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Validity and reliability of a simple, low cost measure to quantify children's dietary intake in afterschool settings

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Abstract

Interest in evaluating and improving children's diets in afterschool settings has grown, necessitating the development of feasible yet valid measures for capturing children's intake in such settings. This study's purpose was to test the criterion validity and cost of three unobtrusive visual estimation methods compared to a plate-weighing method: direct on-site observation using a 4-category rating scale and off-site rating of digital photographs taken on-site using 4- and 10-category scales. Participants were 111 children in grades 1–6 attending four afterschool programs in Boston, MA in December 2011. Researchers observed and photographed 174 total snack meals consumed across two days at each program. Visual estimates of consumption were compared to

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weighed estimates (the criterion measure) using intra-class correlations. All three methods were highly correlated with the criterion measure, ranging from 0.92–0.94 for total calories consumed, 0.86–0.94 for consumption of pre-packaged beverages, 0.90–0.93 for consumption of fruits/vegetables, and 0.92–0.96 for consumption of grains. For water, which was not pre-portioned, coefficients ranged from 0.47–0.52. The photographic methods also demonstrated excellent inter-rater reliability: 0.84–0.92 for the 4-point and 0.92–0.95 for the 10-point scale. The costs of the methods for estimating intake ranged from $0.62 per observation for the on-site direct visual method to $0.95 per observation for the criterion measure. This study demonstrates that feasible, inexpensive methods can validly and reliably measure children's dietary intake in afterschool settings. Improving precision in measures of children's dietary intake can reduce the likelihood of spurious or null findings in future studies.

Keywords

Validity; reliability; child; food intake; diet assessment

INTRODUCTION

Improving nutrition is key to health promotion, including maintaining a healthy weight.[1] Children in the U.S. consume much of their daily food intake in group settings such as schools, child care facilities, and afterschool programs.[2,3] Because these settings reach a large number of children, are often amenable to intervention, and can influence dietary behaviors,[4] they have been a major focus of public health action to improve children's diets.[5–7] Particular interest has grown in afterschool programs, which reach about 8.4 million children and often serve snacks.[8] Therefore, it is important to identify measures that can accurately assess children's dietary intake in such settings.

Many traditional methods of measuring dietary intake are inappropriate for these settings. Twenty-four hour recalls often utilize parent reports since children usually cannot accurately remember intake, but these can be inaccurate for estimating intake outside the home.[9] Food-frequency questionnaires (FFQs) are designed for measuring long-term intake,[10] not intake in a specific setting. Both methods are also associated with a high degree of misreporting before age 12,[9] with correlations between estimates of total energy intake from younger children's recall and criterion measures ranging from 0.23 to 0.59, and correlations between children's FFQ responses and food records even lower.[11] Although some recent evidence from two small studies suggests it may be possible to improve the quality of recalls and other dietary questionnaires in children,[12,13] these types of measures still may reduce precision in estimating intervention effects,[14] and most existing literature suggests that FFQs and recalls are associated with significant degrees of under- and over-reporting of energy intake in children.[15] The degree of error associated with these methods could introduce substantial bias or attenuation of results when attempting to study intake precisely in intervention settings. Direct observation of intake by weighing each food and beverage item before and after consumption and computing the difference is considered the gold standard for measuring intake in a specific setting. However, this method can be difficult to use in the

field, particularly with a large number of study participants during a short period of time (such as during a school meal); it can also be intrusive or disruptive.[16]

Alternative methods for directly observing children's dietary intake in group settings demonstrate tradeoffs among feasibility, validity, accuracy, and the number of study participants who can be observed. Ball, Benjamin, and Ward (2007) developed a reliable method for directly observing intake of morning snacks and lunches in child care programs by estimating preschoolers' consumption of foods to the nearest tablespoon, ounce, or number.[17] However, this method requires a large amount of training (56 hours of laboratory training and two days of field training) for a relatively small number of observations: only three children can be observed at a time. Gray et al (2002) found that recording foods *served* to children for lunch in a school cafeteria allowed the observation of a large number of children, but overestimated consumption.[18] Williamson et al. (2003) found that visual estimates made from examining digital photographs of consumption of cafeteria-provided meals in a laboratory setting were valid compared to weighed estimates, with Pearson's r ranging 0.60 to 0.94, but did not show validity in field settings.[19] Martin et al. (2009) used a similar digital photography method to capture the lunches of sixth grade students in a school cafeteria, but sent the photographs to trained registered dieticians to rate consumption,[20] thus requiring additional cost and resources.

Nonintrusive, inexpensive, practical and valid methods of assessing children's food intake during snacks in an afterschool setting, requiring minimal training, are needed. This study evaluates the validity of three unobtrusive, low-cost methods to measure children's snack intake in an afterschool setting: 1) a simple on-site observational method that compares the portions of foods and beverages a child leaves on his or her plate after finishing the snack to their original serving sizes and rates consumption using a 4-category scale of "none," "some," "most," or "all", 2) digital photographs of children's plates after finishing the snack compared to a photograph of an unconsumed snack rated off-site using the same 4-category scale, and 3) digital photographs rated off-site with a 10-category scale, for which raters estimated consumption in increments of 10%. The methods were developed to require little time and effort to use in the field. The methods were compared in their precision at estimating consumption of total energy (kcals) and consumption of servings of fruits/vegetables, grains, water, and other beverages. The number of staff hours and total cost of all of the observation methods, including the criterion method, were also estimated.

METHODS

Sample

Study participants in this convenience sample were 111 children grades 1–6 attending four afterschool programs in Boston, MA that provided snack every day through participation in the federal National School Lunch Afterschool Snacks program. The programs were located in schools and served between 45–52 students, and had participated in a previous research project with the study authors.[21] Children were recruited by approaching them and their parents at pick-up time at the end of the program and asking them to participate (57% participation). To meet federal program standards, the snacks were composed of some combination of fruits/vegetables, grain products, and milk.[22] Additionally, water was

available as a beverage in these programs. Except for water, which was self-portioned by children, snack components were delivered in standard, pre-portioned servings; serving sizes did not differ by age. Teams of four data collectors (eight total data collectors with varying team roles) observed the snack period at each program for two consecutive days in December 2011, recording 195 total instances of a child consuming a snack; then, four additional data collectors later reviewed photographs of these instances of snack consumption. Of these, there were a total of 174 snack observations where estimates of any snack component were not missing from any of the visual estimation methods, comprising the final sample (89% of the original). To detect a moderate correlation of r=0.40 with 80% power, it was estimated that a sample size of 46 would be needed for each of the meal components examined. This study was approved by the Harvard School of Public Health Committee on Human Subjects and the Boston Public Schools Research and Evaluation Department; participants' parents provided written consent and participants provided verbal consent.

Measures

Criterion Measure—Weighed estimates of consumption were used as the criterion measure. Weights were recorded using a digital scale (Aquatronic Electronic Kitchen Scale, Model 3003, Salter USA, Oak Brook, IL). Prior to the snack period, the first data collector on the team gathered ten samples of each food and beverage served and weighed each item to the nearest gram. An average weight was calculated for each item to be used as the baseline weight. After the snack period was finished and children went on to another activity, the leftover weight of each food/beverage item for each child was recorded to the nearest gram. Children's plates were marked with their study ID numbers to keep track of each observation. For water, the only snack component that was not pre-portioned, the data collector placed a scale next to the water cooler and weighed each child's water cup both pre- and post-consumption.

All visual estimation methods: preparation of baseline comparison snack plate—Before the snack period began, a second data collector photographed each food item from a height of 18 inches above the item to be served to create a visual record of baseline serving sizes. Full servings of beverages in opaque containers (milk and juice) were poured into a clear plastic cup and a "full" line was marked on the cup; the cup was then photographed at eye-level, 18 inches away from the cup. Full servings of foods in opaque containers (such as bagged chips) were emptied onto a paper plate.

On-site observation with 4-category scale—For the on-site observation method, a third data collector, who had been briefly trained by reading over the study protocol, independently recorded the number of servings of each food or beverage taken by each child. This data collector observed children (up to 35 at a time) throughout the snack period to note spilled or traded foods, and a fourth data collector ensured that children did not throw their plates away when finished. At the end of the snack period, after children had left the room, the third data collector examined the leftovers on each child's plate, comparing the leftovers to the original serving sizes on site, and estimated intake of each item served using the 4-category scale. Beverages in opaque cartons (e.g. milk) were poured into the clear

plastic cup with a marked “full” line to compare to the original serving size and foods in opaque containers were also emptied out to facilitate comparisons. Consumption was rated as “none” if none of the item had been eaten; “some” if the child ate less than half of the item; “most” if the child ate half or more of the item; and “all” if the child ate all of the item. These ratings were then quantified as 0% of a serving consumed (“none”), 33% consumed (“some”), 66% consumed (“most”), or 100% consumed (“all”). If a child took multiple servings of an item, the observer recorded how much was consumed of each serving and summed to calculate the child’s total consumption of that item.

Digital photography with 4 and 10 category rating scales—The second data collector, who had originally photographed the baseline serving sizes of each item, photographed each child’s leftover plate (with beverages and foods poured out of opaque containers as described above) after it had been rated by the on-site observer. Later, after the same brief training received by the onsite observer, four research assistants who had not been on-site compared photographs of the initial full serving sizes to the photographs of the plates of children’s leftovers to estimate the proportion consumed of each food and beverage on the plate. Two of the photographic observers used the same 4-category scale that was used on-site and two used the 10-category scale. The 4-category scale ratings were quantified as described above. The 10-category scale ratings were quantified in increments of 10%.

Nutrition information—Detailed nutrient and ingredient information was obtained directly from the records kept by the Boston Public Schools Food and Nutrition Services (which administered the snack program) or from manufacturers’ websites.

Estimation of costs—For each method, the costs per observation associated with raw materials and staff time required for training, making the estimations, and data entry for observing 400 children were calculated; this number was chosen assuming that intervention studies likely to use this measurement approach would use this approximate sample size.[23] Costs for raw materials were calculated using price estimates from amazon.com. The hours needed for each task were recorded, and staff costs were calculated assuming that staff members were paid $18 per hour.

Statistical Analysis

Criterion validity of the three estimation methods was assessed by calculating intra-class correlation coefficients that compared estimates of total kcals consumed and servings consumed of water, other beverages, fruits/vegetables, and grains from each of the visual estimation measures against the weighed (criterion) estimates for each outcome. Differences in the means of each observation method were calculated and tested for statistical significance using ANOVA, as a test comparing all of the methods simultaneously, and individually using Dunnett’s t-test, which compares multiple estimations against a control while adjusting for Type I error. Inter-rater reliability of the digital photograph estimation methods was evaluated using intra-class coefficients comparing the two raters’ estimations for each outcome. All statistical analyses were conducted using SAS version 9.3 (Cary, NC: SAS Institute).

RESULTS AND DISCUSSION

The children whose snacks were observed for this study were racially/ethnically diverse, with 44.1% identified as Hispanic by their parents, 33.3% identified as non-Hispanic black, and 9.7% identified as non-Hispanic white. The mean participant age was 7.7 years old and 56.5% of the children were female. The four programs served snacks consistent with NSLP guidelines. Across the four programs and two days, five types of beverages other than water were observed, four types of fruits/vegetables were observed (three of which were whole fruits/vegetables), and seven types of grains were observed, including different kinds of granola bars, cereals, crackers, and chips/pretzels. Within the 174 total instances of snack consumption observed across the two days of data collection, snack composition varied, with 35 instances of water consumption, 57 instance of other beverage consumption, 49 instances of fruit/vegetable consumption, and 120 instances of grain consumption.

The mean kcals consumed estimated by the visual estimation methods were not statistically significantly different from the criterion estimates (Table 1); similarly, none of the visual estimates of servings consumed of beverages, fruits/vegetables, and grains were statistically significantly different from the criterion estimates. However, the visual estimation methods consistently and significantly underestimated water consumption, by about a third of a serving.

All of the visual estimation methods were strongly correlated with the weighing (criterion) method, further demonstrating criterion validity (Table 2). With regard to water, which was the only snack component self-portioned by children, the direct observation methods were moderately correlated with the criterion method. Inter-rater reliability was good to excellent for both digital photography methods for all of the dietary outcomes, including water (Table 2).

This study shows that unobtrusive (relative to plate weighing or self-report measures), feasible, and inexpensive methods for observing snacks in afterschool programs can be used to accurately estimate children’s food and beverage consumption of standard portion sizes. On-site and photography-based estimations of consumption of total energy, servings of fruits and vegetables, servings of grains, and servings of packaged beverages using either 4-category (none, some, most, all) or more precise (10-category) rating scales were valid and highly reliable when compared to the criterion (weighed estimates of consumption). Although we were unable to assess inter-rater reliability directly for the on-site estimation method, several different individuals assumed the role of the on-site observer in this study (just not simultaneously), enabling us to examine whether criterion validity of the on-site method differed by rater. ICCs for on-site raters compared to the criterion were quite similar between the raters for each outcome (ranging from 0.86 to 0.95) except for water, which was difficult to estimate in this study, as noted above.

Correlation coefficients for observed consumption of self-portioned water compared to the criterion were lower than for the pre-portioned items. Future users should take extra considerations if they estimate items that are not pre-portioned using this method. In this study, children often used the same cup to get multiple servings of water. Because visual

observers rated remnants of packaging, foods, and beverages left on children's plates, but could not see the number of servings of water taken or consumed at the dispenser location, they were unable to see and record extra servings of water taken; therefore, when children had multiple servings of water, visual observers were usually unaware that additional servings had been taken, resulting in lower estimates of water consumption than the true value in these cases. The weight of each serving of water taken by participants, by contrast, was captured at the distribution point by a data collector stationed directly next to the water dispenser. To evaluate whether the visual estimation methods were valid when only one serving was taken, which more closely matches the conditions under which the other, pre-portioned items were estimated, a post-hoc analysis was done, excluding observations where more than one serving had been recorded. In this analysis, the correlations for the visual estimation methods compared to the criterion were similar to those for the other snack components, ranging from 0.74 to 0.95.

Accurately estimating children's dietary intake in field settings has proven challenging, with tradeoffs among accuracy, cost, intrusiveness, and the number of study participants who can be observed. The methods validated in this study, in addition to being precise and requiring few research staff, require few other resources, time, money, or training (Table 3). These results are similar to prior studies of visual estimation methods, [17–20] but demonstrate a method that requires less training, time, and cost and can be easily implemented in an afterschool snack setting. These results are comparable to a recent study describing a similar approach used for quantifying food wasted during school lunches, although the present study found photographic methods to be more precise.[24] This may be because data collectors poured out the contents of opaque containers in order to see leftovers more clearly. Although these methods require some interaction with children and thus increase awareness of being observed, because they still require research assistants to prevent children from throwing away their plates (and, in the case of the on-site observer, still result in an observer present in the room while children are eating), we are unaware of strategies to allow for precise observations and photographs that would not results in children being somewhat aware of the presence of observers. Researchers interested in using these methods could consider approaches to reduce potential observer bias due to children's awareness of being observed, such as not using ID numbers on plates (which would not be necessary in cross-sectional data collection, but was necessary here for comparison of the observations across methods), or planning several days of "practice" observations to acclimate children to the presence of observers before actual data collection.

Researchers interested in using visual estimation methods can choose between different approaches given their study requirements. This study found no substantial differences between on-site visual estimation and estimations from digital photographs, suggesting that either method could be used with similar results in a setting with pre-portioned servings. For example, if an evaluation team did not have access to a digital camera, they could use on-site estimations. Alternatively, if there were concerns about time constraints at a study site or if researchers wanted permanent records, photographic methods could be used. While the 10-category scale appeared to produce slightly more reliable estimates compared to the 4-category scale, the latter still performed well, suggesting that if research staff are more comfortable using the 4 categories this approach could be followed with confidence.

This study had several strengths including the use of a gold standard criterion measure and the documentation of staff time and costs for implementation, which several prior studies of similar methods have not done. However, the validity of these snack consumption methods may not be generalizable to other meal settings or serving strategies. In particular, it is not clear that these methods would be valid when children serve themselves, such as in child care settings where food is served "family style," because the methods employed here used a pre-packaged serving size for reference. These methods may also not be generalizable to younger children, who may spill or play with their food more than older children. The methods may also not be generalizable to other types of meals with more components. A limitation of the photographic method is that it would fail to capture spilled or traded food and may not capture multiple servings of foods if there is no evidence of extra packaging. An additional limitation of the study is that data collectors were not randomly assigned to rating method.

CONCLUSIONS

This study validates three low-cost measurement approaches for researchers and program evaluators interested in assessing children's dietary intake in afterschool settings where foods and beverages are mainly pre-portioned. A quick, feasible, inexpensive visual estimation method with trained research assistants can validly estimate children's dietary intake in these settings, allowing researchers and practitioners to easily and inexpensively collect data on groups of children. Using this precise measure may allow for more accurate findings and less attenuation of study results due to measurement error.

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Table 1

Mean differences in estimation of total energy (kcals) and proportion of food and beverage servings consumed by children in grades 1–6 using three visual observation methods of afterschool snack compared to a weighed estimation methods in 4 afterschool programs in Boston MA.

	Number of observations	Mean (SD) consumed by plate weighing	Mean differences (95% confidence interval) for each estimation method compared to weighed estimation method[b]			*p*-value[a]
			Onsite observation, 4 categories	***Photo raters, 4 categories***	***Photo raters, 10 categories***	
Total calories consumed (kcals)	174	126.4 (83.8)	14.6 (−6.5, 35.7)	11.2 (−7.0, 29.5)	12.6 (−5.7, 30.9)	0.34
Water servings consumed	35	1.35 (0.7)	−0.28 (−0.53, −0.03)*	−0.33 (−0.55, −0.13)*	−0.30 (−0.59, −0.06)*	0.002
Other beverage servings consumed	57	0.60 (0.40)	0.03 (−0.13, 0.19)	−0.001 (−0.14, 0.14)	−0.02 (−0.16, 0.13)	0.91
Fruit/vegetable servings consumed	49	0.44 (0.43)	0.05 (−0.16, 0.27)	0.05 (−0.14, 0.24)	0.06 (−0.13, 0.24)	0.91
Grain servings consumed	120	0.72 (0.46)	0.07 (−0.06, 0.20)	0.05 (−0.06, 0.17)	0.06 (−0.06, 0.17)	0.60

[a] *p*-value is for ANOVA test of overall differences from a criterion mean.

[b] Asterisks show when p-values for Dunnett's t-test, testing for individual differences for each estimation method compared to the weight estimation method while controlling for Type 1 error, were less than p=0.05.

Table 2

Intra-class correlations comparing visual estimation methods (on-site and photo) to weighed estimates of the proportion of total energy and servings of each food or beverage consumed by children in grades 1–6 during afterschool snack in 4 afterschool programs in Boston MA.

	Criterion validity			Inter-rater reliability	
	Onsite observation, 4 categories	***Digital photography, 4 categories***	***Digital photography, 10 categories***	***Digital photography, 4 categories***	***Digital photography, 10 categories***
Total calories consumed (n=174)	0.92 ***	0.91 ***	0.94 ***	0.92 ***	0.95 ***
Water servings consumed (n=35)	0.48 ***	0.46 ***	0.47 ***	0.80 ***	0.90 ***
Other beverage servings consumed (n=57)	0.92 ***	0.86 ***	0.94 ***	0.84 ***	0.93 ***
Fruit/vegetable servings consumed (n=49)	0.93 ***	0.90 ***	0.93 ***	0.89 ***	0.92 ***
Grain servings consumed (n=120)	0.93 ***	0.90 ***	0.91 ***	0.91 ***	0.92 ***

* p<0.05

** p<0.01

*** p<0.001

Table 3

Costs, staff working hours, and feasibility concerns for each dietary intake observation method, assuming the estimation of 400 observations.

Method	Raw materials	Training hours	Estimation hours	Data entry hours	Total staff time	Total cost per observation	Considerations
Weighed estimation method	- Salter Aquatronic Kitchen Scale, Model 3003: $38.81 - Paper plates (400): $24.00 - Lysol cleaning wipes: $2.50 *Subtotal: $65.31*	2 hours *Subtotal: $36.00*	- Initial monitoring of snack period to ensure snacks are not thrown away: 1.5 hours - Weighing time: 10 hours *Subtotal: $207.00*	4.0 hours *Subtotal: $72.00*	17.5 hours	$ 0.95 per observation	- Gold standard - Need space and time before snack period to collect baseline food and beverage weights - Need space and time after snack period to collect weights
On-site 4 category rating scale	- Paper plates (400): $24.00 *Subtotal: $24.00*	0.33 hours *Subtotal: $6.00*	- Initial monitoring of snack period to ensure snacks are not thrown away: 1.5 hours - Rating time: 6.67 hours *Subtotal: $147.06*	4.0 hours *Subtotal: $72.00*	12.5 hours	$0.62 per observation	- Need space and time after snack period to estimate consumption of each plate -Unlike photos, do not have permanent record of original intake
Digital photograph 4 category or 10 category rating scale	- Paper plates (400): $24.00 - Digital camera from staff smartphone ($69.00) *Subtotal: $93.00*	0.33 hours *Subtotal: $6.00*	- Initial monitoring of snack period to ensure snacks are not thrown away: 1.5 hours -Taking pictures: 3.3 hours - Rating: 3.3 hours *Subtotal: $147.06*	Not applicable; data entered as it is coded	8.5 hours	$0.62 per observation	- Need some time and space to photograph snacks after snack period, but less time than needed for estimating consumption on site. -Permanent record of each observation if needed for future analyses.