ABSTRACT

Several factors influence children’s ability to report accurate information about their dietary intake. To date, one understudied area of dietary assessment research relates to children’s ability to estimate portion sizes of food. The purpose of this cross-sectional research was to examine food portion size estimation accuracy in 7- to 18-year-old children with obesity. Two within-subject experiments (Experiment 1: n=28, Experiment 2: n=27) were conducted in Edmonton, Alberta, Canada, during 2007-2008. Three types of portion size measurement aids (PSMAs) (eg, measuring cups and spoons, household objects [full and half-sized], and modeling clay) were counterbalanced in a Latin Square design for participants to estimate four types of foods (ie, solid, liquid, amorphous pieces, and amorphous masses). Analyses of variance conducted on percent of signed and absolute errors yielded significant PSMA type×food type interactions (P<0.01) in both experiments. Across all food types, for Experiments 1 and 2, measuring cups and spoons produced the least accurate estimates (47.9% to 37.2%). Finally, there were significant differences in accuracy between amorphous pieces (eg, grapes) vs amorphous masses (eg, mashed potatoes; P<0.01), indicating that there are qualitative differences in how different amorphous foods are estimated. These data are relevant when collecting food intake data from children with obesity and indicate that different PSMAs may be needed to optimize food portion size estimation accuracy for different food types.


Expert recommendations (1) and clinical practice guidelines (2) for managing pediatric obesity emphasize the importance of making healthy dietary changes. To assess obese children’s dietary intake, registered dietitians often collect dietary data from children and their parents to complete a nutrition assessment that includes a food record or dietary recall. Retrieving the most accurate dietary information possible helps determine recommendations, goal-setting, and follow-up planning. However, achieving an acceptable degree of accuracy from dietary assessments remains a challenge (3), especially when individuals report incorrect portion sizes (4,5). For example, chronic exposure to large portion sizes of food may lead to the normalization of high energy intakes (6,7). Health Canada’s Eating Well with Canada’s Food Guide (8) provides information on standardized serving sizes, but anecdotal experience suggests that, in general, self-selected portion sizes by children and their families can be much larger than those currently recommended. These observations highlight the potential value of portion size measurement aids (PSMAs) in helping individuals to accurately estimate volumes of food.

A number of PSMAs (eg, measuring cups and spoons, household objects [ie, deck of cards], and photographs of foods) are available to estimate volumes of food and inform portion size decisions and descriptions. There is a high level of interest in food portion size and its influence on obesity and weight management (7) because accurate knowledge about what constitutes an appropriate portion size for a variety of foods is an important aspect of successful weight management (6). However, there has been little study in the area of portion size estimation in children with obesity, and few comparisons between different estimation methods. Given children’s autonomy to make healthy nutrition choices for weight management, re-
search with children with obesity can identify whether PSMAs can minimize measurement error and maximize estimation accuracy.

In the context of assessing dietary intake, there are many factors that can influence a child's perception (9-12) and memory. For example, children’s cognitive abilities are relatively underdeveloped, so they may be less accurate than adults when recalling dietary intake and food portions from memory (13,14); they may also not be adept at inferring fractional sizes of whole objects (eg, half of one tennis ball). In addition, household PSMAs have meaning with respect to their actual functions, but children may not be able to dissociate the functional use of an object with its use as a PSMA. With these issues in mind, children may have a reduced ability to accurately estimate food portion sizes, so one or more different PSMAs may help to improve estimation accuracy.

There were three objectives of this study. The first aim was to examine estimation accuracy using different PSMAs. In Experiment 1, estimation accuracy was compared across measuring cups and spoons, household objects, and modeling clay (Play-Doh, Hasbro, Inc, Pawtucket, RI). Because modeling clay is pliable and normally used to represent other objects, it has no particular a priori associations and should help produce more accurate estimates than the other two PSMAs. In Experiment 2, participants were given the further choice of using whole and/or half sizes of household objects, which may also improve estimation accuracy. Thus, the first hypothesis was that estimation accuracy differs among PSMAs, with modeling clay and availability of half sizes of household objects yielding the highest degrees of estimation accuracy.

The second aim was to examine if estimation accuracy varied according to food type. That is, dietetics practitioners have traditionally divided foods into solid, liquid, and amorphous categories (15,16). The second hypothesis was that participants’ estimation accuracy would vary across these three food types because they provide different perceptual challenges.

The third aim was to examine if amorphous foods can be further subdivided into two distinct types that in themselves provide different perceptual challenges. For example, some amorphous foods come in pieces that can be eaten one at a time (eg, baby carrots) whereas others are solid masses (eg, ice cream). In our study, the former are referred to as amorphous pieces and the latter as amorphous masses. The third hypothesis was that participants’ estimation accuracy would vary according to amorphous food type (masses vs pieces).

METHODS

Two independent, cross-sectional experiments using a three (PSMAs: measuring cups and spoons, household objects, and modeling clay)×four (food types: solid, liquid, amorphous masses, and amorphous pieces) within-subjects design were conducted from 2007 to 2008. The experiments differed only in terms of whether or not household objects were provided to participants as whole objects or as both whole and fractional objects; the experiments are described together for parsimony. This research received ethics approval from the University of Alberta Health Research Ethics Board. Informed consent and assent forms for parents and children, respectively, were completed by all participants before participating.

Participant Recruitment

A convenience sample of children with obesity participated in this research. For both experiments, the goal was to recruit at least 25 volunteers. Individuals were referred by local physicians for weight management to the Pediatric Center for Weight and Health, a multidisciplinary weight management clinic at the Stollery Children’s Hospital (Edmonton, Alberta, Canada). All children were invited to participate in this study except for those individuals who presented with cognitive impairments. Participants were eligible if they were aged 7 to 18 years and possessed an age- and sex-specific body mass index (BMI) ≥85th percentile (17). However, all participants had a BMI that exceeded the 95th percentile, which qualifies the sample as obese. Height was measured to the nearest 0.1 cm using a digital, wall-mounted stadiometer (SECA, Hanover, MD) and weight was measured to the nearest 0.1 kg using a digital medical scale (SECA, Hanover, MD); BMI and BMI percentile were then calculated using EpiInfo (version 3.3.2, 2005, Centers for Disease Control and Prevention, Atlanta, GA). Demographic and anthropometric data were collected in a standardized manner during children’s first or second clinical appointments (when this study was conducted) and were retrieved from participants’ medical records for this study. Participants performed the research procedures with registered dietitians (T.G.B. and B.N.B.) before they received any specific training or education on portion size estimation and before initiating weight management techniques.

Design

Each participant made three sets of estimates on the same foods. As shown in Figure 1, the PSMAs used were two sets of measuring cups and spoons, ranging in size.
from ½ tsp to 1 c; two sets of household objects in Experiment 1 and two sets of whole and half objects in Experiment 2; and 500 mL modeling clay. For each PSMA, the task was to select as many items or as much modeling clay as needed to match the amount of the given food item for that trial. PSMA type was counterbalanced in a Latin Square design and randomized in sets of three. Participants were assigned to their particular PSMA condition order in the order they came to the clinic. This quasi-random ordering scheme resulted in an approximately equal sex and age distribution across the three orders of estimation method.

The food types included 20 three-dimensional standardized food replicas (Nabisco Canada, Newmarket, Canada) (see the Table). Four of the items (one for each of the four food types) were always used as practice items, and the remaining 16 were used as test items (four per food type). The test food items for each of the three sets of estimates were given in the same randomized order, but a different random order was used for each participant. Thus, there was one instance of each food type for practice with each estimation method and four instances of each food type for each of the methods.

### Procedures

First, children rated their liking of all 20 food replicas using a developmentally appropriate, validated 5-point Likert scale survey (18). To simply familiarize participants with food items, each food was presented individually and the registered dietitians recorded participants’ responses, which varied from “I like it very much” (score=1) to “I dislike it very much” (score=5). Second, the registered dietitians placed the food replicas (which were hidden from view) one at a time on a white dinner plate that was placed in front of participants. Children then estimated the portion sizes of the food replicas using the three different PSMAs in their assigned order. The registered dietitians recorded participants’ responses; for all portion size estimation tasks, replicas were viewed but not handled by participants.

### Data Analysis

All statistical analyses were conducted using Systat software (version 11, 2004, Systat Software, Chicago, IL); $P<0.05$ was used throughout as the level of significance. Demographic data are reported as means±standard deviations. All portion size estimates were converted to volumes (milliliters) and were used to generate the following two variables that normalized for food size: Percent signed error ([estimated mL–actual mL]/actual mL×100%), computed separately for each item and then averaged across items, and percent absolute error, computed as the absolute values of the signed errors taken before averaging. Percent signed error takes direction into account, but can give a false reading of accuracy if errors are random in both directions; absolute error provides a measure of accuracy regardless of direction. Both measures were analyzed in two-way, within-subjects analyses of variance (ANOVA) with PSMA type and food type included as categorical factors. Planned contrasts on the difference in accuracy between the two types of amorphous foods (pieces vs masses) were also conducted. Neither age nor sex was included in the models because the Latin Square counterbalancing scheme and the quasirandom assignment to conditions meant that these variables were relatively evenly distributed across PSMA. Likeability ratings were not analyzed because the foods were selected nonarbitrarily to correspond to the four food types under investigation and also to be approximately the same range of sizes for each type (see the Table).

### RESULTS

#### Sample Characteristics

In Experiment 1, there were 28 participants (16 boys, 12 girls) ranging in age from 8 to 17 years (mean age 12.2±2.5 years); their average BMI percentile was 97.8±2.5. In Experiment 2, there were 27 participants (13 boys, 14 girls) ranging in age from 8 to 18 years (mean age 12.1±2.5 years); average BMI percentile was 98.7±0.8. All children in both experiments were white.

#### Experiment 1

The ANOVA on the percent signed error yielded a main effect of PSMA ($F[2,54]=21.99; P<0.0001$), a main effect of food type ($F[3,81]=5.80; P<0.001$), and a PSMA type×food type interaction ($F[6,162]=4.40; P<0.0001$) (see Figure 2). In general, measuring cups and spoons and household objects caused overestimations whereas modeling clay caused underestimates, although the degree of estimation error differed according to food type. The planned contrast on amorphous food type was significant ($F[1,27]=9.59; P<0.01$), providing evidence that amorphous pieces and masses were estimated with different degrees of accuracy.

| Table. Stimulus materials as a function of food type, food models used for each type, and size of each model in two experiments of food portion estimation by children with obesity |
|---|---|---|
| **Food type** | **Food** | **mL** |
| Practice-mass | Butter | 5 |
| Practice-solid | Bread (1 slice) | 50 |
| Practice-count | Pretzel sticks | 125 |
| Practice-liquid | Water | 375 |
| Liquid | Salad dressing | 15 |
| Liquid | Orange juice | 125 |
| Liquid | Grape juice | 187 |
| Liquid | Milk | 250 |
| Solid | Candy bar | 45 |
| Solid | Salmon | 90 |
| Solid | Chocolate cake | 140 |
| Solid | Steak | 250 |
| Mass | Peanut butter | 30 |
| Mass | Tuna | 62 |
| Mass | Spinach | 125 |
| Mass | Ice cream | 250 |
| Count | Almonds | 62 |
| Count | Green grapes | 125 |
| Count | French fries | 187 |
| Count | Raspberries | 250 |
The ANOVA on percent absolute error also yielded a significant PSMA type×food type interaction ($F[6,162]=3.16; P<0.006$). As shown in Figure 2, measuring cups and spoons tended to produce the largest absolute errors (especially for solids and amorphous masses) whereas modeling clay produced the smallest errors.

**Experiment 2**

Similar to Experiment 1, an ANOVA on the percent signed error yielded a main effect of PSMA ($F[2,52]=30.48; P<0.0001$), food type ($F[3,78]=13.56; P<0.0001$), and a PSMA type×food type interaction ($F[6,156]=3.72; P<0.01$) (see Figure 2). In addition, the planned contrast between amorphous foods (pieces vs masses) was significant ($F[1,26]=33.93; P<0.0001$), which confirmed the finding from Experiment 1 that amorphous pieces and masses were estimated with different degrees of accuracy.

For the percent absolute error, there was a main effect of PSMA ($F[2,52]=12.30; P<0.0001$), food type ($F[3,78]=11.45; P<0.0001$), and a PSMA type×food type interac-
tion \( (F[6,156]=3.20; \ P<0.01) \) (see Figure 2). In general, the overall pattern of error was the same across the three portion size estimation methods for both solid and liquid foods, but the pattern differed for amorphous pieces and masses. The planned contrast between amorphous pieces and masses foods was significant \( (F[1,26]=36.17; \ P<0.0001) \), as was the PSMA type x food type interaction when pieces and masses were considered exclusively \( (F[2,52]=9.70; \ P<0.001) \).

Examples of the PSMA chosen to estimate a 120-mL model of green grapes for one male 8-year-old in Experiment 2 were: \( 1/3 \) c from the measuring cups and spoons, one half of a deck of cards from the household objects, and 5 mL modeling clay. The same individual, when estimating a 240-mL portion of ice cream, chose \( 1 \) c from the measuring cups and spoons, two one-half pieces of a hockey puck from the household objects, and 80 mL modeling clay. For household objects, participants were not confined to selecting only one object type; for instance, a different participant in Experiment 2 chose one compact disc, one half of a hockey puck, and one half of a deck of cards to estimate a 240-mL model of steak.

**DISCUSSION**

Findings from both experiments highlight the influence that different PSMAs and food types have on the ability of children with obesity to accurately estimate portion sizes. These observations support all three of the study hypotheses. First, the use of modeling clay and half sizes of household objects improved estimation accuracy for some (but not all) food types. At this time, these tools are less commonly used by dietetics practitioners during dietary assessments; the one study that did use modeling clay was a dietary recall and the efficacy of the clay was not reported separately from the other craft objects used (19).

Our findings suggest there may be merit in adding modeling clay and half sizes of household objects to collections of portion size estimation tools. Second, for both signed and absolute errors, there was a significant interaction between PSMA type and food type, which indicates that different food types are estimated to differing degrees of accuracy as a function of PSMA type. This suggests that using a single PSMA type to estimate portion sizes of different food types will fail to minimize the potential bias associated with estimation error. Finally, foods categorized as amorphous pieces and amorphous masses were estimated with different degrees of accuracy. Given that pieces and masses tend to be grouped as a single amorphous food category (16,20), the data suggest that examining the two different amorphous food types separately during dietary assessments of children with obesity may have a positive effect on portion size estimation accuracy.

Several recent reports have investigated different aspects of portion size estimation in children. However, making between-study comparisons in the area of children’s portion size estimation is limited by a number of issues, including methodological differences in estimation tools, a lack of uniformity in how accuracy is quantified across studies, variability in age/cognitive development of study samples, and differences in foods used for estimation tasks (19-21). For example, Foster and colleagues (22) had children estimate the amount of food on a plate that was right in front of them using photographs of food. The findings from this study revealed that only 43% of children’s estimates were within 30% of the actual portion size and that estimation accuracy differed according to food type, although they were unable to identify a discernable pattern related to food morphology. In an earlier study (21), the same researchers showed that both children and adults tended to overestimate portion sizes (46% and 18%, respectively) using photographs of food; however, once children were given age-appropriate photos that included child-sized portion sizes, their degree of accuracy improved dramatically (to 7% portion size over-estimation), a finding that supports the value of using age-appropriate estimation tools. Although adult data are not available to use for comparison purposes, data from children with obesity in our report suggest that modeling clay and household objects (whole and half-sized) are superior, age-appropriate PSMAs compared with measuring cups and spoons.

Although some researchers have shown that younger populations tend to underestimate portion sizes (20), others have demonstrated that overestimation is more common (23). These differences could be the result of numerous factors, but it is important to consider the degree and acceptability of under- and/or overestimation of portion sizes. Data from our study showed that percent absolute errors exceeded 30% across all PSMA and food types when the foods were in sight. When dietary recalls are taken, errors may be even greater.

Differences in estimation accuracy as a function of food type and PSMA type have direct implications for both nutrition research and nutrition counseling for weight management. For example, some studies may require precise and accurate measurements of all types of foods and beverages consumed and thus a greater degree of agreement between actual and estimated intakes. Similarly, some dietetics practitioners will require a precise estimate of clients’ intakes when individuals are following intensive and structured meal plans. In both these cases, researchers and dietetics practitioners may wish to try modeling clay and half sizes of household objects to increase estimation accuracy. Understanding how different PSMAs afford different estimation accuracies as a function of food type should thus help both researchers, dietetics practitioners, and clients gauge the effects of dietary intakes (and changes) on weight loss and obesity-related comorbidities (eg, dyslipidemia).

Our research has a number of noteworthy strengths. For example, the within-subjects study design provided adequate statistical power to obtain and replicate the findings, so the second experiment served to confirm the observations obtained in the first experiment. Further, the novel elements incorporated into this research (ie, including modeling clay and half-sized household objects and subcategorizing amorphous foods) extended the existing literature in dietary assessment methodology. However, there are also limitations to acknowledge. The study samples were relatively small, comprised a range of ages, and included exclusively white boys and girls with obesity. These issues highlight the need to extend this line of research to include other groups (eg, adults with overweight and obesity, individuals from varying cultural groups, and children without overweight) to explore the degree of consistency with our findings. In addition, the
decision to include food replicas (in lieu of real food) was a pragmatic one. Using food replicas on hand minimized study expenses and time related to purchasing, preparing, and storing food. It is unknown if individuals’ estimation accuracy varies according to the realness or appearance of the food they are estimating. Finally, there remained a high degree of error in children’s ability to accurately estimate portions from perception. This underscores the limitations inherent in reporting dietary intake data from memory and supports the application of innovative technologies (eg, smartphones) that may be able to minimize this type of reporting error (24).

CONCLUSIONS

Our study demonstrates that PSMA type and food type (and type of amorphous food, in particular) influence the ability of children with obesity to accurately estimate visible portion sizes. Modeling clay and half sizes of household objects might thus be incorporated more often into dietary assessments. That said, future research is needed to confirm these observations in other groups (ie, adults with obesity, non-whites, and children without overweight), in other contexts (ie, real food vs food replicas), and using cognitive challenges other than estimating from direct perception (ie, estimating foods from memory) to establish if our findings can be generalized to other populations and settings.

STATEMENT OF POTENTIAL CONFLICT OF INTEREST:

No potential conflict of interest was reported by the authors.

FUNDING/SUPPORT: This research was funded by a grant to A.F. from the Natural Sciences and Engineering Research Council of Canada, a Population Health Investigator Award from Alberta Innovates-Health Solutions, and a New Investigator Award from the Canadian Institutes of Health Research to G.D.C.B.

ACKNOWLEDGEMENTS: The authors thank the children and families who participated in this study as well as the staff at the Pediatric Centre for Weight and Health for their administrative and research support.

References