HHS Public Access

Author manuscript

Physiol Behav. Author manuscript; available in PMC 2017 August 01.

Published in final edited form as:

Physiol Behav. 2016 August 1; 162: 18–26. doi:10.1016/j.physbeh.2016.02.019.

Double trouble: Portion size and energy density combine to increase preschool children's lunch intake

Samantha M.R. Kling, **Liane S. Roe**, **Kathleen L. Keller**, and **Barbara J. Rolls**

Department of Nutritional Sciences, The Pennsylvania State University, University Park, PA (SMRK, LSR, KLK, BJR)Department of Food Science, The Pennsylvania State University, University Park, PA (KLK) Kling, Roe, Keller, Rolls

Abstract

Background—Both portion size and energy density (ED) have substantial effects on intake; however, their combined effects on preschool children's intake have not been examined when multiple foods are varied at a meal.

Objective—We tested the effects on intake of varying the portion size and ED of lunches served to children in their usual eating environment.

Design—In a crossover design, lunch was served in 3 childcare centers once a week for 6 weeks to 120 children aged 3 to 5 y. Across the 6 meals, all items were served at 3 levels of portion size (100%, 150%, or 200%) and 2 levels of ED (100% or 142%). The lunch menu had either lowerED or higher-ED versions of chicken, macaroni and cheese, vegetables, applesauce, ketchup, and milk. Children's ratings of the foods indicated that the lower-ED and higher-ED meals were similarly well liked.

Results—The weight of food and milk consumed at meals was increased by serving larger portions ($P<0.0001$) but was unaffected by varying the ED ($P=0.22$). Meal energy intake, however, was independently affected by portion size and ED (both $P<0.0001$). Doubling the portions increased energy intake by 24% and increasing meal ED by 42% increased energy intake by 40%. These effects combined to increase intake by 175±12 kcal or 79% at the higherED meal with the largest portions compared to the lower-ED meal with the smallest portions. The foods contributing the most to this increase were chicken, macaroni and cheese, and applesauce. The effects of meal portion size and ED on intake were not influenced by child age or body size, but were significantly affected by parental ratings of child eating behavior.

Conclusion—Strategically moderating the portion size and ED of foods typically consumed by children could substantially reduce their energy intake without affecting acceptability.

Corresponding Author: Dr. Barbara J. Rolls, Laboratory for the Study of Human Ingestive Behavior, The Pennsylvania State University, 226 Henderson Building University Park, PA 16802, Telephone: 814-863-8482, Fax: 814-863-8574, bjr4@psu.edu.

Research Registration: Registration number: NCT02299531 at http://www.clinicaltrials.gov/

Keywords

preschool children; energy intake; portion size; energy density; eating behavior; obesity

INTRODUCTION

Both the portion size and energy density (ED) of foods have robust effects on energy intake, and these two factors are often implicated as primary drivers of the obesity epidemic. In preschool children, serving larger portions has been consistently shown to increase energy intake (1–5). Less is known about the effects of ED on children's eating behavior, but the available data suggest that variations in ED have potent effects on energy intake (6–8), and higher-ED diets are associated with increased weight gain and weight status (9, 10). Although children are often exposed to multiple foods that are both large in portion size and high in ED, the potential of these properties acting together to influence consumption is not understood. To determine the combined effects of portion size and ED on energy intake, we systematically varied all the foods in a typical meal served in children's usual preschool environment.

Studies in adults have shown that portion size and ED have strong, independent effects that combine to increase energy consumption, but it is unclear whether young children respond similarly. Only two studies have examined the combined effects of portion size and ED at a meal in children (11, 12). One study found that both portion size and ED affected energy intake independently and that the effects combined (11), but another study found that only ED affected energy intake (12). In addition, these studies modified only the main dish, which does not represent children's current eating environment where multiple foods within a meal vary in both portion size and ED. To date, no research has tested whether children adjust their consumption in response to such variations in an entire meal. Most research has focused on how variations in portion size and ED affect intake of components of a meal such as main or side dishes, and few studies have examined these effects when all foods at a meal are varied (5, 7, 13). When children are served an entire meal of large portions of high-ED foods, they might adjust their intake by eating a smaller proportion of all items or by altering their food selection and eating less of the higher-ED options. If such self-regulation does not occur, however, the powerful effects of portion size and ED have the potential to substantially increase energy intake, especially when everything in a meal is changed simultaneously. Given the prevalence of large portions of highED foods (14, 15), it is essential to determine how these factors combine to influence food selection and energy intake in children.

Identifying children at risk for overeating when served large portions and higher-ED foods could lead to the development of targeted recommendations, and thus recent studies have focused on relating individual characteristics to variations in children's responses to these factors. The findings, however, have not led to clear and consistent predictors. In some studies, the response to larger portion sizes has been shown to be related to child age, weight status, or two sub-scales on the Child Eating Behaviour Questionnaire: satiety responsiveness and food responsiveness (1, 4, 5, 16, 17). In several other studies, however,

these characteristics did not influence the relationship between portion size and intake (2, 3, 6–8, 11, 12, 18, 19). Furthermore, there has been limited research on the influence of individual characteristics on the effects of ED. Since children are exposed to foods that differ in both portion size and ED, it is important to test the effect of individual characteristics when these factors are varied simultaneously.

The primary aim of this study was to examine the independent and combined effects on children's intake of changing the portion size and ED of all components of a meal. Using a 3-by-2 crossover design, we systematically varied the portion size and ED of commonly consumed items in a meal served in childcare centers. We hypothesized that increasing the portion size and ED of a meal would have independent effects that combine to increase children's energy intake (20, 21). To investigate whether the effects on intake varied across child characteristics or might differ for individual foods, we tested a larger sample of children than has been previously tested (1–8, 11–13, 16, 18, 19). Determining how typical variations in the portion size and ED of a meal influence preschool children's energy intake is essential in order to understand the environmental factors that affect children's food intake and to develop practical strategies to counter these effects.

SUBJECTS AND METHODS

Experimental design

A within-subjects crossover design was used to evaluate the effect on intake of increasing the ED and portion size of all foods and milk served to preschool children at lunch. On 1 day a week for 6 weeks, the experimental meal was served to children in their classrooms at 3 childcare centers. Across the 6 meals, all foods and milk were served at 3 levels of portion size (100%, 150%, or 200% of reference amounts) and 2 levels of energy density (100% or 142%) and were consumed ad libitum (Figure 1). The order of the six conditions was counterbalanced across classrooms using Latin squares, and classrooms were randomly assigned one of the condition sequences using a random number generator. Since the children were only served one experimental meal per week, they never saw the different meals together. The children's height, weight, and liking of the study foods were assessed after the final experimental meal.

Participant recruitment

Children were recruited by giving letters to parents with 3- to 6-year-old children enrolled at three childcare centers near University Park, PA. Parents provided written consent for the participation of their child in the study as well as their own participation in completing questionnaires. Children with a parentally reported allergy or intolerance to the foods or milk being served were not eligible to participate in the study. Neither parents nor children were informed about the purpose of the study. All procedures were reviewed and approved by The Pennsylvania State University Office for Research Protections.

A power analysis was conducted to determine the number of children needed for the study, based on previous research in a similar population with a similar meal. A clinically significant difference in energy intake was considered to be 48 kcal, which is approximately

15% of typical lunch intake in this population. A power analysis showed that a sample size of 58 children would allow detection of this difference at a significance level of 0.05 and power of 80%. To explore the effect of individual characteristics on the primary outcomes, we enrolled 131 children, which is larger than the sample sizes of previous controlled studies of portion size or ED (1–3, 5–8).

Experimental menu and meal procedures

Experimental menu—The experimental meal consisted of chicken (grilled breast or breaded nuggets), macaroni and cheese, a green vegetable (broccoli or peas), applesauce, ketchup, and milk. This menu was chosen because the foods and milk naturally vary in energy density (ED), are commercially available, and are commonly consumed by preschool children. Across meals, all foods and milk were served at 3 levels of portion size (100%, 150%, or 200%) and 2 levels of ED (100% or 142%) (Figure 1). In the 100% (reference) portion size condition, the amounts of each food and beverage served were based on preschool children's intake in previous studies (7, 12, 19) and met the minimum recommendations from the Child and Adult Care Food Program (22). The larger portions of each food and milk were chosen to be 150% and 200% the size of the reference portion. As described in Table 1, ED was modified primarily by using products and recipes that differed in fat and sugar content. The 42% increase in ED was matched across all items served at the meal; this increase was based on the ED difference between the two types of milk. In addition to milk, children were provided 237 mL of water that was not varied in portion size or ED. The lower-ED meal had 38% of energy as carbohydrates, 34% as protein, and 27% as fat; the higher-ED meal had 41% of energy as carbohydrates, 21% as protein, and 38% as fat.

Meal procedures—Children consumed the experimental meals *ad libitum* in their usual classrooms in the child care centers and at their regularly scheduled lunchtime. Children ate at tables with the same group of three to six children and one adult, which is standard practice at the child care centers. Foods and beverages were pre-portioned into dishware and then set at each child's place at the table before the children were seated. Before the first experimental meal, researchers explained to the children that they could eat as much or as little as they wanted, but could not request more of any food or beverage. During each meal, adults, including teachers and undergraduate research assistants who did not know the purpose of the study, were instructed to redirect conversations about food-related topics to minimize peer influence on children's lunch intake. After all children had finished lunch, researchers returned any dropped and spilled foods to the correct plate or bowl and recovered any spilled beverage with paper towels. To determine the amount consumed, all foods and beverages were weighed before and after the meal in a separate room out of the children's view. Food weights were recorded to the nearest 0.1 g using digital scales (Mettler-Toledo PR5001 and XS4001S; Mettler-Toledo, Columbus, OH). Energy and nutrient intakes were calculated using information from food manufacturers and a standard food composition database (23). Children in the classrooms who did not participate in the study sat at tables out of the view of participating children and were served the childcare center's scheduled lunch menu.

Assessments

Food liking assessments—Liking for the experimental foods and milk was assessed during an individual session with each child using a 5-point cartoon face scale based on a 3-point version used in previous research (24–26). The child was seated at a table with the 5 cartoon faces and was instructed on using them to indicate whether a food was "super yummy," "yummy," "just okay," "yucky," or "super yucky." After instruction, samples of each food and beverage were presented to the child one at a time; the condiment (ketchup) was not assessed since it was a minor component of the meal and is not usually consumed alone. The order of presenting the samples of the five items was randomized and within each item the low-ED and high-ED versions were also presented in a random order. The children were asked to taste the food or milk and indicate their liking for it by pointing to the appropriate cartoon face. Children's liking for the foods and milk was assessed within 2 weeks after the final experimental meal. Food liking assessments were completed by 93 (78%) of the children; the remaining children were absent or declined to participate.

Body weight and height—Body weight was measured to the nearest 0.1 kg using a portable digital scale (Seca Onda model 843; Seca Corporation, Hanover, MD). Height was measured in duplicate to the nearest 0.1 cm using a portable stadiometer (model 214; Seca Corporation, Hanover, MD). Body weight and height were used to calculate body size parameters (sex-specific BMI-for age-percentiles and z-scores) using a software program based on nationally representative data (27). Children with sex-specific BMI-for-age percentiles $\geq 85^{th}$ or $<95^{th}$ percentile were classified as overweight and those with percentiles $\geq 95^{th}$ were classified as obese. Estimated daily energy requirements were calculated using equations for children ages 3 through 5 years with light activity levels (28). Children's weight and height were assessed within 2 weeks after the final test meal. One hundred and five children (88%) completed the assessments for height and weight; the remaining children were absent or declined to participate.

Parental questionnaires—Parents were asked to complete three questionnaires about parent and child characteristics and behaviors related to the eating environment. The 35-item Child Eating Behaviour Questionnaire (CEBQ) evaluates 8 subscales that relate to eating styles and behaviors of the child (29, 30). Example items include "My child is always asking for food" from the 5-item food responsiveness subscale, and "My child gets full before his/her meal is finished" from the 5-item satiety responsiveness subscale. The 31-item Child Feeding Questionnaire (CFQ) assesses 7 subscales that measure perceived weight concerns and feeding practices (31, 32). An example from the 3-item monitoring subscale is "How much do you keep track of sweets (candy, ice cream, cake, pies, pastries) that your child eats?" For these CFQ and CEBQ subscales, the parent rated each item on a 5-point frequency scale (1=never, 5=always); for analyses, a mean score was calculated across all the items in a given subscale. The 16-item demographic questionnaire assesses family demographics and child health. Parents of 106 children (88%) completed the three questionnaires.

Statistical analysis

Data analyses were conducted using a mixed linear model with repeated measures (SAS version 9.4; SAS Institute, Inc., Cary, NC) for the outcomes of total meal intake and intake of the individual foods and milk, both by weight (g) and energy (kcal). Fixed factors in the model were meal portion size (100%, 150%, or 200%), meal ED (100% or 142%), study week, and classroom. All interactions were tested and then removed from the model if not significant. Subjects were treated as a random factor. For outcomes with significant effects, the Tukey-Kramer method was used to adjust significance levels for multiple pairwise comparisons between means. Children who were absent for 3 or more conditions were excluded from analyses. The procedure described by Littell et al. was used to identify children whose intakes were influential on the main outcomes on the basis of extreme values for the restricted likelihood distance (33); no intakes were found to meet the pre-determined criteria.

Analysis of covariance was used to assess the influence of continuous subject characteristics (age, body weight, height, BMI percentile, BMI z-score, CFQ subscales, and CEBQ subscales) on the relationship between ED, portion size, and total meal intake; the children's sex was also tested as a factor in the models. All subject characteristics were tested simultaneously in the final models. Children's ratings of liking for each food were tested as a categorical factor in the model for intake of that food. Ordinal repeated measures logistic regression was used to compare the lower-ED and higher-ED meals as well as individual meal items for differences in the distribution of children's liking ratings; results are reported as odds ratios with 95% confidence levels. *T*-tests were used to evaluate differences between boys and girls in age, body weight, height, BMI percentile, and BMI z-score. Data are reported as means ± standard errors, and results were considered significant at $P<0.05$.

RESULTS

Subject characteristics

A total of 131 children from 11 classrooms at the 3 childcare centers were enrolled in the study from May 2013 to July 2014. Eleven children were excluded from the analysis because they were absent for 3 or more of the 6 experimental meals. Thus, intake data was analyzed for 120 children (61 boys and 59 girls). The children had a mean age of 4.4 ± 0.1 years and a mean sex-specific BMI-for-age percentile of 56.8 ± 2.6 (Table 2). Fifteen children (14%) were classified as overweight or obese. The sample of children was 69% white, 21% Asian, 3% black or African American, and 7% of mixed or another race; 4% were of Hispanic or Latino origin. Based on the 106 parents (88%) who provided family information, household incomes and education levels were above average: 69% of households had an annual income of above $50,000 and 92% of mothers and 90% of fathers had a Bachelor's degree or higher.

Food and energy intakes

Weight of food and milk—There was a significant effect of portion size ($P<0.0001$) but not ED ($P=0.22$) on the weight of the meal consumed (Figure 2A). Compared to the 100% portion size conditions, meal intake was 21% (60 ± 7 g) greater in the 150% portion size

conditions and 26% (74 ± 7 g) greater in the 200% portion size conditions (both P<0.0001). Mean intakes in the 150% and 200% conditions did not differ significantly from each other (P=0.19). A similar weight of food and milk was consumed at the lower-ED and higher-ED meals (328 ± 11 vs. 321 ± 10 g; P=0.22).

The effects of portion size and ED on intake differed for each of the individual foods and milk served at the meal. Portion size had significant effects on the intake of macaroni and cheese, applesauce, milk, and ketchup (all P<0.02; Table 3), but had no effects on intake of chicken or vegetables (both P>0.53). For example, doubling the meal portion size increased intake of macaroni and cheese by 31%, applesauce by 64%, and ketchup by 49%. Energy density had significant effects on the weight consumed of chicken and macaroni and cheese (P<0.0001; Table 3), but had no significant effects on intake of the other foods or milk (all P>0.06). Compared to the lower-ED standard macaroni and cheese, children consumed 21% less of the macaroni and cheese with added fat; compared to the lower-ED grilled chicken, children consumed 53% more of the breaded chicken.

Energy intake—The portion size and energy density of the meals had significant and independent effects on preschool children's energy intakes at lunch (Figure 2B; both P<0.0001). Compared to the 100% portion size conditions, meal energy intake increased by 18% (49 ± 7 kcal) and 24% (66 ± 8 kcal) when children were served the 150% and 200% portion conditions, respectively (both P<0.0001). Meal energy intake at the 150% and 200% conditions did not differ (P=0.09). Increasing meal ED by 42% led to a 103 ± 7 kcal or 40% increase in energy intake at the meal (P<0.0001). The effects of portion size and energy density combined to increase meal energy intake by 79% or 175 ± 12 kcal when the children were served the higher-ED meal with the largest portions compared with the lower-ED meal with the smallest portions (Table 3). Children consumed 20.8 ±0.9% of their estimated daily energy requirements from the smallest portion of the lower-ED meal compared to 35.9 ± 1.4% of their requirements from the largest portion of the higher-ED meal.

The effects of portion size and ED on energy intake differed for each of the individual foods and milk (Table 3). Serving larger portions led to increased energy intake from macaroni and cheese, applesauce, milk, and ketchup (all P<0.03), but had no effect on the amount of energy consumed from chicken or vegetables (both P>0.44). For example, doubling the meal portion size increased energy intake from macaroni and cheese by 31% and applesauce by 63%. Varying the ED of the foods and milk significantly affected the amount of energy consumed from all of these items (all P<0.02). The increased energy intake from the largest portion of the higher-ED meal compared to the smallest portion of the lower-ED meal (175 kcal) was primarily attributable to greater energy intake from the breaded chicken nuggets (60 ± 9 kcal; 34% of the increase), macaroni and cheese with added fat (42 ± 5 kcal; 24%), and sugar-sweetened applesauce (46 ± 4 kcal; 26%).

Energy density—The ED of the food and milk consumed at the meal did not differ by meal portion size (P=0.57), but it was significantly affected by the meal ED served (P<0.0001). ED of food and milk averaged 0.80 ± 0.01 kcal/g at the lower-ED meals and 1.14 ± 0.02 kcal/g at the higher-ED meals (Table 3). Thus, when the ED of the foods and milk served was increased by 42%, the ED consumed at the meal increased by 42%. This

indicates that children did not shift their overall ED of the meal by changing their selection or intake of the individual items to adjust for increases in meal ED.

Macronutrient intake and composition—The portion size and energy density of the meals had significant and independent effects on preschool children's intake of carbohydrate, sugar, and fat (all P<0.0001; Table 3), but only portion size significantly affected protein intake (P=0.01). Compared to the 100% portion size conditions, carbohydrate intake (including sugar) increased by 36%, sugar increased by 42%, fat increased by 19%, and protein increased by 7% when children were served the 200% conditions (all P<0.0001). Increasing meal ED led to a 32% increase in carbohydrate intake (including sugar), a 35% increase in sugar intake and a 94% increase in fat intake (all P<0.0001), but did not affect protein intake (P=0.07).

Food liking ratings

Figure 3 shows the distribution of food liking ratings for the 93 children who completed this assessment. When all the items were considered together, ordinal logistic regression indicated that there was no significant difference in the distribution of liking ratings between the lower-ED and higher-ED meals (P=0.15); the odds ratio was not significantly different from 1.0 (mean 1.22 [95% confidence interval 0.93–1.60]). Likewise, there were no significant differences in the distribution of liking ratings between the lower-ED and higher-ED versions of the individual foods and milk (all P>0.05). Thus, even though children's intake of the chicken and macaroni and cheese differed by ED, their liking ratings did not. All the foods and milk were well-liked; children chose "super yummy" or "yummy" ratings in 73% of the assessments for chicken, 70% for macaroni and cheese, 70% for vegetables, 83% for applesauce, and 76% for milk. Applesauce was the most likely to be rated as "super yummy" and vegetables were the least likely (P=0.02). The children's liking ratings of the foods did not influence the effects of portion size and ED on intake of the individual foods.

Influence of subject characteristics

Analysis of covariance showed that the relationship between the portion size or ED and meal intake by weight and energy was not influenced by children's sex, age, height, body weight, sex-specific BMI-for-age percentile, or BMI z-score. Most of the subscales of the Child Eating Behaviour Questionnaire (CEBQ), including satiety responsiveness, and the Child Feeding Questionnaire (CFQ) did not influence the relationship between the experimental variables and meal intake; however, a few of the subscales did affect these relationships as described below.

Parental ratings of the children's food responsiveness (a 5-item subscale on the CEBQ) significantly affected the relationship between portion size and meal intake by weight (Figure 4; P<0.01). Children who were rated as being more responsive to food had larger increases in intake when served the 150% and 200% portions of the meal than children who were less responsive. When portion sizes were doubled, children with a food responsiveness score of 1 (frequency of responsive behavior = never) increased their meal intake by a non-significant mean of 29 grams, whereas children with a score of 4 (frequency = often) increased their intake by 124 grams. Thus, although most children had increased intake

when served larger portions, children whose parents rated them as the most responsive to food showed an even stronger portion size effect. In addition, ratings of use of parental monitoring on the CFQ significantly affected the relationship between portion size and meal intake; children with the least parental monitoring did not have increased intake when served the 200% portion compared to the 100% and 150% portions ($P<0.02$). For the relationship between meal ED and intake, only ratings of child enjoyment of food on the CEBQ significantly affected the relationship ($P<0.01$); children with highest scores ate more of the lower-ED meal than the higher-ED meal.

DISCUSSION

Variations in the portion size and ED of all foods served at a meal in childcare centers had substantial effects on energy intake of preschool children. The weight consumed of the meal was affected by portion size but not by ED; in contrast, energy intake was independently affected by both properties. When meal portion size and ED were increased simultaneously, the two factors combined to increase children's meal intake by 175 kcal or 79%. Both the lower-ED and higherED meals were well accepted, as indicated by the children's ratings of liking and the consumption of a similar weight of the same portions. These results show that changes in meal portion size and ED have potent effects on children's energy intake and demonstrate that reductions in ED and portion size can moderate these effects without a loss of acceptability.

The combined effects of portion size and ED on intake of multiple items at a meal have not previously been investigated in preschool children. Two studies varied both these factors in a single dish served to children and found inconsistent effects on consumption (11,12). One study found independent effects of doubling the portion of the main dish while also increasing its ED (11), and the other found no effect of a 25% change in the portion of the main dish but a significant effect of changing the ED (12). The lack of a portion size effect in the latter study may have been due to the modest difference that was tested or because even the smallest portion was overly large for the children (34). The results of the present study indicate that when all foods in a meal are varied, children show little evidence of compensatory adjustment to changes in portion size and ED, and these food properties have independent effects that combine to affect energy intake. This is of concern because children are often exposed to large portions of multiple higher-ED foods at a meal; in the longer term, such exposure has the potential to promote overconsumption and lead to excess weight gain.

Strategies to moderate the energy intake of preschool children need to address both meal portion size and ED, since these two powerful factors combine to increase intake. The existing data, however, suggest that reducing ED may be the more effective strategy. The present study found that a 42% increase in ED of all foods increased energy intake by 40%. Likewise, within the range of ED tested, researchers generally find that a given percentage change in ED leads to an equivalent percentage change in energy intake of the varied foods (6–8, 35–37). For example, a 27% decrease in the ED of multiple meals served to preschool children reduced energy consumption at those meals by 25%, which was sustained over 2 days (7). In contrast, the relationship between portion size and intake is curvilinear (34, 38); thus, changes in portion size have proportionally smaller effects on intake than changes in

ED. A 100% increase in portion size increases intake by substantially less than 100%, ranging from 21% to 53% in controlled studies (39) and averaging 24% in the present study. These results suggest that reducing the ED of foods and beverages would lead to more robust reductions in energy intake than similar percentage reductions in portion size, which may be more noticeable and difficult to implement and maintain (40–43).

Interventions to modify portion size and ED should take into account the individual meal components, which can have differential effects on both energy intake and diet quality. In particular, alterations in main dishes should be a primary target of these strategies, since they usually contribute the largest proportion of meal energy (1, 5, 16, 40, 44). Side dishes, however, also play a role (8, 17, 45–47). In this study, larger portions of applesauce promoted energy intake, but if equally palatable, lower-ED versions were served instead of higher-ED, sweetened versions, fruit intake and nutrient density of the diet could be improved with smaller increases in energy consumption. In the present study, serving larger portions of vegetables did not increase vegetable intake or energy intake. Since vegetables were the least likely food to be rated as “yummy” or “super yummy”, increasing the palatability or preference for the vegetables might improve intake (34, 47). Within a complex meal, serving larger portions of fruit and vegetables can be an effective strategy to increase intake; however, consideration needs to be given to the portions of main dishes, the other options in the meal, and the palatability of the foods (47).

Most of the children’s characteristics, including sex, age, body size, and satiety responsiveness, did not influence the effects of portion size and ED on intake, in contrast to some findings from previous studies (1, 4, 5, 16, 17). This disparity may be due to differences in study design; for example, in studies that found an effect of age, the portion sizes were tailored to different age groups (1, 4), whereas in the present study, the same portions were served to all children. Differences in the distribution of child characteristics may also explain their differential influence across studies. In particular, studies that reported an influence of weight status or satiety responsiveness on the portion size effect had a larger proportion of children who were overweight or obese or of lower-socioeconomic status than the sample in the current study (5, 16, 17). However, similar to a previous study (5), we found that children with higher scores for food responsiveness increased their intake of large portions to a greater extent than children with lower scores. The comparable findings across studies suggest that responsiveness to food cues may predict the degree of susceptibility to portion size. The present study suggested that low parental monitoring may lead children to be less responsive to very large portions; however, this effect was not consistent in the two larger portion conditions (150% and 200%) and thus the practical implication of this effect is not clear. In addition, individual characteristics have not been found to substantially influence the effect of ED on intake, but future research should explore how children’s enjoyment of food influences their intake of foods that vary in ED (6–8). Despite differences in response, most of the children tested were susceptible to the effects of both portion size and ED, which indicates that recommendations focusing on these factors should be widely disseminated.

A strength of the present study is the large sample of children whose eating behavior was assessed. Previous studies investigating the effects of portion size or ED with a crossover

design have included an average of 55 children (1–8, 11–13, 16, 18, 19), and only one study of 172 children (4) had a sample size larger than the present study (120 children). A further strength was that the lunch was served in the children's usual environment, and included popular, commonly consumed foods that had typical variations in portion size and ED. In addition, the lower-ED and higher-ED versions of the meals were similar in palatability. Thus, the setting and the meal were generalizable to a wide range of children. However, the meal was pre-plated instead of served family style, a typical practice of childcare centers. To further assess the generalizability of the findings, the effects of portion size and ED should be investigated using family style meals. In addition, intake was measured at a single meal and the effect of meal portion size and ED on later intake was not investigated. Future research should be conducted for longer periods of time on different populations to extend these findings and determine if children adjust for variations in meal portion size and ED at later meals. Previous research suggests the effects of portion size persist up to 24 hours and those of ED up to 2 days (3, 7), but the combination of these factors has not been investigated beyond a single meal in children.

Varying the portion size and ED of multiple items at a meal had a greater effect on energy intake than previously found in studies that manipulated only one of these factors or one food; these changes in all foods led children to consume a sizeable proportion (about 36%) of their estimated daily energy needs at a single meal. This demonstrates that strategically changing portion size and ED of a variety of foods and beverages should be a focus of obesity prevention initiatives at both individual and public levels. In particular, reducing the ED of foods and beverages should be a priority in developing strategies, since modest changes in ED have a large impact on intake and are unlikely to be noticed by most children or adults (6–8, 20, 21, 17).

There are several effective strategies to reduce the ED of meals while maintaining palatability; for example, recipes can be modified by reducing the fat or sugar content or adding water-rich ingredients, including fruits and vegetables (6–8, 37). Another option is choosing palatable lower-ED, commercially available products (such as the unbreaded, grilled chicken pieces and reduced-sugar applesauce used in this study), which may be a more practical strategy for caregivers. With acceptable recipes and products, strategies to reduce ED can be implemented in homes, restaurants, and childcare settings, and can be strategically combined with the beneficial effects of reductions in portion size, for example by serving larger portions of lower-ED foods with smaller portions of higher-ED foods (48). These strategies to moderate the effects of portion size and ED are practical and effective in reducing energy intake; however, caregivers need clear guidance and acceptable products to implement such strategies and counter these pervasive environmental influences.

Acknowledgments

We thank Charlotte Dupont, Brittany James, Alicia Leitch, Cara Meehan, Christine Sanchez, Anne Vos, Faris Zuraikat, and undergraduate students in the Laboratory for the Study of Human Ingestive Behavior for assistance with food preparation and data collection. In addition, the support and participation of staff, parents, and students at the Bennett Family Center, The Child Care Center at Hort Woods, and Step by Step School for Early Learning is greatly appreciated.

The authors' responsibilities were as follows–SMRK: the design of the experiment, collection and analysis of data, and writing of manuscript; LSR: the design of the experiment, analysis of data, and writing of the manuscript; and KLK and BJR: the design of the experiment and the writing of the manuscript. None of the authors had a personal or financial conflict of interest. Supported by NIH Grant R01-DK082580 and USDA National Institute for Food and Agriculture Grant 2011-67001-30117 Program A2121.

Supported by NIH Grant R01-DK082580 and USDA Grant 2011-67001-30117

Abbreviations

ED	energy density

References

1. Rolls BJ, Engell D, Birch LL. Serving portion size influences 5-year-old but not 3-year-old children's food intakes. J Am Diet Assoc. Feb.2000 100:232–4. [PubMed: 10670398]
2. Fisher JO, Rolls BJ, Birch LL. Children's bite size and intake of an entree are greater with large portions than with age-appropriate or self-selected portions. Am J Clin Nutr. May.2003 77:1164–70. [PubMed: 12716667]
3. Fisher JO, Arreola A, Birch LL, Rolls BJ. Portion size effects on daily energy intake in low-income Hispanic and African American children and their mothers. Am J Clin Nutr. Dec.2007 86:1709–16. [PubMed: 18065590]
4. Smith L, Conroy K, Wen H, Rui L, Humphries D. Portion size variably affects food intake of 6-year-old and 4-year-old children in Kunming, China. Appetite. Oct.2013 69:31–8. [PubMed: 23702260]
5. Mooreville M, Davey A, Orloski A, Hannah EL, Mathias KC, Birch LL, Kral TV, Zakeri IF, Fisher JO. Individual differences in susceptibility to large portion sizes among obese and normal-weight children. Obesity (Silver Spring). Apr.2015 23:808–14. [PubMed: 25683105]
6. Leahy KE, Birch LL, Fisher JO, Rolls BJ. Reductions in entree energy density increase children's vegetable intake and reduce energy intake. Obesity (Silver Spring). Jul.2008 16:1559–65. [PubMed: 18451770]
7. Leahy KE, Birch LL, Rolls BJ. Reducing the energy density of multiple meals decreases the energy intake of preschool-age children. Am J Clin Nutr. Dec.2008 88:1459–68. [PubMed: 19064504]
8. Spill MK, Birch LL, Roe LS, Rolls BJ. Hiding vegetables to reduce energy density: an effective strategy to increase children's vegetable intake and reduce energy intake. Am J Clin Nutr. Sep.2011 94:735–41. [PubMed: 21775554]
9. Johnson L, Mander AP, Jones LR, Emmett PM, Jebb SA. Energy-dense, low-fiber, high-fat dietary pattern is associated with increased fatness in childhood. Am J Clin Nutr. Apr.2008 87:846–54. [PubMed: 18400706]
10. Vernarelli JA, Mitchell DC, Hartman TJ, Rolls BJ. Dietary Energy Density Is Associated with Body Weight Status and Vegetable Intake in U.S. Children. J Nutr. 2011; 141:2204–10. [PubMed: 22049295]
11. Fisher JO, Liu Y, Birch LL, Rolls BJ. Effects of portion size and energy density on young children's intake at a meal. Am J Clin Nutr. Jul.2007 86:174–9. [PubMed: 17616778]
12. Leahy KE, Birch LL, Rolls BJ. Reducing the energy density of an entree decreases children's energy intake at lunch. J Am Diet Assoc. Jan.2008 108:41–8. [PubMed: 18155988]
13. Kral TV, Remiker AM, Strutz EM, Moore RH. Role of child weight status and the relative reinforcing value of food in children's response to portion size increases. Obesity (Silver Spring). Jul.2014 22:1716–1722. [PubMed: 24733645]
14. Piernas C, Popkin BM. Food portion patterns and trends among U.S. children and the relationship to total eating occasion size, 1977–2006. J Nutr. Jun.2011 141:1159–1164. [PubMed: 21525258]
15. Young LR, Nestle M. The contribution of expanding portion sizes to the US obesity epidemic. Am J Public Health. Feb.2002 92:246–249. [PubMed: 11818300]
16. Savage JS, Fisher JO, Marini M, Birch LL. Serving smaller age-appropriate entree portions to children aged 3–5 y increases fruit and vegetable intake and reduces energy density and energy intake at lunch. Am J Clin Nutr. Feb.2012 95:335–41. [PubMed: 22205315]

17. Kral TV, Kabay AC, Roe LS, Rolls BJ. Effects of doubling the portion size of fruit and vegetable side dishes on children's intake at a meal. Obesity (Silver Spring). Mar.2010 18:521–7. [PubMed: 19680238]
18. Savage JS, Haisfield L, Fisher JO, Marini M, Birch LL. Do children eat less at meals when allowed to serve themselves? Am J Clin Nutr. Jul.2012 96:36–43. [PubMed: 22648719]
19. Spill MK, Birch LL, Roe LS, Rolls BJ. Eating vegetables first: the use of portion size to increase vegetable intake in preschool children. Am J Clin Nutr. May.2010 91:1237–43. [PubMed: 20219955]
20. Kral TV, Roe LS, Rolls BJ. Combined effects of energy density and portion size on energy intake in women. Am J Clin Nutr. Jun.2004 79:962–8. [PubMed: 15159224]
21. Kral TVE, Rolls BJ. Energy density and portion size: their independent and combined effects on energy intake. Physiol Behav. Aug.2004 82:131–8. [PubMed: 15234601]
22. U.S. Department of Agriculture Food and Nutrition Services. [accessed 25 January 2016] Child and Adult Care Food Program (CACFP) Child Care Meal Pattern. Version current 18 June 2016. Internet: http://www.fns.usda.gov/sites/default/files/Child_Meals.pdf
23. US Department of Agriculture, Agricultural Research Service, Nutrient Data Labortaory. [accessed 9 December 2015] USDA Nutrient Database for Standard Reference. Release 28. Version current 30 November 2015. Internet: http://www.ars.usda.gov/ba/bhnrc/ndl
24. Birch LL. The relationship between children's food preferences and those of their parents. J Nutr Educ. 1980; 12:14–8.
25. Birch LL. Dimensions of preschool children's food preferences. J Nutr Educ. 1979; 11:91–5.
26. Birch LL. Preschool children's food preferences and consumption patterns. Journal of Nutrition Education. 1979; 11:189–92.
27. Centers for Disease Control and Prevention. [accessed 9 December 2015] A SAS Program for the 2000 CDC Growth Charts (ages 0 to <20 y) Version current. May 7. 2015 Internet: http://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm
28. Butte NF, Wong WW, Wilson TA, Adolph AL, Puyau MR, Zakeri IF. Revision of Dietary Reference Intakes for energy in preschool-age children. Am J Clin Nutr. Jul.2014 100:161–7. [PubMed: 24808489]
29. Carnell S, Wardle J. Measuring behavioural susceptibility to obesity: validation of the child eating behaviour questionnaire. Appetite. Jan.2007 48:104–13. [PubMed: 16962207]
30. Wardle J, Guthrie CA, Sanderson S, Rapoport L. Development of the Children's Eating Behaviour Questionnaire. J Child Psychol Psychiatry. Oct.2001 42:963–70. [PubMed: 11693591]
31. Birch LL, Fisher JO, Grimm-Thomas K, Markey CN, Sawyer R, Johnson SL. Confirmatory factor analysis of the Child Feeding Questionnaire: a measure of parental attitudes, beliefs and practices about child feeding and obesity proneness. Appetite. Jun.2001 36:201–10. [PubMed: 11358344]
32. Kaur H, Li C, Nazir N, et al. Confirmatory factor analysis of the child-feeding questionnaire among parents of adolescents. Appetite. Jul.2006 47:36–45. [PubMed: 16624444]
33. Littell, RC.; Milliken, GA.; Stroup, WW.; Wolfinger, RD.; Schabenberger, O. SAS for Mixed Models. 2. Cary, NC: SAS Institute Inc; 2006.
34. Roe LS, Kling SMR, Rolls BJ. What is eaten when all of the foods at a meal are served in large portions? Appetite. 2016; 99:1–9. DOI: 10.1016/j.appet.2016.01.001 [PubMed: 26767612]
35. Bell EA, Castellanos VH, Pelkman CL, Thorwart ML, Rolls BJ. Energy density affects energy intake in lean and obese women. Obes Res. 1997; 5:3S.
36. Rolls BJ, Bell EA, Castellanos VH, Chow M, Pelkman CL, Thorwart ML. Energy density but not fat content of foods affected energy intake in lean and obese women. Am J Clin Nutr. 1999; 69:863–871. [PubMed: 10232624]
37. Williams RA, Roe LS, Rolls BJ. Comparison of three methods to reduce energy density. Effects on daily energy intake. Appetite. Jul.2013 66:75–83. [PubMed: 23523752]
38. Zlatevska N, Dubelaar C, Holden SS. Sizing Up the Effect of Portion Size on Consumption: A Meta-Analytic Review. Journal of Marketing. 2014; 78:140–54.
39. Steenhuis IH, Vermeer WM. Portion size: review and framework for interventions. Int J Behav Nutr Phys Act. 2009; 6:58. [PubMed: 19698102]

40. Rolls BJ, Roe LS, Meengs JS. Larger portion sizes lead to sustained increase in energy intake over two days. J Am Diet Assoc. 2006; 106:543–9. [PubMed: 16567150]
41. Frobisher C, Maxwell SM. The estimation of food portion sizes: a comparison between using descriptions of portion sizes and a photographic food atlas by children and adults. J Hum Nutr Diet. Jun.2003 16:181–8. [PubMed: 12753111]
42. Foster E, Matthews JN, Nelson M, Harris JM, Mathers JC, Adamson AJ. Accuracy of estimates of food portion size using food photographs--the importance of using age-appropriate tools. Public Health Nutr. Jun.2006 9:509–14. [PubMed: 16870024]
43. Byrd-Bredbenner C, Schwartz J. The effect of practical portion size measurement aids on the accuracy of portion size estimates made by young adults. J Hum Nutr Diet. Aug.2004 17:351–7. [PubMed: 15250844]
44. Rolls BJ, Roe LS, Meengs JS. The effect of large portion sizes on energy intake is sustained for 11 days. Obesity (Silver Spring). Jun.2007 15:1535–43. [PubMed: 17557991]
45. Mathias KC, Rolls BJ, Birch LL, et al. Serving larger portions of fruits and vegetables together at dinner promotes intake of both foods among young children. J Acad Nutr Diet. Feb; 2012 112(2): 266–270. [PubMed: 22741168]
46. Rolls BJ, Roe LS, Meengs JS. Portion size can be used strategically to increase vegetable consumption in adults. American Journal of Clinical Nutrition. 2010; 91:913–922. [PubMed: 20147467]
47. Ishdorj A, Capps O Jr, Storey M, Murano PS. Investigating the Relationship between Food Pairings and Plate Waste from Elementary School Lunches. Food and Nutrition Sciences. 2015; 6(11): 1029.
48. U.S. Department of Agriculture. [accessed 9 December 2011] ChooseMyPlate.gov Home Page. Version current 4 November 2015. Internet: http://www.choosemyplate.gov

Highlights

- Meal portion size and energy density (ED) had independent effects on energy intake
- The effects of meal portion size and ED combined to increase energy intake by 79%
- The typical lower-ED and higher-ED meals were similarly well liked by the children
- Strategies to moderate energy intake need to address both portion size and ED

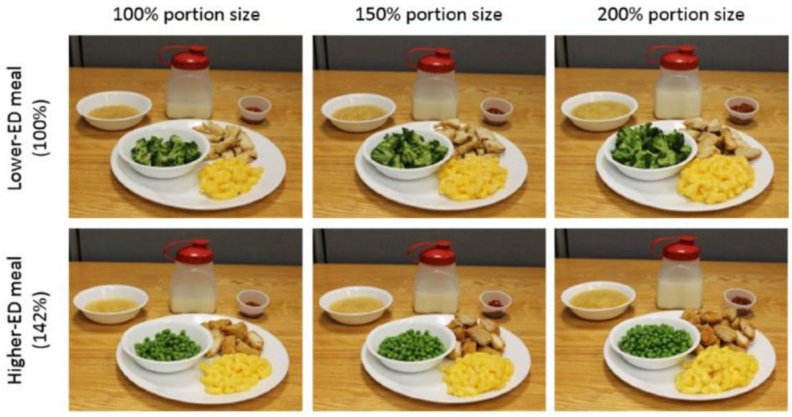

Figure 1.

All foods at the experimental meals were served at 3 levels of portion size (100%, 150%, or 200%) and 2 levels of energy density (100% or 142%). Children were served one experimental meal per week for 6 weeks; thus, they never saw the different meals together.

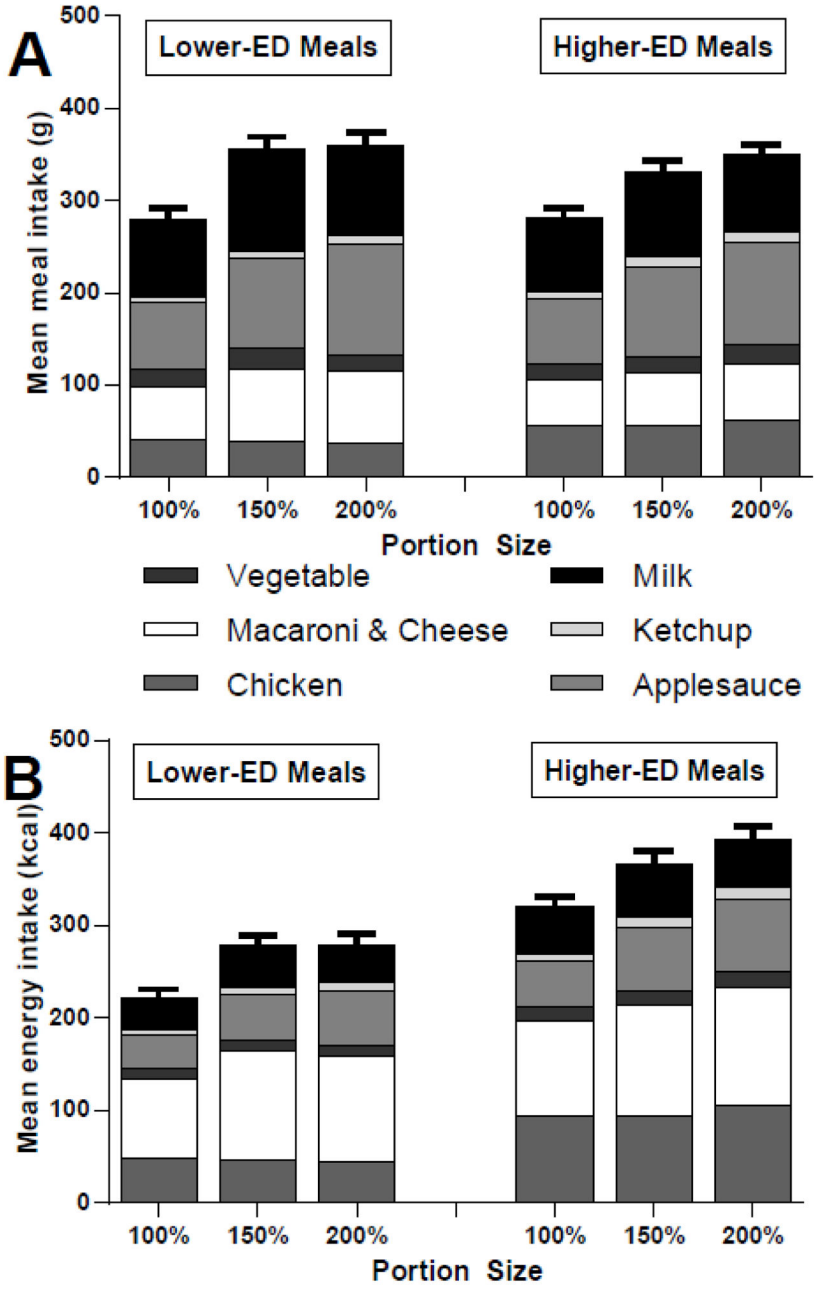

Figure 2.

Mean (±SEM) food and milk intakes (g and kcal) at lunch by meal portion size and energy density (ED) in 120 preschool children. Figure 2A: There was a significant effect of portion size ($P<0.0001$) but not energy density ($P=0.22$) on total meal intake by weight. Across the lower- and higher-ED meals, intake was significantly greater when children were served the 150% and 200% portion size conditions compared to the 100% condition. Figure 2B: There were significant and independent effects of portion size and energy density (both $P<0.0001$) on total meal energy intake. Across the lower- and higher-ED meals, energy intake was significantly greater when children were served the 150% and 200% portion size conditions

compared to the 100% condition (both P<0.0001). Across portion size conditions, increasing meal ED by 42% led to an increase in energy intake at the meal (P<0.0001). The effects of portion size and energy density combined to increase meal energy intake by 79% or 175 ± 12 kcal when the children were served the higher-ED meal with the largest portions compared to the lower-ED meal with the smallest portions.

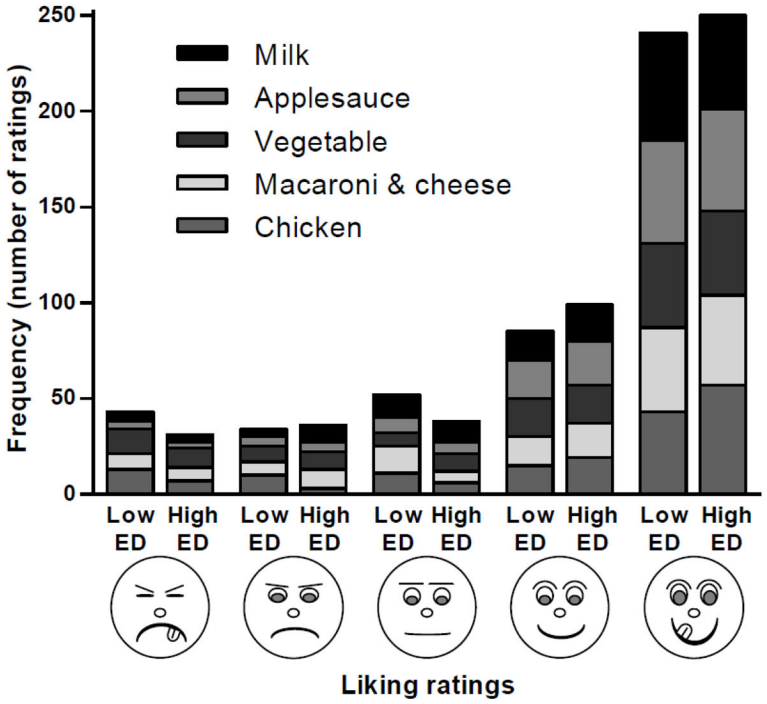

Figure 3.

Frequency distribution of liking ratings (faces from left to right represent “super yucky,” “yucky,” “just okay,” “yummy,” and “super yummy”) for the lower- and higher-energy dense versions of a meal consisting of chicken, macaroni and cheese, green vegetable, applesauce, and milk. There was no significant difference in distribution of the ratings between the two versions of the meal, according to ordinal repeated measures logistic regression (p=0.15). ED, energy density.

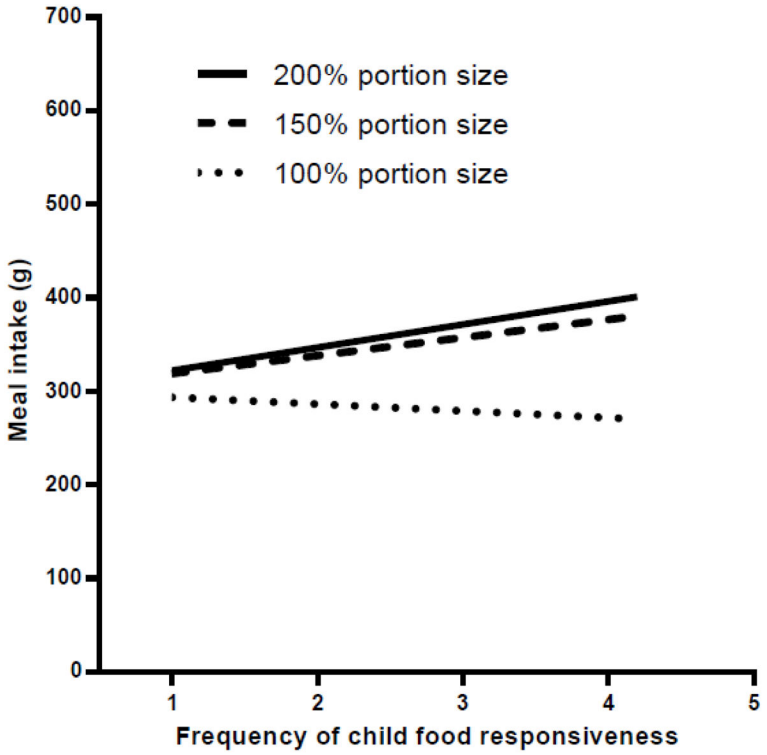

Figure 4.

Effect of parental ratings of child food responsiveness on the relationship between meal portion size and weight of the meal consumed. Scores on the food responsiveness scale indicate the mean frequency of 5 responsive behaviors and range from 1 (never) to 5 (always). Analysis of covariance showed that the slopes of the regression lines for the 150% and 200% portion conditions were significantly greater than the slope for the 100% condition (both $P<0.01$). Thus, children who were rated as being more responsive to food had larger increases in intake when served the 150% and 200% portions of the meal (compared to the 100% condition) than children who were less responsive.

Table 1

Items served in the experimental meals of lower and higher energy density; amounts of weight and energy served are shown for the 100% portion size conditions.

Lower-energy-dense meal				Higher-energy-dense meal			
		100% portion size				100% portion size	
Lower-energy-dense items (kcal/g)	ED[13]	Weight (g)	Energy (kcal)	Higher-energy-dense items	ED (kcal/g)	Weight (g)	Energy (kcal)
Grilled chicken strips[1,2]	1.19	100	119	Breaded chicken nuggets[2,3]	1.68	100	168
Macaroni and cheese[4]	1.50	100	150	Macaroni and cheese with extra butter and oil[5]	2.10	100	210
Broccoli with butter and flavoring[6]	0.57	75	43	Peas with butter flavoring[7]	0.81	75	61
Reduced-sugar applesauce[8]	0.50	100	50	Sweetened applesauce[9]	0.71	100	71
Reduced-sugar ketchup[10]	0.82	20	16	Regular ketchup[11]	1.18	20	24
Low-fat milk (1%)[12]	0.42	183	77	Whole milk[12]	0.61	183	112
Total food served	0.96	395	378	Total food served	1.35	395	533
Total food & milk served	0.79	578	455	Total food & milk served	1.12	578	645

[1] Fully Cooked Chicken Breast Strips, Tyson Foods Inc., Springdale, AR.

[2] Chicken strips and nuggets were cut into similar bite-sized pieces.

[3] Gluten Free Breaded Chicken Breast Nuggets, Bell & Evans, Fredericksburg, PA.

[4] Stouffer's Macaroni and Cheese, Nestle U.S.A. Inc., Solon OH.

[5] Stouffer's Macaroni and Cheese, Nestle U.S.A. Inc., Solon OH; Unsalted Whipped Butter, Land O'Lakes Inc., Arden Hills, MN; Crisco Pure Canola Oil, The J.M. Smucker Company, Orrville, OH.

[6] Petite Broccoli Florets, Hanover Foods Corporation, Hanover, PA; Unsalted Whipped Butter, Land O'Lakes Inc., Arden Hills, MN; Molly McButter Butter Flavor Sprinkles, B&G Foods Inc., Parsippany, NJ.

[7] Sweet Peas, Foodhold U.S.A LLC, Landover, MD; Molly McButter Butter Flavor Sprinkles, B&G Foods Inc., Parsippany, NJ.

[8] Lucky Leaf Premium Blend Applesauce, Knouse Foods Inc., Peach Glen, PA; Lucky Leaf Unsweetened Applesauce, Knouse Foods Inc., Peach Glen, PA.

[9] Lucky Leaf Premium Blend Applesauce, Knouse Foods Inc., Peach Glen, PA.

[10] Tomato Ketchup, H.J. Heinz Co. L.P., Pittsburgh, PA; Reduced Sugar Ketchup with Sucralose, H.J. Heinz Co. L.P., Pittsburgh, PA.

[11] Tomato Ketchup, H.J. Heinz Co. L.P., Pittsburgh, PA.

[12]Giant Food Stores Milk, Foodhold U.S.A LLC, Landover, MD.

[13]ED, energy density.

Author Manuscript
Author Manuscript
Author Manuscript

Table 2

Characteristics of 120 pre.school children participating in a study that tested the effects of increasing portion size and energy density of a meal on lunch intake

	Boys (n=61)[1]			Girls (n=59)		
Characteristic	**n**	**Mean ± SEM**	**Range**	**n**	**Mean ± SEM**	**Range**
Age (y)	56	4.4±0.1	3.2–5.8	56	4.4±0.1	3.1–5.9
Weight (kg)	52	18.2±0.5[b]	11.7–34.5	55	17.0 ± 0.4	11.9–24.2
Height (cm)	53	106.5±1.0	90.4–121.5	55	103.9±0.9	90.5–115.5
Sex-specific BMI-for-age percentile	51	55.6±4.1	0.1–99.9	54	57.9±3.3	1.2–94.4
BMI z-score	51	0.17±0.15[a]	−3.27–2.98	54	0.22±0.10	−2.27–1.59
Daily energy requirements (kcal)[2]	52	1163±13[b]	988–1539	55	1049±9	917–1203
Food responsiveness score[3]	53	2.5±0.1	1.2–4.2	51	2.3±0.1	1.0–3.6
Enjoyment of food score[3]	53	3.6±0.1	2.0–5.0	51	3.6±0.1	1.8–5.0
Monitoring score[4]	53	4.0±0.1	1.7–5.0	50	4.0±0.1	1.7–5.0

[1] Boys and girls were compared with the use of a *t* test. Significant difference between boys and girls according to a *t* test, [a] $P < 0.01$, [b] $P < 0.05$

[2] Daily energy requirements were estimated using equations for children ages 3 through 5 years with light activity levels (28)

[3] Subscale on the Child Eating Behaviour Questionnaire (29, 30)

[4] Subscale on the Child Feeding Questionnaire (31, 32)

Table 3

The effects of increasing meal portion size and energy density on the weight, energy, energy density, and macronutrients consumed from a meal served to 120 preschool children[1]

	Lower-energy-dense meal			Higher-energy-dense meal			
	100% Portion Size (n=106)	150% Portion Size (n=107)	200% Portion Size (n=110)	100% Portion Size (n=114)	150% Portion Size (n=114)	200% Portion Size (n=115)	Significant effects[2]
Total meal intake (g)	280±11	357±14	360±14	283±10	331±13	345±12	PS[3]
Chicken (g)	40±3	39±3	37±3	56±3	56±4	63±5	ED[4]
Macaroni and cheese (g)	58±4	78±5	78±6	49±4	57±5	61±6	PS, ED[5]
Vegetable (g)	20±2	22±3	18±3	18±2	18±2	20±3	--
Applesauce (g)	71±3	97±5	119±7	70±3	98±5	111±7	PS
Ketchup (g)	7±1	9±1	10±1	7±1	10±1	12±1	PS
Milk (g)	84±7	110±9	98±8	82±7	92±8	83±8	PS
Total meal energy intake (kcal)	222±9	279±11	279±12	321±12	366±14	390±15	PS, ED
Chicken (kcal)	48±4	47±4	44±4	95±5	95±7	106±8	ED
Macaroni and cheese (kcal)	86±6	117±8	116±9	102±8	119±10	127±12	PS, ED
Green vegetable (kcal)	12±1	12±2	11±2	15±2	15±2	16±2	ED
Applesauce (kcal)	36±2	49±3	60±3	50±2	70±4	79±5	PS, ED
Ketchup (kcal)	6±1	8±1	8±1	9±1	12±1	14±1	PS*ED[6]
Milk (kcal)	35±3	46±4	41±4	50±4	56±5	51±5	PS, ED
Meal energy intake (% total energy requirements)[7]	20.8±0.9	25.4±1.0	25.7±1.1	29.6±1.1	33.5±1.3	35.9±1.4	PS, ED
Water intake (g)	53±6	42±5	48±5	51±6	46±5	49±5	--
Energy density of food (kcal/g)	0.95±0.02	0.94±0.02	0.92±0.02	1.34±0.02	1.30±0.02	1.30±0.03	PS, ED
Energy density of food and milk (kcal/g)	0.81±0.02	0.80±0.02	0.79±0.02	1.15±0.02	1.13±0.02	1.14±0.02	ED
Carbohydrates (g)	24.2±0.9	32.2±1.3	34.1±1.4	33.5±1.1	40.3±1.4	43.8±1.5	PS, ED
Sugar (g)	12.9±0.5	17.3±0.7	18.6±0.8	17.7±0.6	22.8±0.9	24.6±1.0	PS, ED
Protein (g)	17.1±0.9	19.2±0.9	18.0±1.0	16.3±0.6	17.1±0.8	18.1±0.8	PS
Fat (g)	6.6±0.3	8.4±0.4	8.1±0.5	13.6±0.7	15.1±0.8	15.7±0.9	PS, ED

[1] All values are mean ± SEM

[2] Mixed linear models were used to test the effects of portion size and energy density on all outcomes except for percent energy consumed from carbohydrates, protein, and fat which were analyzed using multivariate analysis of variance.

[3] PS, There was a significant, independent effect of portion size (all $P<0.02$) on the outcome.

[4] ED, There was a significant, independent effect of energy density (all $P<0.01$) on the outcome.

[5] PS, ED, There was a significant, independent effects of portion size (all $P<0.03$) and energy density (all $P<0.009$) on the outcome.

[6] PS*ED, Portion size and energy density significantly interacted to affect energy consumed from ketchup ($P=0.02$).

[7] Daily energy requirements were estimated using equations for children ages 3 through 5 years with light activity levels (28)