



Reliability and Validity of Digital Imaging as a Measure of Schoolchildren's Fruit and Vegetable Consumption

Jennifer C. Taylor, MS; Bethany A. Yon, PhD; Rachel K. Johnson, PhD, MPH, RD

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ABSTRACT

Background As more and more interventions aim to increase schoolchildren's fruit and vegetable (FV) consumption, less resource-intensive yet valid alternatives to weighed plate waste (WPW) are needed for assessing dietary intake.

Objectives We aimed to test the reliability and validity of digital imaging (DI) and digital imaging with observation (DI+O) in assessing children's FV consumption during school lunch.

Design FV consumption (in grams) was assessed on lunch trays from third- to fifth-grade children over eight visits (31 to 68 trays collected per visit) to compare WPW with DI and DI+O.

Setting Two elementary schools (327 and 631 students enrolled, respectively).

Main outcome measures Interobserver reliability of DI. Validity of DI and DI+O compared against WPW.

Statistical analyses Reliability was assessed by percent agreement and intraclass correlation coefficients (ICCs). Validity was assessed by Pearson correlations, paired *t* tests, and Bland-Altman plots.

Results Reliability was acceptable for DI; percent agreement was 96% and the ICC was 0.92. FV consumption assessments by DI and WPW (*n*=159) were highly correlated (*r*=0.96; *P*<0.001). Mean FV consumption using DI (96.7 g) was within 1.0 g of WPW and not significantly different from WPW (*P*=0.56), and Bland-Altman limits of agreement for individual-tray FV consumption were -32.9 to 31.3 g. FV consumption assessments by DI+O and WPW were highly correlated (*r*=0.98; *P*<0.001). Mean FV consumption using DI+O (99.3 g) was within 1.0 g of WPW and not significantly different from WPW (*P*=0.38), and limits of agreement for individual-tray FV consumption were -25.0 to 26.8 g.

Conclusions DI was reliable for assessing children's FV consumption during school lunch. DI and DI+O were valid for assessing mean consumption but less precise for estimating individual-tray consumption. Valid estimations of mean FV consumption were achieved using DI without cafeteria observations, thereby reducing labor and time. Thus, DI is especially promising for assessing children's mean FV consumption during school lunch.

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MOST US CHILDREN FAIL TO MEET NATIONAL recommendations for fruit and vegetable (FV) consumption.^{1,2} Low FV consumption is concerning because FV consumption may reduce the risk of some cancers^{3,4} and cardiovascular disease,^{5,6} and plays an important role in achieving or maintaining a healthy weight.^{7,8} In an effort to address childhood obesity and improve childhood nutrition, the US Department of Agriculture released new school meal standards

in 2012 for the National School Lunch and School Breakfast Programs.⁹ These regulations increase the number of servings of FV and the variety of vegetable items offered and require children to select at least one fruit (breakfast) or one fruit or vegetable (lunch) as a component of the meal.⁹ However, requiring children to select FV does not guarantee consumption. To determine the influence of these school meal standards, as well as other interventions targeting FV consumption, practical yet reliable and valid methods for assessing children's consumption of these foods are needed.

Various dietary assessment methods are used to estimate children's dietary intake in the school environment. Methods relying on self-report are commonly used, although their limitations are well documented.¹⁰⁻¹² Many of these limitations may be overcome using an objective measure based on

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trained researchers' meal observations. Foods may be weighed individually using weighed plate waste (WPW), a method that provides reliable estimates of intake by physically weighing food selections and plate waste¹³ and is recognized as the gold standard for meal observations because it is the most accurate and precise approach.¹⁴ However, this approach is used infrequently because it is time- and labor-intensive.¹⁴

Alternatively, food consumption can be visually estimated using digital imaging (DI); DI may be advantageous because it requires less in-school data collection time than WPW and direct observation. DI was validated against WPW in laboratory^{15,16} and restaurant settings.¹⁷ Although DI has been used in recent studies to estimate children's dietary intake in school cafeterias,¹⁸⁻²⁰ the method has not been validated against WPW in this setting. In addition, whereas some DI procedures used in school cafeterias have reported incorporating observations of children's second servings of foods,^{20,21} earlier studies have not reported collecting observations of trading and sharing of foods. The extent to which these behaviors affect children's true FV consumption needs to be explored to determine whether the absence of cafeteria observations in DI protocols affects the validity of dietary intake estimations.

The purpose of this study was to develop a less resource-intensive, valid method for objectively assessing children's FV consumption during school lunch. The aims of this study were to evaluate the reliability of DI in two unique school environments and determine the validity of DI as well as digital imaging with cafeteria observations (DI+O) compared against WPW.

METHODS

Study Design

Two Vermont elementary schools participated in the study and were selected because they served a wide variety of FV

items with varied preparation and serving styles. The two school cafeteria environments differed in several ways that were expected to affect data collection, including layout of the foodservice area, FV menu offerings, and lunch disposal (Table 1). Written permission was obtained from the school nutrition directors and principals. The study was approved as exempt research by the University of Vermont Institutional Review Board.

Nineteen undergraduate students completed a 12-hour training program developed and facilitated by two graduate nutrition students during fall 2011. Students were trained as research associates to assess FV consumption using meal observation methods. Research associates practiced these methods using a variety of school lunch FV items presented in variable portion sizes. During the final training session, 10 volunteers were observed eating lunch in the laboratory and FV consumption was estimated in real time. Interobserver reliability was evaluated during this school lunch simulation; percent agreement was 94% and the intraclass correlation coefficient (ICC) was 0.89 (95% CI 0.78 to 0.97).

After completing the training, the research team collected school lunch FV consumption data in two elementary schools over eight school visits (four visits per school) during spring 2012. Reliability was evaluated during all school visits in which DI was used. Methods were initially tested separately in each school; DI was the only method used during the first visit to each school, followed by WPW during the second visits. To test validity, trays were assessed using DI, DI+O, and WPW simultaneously during the remaining two visits to each school.

Data Collection

Data were collected on the contents of a random sample of lunch trays from third- to fifth-grade students with no

Table 1. Characteristics of two Vermont elementary schools participating in a study comparing weighed plate waste to digital imaging and digital imaging with observation for the assessment of children's fruit and vegetable consumption during school lunch

Characteristic	School A	School B
Total enrollment	631	327
Grades enrolled	3-6	K-5
Race/ethnicity (%)		
White, non-Hispanic	91	84
Asian/black/Hispanic/other ^a	9	16
Free/reduced meal eligibility (%)	35	52
NSLP ^b participation rate (%)	56	68
Cafeteria environment		
Fruit and vegetable serving style	All items preportioned by staff	Some items preportioned by staff; self-serve items available from salad bar
Layout of foodservice checkout areas	6 registers within 1 centralized checkout station	1 register at each of 2 checkout stations
Layout of disposal areas	Trash barrels dispersed in dining area near tables	1 centralized disposal area

^aOther ethnicities were American Indian/Alaskan Native.

^bNSLP=National School Lunch Program.

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