Reliability and Accuracy of Real-Time Visualization Techniques for Measuring School Cafeteria Tray Waste: Validating the Quarter-Waste Method

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ABSTRACT
Measuring food waste is essential to determine the impact of school interventions on what children eat. There are multiple methods used for measuring food waste, yet it is unclear which method is most appropriate in large-scale interventions with restricted resources. This study examines which of three visual tray waste measurement methods is most reliable, accurate, and cost-effective compared with the gold standard of individually weighing leftovers. School cafeteria researchers used the following three visual methods to capture tray waste in addition to actual food waste weights for 197 lunch trays: the quarter-waste method, the half-waste method, and the photograph method. Inter-rater and inter-method reliability were highest for on-site visual methods (0.90 for the quarter-waste method and 0.83 for the half-waste method) and lowest for the photograph method (0.48). This low reliability is partially due to the inability of photographs to determine whether packaged items (such as milk or yogurt) are empty or full. In sum, the quarter-waste method was the most appropriate for calculating accurate amounts of tray waste, and the photograph method might be appropriate if researchers only wish to detect significant differences in waste or consumption of selected, unpackaged food.
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RELIABLY AND ACCURATELY MEASURING TRAY waste, especially in a school cafeteria, is a key tool to measuring the impacts of food-behavior interventions. Waste measurement has become even more important with the new regulations for the 2012 National School Lunch Program. In the first couple of weeks of the 2012-2013 school year, reports emerged that students were wasting large quantities of foods, especially fruits and vegetables. Although the end result of the regulations is to improve child nutrition, understanding how much food students throw away has become a topic of serious interest.[1] In large-scale studies, it is important to be able to make waste measurements quickly and accurately in order to reduce costs to the researchers and hassle for the schools.

Currently, there are multiple useful methods for measuring tray waste, yet the appropriate method for a study depends on available resources, research questions, and the specific setting. Weighing tray waste, the most reliable method, is highly accurate, but requires a significant amount of space and labor, often severely restricting the number of observations that can be obtained. Visual-measurement methods, on the other hand, require less labor, space, and can be reliable and accurate relative to weighing waste. In addition, school foodservice managers can easily use these visual methods to better understand the consumption patterns in their own schools. This study identifies one particular on-site visual tray waste measurement method, the quarter-waste method, as preferable to two other visual methods due to its reliability, accuracy, and cost effectiveness.

A large body of literature has been devoted to the use of and reliability of various methods for measuring the amount of foods people consume.[2-5] Survey methods, a common technique,[6,7] suffer from reporting biases. Food frequency questionnaires are not only costly but respondents—especially children—have difficulty recalling past food consumption.[8] Manually weighing food waste (weighing method) is highly accurate but costly.[9,10] The weighing method, though, serves as a baseline gold standard against which alternative methods are validated.[4]

Visual estimation methods[4,11,12] are increasing in popularity because of their ease of implementation and cost effectiveness. With visual methods, tray waste can be estimated either on-site[13] or remotely using photographs.[5,14] Yet little is understood regarding the reliability and accuracy of these on- and off-site methods relative to the weighing method, although there is evidence of high inter-method reliability between visual estimation methods.[15]

This study compares three common estimation methods to the weighing method in school cafeterias. Inter-method and inter-rater agreement methods were used to identify the relatively more reliable visual method. In addition, we assess the level of precision inherent in each method. Finally, in the context of an intervention study, results from a power test show which method requires the least number of observations necessary for detecting a 10% decrease in fruit or vegetable waste.

METHODS

This study was conducted with approval from the Cornell University Institutional Review Board. To avoid contamination of waste measures, students were not informed of the study before the implementation date. In a corner of the participating elementary school (kindergarten to grade 5) cafeteria, a series of tables were linked together. Students were instructed to place their trays on one end of the tables when they had completed their meal. From there, trays would move along the tables in assembly-line fashion. Once a tray was left at the station, a researcher placed a sticky note with an identification number on the tray and another researcher took a photograph of the tray. After being photographed, another researcher estimated the amount of each individual item wasted using a visual method that reports whether none, some, or all of a food item is wasted (half-waste method). Another researcher estimated tray waste using a visual method that reports whether none, $^1/_4$, $^1/_2$, $^3/_4$, or all of a food item is wasted (quarter-waste method). In both cases, when a packaged product, such as a milk carton or a yogurt container, was closed and could not be visually estimated, it was picked up to determine whether empty, full, or in between.

These two researchers recorded their estimates on sheets of paper with a list of each possible item next to the tray identification number. The tray then moved to the final location where one of two researchers placed each individual remaining food item on a standard paper plate and weighed the amount of each food item remaining. In order to obtain inter-rater reliability measures for the half-waste and quarter-waste methods, an additional researcher measured tray waste on a random sample of the trays using either the half-waste (n=26) or quarter-waste method (n=27). Items from students who did not purchase a full school lunch were not measured.

Individuals measuring tray waste were internal to the research team. Those conducting the visual-estimation methods either had previous experience measuring tray waste or were trained using protocols and photographed examples. Before the lunch period, researchers assigned to measure waste visually examined a serving of each food item offered and weighed five complete and uneaten servings of each item to generate an average weight per serving. Container and carton weights were also taken for items such as carrots or salad, which were served in small plastic cups, or milk and juice, which were served in cartons. These procedures served two purposes. First, researchers using the visual-estimation methods knew the size of a standard serving and used this to estimate tray waste. Second, average serving weights were used to generate estimates of the grams wasted for each of the visual-estimation techniques.

Several days after the on-site measurements were completed, a researcher used a 10% scale to estimate waste appearing in the tray photographs (none, 0.10, 0.20, . . ., 0.90, or all wasted). For inter-rater reliability, a separate researcher used the same method to estimate tray waste in 40 randomly selected photographs.

Data and Analysis

Tray waste was collected for 197 total trays. This was the total number of students who received a school lunch that day. The menu for the day included four entrée items: chicken nuggets, chicken strips (served once the nuggets were gone), peanut butter and jelly sandwiches, and yogurt. Fruit options included applesauce and oranges. Vegetable options included green beans, salad, and carrots. Grain choices included rice and a bagel. Students could also choose a cookie, a package of sunflower seeds, or a small bag of chips. Beverage options included fat-free milk, 1% white milk, 1% chocolate milk, orange juice, and apple juice.

Inter-method and inter-rater reliability were measured using methods used in previous studies.[16,17] Specifically, correlation coefficients of amounts wasted were calculated to compare the weighing method and the three visual-estimation methods, providing an inter-method reliability score. In addition, correlations of measured waste between researchers, but for the same method, were calculated as an inter-rater reliability score. As a second test of inter-method reliability, correlations between waste measured using the weighing method and the three visual-estimation techniques were calculated for each food item offered.

To test accuracy in waste measures, *t* tests were used to estimate the difference in measured waste between the weighing method and the three visual-estimation methods. This comparison was carried out for each food item offered in the cafeteria that day. Finally, power tests were used to calculate the number of observations necessary to detect a 10% decrease in waste for the weighing method and the three visual methods. In these power tests, average waste for all fruits and all vegetables, as measured with the weighing method, are used. Because intervention studies rely on before-and-after measures, the power tests are based on independent two-sample *t* tests with equal sample sizes and equal standard deviations assumed both before and after the waste decrease.

RESULTS

To demonstrate the reliability, accuracy, and statistical power for each visual estimation technique, results from these methods are reported and compared with the weighing method.

Reliability

Reliability measures (correlations) reveal how closely each visual method's waste measures compare with the weighing method. The quarter-waste method has a reliability measure of 0.90 ($P<0.001$) and the half-waste and photograph methods have reliability measures of 0.83 ($P<0.001$) and 0.48 ($P<0.001$), respectively. Low reliability for the photograph method is due to difficulty in estimating waste in milk and juice cartons as well as other foods that are served in packages or containers that obstruct the view of the remaining

Table 1. Inter-method reliability of visual waste-measurement methods: Observations from 197 trays in a school cafeteria[a]

	Methods		
Food item	Half-waste	Quarter-waste	Photograph
Entrées			
Chicken nuggets	0.93***	0.98***	0.95***
Chicken strips	0.82***	0.89***	0.85***
Peanut butter and jelly	0.85**	0.93***	0.83*
Yogurt	0.97***	0.97***	0.65
Fruit			
Applesauce	0.91***	0.91***	0.78***
Orange	0.53**	0.74***	0.55**
Vegetables			
Carrots	0.93***	0.88***	0.72***
Green beans	0.72***	0.85***	0.90***
Salad	0.80***	0.76***	0.71**
Grains			
Bagel	0.69	0.98***	0.38
Rice	0.82***	0.90***	0.89***
Snacks			
Chips	0.99***	0.93***	−0.08
Cookie	—	1.00***	0.15
Sunflower seeds	0.21	0.32	−0.16
Beverages			
Fat-free milk	0.57*	0.67**	−0.16
1% milk	0.88***	0.94***	−0.12
Chocolate milk	0.87***	0.93***	0.47***
Apple juice	0.78***	0.89***	0.72***
Orange juice	0.92***	0.93***	0.73***

[a]Inter-method reliability scores are calculated as correlations between the amount wasted as measured by the weighing method and the amount wasted as measured by three visual-estimation methods: half-waste, quarter-waste, and photograph methods.
*$P<0.05$.
**$P<0.01$.
***$P<0.001$.

food. Inter-rater reliability indicates high internal consistency for the quarter-waste method (0.95; $P<0.001$) and half-waste method (0.88; $P<0.001$), but relatively lower internal consistency for the photograph method (0.57; $P<0.001$). Again, this might be because of the inability to see inside of cartons, packages, and containers, thus severely biasing visual waste estimates.

Inter-method reliability for specific foods items (Table 1) shows that the photograph method is least reliable for foods in packages and cartons (milk, juice, sunflower seeds, and chips). Specifically, reliability measures from the photograph methods were essentially no different from zero for chips and sunflower seeds, and were very low for chocolate milk. On the other hand, reliability results for the quarter-waste method were 80% or better for 15 of 19 food items compared with 12 of 19 items for the half-waste method.

Accuracy in Waste Measures

Reliability results provide strong evidence that relative to the half-waste and photograph methods, the quarter-waste method most reliably generates waste measures similar to the weighing method. In the next set of tests, differences in waste measured between the weighing method and the visual methods are all compared to identify which visual method is most accurate in terms of a linear difference. Average waste per food item measured by the photograph method is statistically different from that given by the weighing method for chicken nuggets ($P<0.001$), chicken strips ($P<0.01$), applesauce ($P<0.01$), rice ($P<0.05$), chips ($P<0.01$), and apple juice ($P<0.05$). Waste measures for the half-waste and quarter-waste methods are statistically different for rice ($P<0.05$), and the quarter-waste method reports a statistically different amount of green bean waste ($P<0.01$). Of the three methods, the photograph method proved to be the least accurate visual method.

Statistical Power

Although the proximity in waste measure provides evidence for the ability of the visual methods to generate waste measures similar to those reported by the weighing method, variability in within-method measurement could affect the method's ability to detect a difference in the presence of an intervention. Greater variability decreases statistical power and requires larger sample sizes for detecting differences. Sufficiently large sample sizes can be difficult to obtain, especially in a school cafeteria setting, when resources are limited.

Fruit and vegetable waste generated from the weighing method were averaged over the items in the two food groups. Standard deviations of fruit and vegetable waste for each measurement method were calculated (Table 2). With these average waste measures, a 10% reduction in waste was calculated, and power tests were used to determine the necessary sample size to declare this difference as statistically significant. These tests show that the weighing method requires the least number of observations, as expected, for detecting a difference. Interestingly, the photograph method is next and requires 1,400 observations for detecting a 10% decrease in fruit waste and 625 for detecting a 10% decrease in vegetable waste. The quarter-waste- and half-waste methods require the most observations for detecting a 10% decrease in fruit and vegetable waste.

DISCUSSION

There are various methods used for collecting tray waste in school intervention research. These methods vary in terms of time, accuracy, implementation difficulty, and manpower requirements. An appropriate choice of methods depends on the researcher's needs and resources; therefore, identifying the most appropriate method for the situation is an important resource consideration.

In this study, the time to weigh tray waste took approximately 30 seconds per tray. Measuring tray waste using the

Table 2. Comparing the statistical power of waste-measurement methods: Observations from 197 trays in a school cafeteria

	Standard deviation	Sample size required to detect a 10% decrease in waste[a]	Test power
Mean fruit waste=23.7 g			
Weigh	33.70	1,100	0.95
Half-waste	42.84	1,780	0.95
Quarter-waste	40.03	1,550	0.95
Photo	37.91	1,400	0.95
Mean vegetable waste=25.8 g			
Weigh	24.55	500	0.95
Half-waste	32.01	850	0.95
Quarter-waste	35.71	1,050	0.95
Photo	27.53	630	0.95

[a]The test is based on an independent two-sample *t* test with equal standard deviation and equal sample size for both samples. If the sample size necessary to detect a difference is equal to 1,000, then in this comparison, 500 tray waste observations must be gathered both before and after the intervention.

half-waste and quarter-waste methods takes approximately 4 to 5 seconds per tray. The photograph method requires that each tray be labeled, which takes <1 second per tray, and then photographed, which requires an additional 1 to 2 seconds. Then, visually estimating tray waste using digital images takes 4 to 5 seconds per tray, so the photograph method requires approximately 2 more seconds per tray, relative to the on-site visual methods. Visual-estimation techniques take approximately one fifth of the time required by the weighing method, but vary in their reliability and accuracy.

When compared with the half-waste and photograph methods, the quarter-waste method was found to be the most reliable method. The quarter-waste method was more accurate than the photograph method, especially when measuring waste for foods that were prepackaged or beverages served in containers. Indeed, the photograph method both under- and overestimated waste for various items, but consistently overestimated waste when the food or beverage was in a package or container. Neither the half-waste or quarter-waste methods generated consistently biased waste measures. Unless additional care is taken to facilitate visual estimation of tray waste for packaged foods or beverages, the photograph method will not generate reliable waste estimates for these items.

Interestingly, power tests show that the photograph method requires fewer observations for detecting a difference in total fruit or vegetable waste. This is because the photograph method used smaller increments for measuring waste, thus reducing deviation in measurements. If the research goal is to detect a difference in tray waste, then the photograph method requires fewer observations. On the other hand, if the research goal is to generate an accurate (without bias) measure of tray waste, then the quarter-waste method is a cost-effective, reliable, and accurate visual method.

In light of these findings, it is important to note limitations to the study. First of all, tray waste measures were collected for 1 day at one school only, which limited the types of foods measured. The selection of fruits and vegetables offered in cafeterias, however, is typically limited. Yet, the low reliability of the photograph method for foods served in packages and cartons suggests that even with multiple days, the reliability will not improve substantively. Notably, all but three of the food items in this study were served in packages—yogurt, chips, and sunflower seeds—and such foods vary from cafeteria to cafeteria. Milk and juice, however, are universally served in cartons, and accurate waste measures are difficult to obtain via photographs.

Second, photographs of trays were not taken before the student sat down to eat. Relying on the post-consumption photograph only limits the researcher's ability to identify what items were on the tray, especially if all of an item were eaten and left little trace, or if items were served in similar containers, such as salad and carrots. Taking pre-photographs of student's trays, though, requires more resources and additional coordination in order to match the before and after photographs. Although this may not be too difficult, it might be prohibitive for foodservice directors interested in measuring tray waste in their own cafeterias.

Third, because accurate waste measures are a key element in intervention studies, it is important to identify ways to mitigate biases in student behavior stemming from researcher presence in the cafeteria. Regardless of the method used—half-waste, quarter-waste, photograph, or weighing—all are obtrusive and potentially generate biases in behavior. This impact can be limited in the following ways: researchers should establish a measurement station in an obscure location in the cafeteria where students leave their trays; inquisitive students can be given a general answer, such as "We are collecting information about your cafeteria," when they inquire about the researchers' presence; and when space is limited, researchers are instructed to stand close enough to the trash receptacles to see what students are throwing away, but far enough away to remain relatively inconspicuous.

A key contribution of this research is showing that there are visual approaches that come close to approximating the accuracy of the gold standard of weighing every item. Notably, observation methods—particularly the quarter-waste method—were substantially more reliable and accurate than the photograph method. This might raise the question whether an even more granular estimation method—such as a decile approach—would be even better. Results in this study, however, show that a more granular estimation method comes with costs in both accuracy and reliability. Specifically, reliability from a decile-waste method was an unacceptable 0.57 compared with a reliability of 0.95 for the quarter-waste method.

CONCLUSIONS

Identifying an appropriate method for measuring tray waste in school cafeteria or other foodservice intervention research

is not a trivial matter. In this study, three visual-estimation methods were compared with weighing tray waste, which is the most accurate yet time-consuming method. Results from this study show that the visual method in which waste is measured in quarter-waste increments—none, 1/4 , 1/2 , 3/4 , or all wasted—is the most reliable of the visual methods studied. In addition, it is just as accurate as a method in which waste is measured in half-waste increments—none, 1/2 , or all wasted—and more accurate than a photograph method, in which a researcher visually observes tray waste using photographs and estimates waste in 10% increments—none, 0.1, 0.2, . . ., 0.9, or all wasted.

With an increasing number of researchers testing interventions in school lunches, standards for reliable and accurate measures of consumption and waste have become increasingly important to providing policy advice. Increases in fruit and vegetable waste have been of great concern since the introduction of new school lunch guidelines requiring a fruit or vegetable to be included in any meal receiving a reimbursement. With school cafeteria managers concerned about what their students are wasting, how much is being wasted, and how to decrease that waste, the quarter-waste method is an extremely simple tool they can use to measure waste on their own. In addition, this same method can be used in university dining halls, restaurants, and other dining establishments for detecting waste patterns among diners and empowering managers of these establishments to find ways for cutting waste and improving their bottom line.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

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