37% from the vegetable, 13% from the fruit, and 7% from the starch and condiments). There was 32% total food waste, of which 59% was vegetable waste. The average energy consumed from lunch was 342.8 ± 96.4 kcal. The average estimated lunchtime intakes for grams of fat, protein, and carbohydrate were 15.1 ± 5.6 g, 19.5 ± 6.1 g, and 32.4 ± 7.3 g, respectively.

The total gram amount of food consumed and the average nutrient intake of the dinner meal (on 3 separate occasions) served in the home to 12 preschoolers (50% boys, 50% AA) is shown in Table 3. The total amount of food consumed was 154.2 ± 39.0 g (63% from the entrée, 16% from the fruit, 11% from the vegetable, and 10% from the starch and condiments). The amount of food waste and the average energy and macronutrients consumed from the dinner home meal was similar to the lunchtime intakes.

DISCUSSION

The results of this pilot study suggest that the digital diet estimation method may be a valid and feasible method for measuring the food selections, plate waste, and food intake of meals consumed by preschool children in daycare and home settings. The digital diet estimated weights of food were highly correlated with the actual weights but were slightly lower than the correlation reported in 2 studies conducted in a cafeteria setting.^{17,18} A correlation of 0.96 is considerably higher than what has been reported for 24-hour dietary recalls and food frequency questionnaires.^{25,26} The correlation was lowest for the amount of condiments consumed ($r = 0.159$), which has previously been reported.¹⁷ This low correlation may reflect the small mass of most condiments, which makes accurate estimation difficult, particularly when the reference photographs are in 10 gram increments.

To minimize this limitation, the library of reference photographs could be expanded to include photographs in smaller gram increments. The average mean difference in actual weight vs digital diet estimations was only 10.6 g, which is similar to results from other studies.¹⁷ This small mean gram difference resulted in very small differences in the energy and macronutrient content between the 2 methods. Although the difference was significant for the amount of carbohydrate served between the 2 methods, this difference could reflect how the carbohydrate content of food is calculated in most nutrient databases.

For the database used in this study, total carbohydrate values were calculated per 100 g as the difference between 100 and the sum of the percentages of water, protein, fat, ash, and alcohol. The estimated weights using digital diet estimations were found to be comparable to the actual weight with no systematic or magnitude bias. When estimates were biased, there were small underestimations or overestimations by both methods.

A unique aspect of this pilot study was the feasibility of using the digital diet estimation method in both the HS center and the home to estimate the lunch and dinner meals, respectively. The total mean energy intake from the lunch and dinner meals of boys and girls 2–5 years of age in the National Health and Nutrition Examination Survey (NHANES) 2007–2008 was 801 kcal and 723 kcal, respectively.²⁷ The mean number of kcals from these 2 NHANES meals was considerably higher than what was determined using the digital diet estimation method in this study. Although the mean amount reported in NHANES is similar to the mean amount of energy in the food selected at the lunch and dinner meal in this study, the data suggest that the parental recalls in NHANES overreported intakes and may not have considered the amount of plate waste when determining the amount of food their child consumed.

IMPLICATIONS FOR RESEARCH AND PRACTICE

This pilot study is different than those previously published in several ways. The sample included preschool children, and their food consumption was determined in the HS and home environments. It included dinner and lunch meals on 3 separate occasions for each child. And finally, the average macronutrient and energy content of the lunch and dinner meal consumed was calculated, which demonstrates that the digital diet estimation method can provide reasonable estimates of the nutrient content of meals consumed by preschoolers. However, the method is limited in terms of the environment in which it can be used. It has been used only to assess lunch and dinner meals in a child care or home setting and does not translate to measuring the real-life 24-hour dietary intake of preschool children. This method can serve as a methodological foundation for incorporating more technological innovations,²⁰ such as cell phones using computer imaging algorithms,^{28,29} for reducing burden on the respondents and research staff and to measure food intake in near real-time in free-living conditions.^{16,18}

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Figure.

Bland-Altman analysis comparing the digital diet estimation method with weighted energy intake by analyzing the lunch meal data in the Metabolic Research Unit.

Table 1

Validation Study Conducted in the Metabolic Research Unit on Food Selection: Mean $\pm$ Standard Deviation (SD) for Energy, Macronutrients, Food Type and Gram Weights Using the Digital Diet Estimation Method and Actual Weights (n = 22)

A: Food Type and Amount in Grams			
Food Type	Estimated Weight, Mean $\pm$ SD	Actual Weight, Mean $\pm$ SD	Paired <i>t</i> test, <i>P</i>
Entrée (g)	72.8 $\pm$ 16.8	80.6 $\pm$ 19.6	.06
Starch (g)	43.8 $\pm$ 14.5	47.1 $\pm$ 16.5	.33
Vegetable (g)	51.2 $\pm$ 21.2	48.2 $\pm$ 17.3	.48
Fruit (g)	73.9 $\pm$ 14.4	76.4 $\pm$ 22.4	.54
Condiments (g)	3.1 $\pm$ 4.5	3.1 $\pm$ 4.4	.10
Overall Total Food^a	244.8 $\pm$ 28.9	255.4 $\pm$ 29.9	.11
Beverage (g)	229.3 $\pm$ 9.3	229.3 $\pm$ 0.1	.10
B: Mean $\pm$ SD for Macronutrient intake			
Macronutrients	Estimated Weight, Mean $\pm$ SD	Actual Weight, Mean $\pm$ SD	Paired <i>t</i> test, <i>P</i>
Energy (kcal)	431.1 $\pm$ 70.1	455.9 $\pm$ 68.4	.11
Fat (g)	19.4 $\pm$ 4.7	20.5 $\pm$ 4.7	.28
Protein (g)	20.8 $\pm$ 2.9	22.0 $\pm$ 2.4	.05
Carbohydrate (g)	44.5 $\pm$ 5.2	47.1 $\pm$ 4.7	.02

^aOverall: excluded beverage.

Table 2

Feasibility Study Conducted in *Head Start* (HS): Mean $\pm$ Standard Deviation (SD) for Amount of Food Selected, Plate Waste, and Food Intakes from the HS Lunch Meal by Food Type, Total Energy, and Macronutrients Using the Digital Diet Estimation Method (n = 12; children were tested on 3 separate occasions)

A: Food Type and Amount in Grams			
Food Type	Food Selected, Mean $\pm$ SD	Plate Waste, Mean $\pm$ SD	Food Intake, Mean $\pm$ SD
Entrée (g)	84.4 $\pm$ 18.6	21.3 $\pm$ 16.1	63.1 $\pm$ 29.2
Starch (g)	15.9 $\pm$ 9.1	7.6 $\pm$ 11.9	8.3 $\pm$ 7.5
Vegetable (g)	96.1 $\pm$ 41.8	40.9 $\pm$ 27.2	55.2 $\pm$ 41.1
Fruit (g)	19.8 $\pm$ 16.1	0.0 $\pm$ 0.0	19.8 $\pm$ 16.1
Condiments (g)	1.4 $\pm$ 4.1	0.0 $\pm$ 0.0	1.4 $\pm$ 4.1
Overall Total Food^a	217.6 $\pm$ 48.1	69.8 $\pm$ 39.4	147.8 $\pm$ 56.8
Beverage (g)	264.3 $\pm$ 36.8	44.4 $\pm$ 55.6	220.0 $\pm$ 62.7
B: Mean $\pm$ SD for Macronutrient Intake			
Lunch Meal	Food Selected, Mean $\pm$ SD	Plate Waste, Mean $\pm$ SD	Food Intake, Mean $\pm$ SD
Energy (kcal)	456.0 $\pm$ 81.2	113.2 $\pm$ 55.6	342.8 $\pm$ 96.4
Fat (g)	19.5 $\pm$ 4.5	4.4 $\pm$ 2.3	15.1 $\pm$ 5.6
Protein (g)	25.7 $\pm$ 5.5	6.3 $\pm$ 3.3	19.5 $\pm$ 6.1
Carbohydrate (g)	44.6 $\pm$ 8.0	12.2 $\pm$ 8.3	32.4 $\pm$ 7.3

^aOverall: excluded beverage.

Table 3

Feasibility Study Conducted in Children's Homes: Mean $\pm$ Standard Deviation (SD) for Amount of Food Selected, Plate Waste, and Food Intakes from the Home Dinner Meal by Food Type, Total Energy, and Macronutrients Using the Digital Diet Estimation Method (n = 12; children were tested on three separate occasions)

A: Food Type and Amount in Grams			
Food Type	Food Selected, Mean $\pm$ SD	Plate Waste, Mean $\pm$ SD	Food Intake, Mean $\pm$ SD
Entrée (g)	139.4 $\pm$ 46.0	41.9 $\pm$ 23.4	97.5 $\pm$ 50.2
Starch (g)	39.6 $\pm$ 32.1	25.4 $\pm$ 18.3	14.2 $\pm$ 23.0
Vegetable (g)	17.5 $\pm$ 37.3	0.4 $\pm$ 0.9	17.1 $\pm$ 36.8
Fruit (g)	34.2 $\pm$ 29.4	9.9 $\pm$ 13.7	24.3 $\pm$ 27.7
Condiments (g)	1.6 $\pm$ 1.9	0.6 $\pm$ 1.5	1.1 $\pm$ 1.2
Overall Total Food^a	232.2 $\pm$ 44.5	78.2 $\pm$ 23.0	154.2 $\pm$ 39.0
Beverage (g)	175.0 $\pm$ 68.4	50.0 $\pm$ 53.5	119.6 $\pm$ 50.4
B: Mean $\pm$ SD for Macronutrient Intake			
Dinner Meal	Food Selected, Mean $\pm$ SD	Plate Waste, Mean $\pm$ SD	Food Intake, Mean $\pm$ SD
Energy (kcal)	441.4 $\pm$ 123.5	153.6 $\pm$ 78.2	286.9 $\pm$ 86.5
Fat (g)	16.1 $\pm$ 6.4	6.1 $\pm$ 4.0	9.9 $\pm$ 4.8
Protein (g)	20.0 $\pm$ 7.9	7.2 $\pm$ 4.6	37.1 $\pm$ 9.6
Carbohydrate (g)	55.2 $\pm$ 13.7	17.9 $\pm$ 7.9	12.8 $\pm$ 5.7

^aOverall: excluded beverage.