Portion-size estimation training in second- and third-grade American Indian children[1–3]

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ABSTRACT Training in portion-size estimation is known to improve the accuracy of dietary self-reporting in adults, but there is no comparable evidence for children. To obtain this information, we studied 110 second- and third-grade American Indian schoolchildren (34 control subjects were not trained), testing the hypotheses that a 45-min portion-size estimation training session would reduce children's food quantity estimation error, and that the improvement would be dependent on food type, measurement type, or both. Training was a hands-on, 4-step estimation and measurement skill-building process. Mixed linear models (using logarithmic-transformed data) were used to evaluate within- and between-group differences from pre- to posttest. Test scores were calculated as percentage estimation errors by difference and absolute value methods. Mean within-group estimation error decreased significantly ($P < 0.05$) from pre- to posttest for 7 of 12 foods (trained group) by both calculation methods, plus 3 additional foods by the difference method and one additional food by the absolute value method. Significant ($P < 0.05$) between-group differences occurred for 3 foods, reflecting a greater decrease in estimation error for the trained group. Improvement was greatest for solid foods estimated by dimensions ($P > 0.05$) or in cups ($P < 0.05$), for liquids estimated by volume or by label reading ($P < 0.001$), and for one amorphous food estimated in cups ($P < 0.01$). Despite these significant improvements in estimation ability, the error for several foods remained >100% of the true quantity, indicating that more than one training session would be necessary to further increase dietary reporting accuracy. *Am J Clin Nutr* 1999;69(suppl):782S–7S.

KEY WORDS Portion-size estimation, diet assessment, dietary intake, food quantity estimation, schoolchildren, obesity prevention, nutrition education, American Indian children

INTRODUCTION

One limitation of self-reported dietary intake data is the error in estimating the portion sizes of foods. Training in portion-size estimation has been shown to reduce estimation error in adults (1–3), and some of the improvement in estimation accuracy is maintained over time (4, 5). Estimation ability also appears to be affected by the food type (such as solid, liquid, or amorphous), and by the measurement type (such as ounces, cups, or dimensions) (2, 3). Amorphous foods (such as applesauce, peanut butter, and stew) are defined as those less resistant to flow than solid foods and more resistant to flow than liquid foods. Weber et al (3) reported that adults showed the greatest improvement in estimation accuracy for solid foods estimated in cups and for amorphous foods estimated in cups or tablespoons following a 1-h, multimethod training program. Solid foods were also estimated more accurately by dimensions (length × width × height; 19% error) than by ounces (69% error) after training. Yuhas et al (2) reported that adults in their study estimated solid foods (45% error) more accurately than liquid foods (77% error) or amorphous foods (112% error) after a 10-min training program. Although these studies support the concept that training in portion-size estimation improves the accuracy of dietary reporting in adults, no studies have addressed the efficacy of such training in improving dietary reporting accuracy in children.

Pathways is a school-based, primary prevention intervention study designed to reduce the prevalence of obesity in American Indian children. The intervention includes a classroom curriculum, a physical education program, a family involvement program, and a food service program (6). The intervention focuses on increasing energy expenditure (through physical activity) and decreasing dietary fat intake. The dietary focus of the intervention involves both the school meal program and the curriculum.

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TABLE 1
Foods used for portion-size estimation in pre-and posttests of second- and third-grade children in Arizona and New Mexico[1]

Food and unit of measure	Amount		Food type
	Arizona	New Mexico	
Cereal (cups)	1.5	1.5	Solid
Spaghetti noodles (cups)	2	2	Solid
Applesauce (cups)	0.5	0.5	Amorphous
Peanut butter (tbsp)	2	2	Amorphous
Flour tortilla (in)[2]	9	10	Solid
Brownie (in)[3]	$4 \times 3 \times 1$	$4 \times 2 \times 1$	Solid
Pretzels (weighted oz)	8	10	Solid
Stew (cups)	1	1	Amorphous
Bought drink (fluid oz)[4]	32	32	Liquid
Glass drink (cups)	2	2	Liquid

[1] SI conversions: 1 in = 2.54 centimeters; 1 tbsp = 15 mL; 1 cup (fluid) = 250 mL; 1 oz (weighted) = 28.35 g; 1 oz (fluid) = 30 mL. Amorphous foods are less resistant to flow than solid foods, but more resistant to flow than liquid foods.

[2] Measured in diameter.

[3] Measured in dimensions.

[4] Measured by food label.

A reliable method was required to assess the children's self-reported dietary intake. Based on the assumption that improved accuracy in quantifying food intake could increase overall dietary reporting accuracy, we developed and tested a portion-size training activity. We sought to determine whether 1) 45 min of hands-on portion-size training would decrease portion-size estimation error in second- and third-grade American Indian children, and 2) improvement in portion-size reporting ability would be dependent on food type, measurement type, or both. If successful, the resulting portion-size estimation training process could be used with any quantitative self-reported dietary assessment method in children as young as 9 y old.

SUBJECTS AND METHODS

Subjects

Participants were 110 second- and third-grade American Indian children attending school in either Arizona (3 classrooms) or New Mexico (3 classrooms). We used a quasi-experimental design in which the children were randomly assigned to receive either no training (control group; 34 children) or the portion-size training (trained group; 76 children) by classroom.

Training process and testing

All children were pretested in portion-size estimation by using a display of 10 real foods representing solid, liquid, and amorphous food types (**Table 1**). For each food displayed, the children were asked to estimate and record the quantity in cups, tablespoons, inches, or ounces from package labels. The test forms indicated the appropriate unit of measurement to be used for each food item. Measuring devices such as measuring cups, tablespoons and teaspoons, rulers, and package labels were also displayed on the table for reference. Immediately after the pretest, 76 children participated in the 45-min portion-size training activity, and then all 110 children were posttested by using the same 10-food display (training group children took the posttest immediately after the training). The portion-size training activity included 4 steps (**Figure 1**). The children were trained in their classrooms in groups of 4.

Statistical analyses

Portion-size estimation accuracy was determined by subtracting the actual quantity from each child's estimated quantity for each food, dividing that value by the actual quantity, and then multiplying that value by 100 to obtain a total percentage error of estimation (0% error would be a "perfect" score) as follows:

$$\text{Percentage error of estimation} = [(\text{estimated quantity} - \text{actual quantity})/\text{actual quantity}] \times 100 \qquad (1)$$

This calculation was performed by using 2 methods, the difference method and the absolute value method. The difference method distinguishes between overestimations and underestimations (positive and negative scores, respectively), allowing for evaluation of the mean direction of error for the total test and for each food variable. The absolute value method ignores positive and negative signs, thus providing the absolute value of the percentage error of estimation. Larger errors are expected with use of the absolute value method because errors are additive. Ten foods were used in the testing, but 12 food variables were actually tested because one food (the brownie) had 3 estimated quantities (length, width, and height). For each food variable, the difference between the pre- and posttest scores within each group (trained and control) and the difference between groups in the change from pre- to posttest were analyzed by using mixed linear models that included the classroom as the unit of randomization. Because the data were skewed, logarithmic transformations were used. The pretest score for each food variable was used as a covariate in analyses comparing the 2 groups.

RESULTS

Percentage error of estimation scores for second- and third-grade children were combined because scores for the 2 grade levels were not significantly different. The mean percentage errors of estimation for each food variable for both the pre- and posttest in the trained and control groups are shown in **Table 2**. Percentage errors of estimation are presented for both calculation methods (difference and absolute value). Significant differences in between- and within-group comparisons are also shown. Small differences in sample size among the individual food variables are due to missing data (child did not fill in an answer on the test or the answer was unreadable). Larger differences in sample size (lower numbers of trained children for the tortilla and pretzels) were due to test administration errors made with the first class tested.

For the trained group, significant within-group mean differences ($P \leq .05$) from pre- to posttest were found for 7 food variables (out of a total of 12) by both calculation methods. One additional food variable (pretzels) was significantly different ($P < 0.001$) by the absolute value method only, and 3 additional variables (cereal, $P < 0.01$; peanut butter, $P < 0.05$; and tortilla, $P < 0.01$) were significantly different by the difference method only. All differences reflected a decrease in estimation error (except for the tortilla) for the trained group. Only one significant difference ($P < 0.05$) was found for the control group (for stew), which reflected an increase in estimation error for that

Step 1: introduce standard units of measurement and measuring devices

Familiarize children with standard units of measurement and how to write them:

- Cups: 1 cup, 1/2 cup, 1/4 cup
- 1 Tablespoon
- 1 Teaspoon
- Ruler: inches side
- Package labels (weight in ounces) eg, chip bags and fast food cups

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Step 2: practice estimating and measuring foods and beverages

Ask children to:

- Measure a specified amount of food and place it on a plate or pour it in a clear container.
- View the quantity on the plate or in the clear container and compare to the measuring device.
- Measure a different specified amount of food and place it on another plate or in a clear container.
- View the quantity and estimate how much it is in relation to the quantity on the first plate or in the clear container.
- Verify the estimated quantity by using the measuring device.
- Repeat with several examples.
- For foods to be quantified in dimensions:
    - Estimate the length of the sample food item in inches.
    - Verify the estimated length by using a ruler.
    - Estimate the length of another sample food item in inches.
    - Compare the known length of the first item to the length of the second item.
    - Verify the estimated length of the second food item by using a ruler.

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Step 3: practice reporting food quantities from package labels

- Distribute appropriate-size food packages to the children.
- Ask the children to identify which numbers to read from the package for the amount.
- Ask the children to identify what unit of measurement is used to specify the amount.
- Verify the correct responses.

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Step 4: practice choosing the correct measuring device and performing the measurement

- Obtain school lunch trays with real foods.
- Provide each child with a complete set of the measuring devices they were trained to use.
- Ask the children to choose measuring device and measure each food, or indicate the amount of food from the package label.
- Verify that the child used the correct measuring device (or read the label correctly) for each food.
- Verify that the child measured or read the correct amount.

FIGURE 1. Four-step portion-size estimation and measurement training program for children.

food variable by the difference method. Significant between-group differences (P ≤ 0.05) were found for 3 of the 12 foods (stew and glass drink by both methods, brownie length by difference method, and brownie width by absolute value method), with all differences reflecting a decrease in error for the trained group.

For 11 of the 12 food variables, the mean decrease in percentage error from pre- to posttest for the trained group was 93% (range, 24–257% when calculated by the difference method). For one food, the tortilla (diameter in inches), the trained group had a slight increase (10%) in mean percentage error when calculated by the difference method, but a slight decrease (12%) in error when calculated by the absolute value method. When calculated by the absolute value method, mean percentage estimation error for all 12 food variables decreased by 85% (range, 12–262%) for the trained group. The control group also had a decrease in mean percentage error, of 57%, for 9 of the 12 food variables when calculated by the difference method. When calculated by the absolute value method, mean percentage error decreased by 51% for 10 food variables. Once again, the tortilla was estimated with slightly greater error (12%) on the posttest

TABLE 2
Mean percentage errors of estimation of second- and third-grade children by food variable and subject group calculated by the difference and absolute value methods[1]

Food variable and subject group	Pretest		Posttest		Change from pretest to posttest	
	Difference	Absolute value	Difference	Absolute value	Difference	Absolute value
			%			
Cereal						
Control (n = 33)	139	152	98	112	−41	−39
Trained (n = 70)	203	211	93	115	−109[2]	−95
Spaghetti noodles						
Control (n = 33)	164	167	127	133	−36	−33
Trained (n = 71)	235	239	107	118	−127[2]	−120[2]
Applesauce						
Control (n = 34)	547	547	453	453	−94	−94
Trained (n = 74)	539	539	434	436	−105	−103
Peanut butter						
Control (n = 34)	18	47	40	64	23	17
Trained (n = 75)	62	76	37	59	−25[3]	−16
Tortilla						
Control (n = 33)	−6	76	−18	57	−12	−18
Trained (n = 39)	7	43	−17	31	−24[2]	−12
Brownie length						
Control (n = 34)	179	194	146	163	−33[4]	−31
Trained (n = 76)	123	133	38	49	−85[5]	−84[5]
Brownie width						
Control (n = 34)	293	304	167	179	−127	−124[4]
Trained (n = 76)	94	102	42	47	−53[3]	−54[5]
Brownie height						
Control (n = 34)	356	356	234	234	−122	−122
Trained (n = 75)	158	162	107	111	−51[2]	−51[5]
Pretzels						
Control (n = 32)	−20	36	−14	31	6	−5
Trained (n = 50)	51	78	18	30	−33	−48[5]
Stew						
Control (n = 34)	353	353	566	566	213[3,6]	213[4]
Trained (n = 76)	416	416	267	267	−149[2]	−149[2]
Bought drink						
Control (n = 32)	−49	49	−43	45	7	−4
Trained (n = 73)	−49	51	−23	25	26[5]	−26[5]
Glass drink						
Control (n = 34)	389	389	342	346	−47[6]	−43[6]
Trained (n = 73)	422	430	164	168	−257[5]	−262[5]

[1] See Statistical analyses section for explanation of methods.
[2–6] Mixed linear models using logarithmic transformation, with pretest score as a covariate in between-group analyses: [2,3,5] within-group comparison was significantly different, [2] $P < 0.01$, [3] $P < 0.05$, [5] $P \leq 0.001$; [4,6] between-group comparison was significantly different, [4] $P < 0.05$, [6] $P \leq 0.01$.

when calculated by the difference method, but when calculated by the absolute value method, the mean percentage error decreased by 18%. The range for decrease in error was 6–127% by the difference method and 4–124% by the absolute value method. For the control group, percentage estimation error increased for 3 foods by 12–213% (difference method) and increased for 2 foods by 17–213% (absolute value method).

With regard to food type and measurement type, the greatest within-group improvement in estimation accuracy was found for solid foods estimated by dimensions (brownie) and in cups (cereal and spaghetti noodles), for both liquids [estimated by volume (glass drink) and by reading package labels (bought drink)], and for 2 amorphous foods (stew and peanut butter), when calculated by the difference method. When calculated by the absolute value method, all of the same foods except cereal and peanut butter had significant improvement in estimation accuracy, as did 1 additional food, pretzels (estimated by reading the package label). When between-group differences in pre- to posttest changes were analyzed, these food type and measurement type findings were corroborated for 1 liquid (glass drink) and 1 amorphous food (stew) by both calculation methods, and for brownie width by the absolute value method and brownie length by the difference method.

DISCUSSION

Our primary intention in developing and testing a portion-size training program for children was to find out whether portion-size estimation error could be reduced by training children with hands-on activities in a moderate period of time (45 min) in a school setting. We found that mean within-group estimation error decreased significantly from pre- to posttest for 8 (absolute value method) to 10 (difference method) of the 12 food variables for the trained group. There was one significant pre- to posttest change for the control group, reflecting an increase in estimation error. Significant between-group differences were found for 3 foods, reflecting a greater decrease in estimation error for the trained group. One limitation of this study is the large difference between the 2 groups in pretest portion-size estimation errors. This was addressed by using the pretest score as a covariate in the between-group comparisons.

The greatest improvements in estimation accuracy (when calculated by the difference method) for the trained group were for solid foods estimated by dimensions and in cups, for liquids estimated by volume (cups) or by label reading, and for 2 amorphous foods. These findings were confirmed by absolute value method results, with the exceptions of cereal and peanut butter. When calculations were performed with the absolute value method, an additional food estimated by label reading (pretzels) was also estimated more accurately by the trained group at posttest. Amorphous was the food type estimated least accurately both before and after training, which is consistent with reports of portion-size estimation ability in adults (2, 3).

Using the absolute value method of calculating percentage estimation error provides information regarding total error because errors are additive. However, even though percentage estimation error was generally greater by the absolute value method than by the difference method, we found that overall improvement in estimation accuracy was not affected by the calculation method. Using the difference method of calculating estimation error provides information regarding the direction of the error (overestimation compared with underestimation), and thus this method may better reflect true error when applied to self-reporting of actual dietary intake. If both overestimation and underestimation of food portions occurs in dietary reporting, then some misreporting of energy and nutrients will cancel out, perhaps bringing the total reported amounts closer to their true values. However, the potential of this phenomenon to bring reported energy and nutrient values closer to their true values is highly dependent on the energy and nutrient density of the foods being underestimated and overestimated, and could instead result in greater error rather than greater accuracy.

According to the theories of Jean Piaget, at 7–11 y of age children enter the concrete-operational stage of cognition, which enables them to perform several operations important for quantification tasks (7). Examples of these operations include conservation, the ability to compensate by focusing simultaneously on both the height and width of 2 containers, and reversibility, the ability to mentally undo the process of pouring liquid from one container to another container of the same size but different shape and imagining the liquid in its original container. For example, is the amount of orange juice in a short, squat 8-oz (250 mL) glass that is filled to capacity the same as the amount of orange juice in a tall, skinny 8-oz glass that is also filled to capacity? The operation of compensation enables children to recognize that objects may vary on more than one dimension and thus may be grouped or classified in many different ways. Finally, concrete operators are capable of seriation, the ability to mentally arrange items along a quantifiable dimension such as height or weight. The related concept of transitivity encompasses the necessary relations among elements in a series (7). For example, if the oatmeal cookie is bigger (larger diameter, height, or both) than the chocolate cookie, and the chocolate cookie is bigger than the sugar cookie, which is bigger, the oatmeal cookie or the sugar cookie? The ability to compare amounts of different foods to each other, and to standard units of measurement (such as cups and inches) is necessary to render a portion-size training activity meaningful.

Mathematics curriculum guides were used in determining how these cognitive processes are manifested in specific quantitative skills. The third-grade mathematics curriculum in Arizona (8) includes basic measurement concepts such as making comparisons (eg, is the capacity of one container more, less, or about the same as the capacity of another), using models of units, and the role of estimation while learning measurement. Measuring length begins in kindergarten, when children start to make direct comparisons of 2 or more lengths (8). By the second or third grade, children are capable of using units, including both non-standard types such as arm lengths and standard types such as rulers. Children of this age are also generally capable of measuring volume and capacity by making and using measuring cups.

The translation of cognitive capacity for estimation and measurement skills into accurate food estimation ability is likely to require >1 training session, particularly to produce longer-term results. Even though significant training effects were found for the trained group (estimation error decreased from pre- to posttest by 105–257% for 5 food variables), total estimation error was >100% for 5 of the 12 food variables by the difference method after training and 6 variables had >100% estimation error by the absolute value method. Therefore, although children can be trained to decrease their portion-size estimation error, the residual error for many foods remains large. It appears that, although some improvement is obtained from one session, the training must extend beyond one session to achieve the level of effectiveness needed to increase overall dietary reporting accuracy. Gittelsohn et al (9) found that in Nepali adults, repeated portion-size estimation training over a 3-mo period (with 4 mo of follow-up testing) was necessary to achieve desirable estimation accuracy ($r = 0.96$ for estimated food weights compared with actual weights); however, trainees were asked to estimate portion sizes of >200 foods in grams rather than the household measures (such as cups) commonly used in the United States.

By using a 24-h dietary recall assisted by food records in third-grade children, Lytle et al (10) found that children were able to remember the foods they ate in a day, but they had difficulty quantifying portion sizes. The children recalled 628 out of 806 foods observed by adults (parents or staff members), a 78% match. Conversely, only 35% of recalled food portion sizes were within 10% of the observed portion sizes. Forty-two percent of recalled portion sizes were overestimated and 23% were underestimated. Overestimation of food quantities by >100% occurred in almost all of the 24 food groups . The observers were trained (for 6 h) in portion-size estimation skills, but the children were not trained.

Our proposed 4-step process for training children in portion-size estimation skills was designed to utilize quantification skills that second- and third-grade children are generally capable of mastering. The training resulted in a significant improvement in estimation ability, but it seems clear that more than one training session will be needed to further increase the accuracy of portion-size estimation in children of this age.

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